III.2 H2A Delivery Analysis and H2A Delivery Components Model

Olga Sozinova
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401
Phone: (303) 275-3755
E-mail: Olga.Sozinova@nrel.gov

DOE Technology Development Manager:
Monterey Gardiner
Phone: (202) 586-1758
E-mail: Monterey.Gardiner@ee.doe.gov

Project Start Date: 2004
Project End Date: September 2012

Objectives

- Update and maintain the H2A Delivery Components Model.
- Support other models and analysis that include delivery costs.
- Expand the H2A Delivery Components Model by designing new delivery components.
- Apply new delivery components to identify delivery cost reductions.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery section of the Fuel Cell Technologies (FCT) Program's Multi-Year Research, Development and Demonstration Plan:

(A) Lack of Hydrogen/Carrier and Infrastructure Option Analysis

(F) Gaseous Hydrogen Storage and Tube Trailer Delivery Cost

Technical Targets

This project is aiming to improve the efficiency of the hydrogen delivery process through analyzing various delivery pathways to understand the behavior and drivers of the fuel and vehicle markets and to meet Milestone 12 from the FCT Multi-Year Research, Development and Demonstration Plan: "By 2017, reduce the cost of hydrogen delivery from the point of production to the point of use at refueling sites to less than $1 per kg."

Accomplishments

- Upgraded H2A Delivery Components Model with 700 bar and cryo-compressed dispensing and increased tube-trailer delivery pressure to 480 atm.
- Designed seven new delivery components accommodating gaseous hydrogen delivery in composite tubes.
- Updated rail delivery components with new cost and technical input data.
- Performed comparative cost analysis of various delivery pathways for long-distance delivery.
- Completed the first stage of developing multi-node delivery scenarios.

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Introduction

The H2A Delivery Components Model is an Excel-based, publicly available tool that calculates the cost of delivering hydrogen through multiple delivery pathways. The Components Model is part of a larger set of H2A or "Hydrogen Analysis" models, including the H2A Production Model, and the H2A Delivery Scenario Analysis Model (HDSAM). The H2A Production Model calculates the cost of producing hydrogen from a variety of feedstock types. The HDSAM, developed at Argonne National Laboratory, allows the user to choose between multiple production and delivery pathways to calculate total scenario costs. The H2A Delivery Components Model also calculates delivery costs but provides the user with significant flexibility in determining the costs of distinct delivery components, setting unique values for key parameters and constructing customized scenarios. The Delivery Components Model also serves as a tool for generating input delivery cost data for use in other hydrogen models, such as Scenario Evaluation and Regionalization Analysis (SERA), Hydrogen Demand and Resource Analysis (HyDRA), and the H2A Fuel Cell Power Model.

Approach

Since its start in 2004, the project has followed the general H2A approach and guidelines: closely collaborating with industry to update cost data and technical specifications, keeping consistency of the cost inputs across all H2A models, employing H2A standard assumptions, and maintaining publicly available models.

Results

Pursuing the project objectives, we upgraded the H2A Delivery Components Model with new dispensing options and an additional delivery pressure. We added a second dispensing pressure of 700 bar to the gaseous refueling station. At the 700 bar station, hydrogen can be dispensed via a cascade system or booster compressor. We also added a new dispensing option at the liquid refueling station: hydrogen can be dispensed not only as gas, but also as liquid or cryo-compressed fluid. Figure 1 shows the impact of the refueling station upgrade on the station share of hydrogen cost, as well as station capital cost. The gaseous truck-trailer component was upgraded with the second tube pressure of 480 atm. As Figure 2 reveals, pressure boost from 180 atm to 480 atm enables an increase in tube-trailer capacity by 140% and a decrease in the truck-trailer share of hydrogen cost by 37%.

Addressing the barrier (A) - Lack of Hydrogen/Carrier and Infrastructure Option Analysis, we are developing new rail delivery components. Six new rail delivery components include gaseous and liquid production site terminals, rail transport in rail cars and rail tankers, and city gate terminals for both gaseous and liquid hydrogen. At the production site terminal, hydrogen is loaded into rail cars (or tankers). Every day a single train leaves the production site terminal with a sufficient supply of hydrogen to meet city daily demand. At the city gate terminal hydrogen is reloaded from the rail cars to trucks, which deliver hydrogen

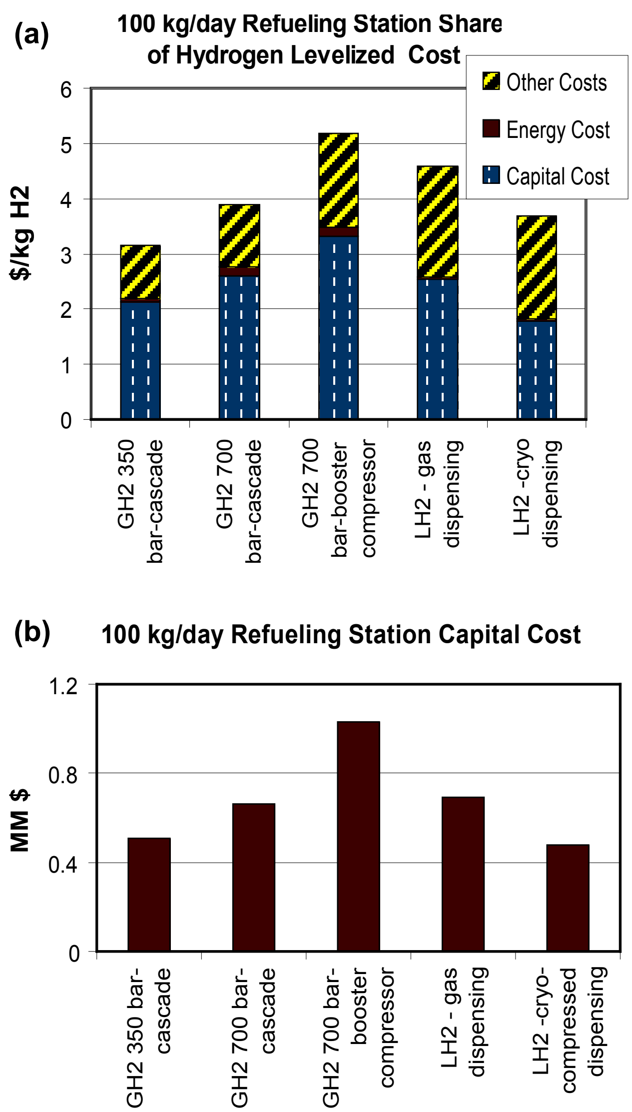

FIGURE 1. Hydrogen refueling station costs: a) station share of hydrogen levelized cost; b) station capital cost. Station capacity is 100 kg/day. (GH2 – gaseous hydrogen, LH2 – liquid hydrogen)

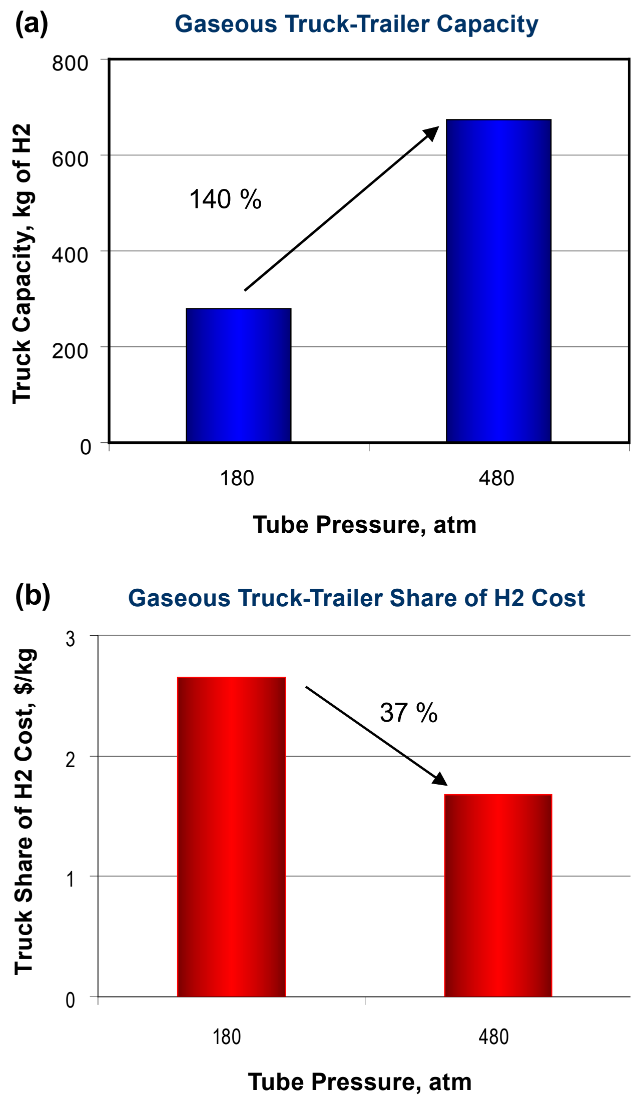

FIGURE 2. Gaseous truck-trailer: a) capacity (kg of hydrogen); b) truck share of hydrogen levelized cost ($/kg). The cost analysis is made for delivery to the refueling station with an average capacity of 100 kg/day.

to the refueling station. Whenever possible, the H2A default sizes have been preserved in designing both types of terminals. This year our update of the rail components concerned freight data, rail car leasing data, and intermodal facility crane technical specifications and cost. The updated rail components were used to perform comparative delivery cost analysis. Figure 3 demonstrates the hydrogen delivery cost sensitivity to the distance. For the distances longer than 1,500 km, liquid hydrogen rail and truck delivery outperform all other options, becoming serious candidates for delivery of hydrogen produced from renewable sources.

Addressing the barrier (F) - Gaseous Hydrogen Storage and Tube Trailer Delivery Costs, we analyzed the possibility for delivering gaseous hydrogen in composite tubes instead of metal tubes. Using composite tubes with a pressure of 250 bar decreases the cost of delivery via gaseous truck-trailer by 20-30% (see Figure 3). Also, preliminary analysis has shown that with a pressure increase to 550 bar, delivery costs drop by 33% for gaseous rail delivery and up to 50% for gaseous truck-trailer delivery.

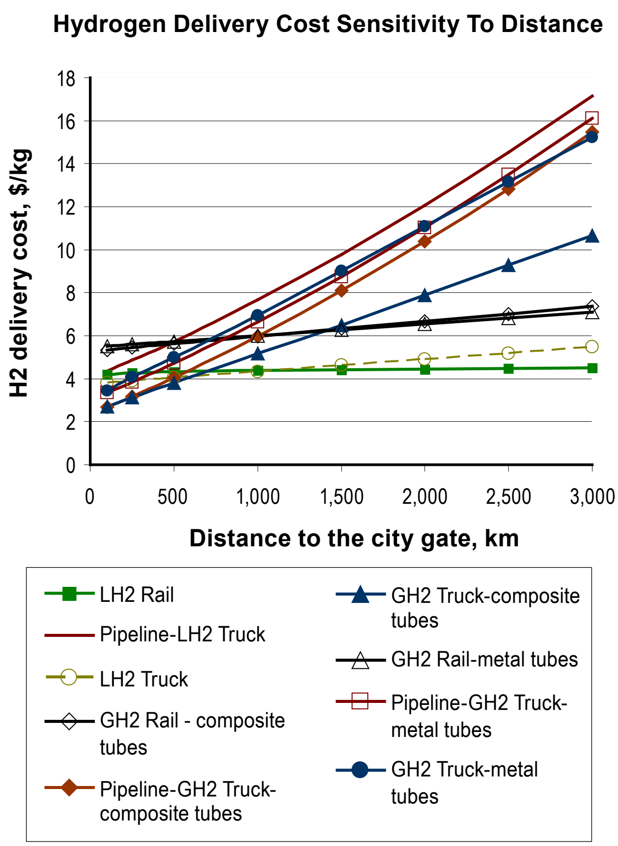

FIGURE 3. Hydrogen delivery cost for various pathways. Assumptions: city demand is 40,000 kg/day; refueling station capacity is 500 kg/day with 350 bar dispensing at the gaseous station and cryo-compressed dispensing at the liquid station; metal tube pressure is 480 atm; composite tube pressure is 250 bar.

Barrier (F) also was addressed through developing a novel method of hydrogen delivery: when a hydrogen plant not necessarily serves only one city, but can accommodate demand from multiple cities. By introducing these multi-node delivery scenarios, we can model pipeline and hydrogen storage systems shared between multiple cities, which potentially can decrease the cost of storage designed for plant outage and demand surge. For designing multi-node delivery networks, we have used the SERA Model. This model is a geographical information system-based dynamic optimization tool that determines optimal production and delivery infrastructure build-outs and their evolution. The first stage of SERA scenario development was completed this year. We coded four delivery components directly into the SERA model in order to gain extensive flexibility of placing delivery components at different geographical locations. Also, we added transmission pipeline branching to allow sharing a production plant between multiple cities. Figure 4 displays an optimized pipeline network, demonstrating mature multi-node delivery at the Midwestern region.

Conclusions and Future Direction

- In Fiscal Year 2010, by introducing new dispensing and delivery options, we reached the following conclusions:
- Gaseous hydrogen tube-trailer capacity can be increased by 140%, and its share of the total cost of hydrogen delivery can be decreased by 37%.
- The cost of gaseous hydrogen delivery via truck can be decreased by 30% by the introduction of composite tubes.
- Liquid rail and truck delivery are the least cost long-distance options for delivering hydrogen produced from remote renewable sources.
- Multi-node delivery configurations have the potential to reduce the cost of storage by sharing systems between two or more production plants.

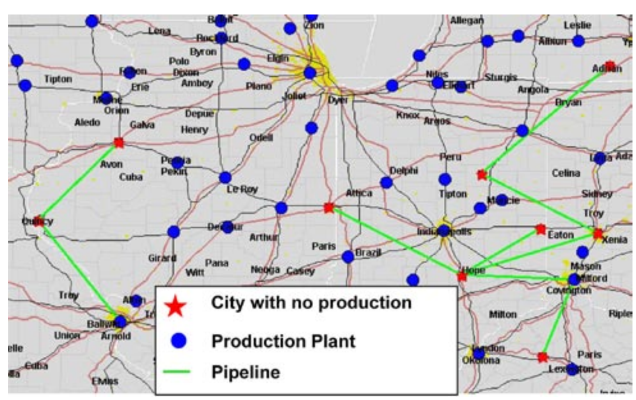

FIGURE 4. Demonstration of the Optimized Pipeline Network at the Midwestern Region

In the upcoming year, the major effort for the H2A Delivery Analysis and H2A Delivery Components Model will focus on:

- Developing go/no-go decision on delivering hydrogen via existing natural gas pipeline network.
- Refining rail delivery components.
- Continuing multi-node delivery scenarios design.
- Developing scenarios for delivering hydrogen that has been produced from wind.
- Maintaining and updating the H2A Delivery Components Model.

FY 2010 Publications/Presentations

1. O. Sozinova, D. Steward, "Wind to Liquid Hydrogen Cost Study: Preliminary Results," Delivery Tech Team Meeting, Washington, DC, April 14, 2010.

2. B. Bush, O. Sozinova, M. Melaina, "Optimal Regional Layout of Least-Cost Hydrogen Infrastructure," National Hydrogen Association Conference, Long Beach, California, May 4, 2010.

3. M. Gardiner, A. Elgowainy, M. Mintz, O. Sozinova, D. Steward, G. Saur, D. Brown, G. Berry, "Liquid Hydrogen and Wind Support Each Other – A Case Study", Low Temperature Liquefaction Workshop, Long Beach, California, May 4, 2010.

4. O. Sozinova, "H2A Delivery Analysis and H2A Delivery Components Model," Annual Merit Review, Washington, DC, June 9, 2010.

5. O. Sozinova, D. Steward, G. Saur "NREL Wind-to-LH2 Case Study," H2A Meeting, Washington, DC, May 7, 2010.