

X.9 Lessons Learned for Refueling Infrastructure

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Subcontractors:

- Energetics, Columbia, MD
- Reneregh, Buenos Aires, Argentina

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Project End Date: January 15, 2009

Objectives

Each of the following objectives guides one of the four project subtasks:

- **Lessons Learned Workshop.** Gather and articulate feedback from a variety of expert stakeholders on lessons learned for hydrogen infrastructure development based upon past experiences with alternative fuels and vehicles and recent experiences with hydrogen station demonstrations.
- **Compressed Natural Gas (CNG) Vehicle Experience in Argentina.** Collect and document empirical data and stakeholder perspectives related to the successful introduction of natural gas vehicles and infrastructure in Argentina.
- **Analogies from Manufactured Gas.** Review the early history of the manufactured gas industry and identify insightful analogies to hydrogen infrastructure development.
- **Retail Station Distributions.** Develop a parametric representation of retail station growth based upon past trends.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section (4.5) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Future Market Behavior

- (C) Inconsistent Data, Assumptions and Guidelines
(D) Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestone from the Systems Analysis section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 4:** Complete a “lessons learned” study of the development of other infrastructures which apply to hydrogen fuel and vehicles (4Q, 2008)

Accomplishments

- Planned and conducted a 1.0-day lessons learned workshop involving 60 participants from industry, government, national labs, non-governmental organizations, and academia.
 - Organized 10 expert presentations on past experiences and suggested lessons based upon a wide range of infrastructure topics.
 - Facilitated three breakout groups that provided feedback on relevant lessons learned and priority action items for future hydrogen infrastructure development.
 - Prepared draft workshop proceedings and circulated these draft proceedings to all workshop attendees to allow for additional input.
 - Completed final proceedings for the lessons learned workshop.
- Initiated subcontract with Reneregh to collect information on the introduction of natural gas vehicles in Argentina.
- Identified relevant analogies between the early history of the manufactured gas industry and future hydrogen infrastructure challenges.
- Quantified key parameters in urban and rural gasoline retail station growth trends.



Introduction

Many lessons can be learned from past experiences with alternative and conventional refueling infrastructure for vehicles. This project draws upon four past experiences to improve our understanding of future

challenges facing hydrogen infrastructure development. The experiences are distinct from one another but are interrelated in terms of the lessons they provide. The cohesive issue is the development of refueling infrastructure to support early hydrogen vehicle markets. The project draws upon past experiences through four subtasks: (1) a lessons learned workshop involving multiple stakeholder types, (2) an empirical study of the successful introduction of CNG vehicles in Argentina, (3) a historical review of the early manufactured gas lighting industry (1816 through the 1920s), and (4) a quantitative assessment of past trends in gasoline retail station distributions in response to urban population growth.

Each of the four subtasks contributes to the DOE technical target for the delivered cost of hydrogen by improving our understanding of the challenges facing near-term infrastructure development. Of these four subtasks, the lessons learned workshop has been completed and involved 60 percent of the total project effort. The other three subtasks are ongoing. Workshop proceedings will prove useful for a range of stakeholders involved in hydrogen infrastructure development efforts. An improved characterization of the successful co-evolution of CNG vehicles and infrastructure in Argentina will help us understand the potential influence of different factors on hydrogen infrastructure development, such as economics, policy support, technology development, and consumer and industry decision-making processes. Analogies drawn between early manufactured gas industry and hydrogen can contribute insights into our conceptual understanding of the challenges facing hydrogen infrastructure development. Finally, a quantitative representation of changing trends in the total number of retail stations serving rural and urban populations can be used in a variety of analysis models that represent stations explicitly.

Approach

Each of the four subtasks entails a distinct research approach. The lessons learned workshop used expert presentations, open plenary discussions, and facilitated breakout groups to collect stakeholder feedback on key infrastructure development issues. The content of the presentations, discussions, and breakout group feedback was summarized in a synthesis report. An early draft was circulated to workshop participants to give them an additional opportunity to provide feedback on particular issues. The second subtask, the empirical study of CNG vehicles in Argentina, employs surveys and interviews and involves the collection of all available information (such as news articles, government documents and public records, business records, etc.) related to the successful introduction of CNG vehicles (for a comparison of international CNG vehicle efforts,

see [1]). The third subtask, the manufactured gas history study, involves a review of primary and secondary sources describing the evolution of the industry between 1816 (first manufactured gas company in Baltimore) through the 1920s (ramp-up of long-distance pipelines for natural gas as a substitute for manufactured gas). Based upon this historical review, analogies are identified that can provide insights into hydrogen infrastructure development challenges. The final subtask, the retail refueling station distribution study, involves the analysis of multiple gasoline station data sources to identify past trends in station distributions. Correlations between changes in the spatial distribution of gasoline stations and changes in demographics can serve as a basis for projecting future station distributions (e.g., out to 2020).

Results

The lessons learned workshop, Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen, was held on April 3, 2008, in Sacramento, California, the day after the National Hydrogen Association's conference, also held in Sacramento. Ten presentations were made in three panel sessions, focusing on: (1) lessons from the alternative fuel vehicle experience, (2) lessons from hydrogen station demonstration projects, and (3) innovation and coordination. Participants were separated into three breakout groups to discuss lessons learned and action items relevant to near-term hydrogen infrastructure development. Each of the breakout groups voted to prioritize action items. Top action items fell into the following five categories (percentages indicate the fraction votes for the top 15 action items, five from each group):

- Station Design, Siting and Availability (34%)
- Policy and Regulatory Issues (29%)
- Insurance and Liability (15%)
- Consumer Focus (13%)
- Incentives (9%)

The workshop proceedings and presentations are posted on the workshop Web site: http://www1.eere.energy.gov/hydrogenandfuelcells/refueling_infrastructure_workshop.html.

The second subtask, the study of the CNG vehicle experience in Argentina, has just been initiated; therefore, results are not yet available.

Results of the third subtask, study of the history of the manufactured gas industry, have revealed insights into the future development of a hydrogen infrastructure. The following brief history helps to illustrate this point. The U.S. gas lighting industry began with the first gas works company in Baltimore in 1816. Gas

was produced by heating coal in oxygen-limited retorts, resulting in a product gas and coke byproduct. Later, “water-gas” was produced by exposing steam to heated, incandescent coke, resulting in a hydrogen-rich product gas. After the discovery of oil in 1859, “carbureted” water gas became competitive. Gas lighting began with public street lighting but remained profitable by providing lighting to businesses and high-income households. Middle and lower income households continued to rely upon candles and whale oil lamps, and later coal oil and kerosene. Eventually, beginning with Edison’s first substation in 1882, electric lighting grew to dominate commercial and household lighting. Manufactured gas production facilities adapted by serving household heating and cooking markets, as well as industrial gas consumers. The following themes within the manufactured gas industry may be drawn upon to develop insightful analogies for hydrogen infrastructure development:

- Introduction on a city-by-city basis.
- Reliance on long-term, negotiable municipal franchises.
- Market pull created by public street lighting applications.
- Increased innovation in reaction to competition.
- Adoption of new marketing metrics and strategies in response to technological changes and the need to expand into new markets.

Preliminary results have been attained from the retail station distribution study, the fourth subtask. Key parameters for the retail station distribution study include station density (stations per square kilometer), population density, gasoline demand density (liters per square kilometer per month), and rates of change for each of these over time. Preliminary results suggest that the number of urban stations has been increasing since 1990 while the nationwide count has been declining. This trend has occurred while urban areas have grown and while the number of urban stations per square mile has declined. These urban and nationwide trends suggest significant atrophy of rural stations since 1990.

Conclusions and Future Directions

- Past experiences with alternative fuels and vehicles can offer a variety of lessons for future challenges facing hydrogen infrastructure development and can serve as a point of departure in multi-stakeholder discussions of actions needed to address these challenges.
- Insightful analogies can be drawn between the early gas lighting industry and future hydrogen systems.
- The number of urban gasoline stations has been increasing while both the density of urban stations and the total number of stations (urban and rural) has been declining.
- Work will continue on the remaining subtasks through 2008, but no additional work is anticipated on this project beyond 2008.

FY 2008 Publications/Presentations

1. Melaina, McQueen and Brinch. Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen. Proceedings from a workshop, April 3, 2008, Sacramento, California (2008).
2. M. Melaina. Lessons Learned for Fueling Infrastructure. Presentation at the DOE Hydrogen Program Annual Merit Review, June 12, 2008, Arlington, VA (2008).

References

1. Yeh, S. “An empirical analysis on the adoption of alternative fuel vehicles: The case of natural gas vehicles.” *Energy Policy* (35:11), (2007), pp. 5865-5875.