III.0 Hydrogen Delivery Sub-Program Overview

Introduction

Hydrogen must be transported from the production site to a fueling station or stationary power site or produced on-site. It also must be compressed, stored and dispensed at refueling stations or stationary power facilities. Due to its relatively low volumetric energy density, current transportation, storage and final delivery entail significant costs and inefficiencies for hydrogen as an energy carrier. The Hydrogen Delivery activity is focused on developing technology to reduce the cost and increase the energy efficiency of hydrogen delivery for the transition to, and long-term use of hydrogen as a major energy carrier.

There are three potential delivery pathways: gaseous hydrogen delivery, liquid hydrogen delivery, and novel solid or liquid hydrogen carriers. A carrier is a material that incorporates hydrogen into a form other than free H_2 molecules. Examples of potential hydrogen carriers include metal or chemical hydrides, nanostructures, and liquid hydrocarbons that can be easily and simply dehydrogenated and re-hydrogenated.

The DOE Hydrogen Delivery sub-program element has now had a healthy level of funding for two years in a row. Fiscal Year 2007 was the first year that Hydrogen Delivery received sufficient funding to begin significant research efforts and similar funding was available in 2008. These two consecutive years have allowed for measurable progress in Hydrogen Delivery research and development.

Goal

Develop hydrogen delivery technologies that enable the introduction and long-term viability of hydrogen as an energy carrier for transportation and stationary power.

Objectives

- By 2014, reduce the cost of hydrogen transport from central and semi-central production facilities to the gate of refueling stations and other end-users to <$0.90/gasoline gallon equivalent (gge) of hydrogen. By 2019, reduce this cost to <$0.60/gge.
- By 2012, reduce the cost of compression, storage and dispensing at refueling stations and stationary power facilities to <$0.80/gge of hydrogen (independent of transport). By 2017, reduce this cost to <$0.40/gge.
- By 2017, reduce the cost of hydrogen delivery from the point of production to the point of use in vehicles or stationary power units to <$1.00/gge of hydrogen in total.

FY 2008 Technology Status

Current costs for the transport of hydrogen, with the exception of that transported through the very limited amount of hydrogen pipelines, are $4-$9/gge of hydrogen. This is based on transport by gaseous tube trailers or cryogenic liquid tank trucks and is very dependent on amounts and distances. Pipeline transport costs are significantly lower but are also very dependent on transport distance and amounts. These transport costs do not include the delivery costs associated with compression, storage and dispensing at fueling sites. These additional costs could be as high as $2-3/gge of hydrogen.

In order to achieve the long-term goal of $1/gge of hydrogen for the cost of hydrogen delivery, and to have commercially viable costs during the transition period, significant technology development is needed. This includes:

- Comprehensive analysis of the options and trade-offs of hydrogen delivery approaches for the near-term and long-term.

- 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.
- Compression: Develop more reliable and lower cost hydrogen compression technology for pipeline transmission and refueling station applications.
- Storage: Develop lower capital cost off-board storage technology; confirm the technical feasibility and adequate availability of hydrogen geologic storage.
- Liquefaction: Dramatically reduce the capital cost and increase the energy efficiency of hydrogen liquefaction.
- Carriers: Leverage the National Hydrogen Storage Project on-board storage program element to determine if a novel solid or liquid carrier might be suitable for hydrogen transport or off-board storage and result in the targeted delivery cost and energy efficiency.

The sub-program also awarded six new competitively selected projects in FY 2008 for $14.09 million over three years, totaling $21.5 million with cost sharing. These six projects were awarded in the areas of compression, liquefaction, and off-board storage with two projects awarded in each area. These new projects will complement the development efforts that were already underway, improve hydrogen delivery technology and lower the cost of transporting hydrogen from a central production facility to the end user.

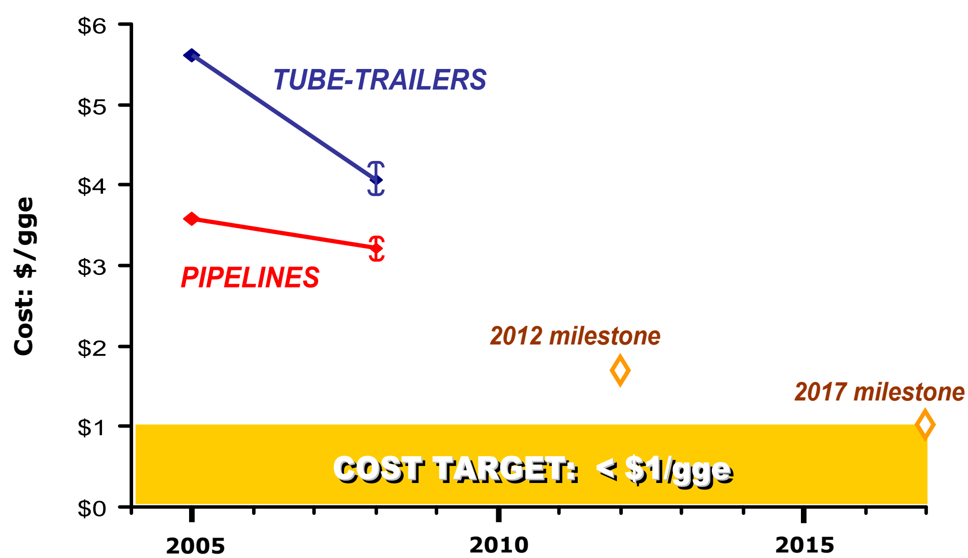
FY 2008 Accomplishments

- Argonne National Laboratory and the National Renewable Energy Laboratory expanded and improved the analysis of the current costs of hydrogen delivery using pipelines, liquid trucks and gaseous trucks. This included a comprehensive analysis of hydrogen hourly, daily, and seasonal demand and supply variations and optimized off-board storage infrastructure to handle these variations, variable-sized refueling sites (50-6,000 kg/day), and improved cost estimates for pipelines, liquefaction, compression, and storage. The use of novel carriers is also being analyzed to determine which approaches might be useful for hydrogen delivery. Updated versions of the H2A Delivery Models and a report summarizing the results of these and prior hydrogen delivery infrastructure analyses were completed and posted (www.hydrogen.energy.gov/Systems_Analysis) for public use in June 2008. Additional work will continue to evaluate 700 bar refueling options, and low-temperature high-pressure hydrogen and advanced carriers as part of the H2A Delivery Models.
- Savannah River National Laboratory and Oak Ridge National Laboratory (ORNL) completed leakage measurements on fiber-reinforced pipelines (FRPs) and verified that the leakage rate was less than 0.5%. These materials meet the 2012 cost target and have good potential to achieve the 2017 cost target of $1.00/gge, assuming that capacity can be met by bundling existing FRPs and that current FRP technology will meet leakage standards to be developed in 2010.
- ORNL and Sandia National Laboratories (SNL) installed and tested equipment for testing materials in high-pressure hydrogen. Testing of initial down-selected commercially available pipeline steels shows that some steels may be more suitable for high-pressure transmission of hydrogen.
- The University of Illinois completed modeling and simulation of fracture events and processes, accounting for the degradation mechanisms at the atomic and microscale. This microstructural characterization aided the development of a predictive hydrogen embrittlement model.
- The Pipeline Working Group initiated and evaluated initial results from national laboratories (SNL and ORNL) round-robin tensile testing to show the effect of hydrogen is relatively consistent between labs but that small quantitative differences need to be resolved. The National Institute of Standards and Technology will also participate in the round-robin and will begin testing samples in 2009.

- Lawrence Livermore National Laboratory identified appropriate glass fiber materials and started initial structure prototyping for a hydrogen tube trailer. They explored the combination of cold gas (-30 to -200°C), and high pressure (100-700 bar) in conjunction with the use of composite material structures. This combination has the potential to significantly reduce the cost of hydrogen storage and delivery to refueling stations. A glass fiber through strut structure with a metal skin packaged in a conventional rectangular steel trailer has been modeled using finite element analysis and shows promise.
- TIAX documented the results of a study which identified the lowest cost combination of cold gas (-40 to -200°C) and high pressure (100-700 bar) that can be used with carbon fiber composite tank technologies.
- Gas Equipment Engineering Corporation demonstrated progress in an advanced liquefaction cycle which uses helium as the working fluid. Expanders have been identified as part of the project to increase efficiency and catalysts have been identified which allow the ortho-para conversion to occur simultaneously during heat exchange with the helium. This conversion of two steps to a single step is the key to reducing the energy requirements for hydrogen liquefaction.
- Fuel Cell Energy developed an advanced electrochemical compression technology. The seals used in this technology have been leak-tested to 280 bar, have operated continuously with no hydrogen leakage at a pressure over 140 bar for 2,000 hours, and they have completed over 100 cycles from near atmospheric pressure to 205 bar.

Delivery Cost Reduced through Advances in Pipelines and Tube-trailers

*(**projected** cost of delivery, using state-of-the-art technology)*

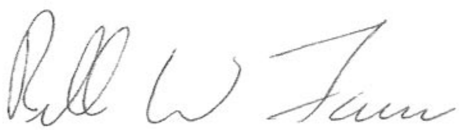


Budget

The President's FY 2009 EERE Hydrogen Delivery budget request was $0 to allow for focused effort on the critical path technologies of on-board storage and fuel cells. (See the Production sub-program overview, II.0)

2009 Plans

EERE projects have been funded into 2009 to allow for the projects to reach a logical stopping point while research and development efforts are shifted to on-board hydrogen storage and fuel cells.



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