III.11 Reference Station Design

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Overall Objective

- Speed acceptance of near-term hydrogen infrastructure build-out by exploring the advantages and disadvantages of various station designs and propose near-term optima

Fiscal Year (FY) 2015 Objectives

- Provide a detailed view of how these stations fit in greenfield and existing sites in relation to the National Fire Protection Association 2 standard
- Help station developers quickly evaluate the suitability of their sites for a particular station type and capacity
- Provide station developers and local authorities a complete picture of the devices, components, and associated costs that make up a station
- Provide a tool that the H2USA financing and market support and acceleration working groups can use to develop station rollout scenarios
- Promote common component sizing and interchangeability

Technical Barriers

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

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

(K) Safety, Codes and Standards, Permitting

Technical Targets

This project aimed to reduce the costs of near-term hydrogen fueling stations by describing cost-effective designs. The DOE 2020 cost target for hydrogen delivery and dispensing in a high-volume market (wherein costs decline due to economies of scale) is $2.00/gge for a fully utilized 1,000 kg/d station. The Reference Station Design task identified four station designs that leverage technologies available today and have a levelized cost of $5.80–$13.30/gge in today's market (assuming the costs of technologies today, and the utilization rates expected in California in the near term).

FY 2015 Accomplishments

- Primary Results
  - Screened 160 station designs that are possible in the near term, and selected five that are the most viable based on economics, technical feasibility, and market need
  - Produced spatial layouts, bills of materials, and piping and instrumentation diagrams for five station concepts that are viable in the near term
- Ancillary Results
  - Assessed several projections of annual fuel cell electric vehicle (FCEV) rollout in the near term
  - Assessed near-term hydrogen station rollout including number of stations, capacity, and overall utilization
  - Compiled current costs for all station components, and compared to default inputs in Hydrogen Refueling Station Analysis Model (HRSAM)
  - Assessed costs of 120 station permutations: capital cost and station contribution to cost of hydrogen, including effect of different utilization scenarios

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INTRODUCTION

The goal of the Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) Reference Station Design Task is to accelerate acceptance of hydrogen infrastructure build-out by exploring the advantages and disadvantages of various station designs. These reference designs will help reduce the cost and speed the deployment of hydrogen stations by providing a common baseline with which to start a design. The designs enable quick assessment of the suitability of a particular site for a hydrogen station, and they drive interchangeability of parts and manufacturing scale by employing uniformly sized components. The station configurations evaluated were not all inclusive. It is not the intent to promote any specific station configuration or exclude any designs, but rather provide a rigorous analysis of a subset of likely near-term station configurations.

APPROACH

The H2FIRST team screened 160 possible station permutations using the Hydrogen Refueling Station Analysis Model developed by ANL. The team developed input parameters and station configurations with feedback from the H2USA Hydrogen Fueling Station Working Group (HFSWG), California Fuel Cell Partnership, California Air Resources Board (CARB), and industry. These station configurations were down selected by evaluating (1) the station contribution to the cost of hydrogen, (2) station capital cost, and (3) time to positive return on investment (ROI). An approximate seven-year ROI was used for all stations. The team then selected stations with the lower of the first two values. This narrowed the list to 15 stations. From this set, the team selected stations to meet projected near-term market needs based on the station classification system described by CARB: high-use commuter, low-use commuter, and intermittent use profiles. This selection narrowed the list to the final set of five stations. The team then developed detailed designs for those final four stations.

RESULTS

Estimated Near-Term Station Utilization

By estimating FCEV rollout scenarios and combining those with station build predictions, near-term network utilization was estimated and used as an input for cost modeling. For modeling purposes, it was assumed that the utilization rate of each individual station would be equivalent to that of the network.

Determined Station Parameters with Near-Term Ranges of Interest

Five parameters were chosen to describe the overall performance of a hydrogen fueling station: (1) design capacity, (2) peak performance, (3) number of hoses, (4) fill configuration, and (5) hydrogen delivery method. The H2FIRST team chose the selected parameters, definitions, and range values through detailed conversations with members of the H2USA HFSWG, DOE headquarters personnel, and ANL personnel in the spring of 2014, and vetted them with the entire H2USA HFSWG membership. Table 1 describes the parameters and ranges of interest chosen for near-term station designs.

TABLE 1. Performance Parameters and Values Used for Screening

Performance Parameter	Values Used for Screening
Design capacity (kg/d)	50, 100, 200, 300
Peak performance	2, 3, 4, 5, 6 consecutive fills per hose
Number of hoses	1, 2
Fill configuration	Cascade, booster compressor
Hydrogen delivery method	Gas (tube trailer), liquid trailer

Estimated Station Capital Cost and Station Contribution to the Cost of Hydrogen

The team used HRSAM to simulate 120 station concepts using the parameters, costs, and ranges defined earlier and the developed utilization and daily demand profiles. The team performed a comparative analysis to select the most cost-effective, near-term station designs for further analysis and design. Some high-level conclusions show the following.

- While the smallest capacity stations have the lowest capital cost, the levelized station contribution to the cost of hydrogen is the highest.
- For each station capacity (50, 100, 200, and 300 kg/d), the station concept that has the lowest capital cost also has the lowest levelized station contribution to the cost of hydrogen.
- The consecutive fill requirement has more of an impact on capital cost than on levelized station contribution to the cost of hydrogen.

In addition, all stations were resimulated using a constant 20% utilization for 10 years in order to compare the effect of low utilization on station economics and found that all station designs are nearly equally affected by the low utilization. In other words, there is no particular station design that is better than another in withstanding a lower-than-expected utilization.

Matched Economically Best-Performing Station Design Possibilities with Market Needs

Station performance parameters were mapped to station classifications as follows.

TABLE 2. Economically-viable station concepts determined by economic screening

Profile	Site Type	Delivery	Capacity (kg/d)	Consecutive Fills	Hoses	Station Contribution to Hydrogen Cost ($/kg)	Capital Cost (2009$)
High Use Commuter	Gas Station or Greenfield	Gaseous	300	6	1	$6.03	$1,251,270
High Use Commuter	Greenfield	Liquid	300	5	2	$7.46	$1,486,557
Low Use Commuter	Gas Station or Greenfield	Gaseous	200	3	1	$5.83	$1,207,663
Intermittent	Gas Station or Greenfield	Gaseous	100	2	1	$13.28	$954,799

- High use commuter: Greenfield or existing gasoline station, high daily capacity, multiple hoses, 5+ consecutive fills per hour per hose
- Low use commuter: Greenfield or existing gasoline station, compressed gas or liquid supply, medium daily capacity, single or multiple hoses, several consecutive fills per hour
- Intermittent: Greenfield, compressed gas supply, low daily capacity, single hose, ability to meet multiple consecutive fills per hour when called for

The most economically viable station concepts determined by economic screening was then selected to fulfill each of these three classifications as shown in Table 2.

Produced Full Station Designs

For each station identified in the above table, the team produced piping and instrumentation diagrams, corresponding component-level bills of materials with individual costs, and spatial layouts considering codified setback distances at both existing gasoline stations and Greenfield sites. (Note: the produced figures are too complex to be reproduced in the size of this report but are available online through the H2FIRST website: http://energy.gov/eere/fuelcells/h2first).

CONCLUSIONS AND FUTURE DIRECTIONS

This work presented the hydrogen community with a uniform, cost-optimal formula for designing and building hydrogen stations. The piping and instrumentation diagrams and bills of materials provided include a level of detail not previously reported publicly. Additionally, through this work the H2FIRST team has identified four primary areas where the design of stations and station networks can be further improved in the near term.

- Component technology: designs are needed for off-the-shelf chillers, cryogenic pumps, evaporators, high-capacity tube trailers, and underground storage.
- Station systems: work to reduce the need to chill hydrogen prior to dispensing, reduce boil off in liquid systems, and utilize more of the hydrogen in a gaseous tube trailer could all have significant impacts on the system cost.
- Codes and standards: this work reinforced the need to use science-based methods to reduce the setbacks required for liquid stations. These setbacks are one of the largest hurdles to the placement of high-capacity liquid hydrogen stations in dense urban areas (where the customer base will be the highest).
- Business practices: utilization is the most important variable to impact the financial viability of a station. To the extent that hydrogen station networks can be optimized to maximize utilization, more of those stations will be self-sustaining and profitable.

Future iterations of the reference station task would likely include the following.

- Assessment of technological and economic changes
- Re-evaluation of parameter ranges of interest to near-term stations
- Re-assessment of economic potential of new station concepts
  - On-site generation
  - Light-heavy-duty mixed stations
- Assisting assessment of economic impact of different business practices
- Production of new station designs that reflect these changes

FY 2015 PUBLICATIONS/PRESENTATIONS

1. D. Terlip, J. Pratt, A. Elgowainy, C. Ainscough, and J. Kurtz, "Reference Station Design," presented at the Interagency Working Group on Hydrogen and Fuel Cells, July 21, 2015.

2. D. Terlip, J. Pratt, A. Elgowainy, C. Ainscough, and J. Kurtz, "Reference Station Design," presented at the H2USA Hydrogen Fueling Station Working Group meeting, May 14, 2015.

3. J. Pratt, "How to Design a Hydrogen Station in Seven Easy Steps (and Why)," presented at Combustion Research Facility Research Highlights Series, April 2, 2015.

4. J. Pratt, D. Terlip, C. Ainscough, J. Kurtz, and A. Elgowainy, "H2FIRST Reference Station Design Task Project Deliverable 2-2," Technical Report NREL/TP-5400-64107 or SAND2015-2660R, April 2015.

5. D. Terlip, J. Pratt, A. Elgowainy, C. Ainscough, and J. Kurtz, "Reference Station Design," presented at the H2FIRST Spring Coordination Panel Meeting, March 18, 2015.