III.0 Hydrogen Delivery Sub-Program Overview

Introduction

Hydrogen must be transported from the production site to the end user (e.g., a fueling station or stationary power site) or produced on-site. It also must be compressed, stored, and dispensed at refueling stations or at stationary power generation sites. Due to hydrogen's relatively low volumetric energy density, the transportation, storage, and final delivery of hydrogen as an energy carrier currently entail significant costs and inefficiencies. The Hydrogen Delivery sub-program activity focuses on developing technologies to reduce the cost and increase the energy efficiency of hydrogen delivery, to enable the widespread use of hydrogen as an energy carrier.

Three potential delivery pathways are being considered: gaseous hydrogen (trucks or pipelines), liquid hydrogen (trucks), and novel solid or liquid hydrogen carriers (trucks or pipeline). A carrier is a material that stores hydrogen at lower pressures and higher temperatures. Examples of potential hydrogen carriers include metal or chemical hydrides, nanostructures, and liquid hydrocarbons that can be easily de-hydrogenated and re-hydrogenated with a round-trip efficiency greater than 60%. In addition, research and development (R&D) activities include work on compression and off-board hydrogen storage development.

Goal

The goal of the Program's hydrogen delivery portfolio is to develop hydrogen delivery technologies that enable the introduction and viability of hydrogen as an energy carrier for transportation and stationary power generation.

Objectives

The objective of the Program's hydrogen delivery portfolio is to reduce the costs involved in delivering hydrogen from the point of production to the end-user and to enable hydrogen to be sold competitively (on a cents-per-mile basis) with gasoline. This overall goal applies to all delivery and dispensing technologies, including those used in centralized hydrogen production pathways and those used in both centralized production and distributed, on-site hydrogen production (e.g., on-site compression, storage, and dispensing). Interim targets and pathway-specific targets are currently being identified. Significant technological advances are needed to lower the cost of hydrogen delivery and to enable a transition to the widespread use of hydrogen. R&D objectives and priorities for hydrogen delivery include:

- **Pipelines:** Resolve hydrogen embrittlement concerns with steel pipelines, reduce capital costs by developing new steel compositions and/or welding and installation techniques, and/or develop viable composite pipeline technology with reduced capital costs.
- **Tube Trailers:** Increase gaseous tube trailer capacity and lower trailer costs to reduce overall hydrogen delivery cost, especially during a market transition.
- **Compression:** Develop more reliable, lower cost, higher efficiency hydrogen compression technology for pipeline transmission and for stationary and refueling station applications.
- **Storage:** Develop lower capital cost off-board storage technology; confirm the technical feasibility and adequate availability of geologic storage for hydrogen.
- **Liquefaction:** Reduce the capital cost and increase the energy efficiency of hydrogen liquefiers and bulk storage (reduce boil-off).
- **Carriers:** Work toward a Go/No-Go decision and leverage research for on-board storage applications to determine if a novel solid or liquid carrier might be suitable for hydrogen transport or off-board storage and result in lower delivery costs and higher energy efficiency. This technology is feasible only if the carrier is used on-board the vehicle.

- **Analysis:** Conduct comprehensive analysis of the options and trade-offs of hydrogen delivery approaches for the near-term and long-term, including: 350-bar, 500-bar, 700-bar, and cryocompressed station and upstream delivery costs.

Fiscal Year (FY) 2010 Technology Status

Current costs for the transport of hydrogen range from $2 to $8/gasoline gallon equivalent (gge) and are dependent on the quantity of hydrogen and the distance that the hydrogen is transported. Pipeline transport costs are at the lower end of the cost range and are also dependent on transport distance and quantities. These transport costs do not include compression, storage, and dispensing at fueling sites, which can add $2–3/gge of hydrogen. Progress toward current goals and targets is summarized below.

Project Category	Goal (Targets to be met by 2020)*	Status**
Tube Trailers	Reach H_2 delivery cost target of $1/gge. Reduce capital cost to <$200,000 Increase capacity to 1,100 kg through the use of carbon fiber or low-cost glass fiber.	$2.85–$3.15/gge (high volume demand projection. Completed system design for 1,100 kg capacity with glass fibers and small-scale prototype development. Completed testing of carbon fiber tank with a capacity of 600 kg.
Pipelines	Reach H_2 delivery cost target of $1/gge. Decrease cost/mile to <$490,000.	$2.20–$2.35/gge (high volume demand projection). Cost/mile (steel): $1M/mile; cost/mile (fiber reinforced plastic): $600,000/mile.
Liquefaction	Reach H_2 delivery cost target of $1/gge. Decrease installed capital cost to $100M. Increase energy efficiency to 87%.	$2.70–$2.90 (high volume demand projection). Installed capital cost: $170M. Energy efficiency: 40%.
Compression	Reduce capital cost to $6.2M (transmission compression). Increase energy efficiency to >98%. Cost contribution: $0.25/kg H_2.	Centrifugal pipeline package cost: $4.5M (projected). Energy efficiency: 98% (projected). Cost contribution: $0.60/kg H_2.
Bulk Storage	Reduce cost of storage tank to $300/kg H_2 stored. Increase volumetric capacity to >0.035 kg H_2/liter of storage volume.	Storage tank cost: $820/kg H_2 stored. Volumetric capacity: 0.025 kg H_2/liter of storage volume.
Carriers	Show a viable carrier material (liquid, non-toxic). Decrease delivery cost contribution to <$1/gge. Increase carrier H_2 content to 13.2% by weight.	N-ethylcarbazole delivery cost: $4.75. N-ethylcarbazole H_2 content by weight: 5.8%.

* Targets shown are currently under review and will be updated in FY 2010 and FY 2011.
** DOE projections—not publicly vetted. Target and Status costs are projected high-volume costs.

FY 2010 Accomplishments

Pipelines

- Savannah River National Laboratory completed a life management plan for fiber reinforced composite (FRC) pipelines, completed a review of existing FRC design specifications/standards, and initiated environmental and flaw tolerance testing of FRC.
- Sandia National Laboratories examined the fracture properties of X52 pipeline steel in high-pressure H_2 gas and established a relationship between hydrogen-assisted fatigue crack growth rate and load-cycle frequency at frequencies prototypic of a pipeline application.

Tube Trailers and Bulk Storage

- Lincoln Composites completed an assembly that includes an International Organization for Standardization (ISO) frame, four pressure vessels, and relevant plumbing. The American Bureau of Shipping approved the entire ISO assembly for manufacture.
- Lawrence Livermore National Laboratory designed a pressure vessel that, when incorporated into a trailer, could deliver hydrogen at a cost below $1/gge (not including forecourt expenses).

Compression and Liquefaction

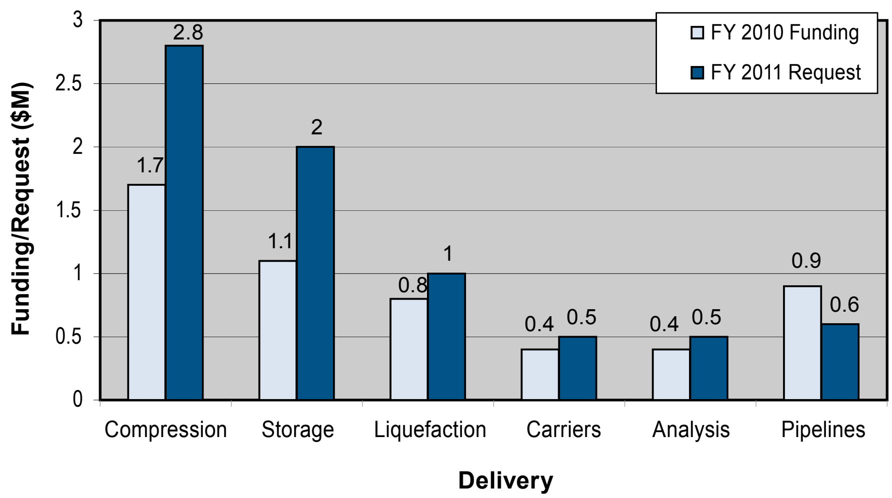
- Concepts ETI Inc. completed a preliminary design of a six-stage hydrogen pipeline compressor capable of delivering 240,000 kg H_2/day at 1,250 psig.
- Five subsystems of a 290 K to 120 K active magnetic regenerative liquefier prototype were designed, fully assembled, and successfully tested by Prometheus Energy.

Analysis

- Argonne National Laboratory upgraded the Hydrogen Delivery Scenario Analysis Model to evaluate three new delivery pathways, two different station configurations for 700-bar dispensing, and an option permitting user selection of station configuration.
- The National Renewable Energy Laboratory upgraded the Hydrogen Rail Components Model with 700-bar and cryo-compressed dispensing and higher tube-trailer delivery pressure, of up to 480 atm.

Budget

The FY 2010 budget provided $5.4 million for continued hydrogen delivery research. The President's FY 2011 budget request includes $40 million for hydrogen fuel R&D, out of which $7.2 million is planned for hydrogen delivery, with an emphasis on lower-cost, higher-efficiency compression technology and lower-capital-cost off-board storage technology.



FY 2011 Plans

Annual reports and final reports documenting progress will be issued in late FY 2010 and FY 2011, respectively. H2A cost projections for delivery pathways, the Hydrogen Delivery Chapter of the Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Multi-Year Program Plan, and the Delivery Roadmap will be reviewed and updated as needed in FY 2011. The applied R&D program in EERE will coordinate with the Office of Science, which plans to include up to $50 million of basic research related to hydrogen and fuel cell technologies. Through basic science activities, a fundamental understanding of issues such as hydrogen embrittlement can help address the challenges of hydrogen technologies in the long term. In addition, through projects funded by the American Recovery and Reinvestment Act of 2009, lessons-learned and best practices related to hydrogen delivery technologies will be developed.

Sara Dillich
Production & Delivery Team Lead (Acting)
Fuel Cell Technologies Program
Department of Energy
1000 Independence Ave., SW
Washington, D.C. 20585-0121
Phone: (202) 586-7925
E-mail: Sara.Dillich@ee.doe.gov