VIII.6 Hydrogen Production Infrastructure Options Analysis

Brian D. James (Primary Contact), Julie Perez, Pete Schmidt
Directed Technologies, Inc.
3601 Wilson Blvd., Suite 650
Arlington, VA 22201
Phone: (703) 778-7114; Fax (703) 243-2724
E-mail: Brian_James@directedtechnologies.com

DOE Technology Development Manager: Fred Joseck
Phone: (202) 586-7932; Fax: (202) 586-9811
E-mail: Fred.Joseck@ee.doe.gov

DOE Project Officer: Jill Gruber
Phone: (303) 275-4961; Fax: (303) 275-4753
E-mail: Jill.Gruber@go.doe.gov

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Objectives

- Develop understanding of how a hydrogen production infrastructure for H_2 fuel cell/internal combustion engine (FC/ICE) vehicles might develop in the U.S.
- Quantify production methods under consistent cost and state-of-technology assumptions.
- Analyze infrastructure development under dynamic conditions over time.
- Determine factors that will drive infrastructure development.
- Define role of externalities such as policy and technology advancement.
- Develop a computational model to aid in the analysis.

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) Lack of Prioritized List of Analyses for Appropriate and Timely Recommendations
(B) Lack of Consistent Data, Assumptions and Guidelines
(D) Stove-Piped/Siloed Analytical Capabilities
(E) Lack of Understanding of the Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy

Accomplishments

- Developed a format for the production database and populated it with 36 distinct production options to consider in the baseline analysis.
- Created a dispensing and delivery database based on extensive usage of the H2A models. These databases are referenced to generate the delivery and dispensing cost of hydrogen.
- Developed a baseline transition model that calculates the projected cost of hydrogen at the pump for a variety of production, delivery, and dispensing pathways. The model includes considerations of underutilization of assets, identifies stranded assets, and identifies which pathways supplies the lowest cost hydrogen and thus are most likely to be built.
- Used the baseline transition model to examine hydrogen production in Los Angeles beginning in 2015.
- Formed relationships with other H_2 experts and drew on their knowledge to improve and validate the logic and algorithms of the model.

Introduction

Historically, getting society to transition to a new technology is a lengthy process. The conversion of gasoline light-duty vehicles to hydrogen fueled vehicles is no exception. Consequently, the challenge is to determine what incentives are necessary to minimize the transition time and cost while maximizing market penetration. This project's goal is to develop a better understanding of how the H_2 production infrastructure to support fuel cell automobiles might develop in the continental U.S. taking into account the dynamic conditions under which it will evolve. The project will provide analysis of the options and trade-offs associated with establishing the required hydrogen production infrastructure to provide hydrogen to fuel cell vehicles in the 2020 timeframe and beyond.

Approach

The primary approach to achieve this goal is through the development and use of a computational model simulating industry's decision making process regarding construction of new H_2 production facilities. In Task 1, a database of key information describing current, emerging, and proposed hydrogen production, delivery and dispensing technologies is created. All data uses a consistent set of economic and performance criteria. The production methods are characterized by feedstock, product form, size and location. Feedstocks explored include coal (gasification), natural gas (steam methane reforming), water (electrolysis), and biomass (gasification). Product forms are gaseous and liquid outputs. The sizes are small (100 kg/day) and large (1.5 TPD) forecourts as well as city-gate (10s of TPD) and central sizes (100s of TPD). Central plants were also distinguished by locations such as inner city, city limits, central and regional. Within the baseline database there are approximately 40 production alternatives that are considered. In Task 2, a computer model is developed using the Task 1 database as input. The computer model performs economic optimization calculations for each of the production/delivery/dispensing infrastructure options, simulating which option is constructed in a given year based on the pathway with the lowest total profited cost per kilogram of hydrogen dispensed. When viewed over multiple years, a clear picture of the transition to the hydrogen economy is presented. The model identifies quantity, type and scale of the hydrogen facilities built in each year, the expected cost of hydrogen at the pump (profited cost), and any stranded assets resulting from lower cost options entering the market in later years. The model is exercised on a Los Angeles transition scenario that serves as a baseline case.

Sensitivity analyses and case studies are part of Task 3. By varying model parameters for hydrogen demand, facility costs, and technological developments, and applying policy drivers (carbon taxes, preferential tax treatment, and H_2 subsidies), one will arrive at the key parameters that influence infrastructure development. The results report is essentially Task 4. Recommendations will be provided to the DOE regarding how to facilitate the development of the production infrastructure for widespread hydrogen fuel cell vehicle usage.

Results

The model was tested with a simulated hydrogen demand curve for Los Angeles which predicts 15% penetration in the first 10 years of the transition and approaches full transition in 50 years. The demand profile and resulting hydrogen infrastructure build-out are shown in Figures 1 and 2. As you can see from Figure 2, the 1500 kgH_2/day forecourt steam methane

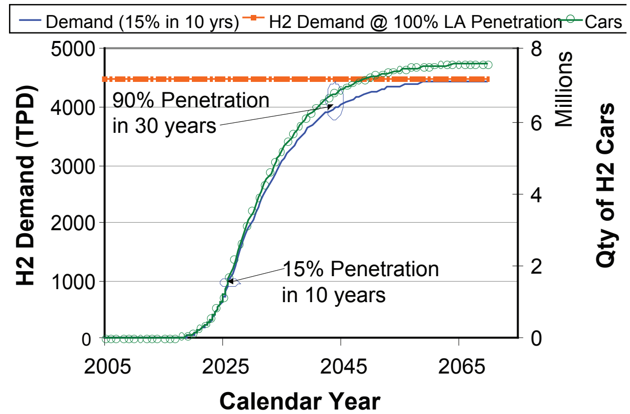

FIGURE 1. Hydrogen Demand Curve for Los Angeles (Baseline)

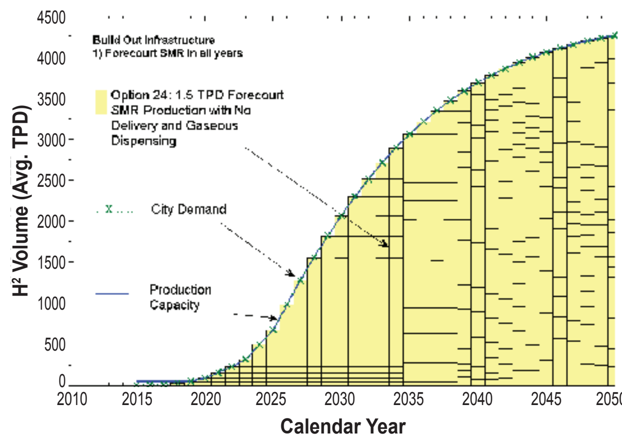

FIGURE 2. Hydrogen Build-Out for Los Angeles (Baseline)

reformer (SMR) is selected every year in the analysis. In Figure 3, the profited cost of several options is plotted against the analysis year. This plot is not inclusive of all the pathways considered but rather is a subset of the infrastructure pathways of interest. From this plot it is evident that the baseline forecourt SMR is always selected because its projected delivered cost of hydrogen is lowest in every year of the analysis period.

However, forecourt production systems employ relatively new technology and consequently have a higher capital cost uncertainty than larger scale, well-established production plants. Therefore, another option evaluated is the "Upper Bound" forecourt SMR with approximately double the total installed capital cost. (While a 2x factor on capital cost may seem extreme, estimates from experts in the community span that range.) Figure 3 shows the profited cost of this option is much greater and thus other options become more competitive if the "Upper Bound" is indeed the more accurate estimate for forecourt production. (Note: While Figure 3 shows the relative

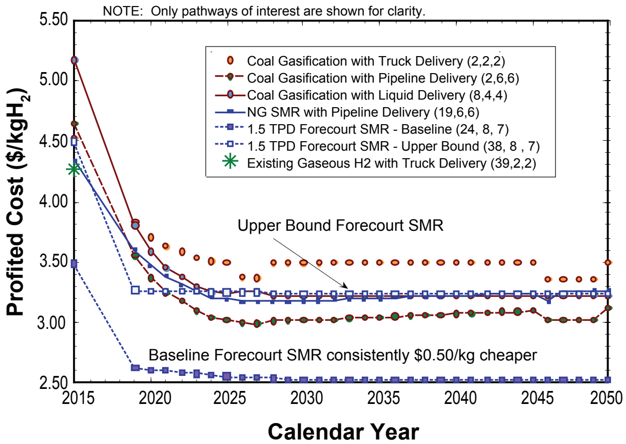

FIGURE 3. Profited Cost Comparison for a Subset of Options

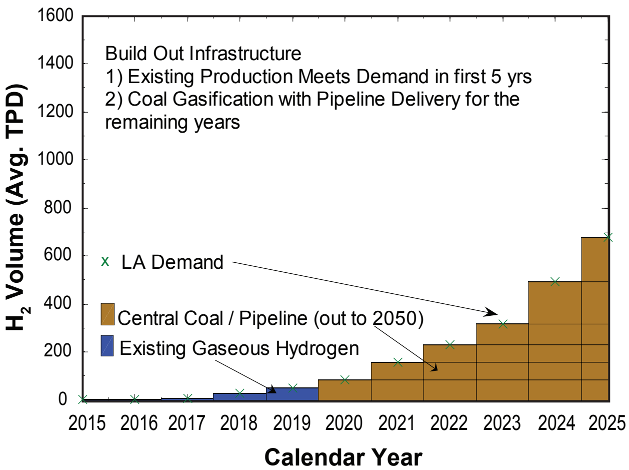

FIGURE 4. Hydrogen Build-Out for Los Angeles (Existing H2)

costs of multiple pathways, the projected cost in each year indirectly depends on the pathways chosen in previous years. Consequently, the analysis needs to be repeated whenever a winning pathway is eliminated from consideration.) With the increased capital cost of forecourt SMR, the infrastructure build-out is quite different as shown in Figure 4. Existing surplus hydrogen available in the Los Angeles basin, delivered by high pressure gaseous trucks, is observed to be the lowest cost source of hydrogen in the initial years, followed by coal derived hydrogen from central plants with pipeline delivery for the remainder of the transition. These outcomes are based strictly on selection of the pathway yielding the lowest profited cost of hydrogen delivered to the pump. Further study of the initial capital investment required is necessary and may suggest other infrastructure options should be selected.

Conclusions and Future Directions

- Many of these technologies are immature which means their costs cannot be verified. Our preliminary results seem to indicate that the error bounds on the cost inputs are cumulatively larger than the price differential between competing pathways. Consequently, decisions based solely on the cost of an infrastructure option may not be realistic.
- The transition model is a tool whose value is in determining the relative relationship and costs between different options since all are evaluated against the same set of assumptions and criteria.
- Additional demand conditions and population densities need to be evaluated to see how the infrastructure is affected by these parameters.
- The amount of subsidies and emission taxes needed to foster the hydrogen infrastructure development will also be evaluated.

FY 2006 Publications/Presentations

1. *'Hydrogen Production Infrastructure Options Analysis'.* Poster Presentation. 2005 DOE Hydrogen Program: Annual Merit Review and Peer Evaluation, Arlington, VA. 26 May 2005.

2. *'Hydrogen Production Infrastructure Options Analysis'.* Presentation. DOE Fuels Pathway Team, Fairfax, VA. 21 Sep 2005.

3. *'Hydrogen Production Infrastructure Options Analysis'* Presentation. DOE Transition Team, Washington, D.C. 26 Jan 2006.

4. *'DOE Hydrogen Infrastructure Analysis'.* Presentation. DTI Advisory Board, Arlington, VA. 20 Apr 2006.

5. *'FPITT Update on Model Status'.* Presentation. DOE Fuels Pathway Team, Washington, D.C. 27 Apr 2006.

6. *'Hydrogen Production Infrastructure Options Analysis'.* Presentation. 2006 DOE Hydrogen Program: Annual Merit Review and Peer Evaluation, Arlington, VA. 18 May 2006.