III.2 H2A Delivery Components Model

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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.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery and System Analysis sections of the Hydrogen, Fuel Cells and Infrastructure Technologies Program (HFCIT) Multi-Year Research, Development and Demonstration Plan:

(C) Lack of Hydrogen/Carrier and Infrastructure Option Analysis (Delivery)

(A) Future Market Behavior (Systems Analysis)

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 HFCIT 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

- Reviewed the H2A Delivery Components Model v. 2.0.
- Developed short guide to the Delivery Components Model.
- Enhanced the capability of the Delivery Components Model by creating an automation code to allow for multiple runs.
- Created a delivery cost database for the Hydrogen Deployment System Modeling Environment (HyDS-ME).
- Designed six pilot rail delivery components for the Delivery Components Model.
- Developed hydrogen delivery scenarios for customized hydrogen co-production sites.
- Analyzed hydrogen city-wide storage and delivery dynamics for the city of Los Angeles.

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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 Delivery Components Model is part of a larger set of H2A or "Hydrogen Analysis" models, including the H2A Production Model, H2A Power Model, and the H2A Delivery Scenario Analysis Model (HDSAM). The Production Model calculates the cost of producing hydrogen from a variety of feedstock types and the Power Model calculates the cost of producing hydrogen from stationary fuel cells systems in combined heat, hydrogen, and power applications. HDSAM, developed at Argonne National Laboratory, allows the end-user to choose between multiple delivery pathways to calculate total scenario costs. The H2A Delivery Components Model also calculates delivery costs but provides the end-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 HyDS-ME, HyDRA, and the H2A Power Model.

Approach

To achieve the project objectives, several improvements to the model have been and continue to be made in collaboration with our partners. A variety of delivery options, as well as refueling station sizes, geographic locations and resource availability are being analyzed. In general, the approach to meeting the project goals is to explore multiple potential pathways to determine promising and economical hydrogen delivery options.

Results

Pursuing the project objectives, a significant effort has been made to review a new version of the Delivery Components Model. In the process of this review, several errors were fixed, the model was debugged, and a review report was provided to DOE. During the past year, the model was maintained by updating supporting cost data tables, which are included in the model. Also, a Short Guide to the Delivery Components Model was written to help users understand the types of capital costs included in each delivery component.

In supporting other models and analysis areas, an automation code was created to provide the ability to run the model multiple times using multiple sets of parameters. This capability is especially important for creating large sets of delivery cost data, such as a database to be used by other hydrogen models. The automation code has been used to create a draft of a hydrogen delivery cost database for use in HyDS-ME. The database was used to support two HyDS-ME scenario studies: a Notional California Case Study [2A] and a regional least-cost optimization study of hydrogen delivered to major urban areas from wind farms [3A].

New rail delivery options have been designed within the Delivery Components Model framework. Rail pathways appear to be a low-cost option when large volumes of hydrogen are delivered from remote locations to large cities. In particular, some renewable hydrogen pathways may involve renewable resources distant from large demand centers. Six pilot rail components have been designed as a first draft toward creating rail delivery pathways. They 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 demand for a number of days equal to the one-way train travelling time. At the city gate terminal hydrogen is reloaded from the rail cars to trucks, which deliver hydrogen to the end consumer. Whenever possible, the H2A default sizes have been preserved in designing both types of terminals. Figure 1 demonstrates the lowest delivery cost regions for delivery to refueling stations requiring 1,000 kg H_2/day. Liquid hydrogen rail delivery is the lowest cost option across a quite large range of demands and distances, becoming the most economical for the large demands and long distances between the production site and the city. As indicated in the figure, gaseous hydrogen rail delivery is the lowest cost option among other delivery options for relatively small demands and moderate distances.

The H2A Delivery Components Model was used to develop hydrogen delivery scenarios from a combined heat, hydrogen, and power (CHHP) facility to a refueling

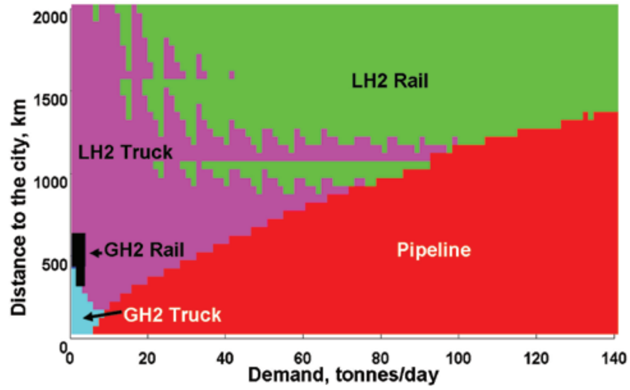

FIGURE 1. Least-cost hydrogen delivery map. Refueling station capacity is 1,000 kg H_2/day. (GH2 – gaseous hydrogen, LH2 – liquid hydrogen)

station (either a public retail station or a fleet refueling station) and to calculate the total delivery cost. In this study generic CHHP delivery scenarios with unique cost assumptions have been analyzed and compared with the scenarios using the H2A default input parameters. Figure 2 shows the total hydrogen delivery cost for one of the generic scenarios called "Onsite Fueling." The jump in cost at the 250 kg/day station capacity is due to an increased compressor capital cost for the flow rates above 250 kg/day. In this case, the refueling station is located at the CHHP site. A short distribution pipeline of 150 ft connects the building where the CHHP system is installed with the refueling station. The pipeline capital costs, operations and maintenance, compressor, and refueling station do not include land costs. Only two compressors are installed at both the CHHP site and the refueling station; and one of each pair is assumed to be working at any time. Friday and summer demand surges are 10% and 8%, respectively. This scenario might apply to facilities with their own land for refueling station equipment. Potential examples of such facilities include supermarkets, airports, university campuses, etc.

City-wide delivery dynamics have been analyzed for the city of Los Angeles. Variations in station sizes across the city area and their evolution over the period 2012-2050 have been taken into consideration. The station size distribution model discussed in [1B] was applied. All refueling stations in the city were divided into three clusters: big (10%), average (30%), and small (60%). Three rates of market growth (scenarios) were considered. Hydrogen was assumed to be produced via steam methane reformer (SMR) technology either at the central production plant or at the forecourt station. Figure 3 shows the station size distribution for all three clusters over the years in one of these scenarios. The costs of delivered hydrogen with respect to station size and types of production and delivery are shown in Figure 4.

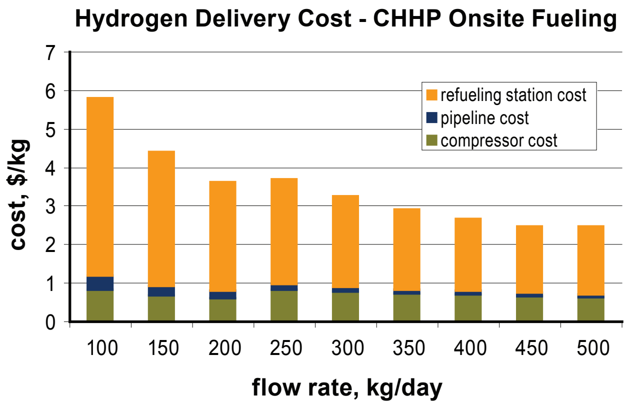

FIGURE 2. Hydrogen Delivery Cost – CHHP Onsite Refueling Scenario

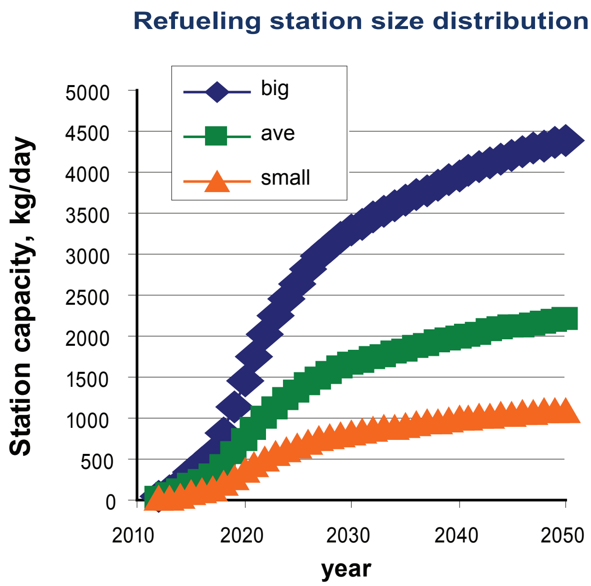

FIGURE 3. Refueling station size distribution in Los Angeles. Distribution sizes divided into three major clusters: big, average, and small. The figure shows the average station size in a cluster.

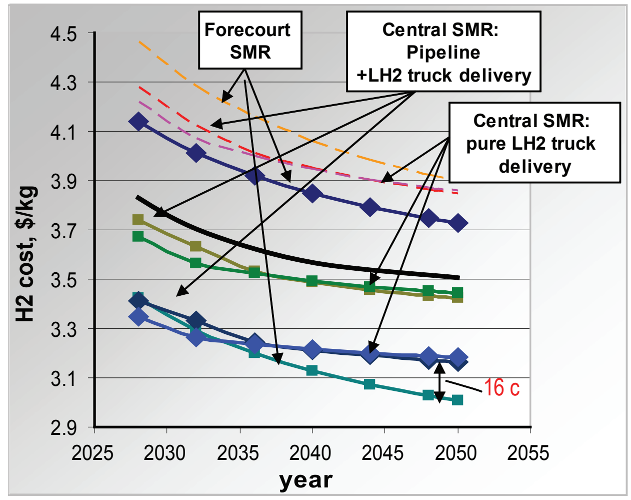

FIGURE 4. Hydrogen delivered cost in Los Angeles. Cost depends on production and delivery pathways, as well as on refueling station size distribution throughout the city. The markers on the graph represent the following: big diamonds - big station cluster, squares – average station cluster, dotted line – small station cluster, bold line – volume-weighted average.

Conclusions and Future Directions

In FY 2009 the Components Model was reviewed and updated. The major goals that have been reached are the following:

- The automation code for the Delivery Components Model was created.
- Large sets of the delivery cost data were obtained for input in other hydrogen models.
- New pilot rail hydrogen delivery options were designed.
- Delivery scenarios from the CHHP sites were developed and analyzed.
- Spread in station sizes and their costs in the city of Los Angeles were studied.

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

- Adding a high pressure (700 bar) gaseous refueling station option.
- Adding an option to dispense gaseous hydrogen via cascade system or booster compressor.
- Adding liquid cryo-compressed refueling station.
- Expanding and finalizing the delivery cost database.
- Refining delivery scenarios for CHHP systems.
- Continuing the development of rail delivery components.
- Adding renewable production technologies to the analysis of Los Angeles station distribution scenarios.

FY 2009 Publications/Presentations

1A. O. Sozinova, Delivery Analysis: Milestone Report (2.7.1) and Deliverable (2.7.1), December 2008.

2A. B. Bush, M. Melaina, O. Sozinova, D. Thompson, “Hydrogen Deployment System Modeling Environment: Notional California Case Study,” National Renewable Energy Laboratory, January 2009.

3A. B. Bush, M. Melaina, O. Sozinova, “Optimal Regional Layout of Least-Cost Hydrogen Infrastructure,” poster presentation at the National Hydrogen Association Conference, Columbia, South Carolina, March 30 to April 3, 2009.

4A. O. Sozinova, ”Rail and Pipeline Networks as New Hydrogen Delivery Options,” Delivery Tech Team Meeting, Cambridge, MD, April 17, 2009.

5A. O. Sozinova, "H2A Delivery Components Model," Annual Merit Review, Arlington, VA, May 21, 2009.

6A. O. Sozinova, "Rail Components and Hydrogen Delivery Networks," H2A Meeting, Arlington, VA, May 18, 2009.

References

1B. M. Melaina, J. Bremson, "Regularities in Early Hydrogen Station Size Distributions," Conference of the United States Association of Energy Economics, Ann Arbor, Michigan, September 24–27, 2006.