

Hydrogen Infrastructure Sub Committee Report

2012 – Draft 6

ACCELERATING THE HYDROGEN INFRASTRUCTURE

OBJECTIVE

The objective of this document is to assemble information on worldwide hydrogen infrastructure development. Key activities are cited that support the growing use of hydrogen as an energy carrier, energy storage media, and fuel. A second objective is to identify hydrogen infrastructure opportunities for the DOE in support of the growing use of hydrogen in the U.S. This discussion includes seven sections as follows:

- Introduction
- Infrastructure activities targeted to automotive programs
- Current non-automotive hydrogen/fuel-cell infrastructure initiatives.
- International infrastructure developments
- Safety, codes, standards, regulations, and permitting
- Hydrogen infrastructure for industrial hydrogen
- Recommendations

Introduction

The primary focus of hydrogen stationary storage technology in the U.S. is the development and implementation of infrastructure at locations targeted for initial introduction of fuel cell vehicles, and other fuel cell and energy storage applications. Successful implementation requires **leadership and vision**. The role of government is a key enabler as is execution by industrial partners (OEMs and hydrogen suppliers). The DOE should set policy, work with Congress to create incentives, and craft a plan with industry and the states. The technology has progressed well. Costs are declining. The move forward is urgent. A National message from the highest levels of government is part of the solution. We need to see continued technology development, infrastructure, and a complete set of final codes and standards.

“As technological progress on vehicle hydrogen storage continues, the lack of hydrogen refueling infrastructure is increasingly cited as a major barrier to commercialization.”

(Ref. B. Bush, O. Sozinova, and M. Melaina in “Optional Regional layout of Least-Cost Hydrogen Infrastructure”)

Simply stated the near term challenge is the transitioning to a hydrogen infrastructure while reducing the near term financial risks. To do so, we need:

- Government leadership and sustained support
- Energy policies that recognize and define the role of hydrogen in transportation
- Sustained incentives that reduce the near term risks for automakers, fuel suppliers, fueling station owners, and consumers

- Assured refueling availability in advance of vehicle introduction including station siting and permitting and nationally and locally accepted codes and standards.

Infrastructure activities targeted to automotive programs

Early deployment. The deployment of hydrogen refueling station networks in concentrated geographic areas is the approach currently being proposed to support early vehicle introductions. The co-location of refueling stations in clusters would minimize travel time to a station and maximize the demand at each station. The US government has an important role to play in station roll out so that stations and vehicles are introduced together. General Motors estimates the installation cost for a station is roughly \$1M for a 100 kg/day facility. The economic risk of a station can be expected to be high for stations built in advance of a significant vehicle population when the utilization is low for the first 3-5 years. Low volume during this early transition period is a significant business challenge and a major issue to be addressed. In fact, even as the vehicle fleet is expanding, fueling infrastructure must be balanced to demand for optimum station utilization and to ensure lowest economic risk for the station operator and fuel cost for the consumer. (Ref. “Hydrogen Fueling Infrastructure Assessment”, General Motors Publication 11,065, Dec. 2007)

The introduction of new infrastructure is challenged not only by the dispersed population areas in the US and financing/ profitability issues but also by the dispersed legislative and regulatory authority. Public policies and streamlining of necessary codes, standards, and regulations need engagement at the state and local level.

A report prepared by McKinsey and Company gives support to the value of fuel cells as part of a national portfolio for energy infrastructure. The report concludes that the infrastructure for FCEVs could be cost efficient within a decade and that mass deployment of FCEVs cannot be left to individual companies. A coordinated investment plan with facilitating legislation is needed and the long lead times create urgency. (Ref. http://www.hydrogen.energy.gov/pdfs/htac_02_2011_mckinsey_thomas.pdf)

There are currently 215 hydrogen fueling stations worldwide (see Table 2 below) and 122 more are in final planning. Twelve new hydrogen stations were opened worldwide in 2011.

Hydrogen Fueling Stations 2011	
Europe	85
US-North America	80
Asia-Pacific	47
Latin America	3
Total	215

(Ref. www. H2stations.org)

Table 1: Hydrogen Fueling Stations worldwide, 2011

Most of these stations are private but the number of public stations is expected to increase in the next 3-5 years.

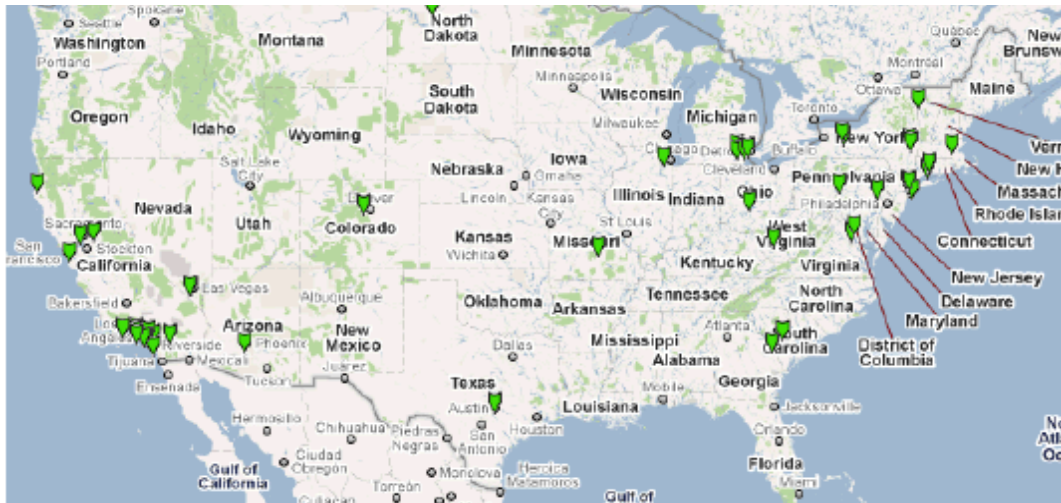


Figure X. Location of hydrogen fueling stations in the US

The three leading deployment areas in the US are Hawaii, California, and New York. Activities for these states are described below.

The state of **Hawaii** has established an objective to reduce fossil fuel consumption and reduce green house gas emissions. In Hawaii GM and The Gas Company are partnering to bring fuel cell vehicles to the state. The plan is to use hydrogen blended with utility gas in the existing pipeline infrastructure on Oahu followed by separation of the hydrogen at fueling stations using known pressure swing adsorption technology. Hawaii has a hydrogen production capability of about 7,000 kg/day (enough to support a fleet of 10,000 to 15,000 vehicles) and existing facilities can increase this production by 40%. As a step towards FCV introduction, on February 23, 2012, a fleet of 16 GM FCVs was commissioned at Fort Shafter in Honolulu to provide the military with data and experience with fuel cell technology, including exportable power for field and emergency operations. The demonstration program also includes the installation and operation of electrolyzer refueling stations at appropriate military facilities across Oahu. The program is supported by the Army Tank Automotive Research Development Engineering Center (TARDEC), Office of Naval Research (ONR) and the Air Force Research Laboratories (AFRL).

In the continental US, **California** leads in the development of infrastructure for hydrogen fueled vehicles. Several models have been developed that can be used to assess the number of refueling stations needed in an urban area. One model is based on driving time to the nearest station and was applied to each of 4 metropolitan areas: Los Angeles, San Francisco, Sacramento, and San Diego. The average travel time was shown to be 7.1 minutes initially and 3.9 minutes as the market expanded. Another model described in the Hydrogen Highway report bases the number of stations on populations and gives a relatively similar result. (Ref. California EPA, 2005, Summary of Findings and Recommendations for the CA H₂ Net, http://www.hydrogenhighway.ca.gov/plan/reports/volume1_050505pdf. And Michael Nicholas, Joan Ogden, "Detailed Analysis of Urban Station Siting for the California Hydrogen Highway Network")

The cost of hydrogen has been forecast for the Los Angeles area based on the number of fuel cell vehicles, the number of refueling stations and their placement for three time periods taking into account the cost of capital, station operating expenses, and the hydrogen production. These calculations forecast that, if the hydrogen can be sold for \$10/kg, the initial investment

can be recouped by 2024. (Ref. An Analysis of Near Term Hydrogen Vehicle Roll Out Scenarios for Southern California. Michael Nichols and Joan Ogden.)

The California Fuel Cell partnership (CaFCP) is a member organization working to identify actions needed for the commercialization of fuel cell vehicles. CAFCP released an action plan in April 2010 entitled "Hydrogen Fuel Cell Vehicle and Station Deployment Plan. A Strategy for Meeting the Challenge Ahead." This report identifies three primary areas of focus: (1) build hydrogen stations in early vehicle introduction sites, (2) support the fuel cell bus program, and (3) develop and implement codes and standards, regulations and a permitting process that will enable retail sale of hydrogen as a fuel. The action plan targets the commercial launch in 2015 and recognizes the need to take steps now and refine strategies as progress is made.

California has 37 hydrogen fueling stations of which 8 are public. Another 15 public stations are under development. Financing for station development has come from the Alternative and Renewable Fuel and Vehicle Technology Program (AB118 program). The California Energy Commission (CEC) awarded the AB118 \$22.7M between 2008 and 2011, including \$15.7M for hydrogen stations. The CEC has budgeted \$18.7M for stations in FY2012 and another \$11 million for FY2013.

Finally, what is believed to be the world's first Trigeneration facility opened in Fountain Valley, CA in August, 2011. This system produces 250 kW of electricity/hr and 100kg H₂/day. A portion of the hydrogen produced is for motor vehicle fuel.

New York State has an initiative underway on "Developing a Hydrogen Powered Economy." State Assemblyman Joseph Morella has been developing a public-private partnership with the New York Legislature, hydrogen infrastructure suppliers, major fuel cell vehicle OEMs, NYSERDA (New York State Energy Research and Development Authority), Brookhaven National laboratory, and others capable of supporting initial fuel cell vehicle commercialization in the 2015 time frame and beyond. Another goal focuses on job creation building on the current supply base being established in part by General Motors in New York. This initiative sets New York on a path to implement Green Technologies and reduce green house gas emissions. The partners recognize the need for a cohesive plan statewide that will include all sectors as well as the planning and decision making needed for infrastructure projects with long lead times.

In December 2011 a 121 foot wind turbine was opened in Hempstead, NY to generate hydrogen for the town's 2 fuel cell vehicles and a hydrogen/natural gas bus.

Other states:

In 2011 the nation's first multi-use fueling station was opened in Graniteville, **South Carolina**. This station supplies hydrogen directly for industrial, commercial and government use.

In November, 2011 in Naperville, **Illinois** a Green fuels Depot was opened that uses a gasifier to convert collected yard residue into three fuels (electricity, hydrogen, and ethanol).

Many states have had policy actions during 2011 that provide incentives for fuel cell and hydrogen fueling stations. These incentives take the form of tax credits, funding, loans, etc. A list is available at <http://www.fuelcells.org/2011StatesH2FCWrapUp.pdf>.

Current Non-Automotive Hydrogen/Fuel Cell Infrastructure Initiatives

Industrial applications are increasing steadily for uses such as distributed power, combined heat and power (CHP) for buildings, industrial equipment (e.g. forklifts), back-up/ stand-by power, and portable power.

There were approximately 3,000 hydrogen fueled forklifts deployed in 2011 and 99% are in the US. The fuel cost is critical and the costs are lower for new warehouses than for existing buildings.

CHP is growing in Japan but almost exclusively in the residential sector.;

International Hydrogen Infrastructure

There are clear benefits of developing and implementing the hydrogen infrastructure in concert with other countries. Hydrogen as a fuel, an energy carrier, and an energy storage media carrier can reduce the global carbon footprint which is a global benefit. Working together creates an economy of scale for market development and will avoid redundancy and enable a global market for products. Reducing petroleum use for transportation will also benefit energy security. and sharing of knowledge and experience can speed implementation. The US can learn from the well coordinated approach to infrastructure roll out in Europe and Japan. Such organization and coordination requires leadership from the highest level of government.. The US needs to move beyond dialogue on infrastructure in order to have a major role and market for our products.

Europe and European Union

The leading European countries in the development of hydrogen infrastructure are Germany, Sweden, Norway, and Denmark. Major activities are noted below.

The Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) is the European private-public partnership working towards acceleration of market deployment of fuel cells and hydrogen technologies: The FCH JU goal is to deliver robust hydrogen supply and fuel cell technologies developed to the point of commercialization. For **the automotive sector**, the aim is to achieve breakthroughs in bottleneck technologies and to enable industry to make the large-scale commercialization decisions necessary to achieve mass market growth in the time-frame 2015-2020. For **stationary fuel cell systems** (residential and commercial) and portable applications, the JU will provide the technology base to initiate market growth from 2010-2015 long-term and breakthrough-orientated research. FCH-JU supports:

- long-term and breakthrough-orientated research
- applied research and technological development
- demonstration programs
- support actions, including pre-competitive research

The European regions and Municipalities Partnership for Hydrogen and Fuel Cells (HyRaMP) was founded in 2008 and is influential in the support of various projects.

Germany is the leading European country for hydrogen and fuel cell technology. The focus of German activity is a national program: The National Organization for Hydrogen and Fuel Cell Technologies, NOW.¹ NOW was conceived as a public-private collaboration and is managed by a board that includes major industrial and public sector institutions. It was given a national mandate by the German government in 2005, with 10 year funding that provides certainty and stability.

NOW coordinates the National Innovation Program for Hydrogen and Fuel Cells (NIP), which has grown into a €1.4 billion (\$1.87 billion²) research and demonstration program. Approximately 55% of NIP program funding supports transportation projects, 35% supports fuel cell development for homes and businesses, and 10% supports development aimed at specialty markets. About 30% of the funds support research and about 70% is earmarked for demonstration programs. Vehicle and infrastructure programs are overseen by the Clean Energy Partnership (CEP), a 13-member consortium; residential fuel cell demonstrations are overseen by Callux, an 11-member consortium.

NOW is a central player in H₂Mobility, an industry coalition with a mandate to develop a business plan for infrastructure deployment in Germany. Launched in September, 2009, H₂Mobility is a 13-member public-private partnership that encompasses a Memorandum of Understanding signed by major companies for the build-up of the hydrogen infrastructure in Germany. The two stages of the plan are: (1) to evaluate options for hydrogen fueling stations and (2) the introduction of hydrogen stations to support the roll out of hydrogen fueled vehicles in 2015. Further a Letter of Understanding was signed in September 2009 by the auto manufacturers which includes a commitment to the development and market introduction of fuel cell vehicles.

(Ref. Ian Williamson, Air Products presentation to HTAC, June 2010). The Clean Energy Partnership is a 15-member auto-oil partnership with the goal to coordinate hydrogen availability and vehicle deployment. One innovation is the development of modular station specifications that are designed to reduce cost through standardization.

In 2011 there were 12 public hydrogen fueling stations in Germany and an additional 4 under construction. Europe's largest hydrogen fuel station was opened in Hamburg on 20 February 2012 with a fueling capacity of 750 kg hydrogen per day.

¹ Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie. Also see: http://www.hpath.org/resources/additional%20material/6_bonhoff_2009_amr.pdf

In **Denmark** the hydrogen initiatives in the Danish Energy Plan 2020 published on 12 March 2012 provide for establishing the hydrogen infrastructure needed to enable market introduction of fuel cell electric vehicles (FCEV's) beyond 2015. (12 Mar 2012).

(Re. <http://www.fuelcelltoday.com/news-events/news-archive/2012/march/danish-government-to-launch-hydrogen-infrastructure-program-continue-fcev-tax-exemptions-throughout-2015>)

Scandinavia as a whole has formed the Scandinavia Hydrogen Highway Project that is managed by three national efforts: HyNor, Hydrogen Link in Denmark, and Hydrogen Sweden. Their goal is to have 15 hydrogen stations plus 30 satellite stations by 2015. Currently there are 3 hydrogen stations in Norway and Sweden, 2 in Denmark, and 3 under construction.

In the **United Kingdom** UKH₂Mobility is a new government-industry program with the goal to make hydrogen powered travel in the UK a reality. The new UK based Low-Carbon Vehicle Partnership, announced January 18, 2012, will evaluate the potential of hydrogen fuel cell vehicles as a solution to de-carbonize road transit and to quantify emission benefits. They will also review the required investment to commercialize the technology and identify what is needed to make the UK a leading global player in HFC vehicle manufacturing. Partners in the study are three Government Departments and industrial participants from the utility, gas, infrastructure, and global car manufacturing sector (Air Liquide, Air Products, Daimler AG, Hyundai, Nissan UK, Tata Motors European Technical Centre, Toyota, Vauxhall, Intelligent Energy Ltd., ITM Power, Johnson Matthey, BOC Group, and Scottish and Southern Energy

In **Japan** the Ministry of Trade, Economy, and Industry METI (April, 2012) has announced that funding for hydrogen and fuel cell research in Japan topped \$240M in the current fiscal year - which is more than twice the amount spent by the US DOE (see Table 2 below). Funded activities include residential fuel cell installations and a variety of research and demonstration activities. The Japanese government will make a decision later this year on the budget for the installation of 100 hydrogen fueling stations to support the initial sale of fuel cell vehicles in 4 major cities: Tokyo, Kyushu, Chubu, and Kansai.

Table 2

Hydrogen and Fuel Cell Research in Japan, FY 2012		
	¥ Billion	\$ Million
H2 infrastructure & vehicle demo.	3.0	37.7
ENE-FARM	9.0	112.8
H2 production, transport and storage	1.5	18.8
PEM systems	3.5	43.9
SOFC research	0.6	7.8
Industrial SOFC	0.9	11.3
Basic hydrogen research	0.8	10.02
Total	¥ 19.3	\$ 242.2

Yen converted at 2011 average annual rate of 79.81 yen to the dollar

Ref. www.fuelcell.org April 13, 2012

METI, under the Hydrogen Energy Social Infrastructure Development Demonstration Project, launched on January 15, 2012 the “Hydrogen Town Project” in which hydrogen produced by Nippon Steel Corporation is supplied via pipelines for use in the operation of fuel cells in both the home and business in the urban area in the vicinity of the Kitakyushu Hydrogen Station in this first in the world community level demonstration.

Japan currently has 12 hydrogen stations including 6 in Tokyo. The Hydrogen Highway Project is to provide expressway services using Fuel Cell buses/vehicles.

A new organization The Research Association of Hydrogen Supply/Utilization Technology was formed in 2009 to support the expansion of hydrogen fueling infrastructure in Japan. This 18-member organization has strong oil company participation and is working with the government to revise safety codes and standards to facilitate station construction.. At present retail filling stations must meet the stringent standards developed for large industrial hydrogen facilities. This drives up station cost and complicates deployment.

South Korea is developing a Hydrogen Highway System in a cluster model around major cities. The South Korean government is working with Hyundai/Kia in the testing of fuel cell vehicles and to provide hydrogen fueling stations. Currently there are 13 hydrogen fueling stations in South Korea with 9 in the Seoul area. Hyundai/Kia has announced a goal to manufacture 10,000 FCVs in 2015 and to pursue markets in Europe and in Korea.

Safety Codes, Standards, Regulations, and Permitting

Internationally accepted codes and standards are needed that support the development and growth of the refueling infrastructure and overcome the often slow and cumbersome local permitting process.

A U.S. group working on standards for hydrogen is CSA Group (CSA). CSA is a not-for-profit organization that develops rules and guidelines for areas such as health, safety, and the environment. CSA is a Nationally Recognized Testing laboratory (NRTL). Areas of activity related to the development of the hydrogen infrastructure include (1) hydrogen fueling station standards, (2) hydrogen gas vehicle fueling station compressors and (3) materials compatibility for use in hydrogen applications. CSA is collaborating on standards development with the SAE International Fuel Cell Interface Working Group. For the fuel (dispensing) station guidelines have been developed for hydrogen fuel quality (SAE J2719) and for dispenser performance (SAE J2601 published as guidelines but not yet a standard). Beyond the standard itself, there is need for an incentive or mandate to certify, a NRTL with the testing capability, and an accredited certification agency to review results and issue a formal certification.

(Ref. National Hydrogen and Fuel Cell Coordinating Committee, January, 2012 Teleconference and http://www.hydrogenandfuelcellsafety.info/2010/oct/JULIE%20CAIRNS%20CSA_America_NExt_Energy_9-21-2010_.pdf)

Hydrogen Infrastructure for Industrial Hydrogen –Production and Delivery

Production:

The global production of hydrogen was estimated to be 53 million metric tons in 2010. Most of this hydrogen is produced by steam reforming of natural gas (methane). The largest market for hydrogen production was the Asia and Oceanic region (21M metric tons) where hydrogen is used in refineries and ammonia production. Europe and Eurasia are second in global hydrogen production followed by North America. Captive hydrogen production refers to hydrogen used by the company that produces it and represented about 88% of the 53 million metric tons produced in 2010. Merchant hydrogen production refers to hydrogen that is purchased from another company. North America was the largest market for merchant hydrogen (60% of the global merchant hydrogen produced) and the US was the largest producer of merchant hydrogen (22% of the global merchant produced).

Ref. <http://www.marketsandmarkets.com/Market-Reports/hydrogen-generation-market-494.html>

Within the US, hydrogen production is concentrated in refinery centers along the Gulf Coast and in the Farm Belt and in California (See Figure Y). The existing U.S. hydrogen pipeline transmission system is estimated at 450-800 miles (depending on criteria used) and is mostly along the Gulf Coast to connect producers with well established customers. Petroleum refining and petrochemical industries account for more than 90% of the hydrogen used.

Air Products continues to add new hydrogen capacity in the Gulf Coast, with recent start-ups of plants in Garyville and Baton Rouge, Louisiana, in 2010, as well as a new world-scale hydrogen production plant currently under construction in Luling, Louisiana. In addition, Air Products recently acquired and commissioned a new standalone hydrogen plant in Corpus Christi, Texas (Air Products, 2010). Praxair started up two new steam methane reformers producing hydrogen in the fall of 2010 to supply BP's Whiting, Indiana refinery with a total capacity of 200 million standard cubic feet per day (176,000 metric tons per year) (Praxair, 2010).

The existing hydrogen production infrastructure can support near term hydrogen demand for fuel cell electric vehicles. General Motors Publication R&D 11,065, "Hydrogen Fueling Infrastructure Assessment."

Hydrogen quality requirements for industrial processes such as ammonia and methanol production or petroleum refining are much less stringent than those for fuel cells. Industrial hydrogen must be purified using pressure swing adsorption (PSA) or other separation methods before it can be used as a vehicle fuel.

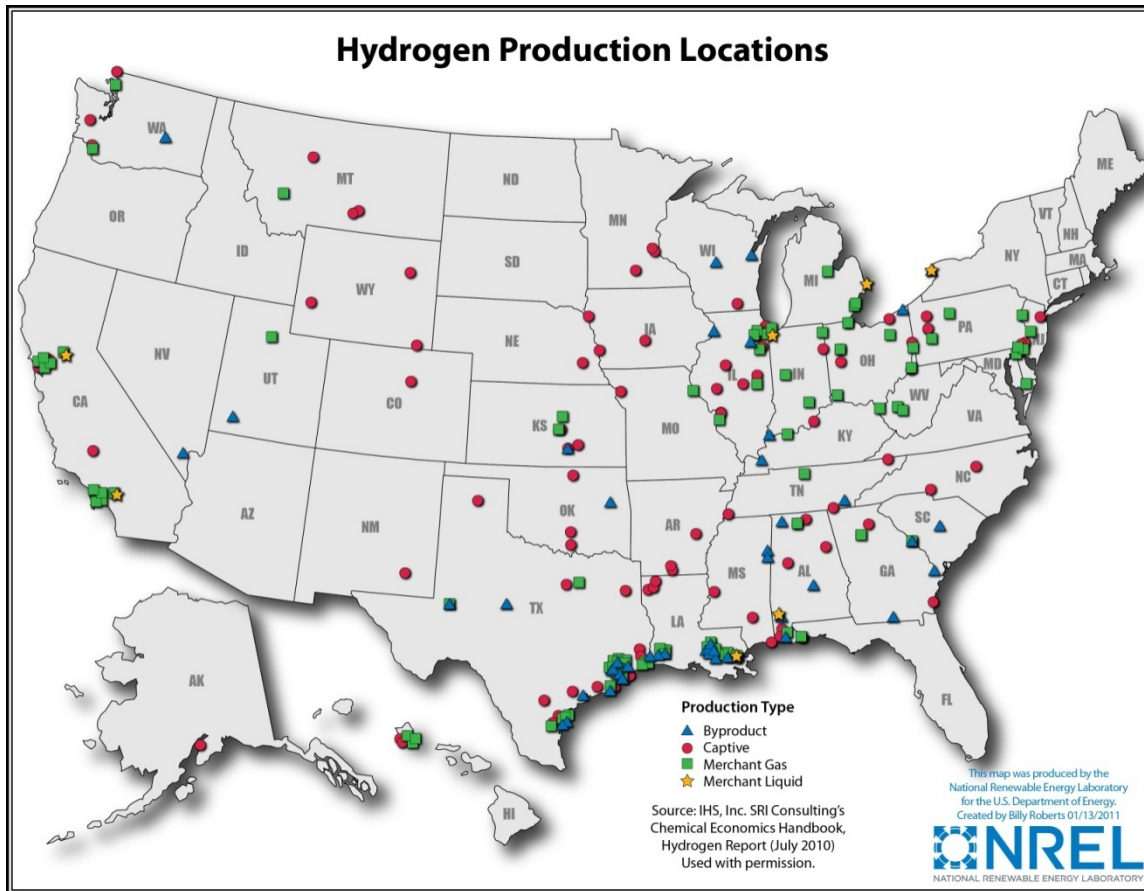


Figure Y U.S. Hydrogen Production Locations. Captive facilities are dedicated hydrogen production plants co-located with industrial petroleum or chemical processing plants that utilize the hydrogen produced. Merchant hydrogen is produced by an industrial gas supplier and delivered to hydrogen customer(s)...

Tables 3. & 4, show the top hydrogen producers in the U.S. and Canada. Two companies, Air Products and Praxair, clearly dominate the merchant market.

Company	Percent of Total
Chevron	16.4%
Valero	14.9%
Conoco Phillips	9.3%
BP	9.7%
Exxon Mobil	7.6%
WRB	6.5%
Shell Oil	6.5%
Flint Hills	5.9%
Motiva	4.5%
Tesoro	3.8%
Deer Park	3.6%
Other	11.3%
Totals	100.0%

Table 3. Top Refinery Hydrogen Producers (PNNL, 2011)

Company	Percent of Total
Air Products	46.8%
Praxair	30.4%
Air Liquide	10.7%
BOC-Linde	6.5%
Equistar	2.3%
T&P Syngas Supply	1.2%
Markwest Javelina	1.0%
Tessengerlo	1.0%
Industrial Gas Products	0.0%
General Hydrogen	0.0%
Holox	0.0%
Air Gas	0.0%
Prime Gas	0.0%
Totals	100.0%

Table 4 Merchant Compressed Gas Hydrogen Producers (PNNL, 2011)

Company	Percent of Total
Praxair	47.8%
Air Products	41.8%
BOC	6.1%
HydrogenAI	4.3%
Totals	100.0%

Table 5 Merchant Cryogenic Liquid Hydrogen Producers (PNNL, 2011)

Delivery:

Most of the hydrogen produced is for use in petroleum refining, the production of fertilizers, and for industrial chemicals. The large users generally produce the hydrogen on site (captive) or supplied by nearby suppliers (merchant).

Air Products plans to construct a new 180-mile long pipeline connecting its existing Louisiana and Texas hydrogen pipeline systems, creating the world’s largest hydrogen plant and pipeline supply network. This integrated pipeline system will unite over 20 hydrogen plants and over 600 miles of pipelines to supply the Louisiana and Texas refining and petrochemical industries with over 1 billion cubic feet of hydrogen per day (880,000 metric tons per year). The new Gulf Coast hydrogen pipeline network is expected to be operational in mid-2012 (CommodityOnline, 2010).

Praxair’s 310-mile hydrogen pipeline on the U.S. Gulf Coast is one of the world’s largest, serving more than 50 refineries and petrochemical plants (Praxair, 2010).

California Hydrogen Pipeline announcement. The first pipeline fed hydrogen fueling station in the US was opened in Torrence, CA in May 2011. The station is fed by an active industrial

hydrogen pipeline. Collaborators in the project are Toyota, Air Products, Shell, and the South Coast Air Quality Management district, and the Department of Energy.

(Ref. <http://www.hydrogenhighway.ca.gov/>)

Other delivery. Hydrogen delivery for small users is generally by truck (cylinders for 0.5-50kg), tube trailer (100-300 kg), or liquid tanker trucks (2000-2400kg). Hydrogen for transportation falls into the small user category. Air Products has developed a new truck for the purpose of delivering hydrogen to remote backup power sites. On site production of hydrogen using electrolyzers or natural gas reforming is growing as a means of supply for small users.

Delivery – International:

Europe currently has around 1,000 miles of hydrogen pipelines divided between 15 larger pipeline networks with single ownerships. The owners are Air Liquide, Linde/ BOC, Air Products (Sapio) and some smaller network operators as well as two energy projects that intend to build a specialized pipeline within their project. The largest network of pipelines is operated by Air Liquide and runs across northwest France, Belgium and part of the Netherlands.

(Roads2Hy.Com).

Recommendations

1. DOE needs to support the initiatives in California, Hawaii, New York, and other states from a regional perspective and use these experiences to develop a national rollout plan.
2. The United States government needs to publicly and emphatically state its support for the global FCEV initiative and work closely with leading countries (Germany, Japan, Korea, UK, etc). to develop credible and consistent rollout plans
3. These efforts need to be integrated with a well thought out strategy to support both 2016 and 2025 CAFE mileage standards recognizing that BEVs, biofuels, and hybrids will not alone address the requirements. The hydrogen fueling infrastructure build-out should be part of a comprehensive National Energy Policy.
4. The nation should continue a strong commitment to R&D initiatives to insure US technology leadership and to build on the current knowledge base.

APPENDIX A Subcommittee Members

Automotive Applications

Charles Freese (General Motors)
Matt Fronk (Matt Fronk & Associates)
John Hofmeister (Shell Oil Company, Retired)
John Love (NYSERDA)

Joan Ogden (U. CA Davis)
R. Rhoads Stephenson (NASA/JPL, Retired)

International

Richard T. Carlin (Office of Naval Research)
Geraldine Richmond (U. Oregon)

Non-Automotive Hydrogen/Fuel Cell Infrastructure Initiatives

Mark Cardillo (Camille & Henry Dreyfus foundation)
Harol Koyama (Ida Tech)
Alan Lloyd (International Council on Clean Technologies)
Robert R. Rose (BTI/Fuel Cell & Hydrogen Energy Association)

Safety Codes, Standards, Regulations, and Permitting

Maurice Kaya (State of Hawaii, retired)

Hydrogen Infrastructure for Industrial Hydrogen

Kathleen C. Taylor (General Motors, retired)

APPENDIX B Organizations Supporting Hydrogen Infrastructure Development

- Argentina: Association Argentina del Hidrógeno
- Australia: Australia Association for Hydrogen Energy
- Brazil: Development Commerce Transport (DCT) Energia (Interim Member*)
- Canada: The Canadian Hydrogen and Fuel Cell Association
- China: China Association for Hydrogen Energy
Taiwan Association for Hydrogen Energy
- EU: European Hydrogen Association , <http://www.h2euro.org/>
- France: Association Française de l'Hydrogène
- Germany: Deutscher Wasserstoff- und Brennstoffzellen-Verband (DWV)
 - NOW (National Organization for Hydrogen and Fuel Cell Technology) and Hydrogen Mobility
- Italy: Italian Hydrogen and Fuel Cell Association
Italian Hydrogen Forum
- Japan: Hydrogen Energy Systems Society of Japan
- Malaysia: Universiti Teknologi Malaysia (Interim Member*)
- Mexico: Sociedad Mexicana del Hidrógeno
- New Zealand: Massey University Centre for Energy Research (Interim Member*)
- Poland: Polish Hydrogen and Fuel Cell Association
- Sahara Wind
- Spain: Asociación Española del Hidrógeno
- United Kingdom: U.K. Hydrogen and Fuel Cells Association
- International Partnership for the Hydrogen Economy, www.iphe.net/
- UNIDO International Centre for Hydrogen Energy Technology (<http://www.unido-ichet.org/>)
- United States: Fuel Cell and Hydrogen Energy Association , <http://www.fchea.org>, CESA: Clean Energy States Alliance www.cleanenergystates.org/

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