X.7 Hydrogen Station Economics and Business (HySEB)—Preliminary Results

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Project Start Date: October 1, 2013
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Develop a model that optimizes hydrogen station deployment for business success
- Analyze profitability, risk, and public-private partnership in hydrogen station deployment
- Develop more understanding of the hydrogen supply infrastructure and the interplay between infrastructure and fuel cell electric vehicle (FCEV) demand

Fiscal Year (FY) 2014 Objectives

- Develop a preliminary version of the Hydrogen Station Economics and Business (HySEB) model
- Analyze station network economics with the cluster strategy

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(A) Future Market Behavior

(B) Stove-Piped/Siloed Analytical Capability

(D) Insufficient Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Milestone 1.12: Complete an analysis of the hydrogen infrastructure and technical target progress for technology readiness. (4Q, 2015)
- Milestone 1.15: Complete analysis of program milestones and technology readiness goals - including risk analysis, independent reviews, financial evaluations, and environmental analysis - to identify technology and risk mitigation strategies. (4Q, 2015)
- Milestone 1.16: Complete analysis of program performance, cost status, and potential use of fuel cells for a portfolio of commercial applications. (4Q, 2018)
- Milestone 1.19: Complete analysis of the potential for hydrogen, stationary fuel cells, fuel cell vehicles, and other fuel cell applications such as material handling equipment including resources, infrastructure and system effects resulting from the growth in hydrogen market shares in various economic sectors. (4Q, 2020)
- Milestone 2.2: Annual model update and validation. (4Q, 2011 through 4Q, 2020)

FY 2014 Accomplishments

- Developed a preliminary version of the HySEB model, which trades off infrastructure cost and fuel accessibility cost to find an optimal station deployment strategy that maximizes profitability for hydrogen station business.
- Completed the analysis of station network cash flow at the city level. Annual cash flow would be negative for about a decade. Building large stations first takes advantage of station economy of scale and delays the construction of additional stations for meeting fuel demand. Thus, compared with building small stations first, large-stations-first strategy has better cash flow and 8% lower system cost (the sum of infrastructure cost and fuel accessibility cost).
- Next-N-year net present value (NPV) is calculated to understand the risks perceived by investors and the relationship with investment planning horizon. It also builds a platform for analyzing public-private partnership in station economy.

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INTRODUCTION

Deployment of the hydrogen supply infrastructure is one of most critical issues that must be addressed for a successful market transition to FCEVs. Not only must hydrogen refueling infrastructure be constructed, it must also be commercially viable and sell hydrogen to customers at retail prices that will encourage the continued expansion of the vehicle market. The objective of this project is to develop a station deployment optimization model and analyze station network economics, risk of investment, viable business strategies, public-private partnership, and the interaction with consumer demand for FCEVs. This project will help the Fuel Cell Technologies Office explore scenarios of station deployment and business models that enable commercially viable early hydrogen refueling infrastructure. Understanding how long, at what cost, and by what processes the U.S. can transition to a market-driven, self-sustaining hydrogen supply industry is highly relevant to industry confidence, investment risk management, government policy effectiveness, and R&D planning.

APPROACH

The HySEB model optimizes key deployment decisions to meet fuel demand by trading off infrastructure cost and fuel accessibility cost. Decision variables are when, where to build, and the size of stations. Fuel accessibility cost is relative to gasoline, measured by additional detour time in order to access hydrogen refueling stations. Apparently, early FCEV buyers would prefer high fuel availability (measured by the ratio of the number of hydrogen stations to the number of gasoline stations); however, to achieve high fuel availability in early commercialization implies deploying more small-sized stations and/or lower station utilization, which in turn leads to the loss of station scale economy and increased hydrogen cost. The model also considers driving pattern heterogeneity in order to more accurately estimate hydrogen fuel demand in the region of interest. Driving pattern data is obtained from the 2009 National Household Travel Survey. We classified California drivers into six groups: frequent driver and long commute (FLC), frequent driver and short commute, average driver and long commute, average driver and short commute, moderate driver and long commute, and moderate driver and short commute (MSC). For each driver group, fuel demand at location stations is calculated (assuming refueling at connector stations if daily driving distance is greater than a threshold value). A higher share of frequent drivers with long commute distance is expected to contribute more to local station business.

FCEV market penetration is assumed to be exogenous, constrained by the zero-emission-vehicle mandate. Station deployment scenarios are developed based on clustering strategy [1]. All station capital, operating and maintenance (O&M) costs, and efficiency data are consistent with Ref. [3] and the H2A model. Station network economics and investment risks at the city level are analyzed.

RESULTS

The project developed an Excel-based model, which takes input of FCEV attributes and penetration assumptions, driver characteristics including driving pattern, value of time, and discount rate, as well as infrastructure assumptions including station capital cost and O&M cost as a function of station size and type. The model outputs station deployment solutions (when and where to build and station size) and calculates cash flow and total system cost (infrastructure cost plus fuel accessibility cost). The model will be continuously expanded and improved with the goal to facilitate Fuel Cell Technologies Office discussions on economics and business models of early hydrogen refueling infrastructure.

Based on clustering strategy of station deployment [1], the case study focuses on station network in a cluster (a small city). The optimization algorithm is still under development. In FY 2014, the project is evaluating three station build-out scenarios which meet exogenous fuel demand: small station first (SSF), uniform-size station, and large station first (LSF). Total number of stations is a user input (it will be provided by the optimization model in the future work). The SSF scenario refers to deploying small-size stations first, then medium-size stations, and finally large stations. By contrast, the LSF scenario deploys larger stations first and smaller stations later. The scenarios are designed to examine the importance of station scale economy and timing of roll-out. Compared with small stations, large stations have better scale economy in terms of both capital cost and O&M cost but have lower utilization rate, particularly in the early market.

Cash flow analysis at the city level was conducted for all three scenarios (Figure 1 for the SSF scenario and Figure 2 for the LSF scenario). Positive cash flow includes hydrogen sales revenue and negative flow includes capital cost as a lump sum payment and annual O&M cost. Station owners endure net loss for about a decade before the break-even point. Figure 1 shows annual cash flow becomes positive around 2025 and cumulative flow is negative until 2029. Figure 2 for the LSF scenario shows slightly improved station economics—cumulative cash flow is already positive in 2027.

Next, we examined risks of investment and implications for public-private partnership (Figure 3). Since station cash flow is negative for at least a decade, investors' planning horizon is an important factor to determine how they perceive the risk of the investment. Figure 3 shows next-N-year NPV at each year, which is defined as NPV of the cash flows during the next N years. As expected, investment risk will be (perceived) smaller if the investors enter the market late or if they are more patient (indicated by a longer planning horizon). Comparing SSF and LSF scenarios, LSF

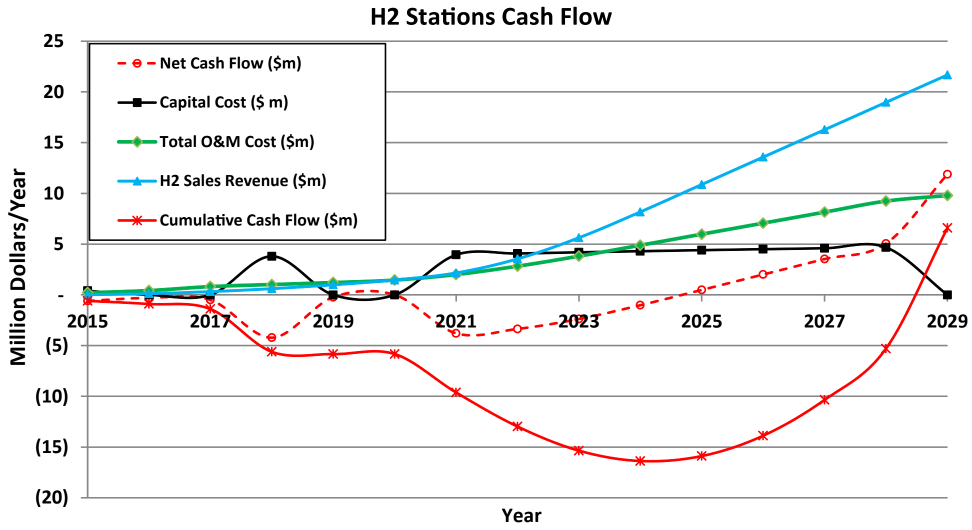

FIGURE 1. Hydrogen Stations Cash Flow for the SSF Strategy

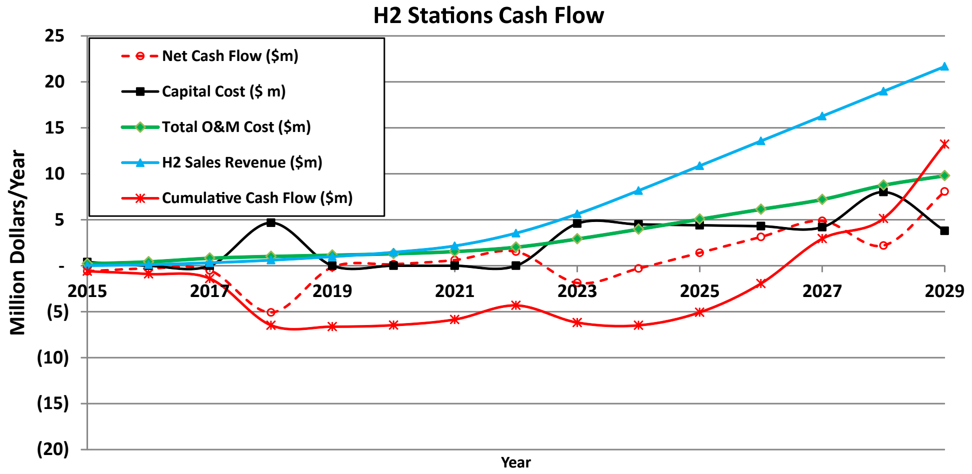

FIGURE 2. Hydrogen Stations Cash Flow for the LSF Strategy

has higher next-N-year NPV in the early period. LSF also has smaller government buy-down cost, which is defined as the cumulative sum of negative cash flows over the period. Namely, buy-down cost measures government subsidy cost if it wishes to pay for all losses before positive cash flows.

Table 1 shows total system cost (and infrastructure cost component in the parentheses) for the SSF and LSF scenarios under different assumptions of driving pattern. The reference driving pattern assumes drivers consists of 2% FLC, 2% frequent driver and short commute, 25% average driver and long commute, 25% average driver and short commute, 23% moderate driver and long commute, and 23% MSC. The percentage is calibrated to the 2009 National Household Travel Survey data. 100% FLC assumes early FCEV drivers are all frequent drivers with long commutes who have the highest fuel demand at local stations in the city, while 100% MSC assumes early FCEV drivers are all moderate drivers with short commutes who have the lowest fuel demand at local stations in the city. Table 1 shows the LSF scenario has lower system cost than the SSF scenario while the 100% FLC driving pattern leads to lower system cost than other mixes of driver groups.

TABLE 1. Total System Cost (and infrastructure cost component in the parentheses) for the SSF and LSF Scenarios

	Small Station First	Large Station First
Reference Driving Pattern	12.4 (9.2) $/kg	11.4 (7.8) $/kg
100% FLC	9.4 (5.9) $/kg	9.7 (6.4) $/kg
100% MSC	14.7 (11.7) $/kg	12.3 (8.5) $/kg

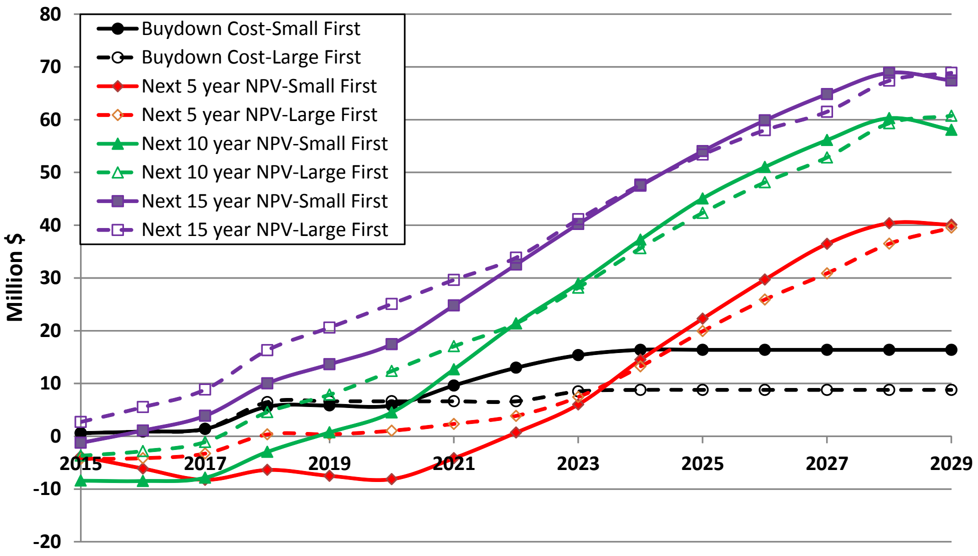

FIGURE 3. Buy-Down Cost and Next-N-Year NPV

CONCLUSIONS AND FUTURE DIRECTIONS

In summary, the project developed a preliminary version of the HySEB model that trades off infrastructure cost and fuel accessibility cost to find the optimal station deployment strategy. Cash flow analysis results suggest station networks at the city level may endure negative cash flows for about a decade. Station scale economy is important in planning station build-out, as illustrated by better cash flow and lower system cost of the LSF strategy. LSF delays the construction of additional stations for meeting early fuel demand. Investment risks perceived by investors would depend on their planning horizon, i.e., their investment patience. Limiting public subsidy would require more investor patience, and investors may be more patient if they perceive less technological and policy risk.

Future work will focus on model upgrade, uncertainty analysis, and public-private cost share mechanisms.

- Develop an optimization algorithm that identifies station placing and sizing strategy to minimize system cost
- Conduct uncertainty analysis, especially on fuel demand and station cost
- Integrate with consumer choice model and analyze the interplay between infrastructure and vehicle penetration by representing investor patience, risk, and hydrogen pricing
- Determine business viability for connector stations
- Conduct more analysis of public-private cost share mechanisms.

FY 2014 PUBLICATIONS/PRESENTATIONS

1. Zhenhong Lin, Changzheng Liu, and David Greene, Hydrogen Station Economics and Business (HySEB) -- Preliminary Results, 2014 DOE Fuel Cell Technologies Program Annual Merit Review June 17, 2014.

REFERENCES

1. Ogden, Joan M. and Michael A. Nicholas (2011) Analysis of a "Cluster" Strategy for Introducing Hydrogen Vehicles in Southern California. Energy Policy 39 (4), 1923–1938.

2. Joan Ogden, Design and Economics of an Early Hydrogen Refueling Network for California, 2013 DOE Fuel Cell Technologies Program Annual Merit Review, May 14, 2013.