V.F Delivery Analysis

V.F.1 Hydrogen Delivery Analysis

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Objectives

- Quantify the cost of delivering hydrogen by different modes and technologies under alternative types and levels of market demand by light-duty vehicles
- Compare alternative delivery modes on a consistent, transparent basis
- Identify delivery modes and infrastructures with potential to meet program delivery targets

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery Section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A Lack of Hydrogen/Carrier Options Analysis
- F. Hydrogen Delivery Infrastructure Storage Costs

Technical Targets

Under this project a Hydrogen Delivery Scenarios model is being developed to simulate the distribution of hydrogen from plant gate to dispensing onboard a vehicle. The model links the Hydrogen Delivery Components and Forecourt models, both of which were developed under the H2A project, in a systematic market setting to develop capacity/flow parameters for a hydrogen delivery infrastructure. Using that system level perspective, the model calculates the full cost (i.e., summed across all components) of hydrogen delivery, accounting for tradeoffs among the various component costs. As such, it is not a technical activity that can be measured against program targets but a tool that can be used to set such targets.

Approach

- Develop a set of scenarios to capture those parameters relevant to the delivery of gaseous or liquid hydrogen for light-duty transportation vehicles. Estimate hydrogen demand under those scenarios.
- Characterize likely pathways from the plant gate of a centralized hydrogen production facility to the tank of a hydrogen-fueled vehicle and the equipment/components needed to accomplish this.
- Review the technical literature and work with industry experts to develop the data and assumptions needed to model pathways and components.

- Develop a Hydrogen Delivery Scenarios model to link components characterized in a separate Hydrogen Delivery Components model in order to simulate the distribution of hydrogen fuel via these pathways. Use scenario estimates of demand to size the broad classes of equipment characterized in the Delivery Components model.
- Run the resulting linked models to estimate the cost of each component and the total cost (summed across components) for delivering a scenario-defined quantity of hydrogen to a given market.
- Calculate cash flow and other financial parameters associated with each pathway under each scenario.

Accomplishments

- Characterized urban and rural demand for light-duty vehicular fuel in terms that could be modeled in a limited set of urban and rural scenarios. Constructed GIS maps depicting population by size of urbanized area, by location vis a vis the U.S. interstate highway system and the natural gas transmission pipeline system, and by interstate travel density.
- Completed version 1.0 of the Hydrogen Delivery Scenarios model and distributed it to a select group of industry, national lab and DOE reviewers.
- Ran 32 permutations defined by market type, penetration level and delivery mode to yield model estimates of hydrogen delivery costs (excluding forecourt) ranging from less than $.50/kg to over $7.00/kg.
- Began sensitivity analyses of input parameters.

Future Directions

- As needed, update version 1.0 of the Hydrogen Delivery Scenarios model to reflect review comments.
- Expand the Hydrogen Delivery Scenarios model to simulate additional markets and penetration levels, additional delivery components and pathways, and additional infrastructure configurations.
- Enhance reporting capabilities of the Hydrogen Delivery Scenarios model. Automate the generation of tornado charts and other sensitivity analyses.
- Conduct internal and external model reviews.
- Document the model and results.

Introduction

This work evolved from the H2A project which focused on developing consistent, transparent tools to model the three major sets of infrastructure (production, delivery and forecourt) that contribute to the cost of hydrogen fuel. Historically, considerable effort has been devoted to hydrogen production analysis. Process modeling tools and the knowledge base to apply them are readily available. This is not true for delivery analysis, a relatively recent addition to the DOE Hydrogen Program, where model development continues.

Delivery analysis seeks to characterize the cost of the various pieces or "components" of alternative pathways that hydrogen fuel can take from a central production facility to the tank of a hydrogen-fueled vehicle. Coupled with scenario analysis, which is used to estimate the quantity of hydrogen needed to satisfy market demand, the cost of appropriately-sized components can be estimated and summed to calculate the cost of entire paths for delivering hydrogen. This was accomplished in the past year by constructing a Hydrogen Delivery Scenarios model which estimated market demands and linked components characterized in a separate Hydrogen Delivery Components model. Models such as these can be used in the future to refine program targets, investigate tradeoffs and synergies among targets and identify the impacts of technology improvements on cost targets.

Approach

As with other parts of the H2A project, this work is intended to develop a tool to produce consistent, transparent estimates of a specific portion of the cost of hydrogen – in this case, the cost for the chain of activities needed to bring hydrogen from its production site to a vehicle. The tool is an Excel-based spreadsheet model.

Results

In FY 05, Version 1.0 of the Hydrogen Delivery Scenarios model was completed. Figure 1 provides a conceptual overview of the model's three blocks or streams. On the right is the scenario-definition block where the user selects a combination of market, penetration level and delivery mode which the model uses to estimate the quantity of hydrogen to be delivered. In the center block the model calculates the capacities/flows needed for the various components comprising the pathway being modeled and the resulting costs of those components. In the Inputs section the user can override many of the default parameters that go into these calculations. Estimates of delivery cost are then displayed in various ways in the Results block.

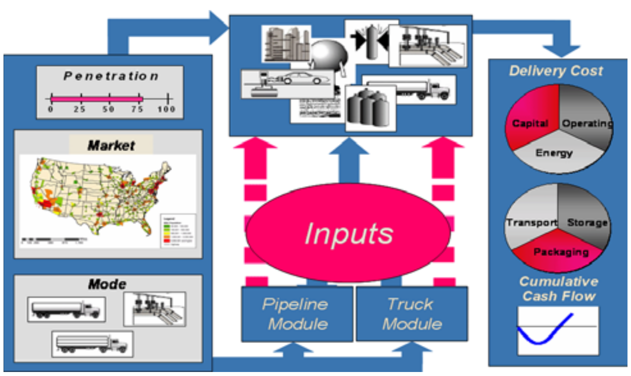

Figure 1. Hydrogen Delivery Scenarios Model

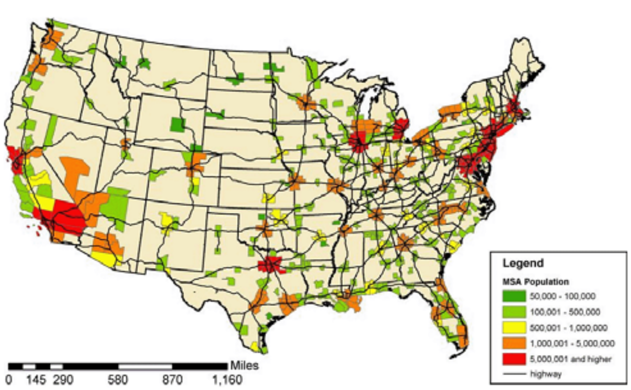

Figure 2. Urbanized Areas by Size and Location

Figures 2-3 show some of the GIS analyses used to develop scenario parameters. In addition to characterizing urbanized areas by population and vehicle ownership, data were also developed on distances between urbanized areas, traffic densities on rural interstate highways, and the proximity between natural gas transmission pipelines and interstate highways.

Note that DVMT/mi (daily vehicle-miles traveled per mile of road), the measure of traffic density displayed in Figure 3 is equivalent to average daily traffic volume.

Figures 4-5 show selected results. Delivery cost is highly dependent on scale. Thus, the cost to deliver hydrogen to larger markets, particularly under higher market penetration levels, is significantly less than for smaller markets under lower penetration. Delivery via gaseous pipeline is generally less expensive than delivery via liquid tank

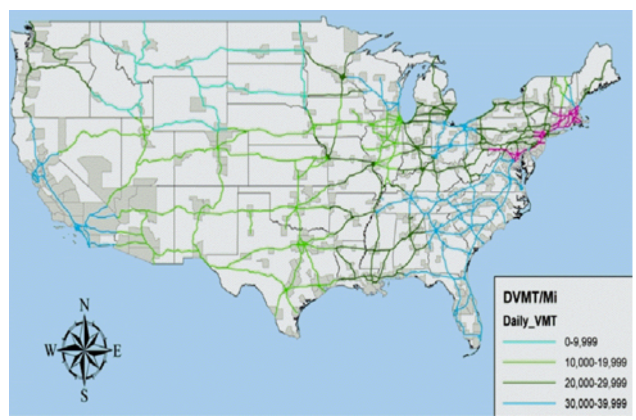

Figure 3. Urbanized Areas, Interstate Highways and Traffic Density

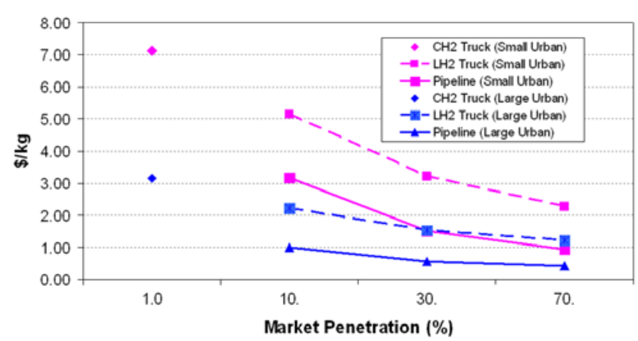

Figure 4. Hydrogen Delivery Cost by Urban Area Size, Market Penetration and Delivery Mode

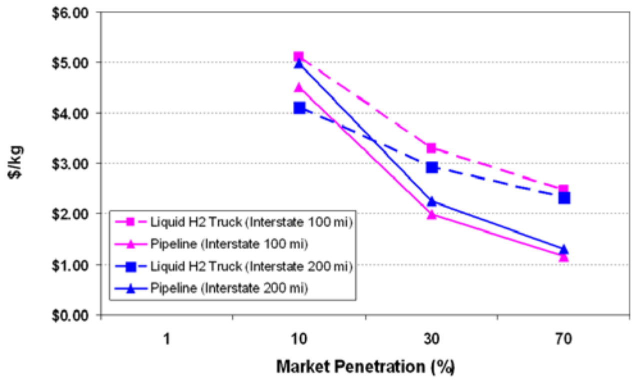

Figure 5. Hydrogen Delivery Cost to Interstate Highway Markets by Scale and Delivery Mode

truck (LH2) which in turn is less expensive than delivery via compressed gas tube trailer (CH2).

Conclusions

- With current technologies, delivery costs do not approach program goals until and unless large-scale systems are available.
- Delivery costs are particularly high for rural/interstate delivery via conventional technologies.
- For pathways modeled, packaging (liquefiers, compressors) and pipelines account for the largest shares of capital cost.
- Mixed systems of urban and rural delivery may reduce rural delivery costs.
- Additional pathways and technologies (e.g., high pressure tube trailers, hydrogen carriers) should be examined to reduce delivery costs.

FY 2005 Publications/Presentations

1. Mintz, Marianne, Jerry Gillette, Jay Burke, John Molburg and Joan Ogden, *Hydrogen Delivery Scenarios Model*, Presented at the National Hydrogen Association Annual Meeting, Washington, DC (March 30, 2005)
2. Molburg, John, Marianne Mintz and Jerry Gillette, *Modeling Pipeline Delivery of Compressed Gaseous Hydrogen to Urban Refueling Stations*, Transportation Research Board Annual Meeting, Washington, D.C (January 10, 2005)

Special Recognitions & Awards/Patents Issued

1. 2005 DOE Hydrogen Program R&D Award "In recognition of outstanding achievement in developing a hydrogen production cost model known as H2A".