HYDROGEN & FUEL CELLS
Interagency Action Plan

A document prepared by the
Interagency Working Group on Hydrogen and Fuel Cells

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www.hydrogen.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

About the Hydrogen and Fuel Cells Interagency Action Plan

The *Hydrogen and Fuel Cells Interagency Action Plan* describes an integrated plan for coordinating U.S. federal agency efforts to research, develop, demonstrate, and deploy hydrogen and fuel cells. The document was collaboratively developed by the Hydrogen and Fuel Cell Interagency Working Group.

This document is intended to be goal-setting in nature. Given the limitations that the budgeting and appropriations process places on each agency, it by no means attempts to mandate the funding of each activity of the Interagency Action Plan. Rather, it is a guide to what the power of collaborative work across the federal government can achieve in growing a clean energy economy. To submit any questions or comments, please send your message to FCActionPlan@ee.doe.gov.

About the Hydrogen and Fuel Cell Interagency Working Group

The Hydrogen and Fuel Cell Interagency Working Group (IWG) provides a forum for sharing research results, technical expertise, and lessons learned about hydrogen and fuel cell program implementation and technology deployment, as well as coordinating related projects to ensure efficient use of taxpayer dollars. Co-chaired by the Office of Science Technology and Policy (OSTP) and the Department of Energy (DOE), participating agencies include the Department of Agriculture (USDA), Department of Commerce (DOC), Department of Defense (DOD), Department of Homeland Security (DHS), Department of Transportation (DOT), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation(NSF), Office of Management and Budget (OMB), and U.S. Postal Service (USPS). DOE, DOT, the EPA, and the National Institute of Standards and Technology (Department of Commerce) also coordinate their activities involving safety, codes and standards, and regulations.

About the Hydrogen and Fuel Cell Interagency Task Force

The Hydrogen and Fuel Cell Interagency Task Force (ITF) includes senior-level representatives from agencies participating in the IWG. Members are at the functional level of assistant secretary, providing the ITF with the ability to make departmental decisions that can influence the development and implementation of hydrogen and fuel cell programs, as directed by section 806 of Energy Policy Act of 2005 (EPACT 2005). Work resulting from decisions by the Task Force is complemented and supported by the staff-level Interagency Working Group. To date, the ITF has focused its efforts on facilitating hydrogen and fuel cell demonstrations and deployments to help federal agencies meet the requirements of EPACT 2005 Sections 782 and 783, Executive Order 13423 “Strengthening Federal Environmental, Energy, and Transportation Management,” and Executive Order 13514 “Federal Leadership in Environmental, Energy, and Economic Performance.”

For a detailed description of hydrogen and fuel cell activities across the federal agencies, visit www.hydrogen.gov.

Hydrogen and Fuel Cells Interagency Action Plan

It is vital that the United States be at the forefront of the science, engineering, and innovation required to meet the energy needs of the 21st century. Pursuing the key national goals of reducing greenhouse gas emissions and ending our dependence on imported oil also provides significant economic opportunities—building and enhancing systems for the production and use of energy will help to support domestic manufacturing and create high-skilled jobs in emerging technical sectors.

The federal government is working to advance a portfolio of energy technologies that produce and use domestic resources more efficiently and with fewer emissions. Developing and adopting hydrogen and fuel cells is a key part of this strategy, because their use offers unique and complementary advantages including higher efficiency and reliability, lower emissions and a number of ancillary benefits such as reduced noise pollution and fuel flexibility. Along with expansion of the fuel cell industry comes tremendous potential for long-term employment growth. Estimates show that fuel cell market maturity over the next 10 to 20 years could produce revenues globally of between $43 and $139 billion annually. Such growth could help revitalize the US manufacturing sector adding more than 180,000 new jobs to the U.S. economy by 2020, and more than 675,000 jobs by 2035.[1]

The Hydrogen and Fuel Cells Interagency Action Plan lays out an integrated plan for coordinating U.S. federal agency efforts to research, develop, demonstrate, and deploy these important technologies. Section 1 of the plan provides the context for and status of federal hydrogen and fuel cell activities and Section 2 presents the action plans for five broad activity areas:

- Address technical challenges through research and development
- Support development and adoption of codes, standards, and regulations
- Validate technologies in real-world operating conditions
- Adopt hydrogen and fuel cell technologies in federal government operations
- Track and communicate results

[1] *http://www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf*

The Important Role of Hydrogen and Fuel Cells

Achieving emissions reduction goals and strengthening our national and economic security will require a diverse portfolio of carbon-neutral energy resources, including renewable resources, coal with carbon sequestration, natural gas, and nuclear energy. Hydrogen and fuel cell technologies can address energy and environmental challenges facing the United States across diverse applications

REDUCING GREENHOUSE GAS EMISSIONS

Currently, the United States generates approximately 6 gigatons of carbon dioxide (CO_2) emissions each year and accounted for 21.3% of the World's carbon emissions in 2005, with only 4% of the global population. Nearly half (44%)of the U.S. carbon emissions are from oil use.[2] Air quality is also a significant issue in many parts of the United States—the U.S. Environmental Protection Agency estimates that 50% of Americans live in areas where levels of air pollutants are high enough to affect public health and/or the environment.[3]

The use of hydrogen and fuel cells in transportation and stationary power generation could substantially reduce emissions of CO_2 and criteria pollutants. Because fuel cells operating on hydrogen produce only water and heat as products, they do not create direct emissions of CO_2 or criteria pollutants at the point of use. Hydrogen and fuel cells have the greatest potential to reduce CO_2 emissions in the transportation sector, particularly in light-duty vehicles. Most U.S. transportation sector carbon dioxide emissions come from petroleum fuels (98%) and motor gasoline has been responsible for about 60% of U.S. carbon dioxide emissions over the last twenty years.[4] A fuel cell vehicle enables a 60% to 90% reduction in direct CO_2 emissions when compared to a gasoline vehicle and a cumulative CO_2 emissions reduction of 2.5 gigatons by 2050.

Further economic, environmental, and energy efficiency benefits could be realized with the development of fuel cells for use in large central power generation. Currently, DOE and SECA are exploring the issue of fuel cell scalability and their integration with advanced generation central power plants including coal integrated gasification fuel cell (IGFC) plants. This research could potentially result in net-zero emissions in coal-fired central power station applications when coupled with solid oxide fuel cells (SOFC)[5]. In addition to the potential for fuel cells in central power generation, fuel cell technology as a whole could be greatly advanced and a reduction in cost could occur as a result of the experience and knowledge gained from using these larger applications. These advancements could potentially open the door to a multitude of other applications including distributed generation (DG).

BOOSTING THE NATION'S ECONOMY

Worldwide interest in hydrogen and fuel cell technologies is substantial and growing. Nations within Asia and Europe are making large commitments to federal government sponsored fuel cell and hydrogen infrastructure research and technology development. To be globally competitive in current and future markets for hydrogen and fuel cell technologies, the United States will have to keep pace with these growing investments. Within the hydrogen and fuel cells industry, a net increase of 361,000 to 675,000 jobs is possible by 2035 which can revitalize the manufacturing sector across a number of industries.[6]

The market for hydrogen and fuel cell technologies offers a valuable opportunity for boosting the nation's economy and improving overall U.S. economic competitiveness. The United States is currently a world leader in research and development (R&D) expenditures, sales, and employment in hydrogen and fuel cells. Since pioneering these technologies, the United States has been at the forefront of advancing their progress, but the growing investments of foreign governments and companies are eroding this lead. Continued funding for research, development, and demonstration (RD&D), increased investments at the university level for developing human capital, and further development of manufacturing capabilities in the hydrogen and fuel cell industries will enable the United States to remain competitive.

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[2]U.S. Department of Energy, Energy Information Administration, International Energy Outlook 2008, Washington, DC, September 2008, Tables A10 and A11.

[3]DOE Hydrogen Program Record #8013, "Air Quality and Population", www.hydrogen.energy.gov/program_records.html

[4]U.S. Department of Energy, Energy Information Administration, Emissions of Greenhouse Gases in the United States, 2007, Washington, DC, November 2008, Table10.

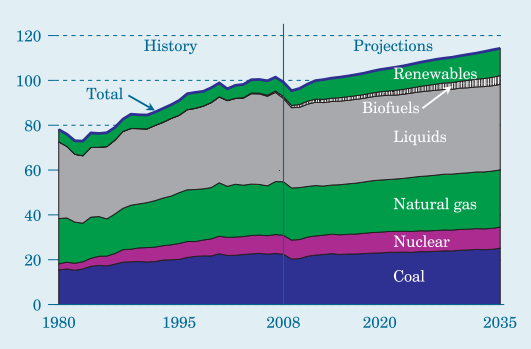
[5]www.netl.doe.gov/energy-analyses/pubs/AdvancedPowerSystemsPathwayVol2.pdf

[6]U.S. Department of Energy, Effects of a Transition to a Hydrogen Economy on Employment in the United States: Report to Congress, Jul. 2008.

ENDING DEPENDENCE ON FOREIGN OIL

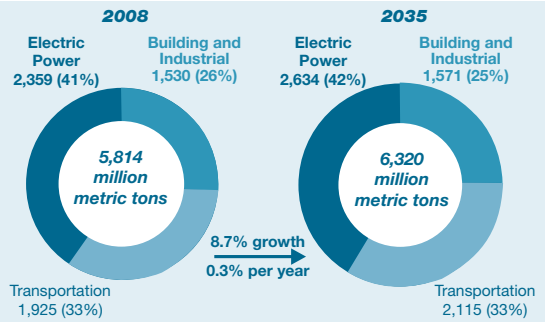
Today, the United States is the world's largest user of oil and refined petroleum products. Much of this demand is created by the transportation sector, which is almost entirely dependent on petroleum products. The Energy Information Administration (EIA) projects that even with anticipated improvements in automotive fuel economy and increased use of biofuels, we will continue to rely on imported oil, with imports accounting for up to 62% of domestic oil consumption in 2035.[7] The ever present possibility of unanticipated supply disruptions can also cause extreme price volatility.

Alternative, domestically produced transportation fuels are needed to break this dependence and end U.S. reliance on oil imports and economic vulnerability to oil supply disruptions. Domestically produced hydrogen can reduce U.S. imported energy dependence in the transportation, industrial, and electric power sectors. Hydrogen can be produced from diverse domestic sources of renewable, nuclear, and fossil energy. Its use as an energy carrier would provide the United States with a more efficient and diversified energy infrastructure, increased options for electric power generation, and domestic fuel production for vehicles.



U.S. Primary Energy Consumption, 1980-2035, Quadrillion Btu

(EIA Annual Energy Outlook 2010, Figure 1): http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf)



U.S. Energy-Related Carbon Dioxide Emissions by Sector, 2008 and 2035

(EIA Annual Energy Outlook 2010, Figure 4): http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf)

Current Progress in Hydrogen and Fuel Cells Development

Hydrogen and fuel cell technologies have been progressing significantly in terms of commercial deployment of early market products and design innovations that are improving the cost competitiveness of these early market products. As commercial sales grow and the pace of product improvement continues, several early market products are becoming cost competitive with incumbent technologies in some duty cycles[8] and many fuel cell companies are beginning to progress past the early commercial stage. Following is a description of these advances in both technology development and product sales.

TECHNOLOGY PROGRESS

Several fuel cell technologies have experienced significant progress in recent years, reflecting success in government-sponsored and private industry research to reduce cost and improve durability and performance. Several notable innovations have resulted in cost reductions, including catalyst materials with little or no platinum, membranes that achieve high conductivity at higher temperatures, and a manufacturing process for making nanostructured composite membranes more durable.

Reflecting these and other innovations, the estimated cost for a transportation fuel cell system (2010 technology) for high-volume manufacturing (500,000 units annually) is approximately $50/kW, which is 30% less than the 2008 estimated cost, 80% less than the 2002 estimated cost, and approaches the 2017 cost target of $30/kW. Research and development efforts

[7] *U.S. Department of Energy, Energy Information Administration, International Energy Outlook 2010, Washington, DC, May 2010.*

[8] *Sandra Curtin and Jennifer Gangi, The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today, (Washington, DC: Fuel Cells 2000, September 2010), http://www.fuelcells.org/BusinessCaseforFuelCells.pdf*

appear to be on track to achieve cost competitiveness, i.e., $30/kW, with internal combustion engines within the next few years.[9]

Government-sponsored and private industry research efforts have also contributed to significant reductions in the cost of hydrogen, reflecting major improvements in electrolyzer and reformer technology. Since 2007, the cost of electrolyzer stacks on a $/kW basis has declined 60%.

According to the Clean Energy Patent Growth Index[10], fuel cell patents lead in the clean energy field with nearly 1,000 fuel cell patents issued worldwide in 2010—an increase of more than 57% in just one year. This amount is three times greater than solar, in second place with about 360 patents. The United States holds 47% of fuel cell patents registered between 2002 and 2010.[11]

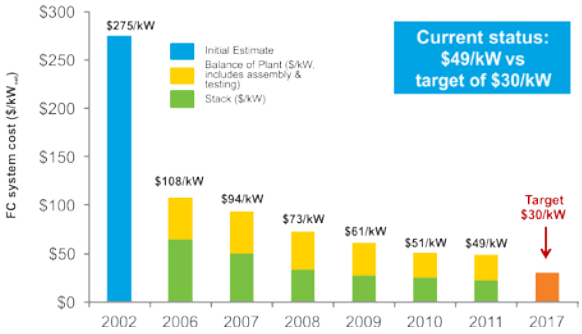
SALES PROGRESS

With these advances, the sales volumes of commercial fuel cell systems continue to grow. Worldwide, nearly 16,000 fuel cell systems were shipped in 2010, which is more than double the total number of units shipped in 2008.[12] Both North America and Japan have experienced major increases in sales, despite the global financial crisis that began in 2008. The number of fuel cell units shipped from North America quadrupled between 2008 and 2010.[13] U.S. fuel cell companies shipped about 40 MW of fuel cell systems in 2010—about one-half of the worldwide total in terms of MW shipped.[14]

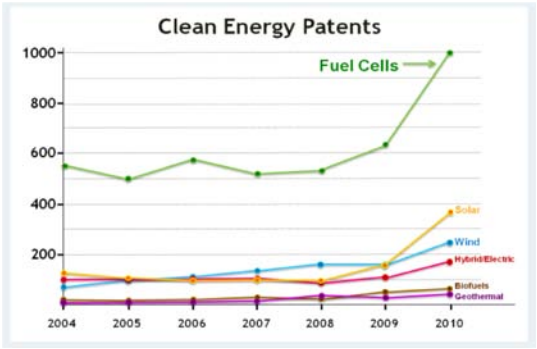
The pace of sales growth reflects the ongoing trend toward commercialization in the stationary power market, including primary power, backup power, and combined heat and power (CHP) products, and in the transportation power market, largely in materials-handling vehicles (e.g., forklifts). Federal and state incentives and grant programs have also contributed to sales growth worldwide, notably Japan's residential fuel cell program and the American Recovery and Reinvestment Act.

The Challenges Facing Hydrogen and Fuel Cells

Despite the promise of hydrogen and fuel cell technologies, challenges to their development and adoption lie ahead. As with many emerging energy technologies, cost and durability, storage and infrastructure issues, and codes and standards must all be addressed.



Projected Transportation Fuel Cell System Cost -projected to high-volume (500,000 units per year)



Clean Energy Patents

(Cleantech Group - Heslin Rothenberg Farley & Mesiti P.C., Clean Energy Patent Growth Index, http://cepgi.typepad.com/heslin_rothenberg_farley_/)

COST AND DURABILITY

In order to be competitive with other technologies, fuel cells will have to be less expensive and more durable than they are today and their performance must meet or exceed that of competing technologies.

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[9] *U.S. Department of Energy, DOE Hydrogen Program Record #104 (Washington, D.C., U.S. Department of Energy, 2010), http://www.hydrogen.energy.gov/pdfs/10004_fuel_cell_cost.pdf*

[10] *Cleantech Group - Heslin Rothenberg Farley & Mesiti P.C., Clean Energy Patent Growth Index, http://cepgi.typepad.com/heslin_rothenberg_farley_/*

[11] *Sandra Curtin and Jennifer Gangi, The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today, (Washington, DC: Fuel Cells 2000, September 2010), http://www.fuelcells.org/BusinessCaseforFuelCells.pdf*

[12] *Office of Energy Efficiency and Renewable Energy, 2010 Fuel Cell Technologies Market Report, (Washingrton, D.C., U.S. Department of Energy, 2011), http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2010_market_report.pdf*

[13] *IBID*

[14] *IBID*

PRODUCTION, DELIVERY, STORAGE AND INFRASTRUCTURE

The cost of hydrogen production and delivery technologies, particularly with renewable or low carbon approaches, must be reduced to be competitive with other fuels. Hydrogen's relatively low volumetric energy content poses a challenge for storage. This challenge is most acute in light-duty vehicles, as storage systems for vehicles must operate within stringent size, weight, and refueling constraints and enable a driving range over 300 miles, across different vehicle types. In addition, fully realizing the benefits of hydrogen requires large-scale, centralized production, which in turn requires an extensive delivery infrastructure.

LACK OF UNIFORM CODES AND STANDARDS

Guidelines are necessary for safe system design and operation for hydrogen and fuel cell technology. Government agencies must work together on efforts to develop and harmonize standards and regulations across the nation and around the globe to allow end users and others, such as first responders, to understand and safely use hydrogen and fuel cell technology.

Federal Activities

To begin to address the challenges to hydrogen and fuel cell development and deployment, the federal government is supporting R&D, conducting early adoption efforts, establishing interagency collaboration and partnerships, and stimulating the market through policy and market transformation activities.

RESEARCH AND DEVELOPMENT

Federal funding for hydrogen and fuel cells has focused on R&D, helping to make costs and performance more competitive with current and other emerging technologies. Sustained R&D on hydrogen production, storage, and infrastructure technologies is needed to continue making progress on low-cost pathways for producing, storing, and delivering cost-competitive carbon-free hydrogen fuel. While fuel cell cost and performance are approaching targets, further R&D is still required to lower cost and meet durability requirements.

EARLY ADOPTION EFFORTS

U.S. policies today require government agencies to meet strict energy efficiency guidelines. Federal adoption and data collection from early adoption activities is helping steer future R&D and creates a pool of subject matter experts to support the use of hydrogen and fuel cell technologies in both the government and the private sector. Specifically, EPACT 2005, the Energy Independence and Security Act of 2007 (EISA 2007) and Executive Order 13514 provide guidance to federal agencies for further energy efficiency.

INTERAGENCY COLLABORATION AND PARTNERSHIPS

EPACT 2005 established key groups to ensure close coordination of federal efforts and key oversight of RD&D efforts for hydrogen and fuel cells, including the Hydrogen and Fuel Cell Technical Interagency Task Force. Other interagency groups such as the Interagency Working Group on Hydrogen and Fuel Cells (IWG) use and enhance existing interagency coordination mechanisms to ensure clear communication between federal agencies and regularly report results of hydrogen and fuel cell activities.

The IWG is also key in engaging and leveraging existing partnerships with trade groups and stakeholder organizations such as the U.S. Fuel Cell and Hydrogen Energy Association, and the California Fuel Cell Partnership. The IWG provides a forum for coordinating hydrogen and fuel cell R&D, interagency policy, programs, and activities related to safe, economical, and environmentally sound hydrogen and fuel cell technologies.

POLICY AND MARKET TRANSFORMATION

While there is a substantial amount of work to be done to research, develop, demonstrate, and deploy hydrogen and fuel cell technologies, significant progress has been made. Fuel cells are already economically competitive in some specialty markets such as in-door lift truck and emergency backup power applications. While fuel cell technology is commercially viable in these small markets, it is not yet economically competitive in larger markets such as automotive and stationary prime power applications.

The federal government is working to develop strategies to further stimulate the market and conduct "market transformation" activities, such as the purchase of fuel cells by federal agencies to support early market growth. As more technologies become economically viable, greater adoption will help to reduce costs through high volume manufacturing, economies of scale, promote consumer acceptance, and develop infrastructure and a domestic supply base, paving the way for more applications in the future.

Early Markets

Despite the high costs associated with most fuel cell technologies, fuel cells provide several unique advantages over traditional power systems. Typically these advantages are seen in niche markets where functionality, reliability, and environmental factors take precedence over cost as the main driver.

BACKUP POWER

Hydrogen fuel cells are emerging as an economically viable option for providing backup power, particularly in the telecommunications sector. Compared with batteries, fuel cells offer a longer, continuous run time and greater durability in harsh outdoor environments under a wide range of temperature conditions. Compared with generators, fuel cells are quieter and have no harmful emissions. They require less maintenance than both generators and batteries, and they can also be monitored remotely to reduce maintenance time.

SPECIALTY VEHICLES

Fuel cells are also becoming a cost-competitive option for powering specialty vehicles such as lift trucks. Many specialty vehicles require power in the 5- to 20-kilowatt range, and they often use lead-acid batteries, especially in locations where air quality is important and internal combustion engines cannot be used. Like batteries, fuel cells produce no harmful emissions at the point of use, but fuel cells can be rapidly refueled, eliminating the time and labor spent changing batteries. This makes fuel cells a particularly appealing option for continuously used lift trucks running two or three shifts per day and requiring multiple battery change-outs. Hydrogen used in these vehicles can either be delivered and stored in high-pressure tanks or produced on-site through electrolysis (water splitting using electricity) or natural gas reforming.

AUXILIARY POWER UNITS

Fuel cells using natural gas or propane have already entered the markets for auxiliary power for recreational vehicles and stationary power for critical-load facilities. APUs running either on diesel or hydrogen for use in heavy-duty vehicles can significantly reduce energy and environmental impacts - particularly by reducing engine idling. Aircrafts can also benefit from fuel cell auxiliary power units and can save fuel and reduce emissions.

PORTABLE POWER

Some small fuel cells are commercially available for portable consumer electronic devices. Portable fuel cells provide high efficiency and power density and can use liquid fuels such as methanol. Applications include backup power, battery chargers, soldier power, and use for security and surveillance equipment.

STATIONARY POWER (CENTRAL GENERATION FACILITIES, CRITICAL LOAD FACILITIES, COMBINED HEAT AND POWER, AND BIOGAS POWER)

Fuel cells are already in use for buildings, data centers, telecommunications applications, power for remote locations, distributed power generation, and cogeneration (in which excess heat released during electricity generation is used for other applications). Waste heat from fuel cells can also drive space chillers to provide both heating and cooling for diverse applications. Fuel cells provide decreased noise in stationary power applications, as opposed to diesel generators, thereby allowing them to be located inside buildings in dense urban locations. While fuel cells are ideal candidates for distributed generation, they also have great potential to serve larger-scale power needs in the form of central generation facilities. With larger system sizes, fuel cells may be able to achieve higher overall efficiencies due to the more effective utilization of waste heat, ultimately resulting in more favorable economics.

Interagency Action Plan

Purpose: To coordinate and facilitate federal agency efforts to overcome challenges in developing and commercializing hydrogen and fuel cell technologies for a variety of stationary, portable, and transportation power applications.

STRENGTHEN & ACCELERATE *Research and Development*

Goals

Strengthen the national research community in conducting hydrogen and fuel cell R&D activities that address national energy and environmental needs such as reducing petroleum consumption, greenhouse gas emissions, criteria pollutants, land use and water consumption.

Activities

- Develop technologies to lower the cost and improve the durability of **fuel cells** in stationary, portable, and transportation applications
- Develop technologies to lower costs and improve the environmental footprint of different domestic **hydrogen production and delivery pathways** at scales ranging from large, centralized production to small, local (distributed) production
  - Develop **hydrogen storage systems** that are more compact, provide higher capacity, and are less costly
  - Conduct **crosscutting research**, including **basic research** on transformative materials and processes and **manufacturing research** to lower high-volume production costs

FACILITATE *Codes and Standards and Safe Practices*

Goals

Identify critical technology gaps, then **develop and validate the scientific data needed** to provide a solid, accepted basis for developing performance-based codes, standards, and regulations.

Develop and disseminate information on the safe operation, handling, and use of hydrogen and fuel cell systems.

Activities

- Research **materials** and **safety** issues
- Research, test, and certify **infrastructure** components
- Develop/evaluate **leak-detection** strategies and provide data on hydrogen leaks
- Develop **training** for emergency personnel
- Provide guidance on **permitting**
- Organize **data sharing** systems
- Develop **fueling quality standards** and test methods
- Create **model codes** and standards
- **Harmonize** at global scale

PARTNERS Include many offices and programs within the following:

- U.S. Department of Agriculture
- U.S. Department of Commerce
- U.S. Department of Defense (including Military Services)
- U.S. Department of Energy
- U.S. Postal Service
- U.S. Department of Transportation
- U.S. Environmental Protection Agency
- Federal Aviation Administration
- U.S. General Services Administration
- U.S. Department of Homeland Security
- National Aeronautics and Space Administration
- U.S. National Park Service
- National Institute of Standards & Technology and university partners
- U.S. National Science Foundation

VALIDATE *Technologies*

Goals

Validate and communicate the real-world performance of pre-commercial hydrogen and fuel cell systems in stationary, portable, and transportation applications.

Activities

- Validate fuel cell and fueling infrastructure **technologies for stationary and portable applications** such as mobile microgrid power generation, fuel cells for back up power and remote use, residential and commercial Combined Heat & Power, and lower-cost technologies
- Validate fuel cell and fueling infrastructure **technologies for transportation applications** such as light-duty (cars) and heavy-duty (buses and trucks) vehicles, material handling equipment, Auxiliary Power Units for tractor trailers and other applications, and renewable-to hydrogen technologies for refueling operations
- Evaluate **alternative fuels** for stationary generation technologies
- Validate **integrated wind- and solar-to-hydrogen** systems as energy storage for variable renewable power
- Create framework for cross-agency **data collection and analysis**
- Report **demonstration results, identify gaps and feed back to R&D**

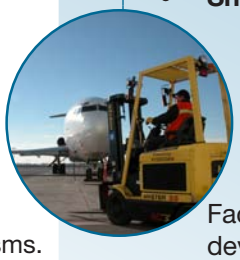
ADOPT TECHNOLOGIES *in Federal Government Operations*

Goals

Become a User – proactively adopt early-market hydrogen and fuel cell fueling systems where economically and environmentally beneficial.

Enable easy procurement of fuel cells within government through existing and new mechanisms.

Identify roadblocks/ limitations and legislative and executive-level solutions



Activities

- Identify and **assess best opportunities** for hydrogen and fuel cell use
- **Showcase** the use of early-market hydrogen and fuel cell products:
  - Lift trucks in warehouses and fleet vehicles
  - Back up power at data centers and communication towers
  - Distributed power generation for building heat and electricity
  - Hydrogen production and fueling installations
  - Quantify deployments and their benefits

  Facilitate the **procurement and/or financing process** (e.g., through development of General Services Administration schedules and model contracts)
- Establish **regional working groups** to collaborate on installation and operations best practices
- Provide **training** for facilities operations and administrative staff
- Support international **partnerships to accelerate deployments**

COMMUNICATE *Results*

Goals

Provide credible, easily accessible, public information on the results and impacts of agency activities in hydrogen and fuel cells through web-based tools, workshops, partnerships, and events.

Activities

- Continue **interagency working groups** on hydrogen and fuel cells
- Improve and maintain **public website** as an information gateway
- Build on partnerships to improve **information exchange** with industry, academia, trade groups, and other stakeholders
- Continue **regional and state outreach**

ACTION AREA 1: *Strengthen and Accelerate Research and Development*

GOAL

Strengthen the national research community in hydrogen and fuel cell R&D activities that address national energy and environmental needs such as reducing petroleum consumption, greenhouse gas emissions, criteria pollutants, land use and water consumption.

While a handful of fuel cell technologies are already on the market today, others require more research and development (R&D) to make costs and performance competitive with conventional and other advanced technologies. R&D on automotive fuel cells and certain classes of stationary and portable power generation fuel cells is needed to overcome cost and performance barriers and make these highly efficient technologies available in applications throughout the economy. Likewise, research on hydrogen production, storage, and infrastructure technologies is needed to continue making progress on low-cost pathways for producing, storing, and delivering cost-competitive carbon-free hydrogen fuel. In accord with their missions, a number of federal agencies are funding hydrogen and fuel cells R&D activities, and interagency collaboration will help to coordinate and enhance these research efforts.

KEY BARRIERS OR CHALLENGES

- **The high cost of system components** and processes for fuel cells and for hydrogen production, delivery and storage systems.
- **Performance including size, weight, reliability, and durability improvements** in fuel cells manufactured at high volumes to ensure their commercial viability for stationary, portable, and transportation applications.
- **Limitations in domestic manufacturing** capabilities.

By sponsoring basic and applied R&D on hydrogen and fuel cells, the federal government helps address the cost and performance barriers to commercialization and provides support for the domestic supplier and manufacturing base.

Critical Needs

Improve fuel cells: Reduce the cost and improve the durability of stationary, portable, and transportation fuel cells.

- Stationary: Develop, characterize, and analyze high-temperature fuel cell technologies (for example, those that are compatible with advanced coal or biomass integrated gasification).
- Portable: Develop, characterize, and analyze hydrogen PEM fuel cell, direct methanol fuel cell and micro solid oxide fuel cell technologies.
- Transportation: Address components such as membranes, catalysts and supports, water transport in the fuel cell stack, balance-of-plant, effects of impurities on fuel cell performance, and characterization and analysis.

Improve hydrogen production and delivery: Reduce the cost and improve the environmental footprint of different domestic hydrogen production and delivery pathways, at scales ranging from large, centralized production to small, local (distributed) production.

Improve hydrogen storage: Develop more compact, higher-capacity, lower cost hydrogen storage systems, with a focus on advanced materials that could store hydrogen at lower pressures and near-ambient temperatures, with reduced volume and weight.

Conduct **crosscutting R&D**, including **basic and applied research** on materials and processes to achieve breakthrough transformations and **manufacturing R&D** to lower component fabrication and stack assembly costs for both stationary and mobile applications. This includes innovative R&D to identify and develop alternative fuels and processes beyond conventional hydrogen or PEM fuel cell systems. Also included is safety related R&D (sensor technologies and risk mitigation strategies) to enable the safe operation of hydrogen and fuel cell technology and the development of appropriate design, codes, standards, and/or enforcement and regulatory mechanisms.

Benefits

Addresses cost and performance barriers to advance hydrogen and fuel cell technologies for widespread commercialization in multiple locations.

Enables a domestic supply base and manufacturing capabilities, including mass commercialization for multiple hydrogen and fuel cell applications.

Develops **transformative materials and increases understanding** through basic and applied research.

ACTION PLAN

Federally-sponsored R&D in five key areas is needed to accelerate the development of hydrogen and fuel cell technologies that can be employed widely throughout the Nation for low cost, safe, efficient, and environmentally sustainable energy:

- Fuel cells
- Hydrogen production
- Hydrogen delivery
- Hydrogen storage
- Cross-cutting R&D (including basic science and manufacturing R&D)

Research to support the development of codes and standards is also needed, as described in the next section of this action plan.

Fuel Cells R&D: R&D that will improve the durability and performance of fuel cell systems and components while reducing cost.

DOD-Army	DOD-DLA	DOD-Navy	DOD-USMC	DOD-DARPA	DOD-Air Force	DOE-EERE	DOE-FE	DOE-SC-BES	DOT	NSF	NASA	NIST	USPS	Activities and Outcomes
✔	✔	✔	✔		✔	✻		✔		✔	✔	✔		**Polymer electrolyte membrane fuel cells:** • New low-platinum-alloys and non-precious metal catalysts • New water, air and thermal management concepts • Characterization of catalyst degradation mechanisms • Chemical and physical system sensors • Molecular modeling
✻		✔		✔		✔		✔		✔	✔			**Direct methanol /liquid fuel cells:** • New catalysts • Molecular modeling • Materials and component design
✔		✔				✔	✻	✔		✔	✔	✔		**High-temperature fuel cells:** • Lower operating temperature electrolytes • Mixed (ionic and electronic) oxide for electrodes • Characterization of reaction processes • Interfacial phenomena and degradation processes
✔		✔				✻	✔		✔				✔	**Hydrogen combustion:** • Internal combustion engines • Turbines • Hydrogen combustion behavior

✻ Activity Lead

Hydrogen Production R&D: R&D that will deliver technical advances and breakthroughs to improve production efficiency, environmental performance, and economics.

DOD-Army	DOD-NAVSEA	DOE-NE	DOE-BER	DOE-EERE	DOE-FE	DOE-SC	NSF	NASA	USDA	Activities and Outcomes
	✔			✔		✻	✔		✔	**Biological processes:** • Biocatalysts • Biomass processes • Fermentation production • Photobiological production • Energy-coupled systems and bioenergetics • Feedstock production
✔	✔			✔	✻	✔		✔		**Fossil-based production:** • Large-scale gasification • Carbon dioxide separation, capture, and sequestration • Distributed production from natural gas/liquid fuels • On-board reformers • Synthesized liquid fuels
	✔	✔		✻		✔	✔	✔		**Electrolytic processes:** • Electrocatalysts • Renewable energy technologies • Small and large-scale systems • High-temperature steam electrolysis
	✔			✻		✔	✔			**Advanced thermochemical processes:** • High-temperature and ultrahigh-temperature water-splitting processes
✔	✔			✔		✻	✔	✔		**Alternative approaches:** • Photocatalytic and photoelectrochemical water splitting • Biomimetric and bio-inspired systems • Methane splitting by solar energy
	✔			✔	✻	✔	✔	✔		**Hydrogen separation and purification:** • New membranes • Advanced purification systems

✻ Activity Lead

Hydrogen Delivery R&D: R&D that will lead to advances that improve delivery safety, range, and energy efficiency, while reducing cost.

DOD-Army	DOD-NAVSEA	DOE-EERE	DOT-PHMSA	NASA	NSF	NIST	DOE-SC-BES	Activities and Outcomes
✔	✔	✻	✔	✔		✔		**Gaseous hydrogen delivery:** • New low-cost pipelines • Use of existing natural gas pipelines, • Fueling stations • Metering and physical properties • Procedures and legal metrology for refueling
	✔	✻	✔	✔				**Liquid hydrogen delivery:** • Liquefaction pipeline • Metering and physical properties
		✻		✔				**Bulk hydrogen storage:** • Underground storage • Gaseous storage • Cryogenic storage
		✻			✔	✔	✔	**Addressing embrittlement, materials development, and diagnostics/characterization**

✻ Activity Lead

Hydrogen Storage R&D

Hydrogen storage is a key enabling technology for the advancement of hydrogen and fuel cell technologies. The DOE Hydrogen Storage R&D activity for vehicle applications supports the development of safe, compact, lightweight, low-cost, durable, and efficient storage systems to achieve a driving range of greater than 300 miles across a range of vehicle platforms. Through three Hydrogen Storage Materials Centers of Excellence (2005–2010), DOE funded national laboratory, industry, and university projects to develop advanced materials solutions for low pressure, on-board hydrogen storage. These centers focused on high capacity metal hydrides; solid and liquid chemical hydrogen carriers; and novel sorbents. Together, they have investigated over 400 different candidate storage systems and produced recommendations on candidate systems for further research.

Additional hydrogen storage R&D investigates advanced conformable and low-cost tank technologies; synthesizes innovative materials; investigates the reactions and kinetics associated with the most promising materials systems; validates the performance for selected materials; and analyzes hydrogen storage systems analysis to assess performance, cost, life-cycle energy efficiencies, and environmental impact.

The DOE R&D investment also includes critical engineering efforts to enable compact, efficient, and lightweight reactor designs and components for on-board vehicular hydrogen storage. The Hydrogen Storage Engineering Center of Excellence, formed in 2008, directs the work of industry, academic, and national laboratory partners to research and develop the necessary engineering models, analyses, data, and system integration issues such as thermal management, to enable the design of improved systems, components, and prototypes with the potential to meet DOE's 2015 and ultimate system targets.

Partners: DOE, NIST

Hydrogen Storage R&D: R&D that will lead to advances that reduce the weight, size, and cost of hydrogen storage systems, while meeting other requirements such as driving range and energy efficiency, refueling, and discharge kinetics.

DOD-Army	DOD-NAVSEA	DOE-EERE	DOE-SC-BES	NSF	NASA	NIST	Activities and Outcomes
	✔	✻		✔		✔	**High pressure gas-phase storage:** • Outer/inner tank • Novel systems • Demonstrations
	✔	✻	✔	✔		✔	**Sorbent/Carbon materials:** • Sorbent nanotube/nanoparticle design and modeling • Manufacturing processes • Novel carbon-related spillover materials • Metal-organic framework (MOF) materials
		✔	✔	✻		✔	**Metal hydrides:** • Storage materials • Complex structures • Characterization of materials • Containment materials • Molecular modeling
		✔	✻		✔		**Alternative chemical storage:** • Liquid carrier materials • Liquid carrier/regeneration processes • Novel chemical storage materials • Characterization of physical mechanisms • Metal-organic framework
✔		✻			✔		**Cryogenic storage:** • Outer/inner tank • Cryo-compressed approaches • Propellants

✻ Activity Lead

Cross-Cutting R&D: Including **basic R&D** that will yield transformative materials and understanding that leapfrogs current incremental improvements to bring more advanced products to market more quickly and **manufacturing R&D** to lower high-volume production costs.

DOD-Army	DOD-DLA	DOE-NAVSEA	DOD-ONR	DOE-EERE	DOE-FE	DOE-SC-BES	NSF	NASA	NIST	Activities and Outcomes
✔	✔	✔	✔	✔	✔	✻	✔	✔	✔	**Novel materials:** • Multifunctional materials and structures • Catalytic materials • Hydrogen storage materials • Membrane materials
✔		✔	✔	✔	✔	✻	✔		✔	**Physical, chemical, and biological processes:** • Catalysis, separations, physical and chemical interactions of materials with hydrogen • Analytical and characterization tools • Biological and biomimetic/bio-inspired hydrogen production • Photocatalytic and photoelectrochemical hydrogen production
		✔		✻	✔				✔	**Manufacturing research:** • Component and system fabrication • Measurements and standards (metrology) for fuel cell manufacturing process control • Quality control and sensors
✔			✔	✻						**Hydrogen Energy storage:** • Enabling intermittent renewable energy resources to be more fully utilized

✻ Activity Lead

ACTION AREA 2:

Accelerate Development & Adoption of Codes, Standards and Safe Practices

GOALS

Identify critical technology gaps, then develop and validate the scientific data needed to provide a solid, accepted basis for performance-based hydrogen and fuel cell codes, standards, and regulations.

Develop and disseminate information on the safe operation, handling, and use of hydrogen and fuel cell systems.

The commercial use of hydrogen and fuel cell technologies depends on the availability of codes and standards for their safe installation, use, operation, and disposal. Regulations are also required where federal oversight or authority is needed. These codes, standards, and regulations provide guidelines for safe system design and operation, that are vital to various personnel including zoning and permitting officials as well as first responders, and encapsulate a detailed understanding of hydrogen behavior that helps first responders who need to react swiftly and effectively to incidents. The federal government can help advance hydrogen and fuel cell technologies by developing and validating the data that are needed to inform consensus-based development of codes and standards, and by expediting the regulatory process. Government agencies can also work together on efforts to develop and harmonize standards and regulations across the nation and around the globe.

KEY BARRIERS OR CHALLENGES

- **Scattered or overlapping roles and responsibilities** among standards and code development organizations and the federal government, which can lengthen or complicate the development of codes, standards, and regulations.
- **Slow adoption or inconsistent interpretation** of codes and standards by state and local code officials.
- **The need for adequate U.S. technical representation from the private sector** at international codes and standards development forums and technical committees.
- **The lack of available data** needed to develop and validate codes, standards, and regulations.
- **The lack of affordable insurance** to cover liability issues.

The federal government is in a unique position to take on certain roles and accomplish certain functions that can help to expedite the process of developing robust codes and standards for the safe deployment and use of hydrogen and fuel cell technology.

Critical Needs

Strengthen the supporting scientific data: Develop and distribute data to strengthen the scientific basis for performance-based codes, standards, and regulations. This work may include R&D, modeling and simulation, development of test methods and certification procedures, and testing and validation.

Develop useful metrics: Develop and disseminate measurement standards to ensure operational safety, accuracy in fuel dispensing, and performance evaluations of fuel cell devices.

Coordinate activities: Facilitate coordinated national and international efforts to prepare, review, and promulgate harmonized codes and standards for infrastructure development and hydrogen technology use. Provide expert technical representation at key industry forums and codes and standards development meetings and develop a global technical regulation for hydrogen technology systems.

Develop and promulgate safety procedures: Establish and ensure safe practices and communicate lessons learned.

Support effective outreach: Prepare and provide timely, accurate, and relevant data, training tools, and other information for stakeholders, including state and local code officials and first responders.

Promote stakeholder acceptance and adoption: Conduct and participate in stakeholder meetings and technical forums to improve understanding of available codes and standards.

Benefits

Expedite development of consensus on consistent, performance-based standards and codes needed for commercialization.

Leverage resources by reducing duplication of effort, combining activities, increasing collaboration, and reducing overall cost.

Provide credible data and information in a timely manner, including data to support risk assessment and quantify risk for underwriters.

Improve outreach, education, and training for state and local code officials and first responders to increase adoption, familiarity, and consistency in the application of codes and standards.

Ensure qualified and sufficient expert representation of U.S. interests and ensure harmonization to represent U.S. interests and ensure harmonization via participation in technical committees.

Develop a useful framework to identify and prioritize data needs, reduce duplication of efforts, and enhance collaboration.

ACTION PLAN

Interagency collaboration in three critical activity areas will accelerate the development, deployment, acceptance, and use of uniform codes, standards, and regulations for hydrogen and fuel cell technologies:

- Research and testing
- Safety and training
- Standards facilitation

Research and Testing

DOE-EERE	DOT	EPA	NIST	Activities	Outcomes
✔	✔		✻	**Research materials issues:** Conduct R&D on materials compatibility issues associated with hydrogen technologies.	**Reliable materials:** Development of safe and durable materials for use in systems such as pipelines and pressurized storage vessels.
✻	✔	✔		**Research safety issues:** Conduct research to support promulgation of standards that provide a level of system safety equal to or higher than existing standards for fuel production, delivery, storage, and use.	**Safety standards and procedures:** Federal Motor Vehicle Safety Standards test procedures and criteria for assessing post-crash hydrogen leakage; electrical isolation of high-voltage components; and hydrogen storage container strength, durability, and fire safety.
✔	✻			**Research, test and certify vehicle and fueling infrastructure components:** Conduct research, testing, and certification for hydrogen and fuel cell vehicle components, subsystems, and equipment.	**Central repository for hydrogen data:** - A comprehensive database containing critical information on the certification and performance of hydrogen fueling components, subsystems, and equipment. - A framework to identify and prioritize data needs reduce duplication of efforts, and enhance collaboration.
✻				**Develop/evaluate leak-detection strategies:** Develop and test technologies to sense, detect, and monitor hydrogen leaks. Evaluate tracers and other detection additives. Develop risk mitigation strategies.	**Reliable leak detection:** Accurate and reliable hydrogen leak detection technology.

Safety and Training

DOE	DOT	Activities	Outcomes
✻		**Provide data on hydrogen leaks:** Evaluate and validate data on unintended hydrogen release for use in developing codes, standards, and emergency response procedures.	**Improved public safety:** Protection of the public, emergency responders, and property from unintended hydrogen fuel releases.
✻	✔	**Develop training for emergency personnel:** Establish training programs for first responders and fire and rescue personnel.	**Trained responders:** Safety training programs specifically designed for first responders.
✻	✔	**Provide guidance on permitting:** Develop materials to facilitate the permitting process for hydrogen fueling stations.	**Reliable information for permitting officials:** A working relationship with local permitting officials that facilitates the adoption of the latest hydrogen fueling and fuel cell system installation codes.

✻ Activity Lead

Standards Facilitation

DOD-DLA	DOE-EE	DOT	EPA	NIST	Activities	Outcomes
✔	✻	✔	✔		**Organize data sharing systems:** Create a combined data collection and analysis framework system that enables data on codes, standards, and regulation projects to be shared among agencies.	**National data analysis system**: Implementation of a common data collection and analysis system in all federally funded codes and standards activities. **Federal responsibility mapping**: A central, publicly accessible database of all federal regulatory roles and responsibilities. *www.eere.energy.gov/hydrogenandfuelcells/codes/*
	✻	✔			**Create model codes and standards:** Facilitate the creation and adoption of model building codes and equipment standards for hydrogen systems.	**National template to clarify and coordinate efforts:** A national template that identifies key standards and codes required for each component of a hydrogen or fuel cell system, controlling government authorities, and which code development organization or standards development organization leads development in each area. **Guidebook for code officials:** A hydrogen-specific and comprehensive building codes document issued by the National Fire Protection Association.
	✻	✔		✔	**Develop fueling standards and test methods:** Establish measurement standards and test methods to ensure the accurate metering of hydrogen at the point of sale and to assist in determining fuel product specifications.	**Fuel quality standards:** A prescribed limit on various impurities in retail fuel, to which fuel cells and fuel production can be engineered. **Commercial standards for hydrogen dispensing:** Development of commercial hydrogen measurement standards, including equipment and quality standards and test procedures, to ensure accurate measurements and fair trade.
	✻	✔			**Harmonize at global scale:** Facilitate the national and international harmonization of regulations and standards for hydrogen fuel cell systems.	**Harmonization of international regulations and standards for fuel cell vehicles, including**: - Comparative testing and evaluation of European and Japanese regulations. - Evaluation and validation of International Organization for Standardization and SAE International standards for fuel cell vehicles. - Leadership of efforts in the World Forum for Harmonization of Vehicle Regulations (WP.29's) Subgroup on Hydrogen Safety to develop a global technical regulation for fuel cell vehicles.

✻ Activity Lead

First Responders Get Hands-On Safety Training

In 2009, DOE launched a one-day course to train first responders to react safely and appropriately to incidents involving hydrogen technologies. The course features hands-on training with a mock fuel cell vehicle to demonstrate conditions that may be encountered when controlling or suppressing a fire in or around a fuel cell vehicle.

The course is helping to raise awareness of fuel cell vehicle safety and procedures. The curriculum reflects input from manufacturers, energy companies, fuel cell vehicle organizations, firefighting organizations, and technical experts from national laboratories. Over 300 (in-person) users have participated to date. An additional 17,000 users have accessed the web-based "Introduction to Hydrogen Safety for First Responders" course.

Partners: DOE, PNNL, Volpe, Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center, and California Fuel Cell Partnership

ACTION AREA 3: *Work with Industry to Validate Technologies under Real-World Operating Conditions*

GOAL

Validate and communicate the performance of pre-commercial or early-market hydrogen and fuel cell systems in real-world stationary, portable, and mobile applications.

Technology validation is essential to demonstrate the viability of pre-commercial hydrogen and fuel cell technologies and to gather real-world data to improve performance and safety. Validation is also essential to conduct "learning-by-doing" that feeds back into the research and technology development cycle and to encourage investments that will allow emerging technologies to bridge the gap between development and commercialization. Federal leadership can facilitate collaborative, public-private validation and demonstration projects that distribute cost and risk while building a repository of publicly accessible, real-world performance data.

KEY BARRIERS OR CHALLENGES

- **The lack of publicly available, credible data** on technology status, cost, performance, and safety.
- **The ability to share or report** on company sensitive data and return feedback on relevant results to refocus R&D can be challenging.

By partnering with industry, states, and others to test and validate technologies, the federal government can fill a necessary role in moving new hydrogen and fuel cell technologies towards markets—by providing platforms for demonstrations and acting as a trusted third party for data collection and analysis efforts.

Critical Needs

Produce validated data on real-world operating performance and costs: Work in partnership with industry to plan and conduct real-world operational tests of integrated systems that are not fully proven in everyday commercial use.

- Validate systems in enough installations to provide statistically significant data on system cost, performance, and safety.
- Evaluate systems against technology and application specific R&D targets and metrics.
- Incorporate robust data collection efforts to measure cost and performance metrics as part of the validation programs.

Make information on technology performance publicly available: Collect, analyze, and publish available data on technology performance, cost, and safety.

- Create data sets and document lessons learned that otherwise would not be available to the private sector.
- Provide performance data to all stakeholders (researchers and technology developers, end - users, capital investors, and others in the project development community, Congress and other policymakers, regulatory agencies and codes and standards groups, and the general public).

Benefits

Leverages resources (financial, manpower, and real property) to reduce any single entity's cost and risk.

Facilitates the development and implementation of standard data collection efforts. Federal partnership will make data public and provide third-party or "honest broker" data validation. It will also facilitate public access to testing facilities and resources. The research, regulatory, and business communities can use this data to assess progress toward R&D targets, identify remaining challenges, and improve their ability to meet all safety codes and standards.

ACTION PLAN

Interagency action and collaboration in three key areas will accelerate the validation of integrated hydrogen and fuel cell systems in multiple systems and applications and provide a framework and mechanism for data gathering and information sharing:

- Stationary and portable power applications
- Mobile applications
- Crosscutting data sharing and technology needs

Stationary and Portable Power Applications

DOE-FE	DOD-Army	DOD-USMC	DOE-EERE	Activities	Outcomes
	✻			**Mobile microgrid power generation system:** Validate a mobile microgrid with up to a 50 kilowatt generation capacity.	**Real-world cost and performance data for distributed stationary power generation:** • Verification and documentation of mobile microgrid hardware with ability to manage and control critical load distributed power generation from renewable sources. • Fuel cells as replacements for diesel generators/ other technologies as backup power in poor air quality areas (e.g., South Coast Air Quality Management District). • Alternative high-efficiency solid oxide fuel cell (SOFC) technologies and system configurations. • Fuel cell CHP systems, including verification of commercial readiness and system durability.
	✻	✔	✔	**Backup power generation:** Validate fuel cell backup power as a replacement for diesel generators or batteries.	
✻			✔	**Stationary generation technologies and fuels:** Validate novel fuel cell systems operating on a variety of fuels for stationary power generation.	
	✔		✻	**Residential and commercial CHP:** Validate fuel cell combined heat and power (CHP) systems in residential and light commercial applications.	
	✻		✔	**Direct methanol fuel cells (DMFCs), SOFCs, reformed methanol fuel cells (RMFCs) and hydrogen PEM fuel cells for portable applications:** Validate fuel cell technologies for portable fuel cell applications.	**Real-world cost and performance data for portable power generation:** • Improved DMFC system performance and projected cost for portable fuel cell applications. Development of manufacturing processes to facilitate commercialization.

✻ Activity Lead

Mobile Applications

DOE-EERE	DOE-FE	DOD-DLA	DOD-Army	DOD-Navy	DOD-USMC	USPS	DOT-FTA	DOI-NPS	Activities	Outcomes
✻			✔						**Light-duty fuel cell vehicles:** Validate light-duty PEM fuel cell vehicles and fueling infrastructure under real-world operating conditions, in conjunction with vehicle producers and fuel suppliers.	**Real-world cost and performance data for fuel cell vehicles, forklifts, and fueling infrastructure:** Publicly available composite data products documenting the following: • Light-duty vehicle technology status relative to specific targets including fuel cell durability, efficiency, vehicle driving range, and fuel cost. • Fuel cell bus durability, efficiency, vehicle driving range, fuel cost, and emissions. • Fuel cell lift truck and airport ground support equipment cost and business value proposition. • Vehicle fueling performance, safety, cost, and benefits.
✔		✔	✔				✻		**Heavy-duty fuel cell vehicles:** Validate heavy-duty fuel cell vehicles (e.g., buses) and fueling infrastructure under real-world operating conditions, in conjunction with vehicle producers and fuel suppliers.	
✔			✻	✔					**Auxiliary Power Units (APUs) for tractor trailers:** Validate fuel cell APUs in tractor trailer trucks as replacements for diesel APUs.	**Real-world cost and performance data for fuel cell APUs:** Documentation of the performance of fuel cell APUs compared to that of alternatives (e.g., diesel APUs) with respect to reliability, efficiency, cost, environmental emissions, user operation, and safety.
✻			✔						**Renewable hydrogen fueling stations:** Demonstrate hydrogen production using renewable energy sources to power hydrogen vehicle fueling stations.	
✔			✔				✻		**Develop fuel cell fleet strategies:** Validate a fuel cell bus "fleet strategy" program.	**Business case for fleet adoption of urban fuel cell buses:** Establish the business case for fleet-wide adoption of fuel cell buses in metropolitan areas.
✻			✔						**Demonstrate fuel cell combined heat, hydrogen, and power (CHHP) systems** as a source of distributed heat/power and hydrogen vehicle fuel.	**Increased hydrogen fueling infrastructure availability:** For example, DOE demonstration of CHHP in Fountain Valley, CA supports federal hydrogen fuel cell vehicle deployments in and around Orange County, CA.

✻ Activity Lead

Crosscutting Data Sharing and Technology Needs

DOE-EERE	DOE-FE	DOD-DLA	DOT	DOT-FTA	DOD-ONR	Activities	Outcomes
✻	✔	✔	✔	✔		**Report technology validation results:** Publish an annual report on the results of demonstrations funded by federal government agencies with input from all agencies supporting technology validation projects.	**Public reports:** Public reports documenting the results of all federally funded hydrogen and fuel cell technology validation efforts.
✻	✔	✔	✔	✔	✔	**Create a framework for cross-agency data collection and analysis:** Create a combined data collection and analysis system to support the sharing of technology validation project data among agencies.	**Central repository of demonstration activities:** Implementation of a common data collection and analysis system used by all federally funded demonstration activities creates a central, credible, publicly accessible database on technology validation results.

✻ Activity Lead

Hydrogen Road Tour 2008

From August 11–23rd, several hydrogen-powered vehicles[1] toured the United States, going through 31 cities in 18 states over 13 days. The tour educated the crowds in each city about hydrogen as a transportation fuel and the progress the technology has made. Representatives from the U.S. Department of Transportation and DOE spoke on the progress being made to:

- Ensure that hydrogen transportation technologies are safe.
- Define design standards for future hydrogen vehicles and infrastructure.
- Accelerate technology transfer.
- Increase public understanding of hydrogen-powered transportation.

[1]BMW Hydrogen Series 7, Daimler Mercedes-Benz F-Cell, GM Chevy Equinox FCV, Honda FCX Clarity, Hyundai Tucson FCV, Kia Sportage FCV, Nissan X-Trail FCV, Toyota Highlander FCHV, and a Volkswagen Touran and Tiguan HyMotion

ACTION AREA 4: *Adopt technologies in U.S. government operations*

GOALS

Using early market hydrogen and fuel cell fueling systems to meet agency federal government energy and environmental goals.

Enable easy procurement of fuel cells within government through well-known mechanisms such as single contract authorities and General Services Administration schedules.

As one of the nation's largest energy consumers, the federal government has a tremendous opportunity in using advanced energy technologies in its facilities and operations. Adopting early-market hydrogen and fuel cell technologies will strengthen the government's efforts to improve its energy efficiency and environmental sustainability. In addition, federal early adoption will create a much-needed market "pull" that will drive further commercialization of these technologies, exercise codes and standards, and reduce perceived risks that drive up costs such as insurance. Activities to analyze operational experience and evaluate and communicate the value proposition will help others understand the benefits of fuel cells in different applications. Improvements realized in early markets will also help to support technology advances needed for widespread use of hydrogen and fuel cells in a broad range of consumer applications.

KEY BARRIERS OR CHALLENGES

- **The risk of technology use is high, and the financial pay-off is long-term or high-risk.** Therefore, there are few end-users, financers, insurers, and project developers willing to adopt technologies with unproven performance or return on investment in real-world operating environments.
- **End users are unfamiliar with hydrogen and fuel cells** and hesitant to adopt new technology.
- **Lack of experience** with implementing new or unfamiliar codes and standards for hydrogen and fuel cell projects.
- **Higher first-cost compared to conventional technologies** make it difficult to justify procuring a fuel cell system, and life-cycle benefits are not well understood or documented. Potential users do not understand how to benefit from tax incentives.
- **Procurement guidelines or procedures that hinder purchasing,** including limitations on the incremental cost allowed for alternative energy technologies or lack of methods to fully monetize costs and benefits of alternative systems.

Federal agencies can help establish early markets for hydrogen and fuel cells, improve their own energy and environmental performance, and demonstrate the technology cost and performance benefits to potential users in both the public and private sectors.

Critical Needs

Provide early markets for hydrogen and fuel cell technologies: Use commercially ready hydrogen and fuel cell products for stationary, portable, and transportation applications in federal operations.

Ease federal purchasing: Facilitate the procurement and/or financing process by providing model language, technical assistance, training, and contract/purchasing mechanisms that encourage the inclusion of hydrogen and fuel cell technologies into requests for proposals, facility energy assessments and recommendations, bulk/bundled purchases, the General Services Administration (GSA) schedule, power purchase agreements, and loan and grant awards.

Promote tax benefits: Demonstrate how existing tax credits and grants can be used to minimize the government's cost for hydrogen and fuel cells.

Provide unbiased performance data and demonstrate the value proposition: Collect, analyze, and publish data on technology performance, life-cycle cost, and the safety of federal deployments to show performance history and business/value proposition.

Raise public awareness: Conduct public outreach and education activities, such as visible demonstrations at public or prominent locations (e.g., national parks) and distribute case studies and success stories.

Build end users' technical expertise: Provide technical information to support workforce training and enable interagency mentoring to share lessons learned and best practices.

Make refueling easy: Establish publicly accessible hydrogen fueling stations to provide network nodes for early fueling infrastructure; open existing federal hydrogen stations to all authorized users.

Support state and local government users: Partner with state and regional programs to facilitate fuel cell use at federal field offices and state and local government levels (including U.S. Environmental Protection Agency Regional Offices and U.S. Department of Agriculture (USDA)-Rural Development).

Benefits

Expands the venues for technology deployment to include the wide range of facilities and equipment owned and/or operated by the federal government.

Increases adoption of hydrogen and fuel cells across the federal government and provides certainty for potential private industry users.

Exercises codes and standards to assist further development of best practices and case studies.

Raises the visibility of hydrogen and fuel cells as a viable option for use by other public- and private-sector users and demonstrates applications that are best served by the different technologies.

Provides business case data that enables potential users to assess the life-cycle benefits of hydrogen and fuel cells relative to alternative technologies.

Provides opportunities and mechanisms for agencies to coordinate on bulk or bundled purchases of hydrogen and fuel cell equipment to streamline the procurement process and lower unit costs.

Increases the market demand for hydrogen and fuel cell technologies, which will increase manufacturing capabilities, establish a domestic supplier base, and reduce consumer cost through market competition and economies of scale.

ACTION PLAN

Interagency collaboration in four critical activity areas could realistically accelerate adoption of hydrogen and fuel cell technologies in federal facilities while reaping national energy efficiency and environmental benefits and creating and sustaining the domestic market for fuel cell technologies:

- Assessment and evaluation
- Purchasing and financing
- Outreach and information-sharing
- Deployment and installation

Assessment and Evaluation

DOD-Army	DOE-EERE	DOD	FAA	GSA	Activities	Outcomes
	✻	✔		✔	**Provide technical support for distributed power project assessment:** Make technical experts available to assist in evaluating project feasibility and engage government facilities managers.	**Facilitated use of fuel cells:** U.S. Department of Energy (DOE) technical assistance is provided to evaluate projects technical feasibility and determine the best financing options. GSA facilities personnel work closely with tenant organizations.
	✻	✔			**Assess federal facilities:** Conduct assessments of federal facilities and installations, to identify the best opportunities for using fuel cells.	**A report documenting opportunities in federal facilities:** A report that identifies, by major installation and region, the best target applications for fuel cells in federal facilities and installations.
✻	✔		✔		**Fuel cells for remote use:** Operate and verify fuel cell backup power systems in remote and emergency telecommunications applications.	**Real-world cost and performance data for distributed stationary power generation:** Fuel cells as replacements for battery power backup in remote locations and emergency telecommunications.

Purchasing and Financing

DOD-DLA	GSA	Activities	Outcomes
✔	✻	**Ensure GSA schedule incorporation:** Ensure fuel cell products and services are on GSA schedules.	**Streamlined purchasing mechanisms:** GSA schedules that contain preapproved rate agreements allow federal buyers to easily procure fuel cells for a variety of applications.
✻		**Provide support for special contracting mechanisms:** Ensure that federal agencies without in-house contracting experience can utilize financing/contracting mechanisms such as utility energy service contracts (UESCs), energy saving performance contracts (ESPCs), and power purchase agreements (PPAs).	**Leveraging and sharing of procurement expertise:** The contracting expertise of U.S. Defense Logistics Agency (DLA) Defense Energy Support Center and DOE is available to support other federal agencies that want to use ESPC, UESC, and PPA procurements.

✻ Activity Lead

Outreach and Information Sharing

DOE	DOE-EERE	USDA	DOD-Army	DOD-DLA	DOD-ONR	DOT-FTA	DOC	DOI-NPS	FAA	NASA	DOD-Marine Corps, Army, Navy, Air Force	Activities	Outcomes
✻			✔	✔			✔					**Create needed training resources:** Coordinate the development of training modules that can be used by agencies implementing fuel cell projects.	**Training materials:** Training modules are available online to agencies implementing hydrogen and fuel cell projects. Topics include general awareness, hydrogen safety/first response, fueling, and operations.
✔			✻	✔				✔	✔	✔	✔	**Gather and share lessons learned:** Showcase the use of hydrogen and fuel cells in operations and educate other federal agencies on the experiences learned from using fuel cells.	**Encouragement for early adopters:** Feedback from agencies that have successfully deployed hydrogen and fuel cells builds confidence for first-time early adopters.
	✻				✔							**Renewable-to-hydrogen technologies:** Operate and verify integrated wind-to-hydrogen and solar-to-hydrogen fuel cell systems performance as energy storage solutions for intermittent renewable resources.	**Develop value proposition of hydrogen production and fuel cell technologies as energy storage for wind and solar resources**

✻ Activity Lead

The Defense Logistics Agency Hydrogen and Fuel Cell Pilot Program

The Defense Logistics Agency (DLA) Hydrogen and Fuel Cell Pilot Program serves a dual purpose: encouraging a manufacturing base for hydrogen and fuel cell technologies and evaluating technology applications for practical uses in the U.S. Department of Defense and the broader commercial marketplace. The program has been targeting warehouse operations, retrofitting and supplying new forklifts with fuel cells powered by hydrogen dispensed on site.

The program is implementing four pilot projects at sites around the country. The ribbon cutting ceremony at the Defense Depot Susquehanna, Pennsylvania (DDSP), the first to begin operations, took place on February 10, 2009. There, 20 existing forklifts and 20 new forklifts were outfitted with fuel cells from two different fuel cell producers. A storage and indoor hydrogen dispensing system also opened at the depot. As part of the program, operators received training on the safety and dispensing of hydrogen, while other employees received general hydrogen and fuel cell awareness training. The forklift fleet utilizes nearly 750 kilograms of hydrogen through roughly 1,200 refuelings per month, making it one of the largest of its kind in the nation. A new project at Warner Robins, GA has commenced, and two other sites are expected to begin over the next two years.

The pilot program has been further enhanced through coordination between DLA and the DOE's National Renewable Energy Laboratory (NREL). NREL provided a fire hazard analysis that ensured that the indoor dispensing infrastructure design included safety requirements. This effort produced a template for use in future public and private sector applications that had not previously existed. Data from this program are also being aggregated with other data that NREL has been gathering for several years to track the performance of a range of fuel cell technologies in various applications. The data are also part of an effort to create and expand the business case for hydrogen and fuel cells.

Partners: DOE, DOD-DLA

Deployment and Installation

DOE	DOE-EERE	Air Force	NASA	USPS	DOD-Army	DOD-Navy	Marine Corps	DOD-DLA	DOT-FTA	USDA	DOI	FAA	Activities	Outcomes
✻										✔			**Install and use fuel cells for stationary power production or combined heat and power (CHP) in federal facilities** to produce clean, reliable power and provide a more efficient means of heating and cooling.	**Fuel cell CHP for federal facilities:** For example, 200-kilowatt fuel cells installed in combination with absorption chillers/other heat recovery devices provide utility-grade electrical power to an Air National Guard complex.
	✔			✔	✔			✻				✔	**Install and use fuel cell-powered material handling and ground support equipment,** including forklifts and other material handling equipment.	**Business case for fuel cell materials handling and airport ground support equipment:** For example, the use of fuel cell-powered material handling equipment in DLA warehouses (and associated analysis of performance data) provides data to develop a business case for their use by other federal agencies and private businesses. Disseminate information from Recovery Act deployments.
	✔	✔			✔			✻				✔	**Fuel cell-powered material handling equipment and airport ground support equipment:** Operate and verify fuel cell-powered material handling equipment and associated fueling infrastructure at warehouse and shipping facilities.	
✔		✔	✔		✻		✔		✔		✔		**Install and use fuel cells for back-up power** or in uninterrupted power supply systems for fail-safe applications.	**PEM Fuel Cell Backup Power:** For example, FAA effort covering 25 Federal telecommunications installations. These projects will provide five years of turnkey emergency backup power.
✔	✻					✔							**Install and use integrated renewable systems** to support energy storage of intermittent renewables.	**Improved renewable energy storage and system reliability:** DOE/DOD project demonstrates viability of hydrogen and fuel cell as an energy carrier/producer during times of renewable variability.
	✔								✻				**Support global fuel cell bus programs:** Continue collaborating with international organizations on use of hydrogen fueled buses.	**Information sharing on bus deployments:** Continued collaboration with international organizations on deployment and demonstrations of hydrogen buses around the world; development of lessons learned.

✻ Activity Lead

ACTION AREA 5: *Track and Communicate Results*

GOAL

Provide credible, easily accessible public information on the results and impacts of agency activities in fuel cells through web-based tools, workshops, partnerships, and special events.

Communicating the results and achievements of hydrogen and fuel cell research, developments, and demonstration (RD&D) programs is essential to accelerate progress, show proper stewardship of federal resources, encourage public interest in and use of these technologies, and build the information sharing and partnerships among industry, government, and academia that are essential to successful RD&D and commercialization. Clear, effective communications and easy-to-use mechanisms to track technology demonstrations and deployments will help raise knowledge and awareness about the benefits and applications of hydrogen and fuel cells and increase market acceptance.

KEY BARRIERS OR CHALLENGES

- **Maintaining and distributing publicly available, up-to-date, validated data and information** to increase public understanding of and access to federal hydrogen and fuel cell activities.
- **Providing effective interagency communication mechanisms** to ensure that projects are coordinated, information is shared, and experiences are exchanged.

By providing technically accurate, trusted information in a timely manner, and in formats and forums that are most useful for end users, the federal government can play an important role in increasing knowledge and awareness of the status, progress, and applications of hydrogen and fuel cells and promote information exchange with industry, academia, state and regional stakeholders, safety and code officials, and federal agency peers.

Critical Needs

Ensure effective information sharing: Use and enhance existing interagency coordination and outreach mechanisms to ensure clear communication among federal agencies and regularly report results of hydrogen and fuel cell research, development, demonstration, and deployment activities. This work may include the following:

- Use the Interagency Working Group and Interagency Task Force to share results and identify opportunities for projects that leverage resources and agency expertise.
- Enhance the interagency website to make it a more comprehensive, transparent public gateway to data, information products, and training tools resulting from federal hydrogen and fuel cell activities.
- Leverage existing partnerships with trade groups and stakeholder organizations such as the U.S. Fuel Cell Council, National Hydrogen Association, Clean Cities Partnership, and the California Fuel Cell Partnership (and other state-based organizations).

Use public forums to disseminate information and gather feedback: Use public events and national conferences to share results and obtain input from industry, safety and code officials, state and local governments, trade groups, researchers, educators, and other organizations.

Benefits

Translates RD&D and programmatic information into easily accessible print, multimedia, and online resources (such as the hydrogen.gov website) that keep the public updated on hydrogen and fuel cell program activity.

Facilitates regular, easy information exchange among federal agencies about ongoing and planned hydrogen and fuel cell activities.

ACTION PLAN

Federal agencies will pursue a range of activities to track and communicate results on hydrogen and fuel cell RD&D, both to inform outside stakeholders and to share information among federal programs.

DOE	DOD	DOT	NIST	USDA	All federal agencies with interest	Activities	Outcomes
✻	✔				✔	**Increase interagency information sharing:** Use the Interagency Working Group and Interagency Task Force meetings to share results and identify opportunities for projects that leverage resources and agency expertise.	**Task force and working group information sharing:** Monthly Interagency Working Group meetings and periodic Interagency Task Force meetings facilitate regular updates and information exchange on RD&D progress and plans across federal agencies at the staff and senior program management levels.
✻					✔	**Improve public website:** Enhance and maintain the interagency website *www.hydrogen.gov* to make it a more comprehensive, transparent public gateway to data, information, and training tools resulting from federal hydrogen and fuel cell activities.	**Comprehensive web portal:** The interagency website presents up-to-date, easily accessible information on hydrogen and fuel cells, including agency budget information and provides an organized method of tracking agency projects.
✻	✔	✔	✔	✔		**Increase information sharing with industry and academia:** Use public events such as the U.S. Department of Energy (DOE) Annual Merit Review to share results and obtain input from industry and academia.	**Information exchange at Reviews and Workshops:** Meeting such as the DOE Annual Merit Review and Peer Evaluation and the annual SECA Workshop provides an annual forum to communicate progress on RD&D projects and to gather feedback from peer reviews conducted by outside experts.
✻						**Use Hydrogen and Fuel Cells Technical Advisory Committee (HTAC) meetings to improve information sharing:** Use HTAC meetings to share the results of federal agency hydrogen and fuel cell activities and obtain input from industry and academia.	**Technical input to support programmatic decision-making:** HTAC provides advice to the Secretary of Energy on technical and programmatic issues related to DOE's hydrogen and fuel cell RD&D program.
✻						**Continue regional and state outreach:** Continue State and Regional Hydrogen Initiatives Group participation and outreach.	**State and regional information sharing:** The bimonthly webinars and annual meeting of the State and Regional Hydrogen Initiatives Group provide state and regional initiative leaders with an opportunity to share information and lessons learned.
✻						**Increase international information sharing:** Use groups such as The International Partnership for Hydrogen and Fuel Cells in the Economy and the International Energy Agency to update international partners on hydrogen and fuel cell activities and monitor global progress.	

✻ Activity Lead

Hydrogen Analysis Resource Center Website

The Hydrogen Analysis Resource Center website (www.hydrogen.pnl.gov), supported by DOE-EERE, provides well-documented, reliable data for the analysis of hydrogen and fuel cells in the United States. The website includes several calculators that perform useful conversions and other simple calculations relevant to hydrogen and fuel cells. The site also links to websites housing more sophisticated analysis tools, such as the Hydrogen Analysis (H2A) Project website; the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) website; and others.

The data and tools collected on this website give users the information and instruments needed to further their own knowledge of hydrogen and fuel cells. The website contains data from a number of federal agencies, national laboratories, and private organizations—including the U.S. Department of Energy, the U.S. Department of Commerce, the U.S. Department of Transportation, the U.S. Environmental Protection Agency, the Energy Information Administration, Argonne National Laboratory, National Renewable Energy Laboratory (NREL), the Pacific Northwest National Laboratory, the National Academy of Engineering, and the National Institute of Standards and Technology.

By collaborating to generate and share the best information available, these government agencies and organizations are promoting the use of hydrogen and fuel cells by providing students, researchers, and other interested parties the information and data they need to perform accurate and thorough financial and technical analyses.

Partners: DOE, DOC, DOT, EPA

Federal Hydrogen and Fuel Cell Web Sites	
DOE-EERE	hydrogen.energy.gov/
DOE-FE	www.seca.doe.gov
DOT	hydrogen.dot.gov
NASA	www.nasa.gov/vision/earth/technologies/hydrogen.htm
NIST	www.nist.gov/hydrogen.cfm
USPS	www.usps.com/green/factsheets/vehicles.htm

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