VIII.12 Geographically-Based Hydrogen Consumer Demand and Infrastructure Analysis

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Objectives

- Quantify hydrogen demand across the country and in targeted metropolitan areas.
- Estimate costs to support infrastructure development to meet emerging hydrogen demand.
- Understand issues related to sustainability of emerging hydrogen infrastructure.

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:

(E) Lack of Understanding of the Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy

Accomplishments

Identified key U.S. metropolitan areas that have a higher likelihood of early adoption of hydrogen fuel cell vehicles.

Introduction

Infrastructure development analysis seeks to understand the benefits and drawbacks of various options for installing hardware for a developing hydrogen demand. Critical to infrastructure analysis is the spatial component of understanding how to match vehicles with refueling infrastructure to determine optimal locations for hydrogen production and distribution systems.

Infrastructure has been a stumbling block in the transition to alternative transportation fuels. Most alternative fuel experts agree infrastructure issues are among the top barriers to transition. Therefore, infrastructure analysis is a key component in the hydrogen transition strategy. On a regional scale, the California Hydrogen Highway Network and the Upper Midwest Hydrogen Initiative are examples of infrastructure proposals to facilitate travel throughout a region. The National Renewable Energy Laboratory's fiscal years (FY) 2004 and 2005 infrastructure work had a similar focus: to facilitate interstate travel. While these initiatives have considered placement of infrastructure along major traffic routes to ensure mobility between metropolitan areas, a broader analysis to identify where hydrogen demand would first develop and what types of infrastructure would be needed to support that demand nationwide is an important next step to support the hydrogen transition.

Approach

To quantify the infrastructure necessary to support emerging hydrogen demand, that demand must first be understood and represented spatially. By identifying key attributes that influence whether a hydrogen fuel cell vehicle will be accepted by consumers and representing these attributes in a spatial format, we can predict demand. Then appropriate infrastructure options to meet that demand can be described. The following methods are being used in support of these objectives:

- **Define Demographics –** Key attributes affecting consumer acceptance of a hydrogen fuel cell vehicle will be identified and spatially analyzed using geographic information systems (GIS).
- **Assign Scores or Weight Each Attribute –** Assign values to each attribute and identify a total "score" that represents the likelihood to purchase/operate a hydrogen fuel cell vehicle.
- **Conduct Sensitivity Analyses and Stakeholder Review –** Sensitivity analysis and stakeholder review will ensure that the scores assigned for each demographic/characteristic are acceptable.
- **Define Infrastructure Scenarios at Various Penetration Rates –** Hydrogen demand will be evaluated for various rates of hydrogen

vehicle penetration (such as 5%, 10%, 30%) for each transitional demand scenario (TDS), the infrastructure will be spatially defined using GIS in terms of quantity of hydrogen required, station configuration, production and distribution, and percentage of population with access to hydrogen.

Specific attributes that have an impact on consumer choices in regards to purchasing a hydrogen fuel cell vehicle were selected. Each attribute was determined to have an influence on hydrogen vehicle adoption during the transition. The overall demand is a function of the following attributes.

Hydrogen Vehicle Demand = n *(income, education, commute distance, vehicles per household, registered hybrid vehicles, state vehicle incentives, local air quality, presence of a Clean Cities coalition, presence of a zero-emission vehicle, or ZEV, mandate)*

The attributes affecting demand and the data used to quantify those attributes are described in Table 1.

TABLE 1. Attributes Affecting the Purchase of Hydrogen Vehicles

Attribute	Data Classification
Household Income	Median household income
Education	Number of people with college degrees or higher
Commute Distance	Number of workers who commute 20+ minutes
Households with 2+ Vehicles	Number of households that have two or more vehicles
Registered Hybrid Vehicles	Number of hybrid vehicles registered
State Incentives	Number of incentives per state
Air Quality	Areas in non-attainment
Clean Cities Coalition	Area covered by a Clean Cities coalition
ZEV Sales Mandate	States that have adopted ZEV mandates

Using GIS techniques, the attributes from Table 1 were processed using a 20-mile by 20-mile grid across the United States. Each grid element was given a score for each attribute. The attribute score was based on the data value within that gird. A natural break ranking system of 1 to 7 was employed to classify the values within each attribute used in the hydrogen demand model. A variable was given a score of 1 if the values had a "very low" influence on the chosen strategy (for example, the lowest population would have the lowest likelihood of hydrogen demand). Variables were scored 7 if the values had "very high" influence (highest population would generate the highest demand).

Once each attribute was scored internally (based on the natural break of its data values), it was weighted relative to the other attributes based on its likely contribution to hydrogen vehicle adoption. This created an overall influence score for each attribute.

Attribute Influence Score =
Internal Data Score x Weighting Factor

To determine the overall likelihood of hydrogen vehicle adoption in each cell, the attribute influence scores were summed. Cells with the highest scores had a higher relative likelihood of adopting the technology than the cells with a lower score.

A baseline case was selected based on input from transportation transition experts and literature review. Two additional scenarios were also considered.

Demographic Emphasis Scenario: Under this scenario, attributes related the consumer was given the most weighting. In this case, "who the consumer is" was very important, while their environment, such as air quality or government policies, was given less importance.

Policy Emphasis Scenario: Under this scenario, attributes related to or leading to government policy were considered most important, while demographic information on the consumer was minimized.

Table 2 shows how each attribute was weighted to support the baseline case and the alternative scenarios.

TABLE 2. Attribute Weighting for Base Case and Two Scenarios

Attribute	Base Case	Demographic Case	Policy Case
Households with 2+ Vehicles	High	High	High
Household Income	High	High	Low
Education	Medium	High	Low
Commute Distance	Medium	High	Low
Registered Hybrid Vehicles	Medium	Medium	Medium
State Incentives	Medium	Low	High
Air Quality	Medium	Low	High
Clean Cities Coalitions	Medium	Low	High
ZEV Mandates	Medium	Low	High

Results

Results for three scenarios are presented in Figures 1, 2, and 3. Under the baseline scenario, 10% of the land area of the United States are areas with a good to a very high likelihood of hydrogen demand. In the demographic and policy scenarios, these areas are 5% and 15% respectively.

Conclusions and Future Directions

This analysis identifies the top 20 metropolitan areas for likely penetration of hydrogen fuel cell vehicles during the transition.

- Los Angeles/San Diego
- San Francisco/Sacramento
- New York/Boston
- Chicago/Gary, Indiana
- Houston
- Dallas
- Washington/Philadelphia
- Atlanta
- Minneapolis
- Detroit
- Cleveland
- Buffalo
- Denver
- Phoenix
- Salt Lake City
- Pittsburgh
- Portland
- Miami
- Seattle
- Indianapolis

This work also demonstrates that policies can have a significant impact on expanding the opportunity for hydrogen vehicle transition.

During the remainder of FY 2006, the following will be incorporated into the analysis:

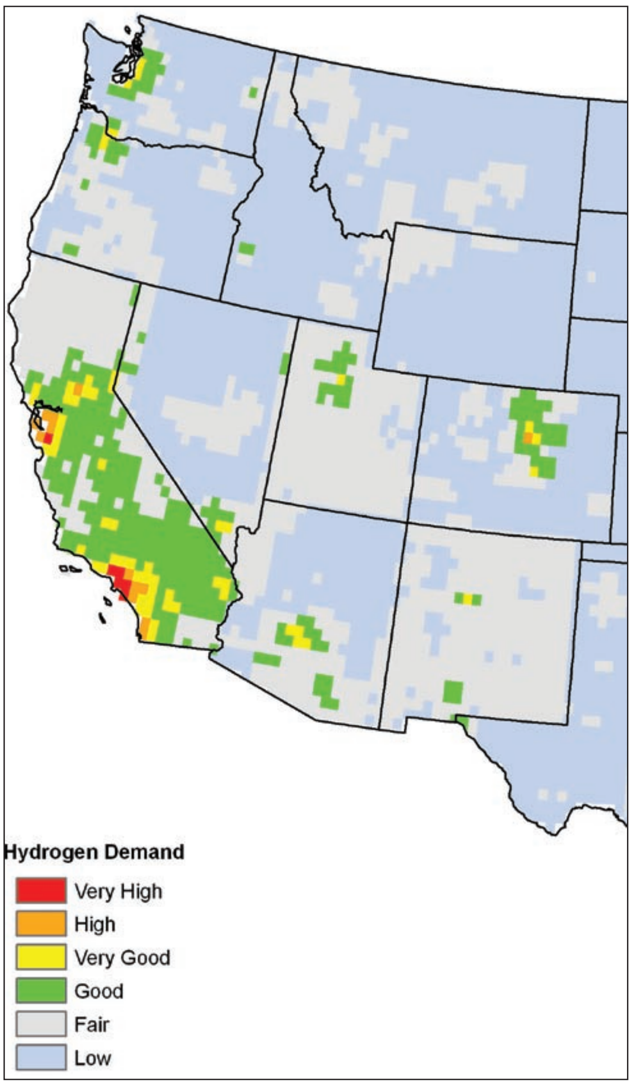

FIGURE 1. Hydrogen Vehicle Demand—Consumer Strategy Baseline Scenario (only western states shown)

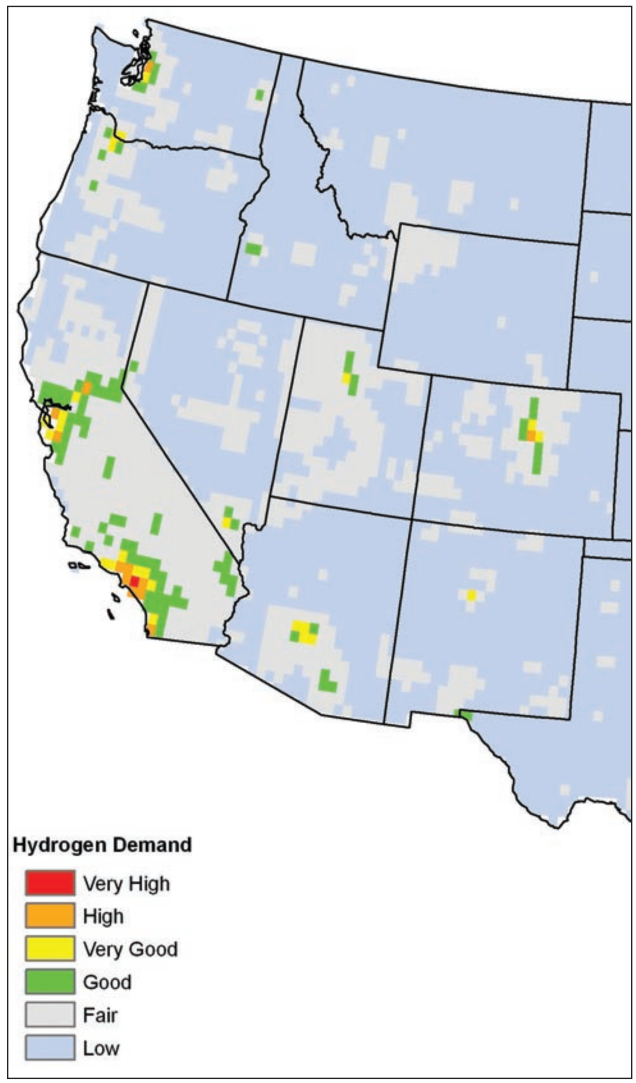

FIGURE 2. Hydrogen Vehicle Demand—Consumer Strategy Demographic Scenario (only western states shown)

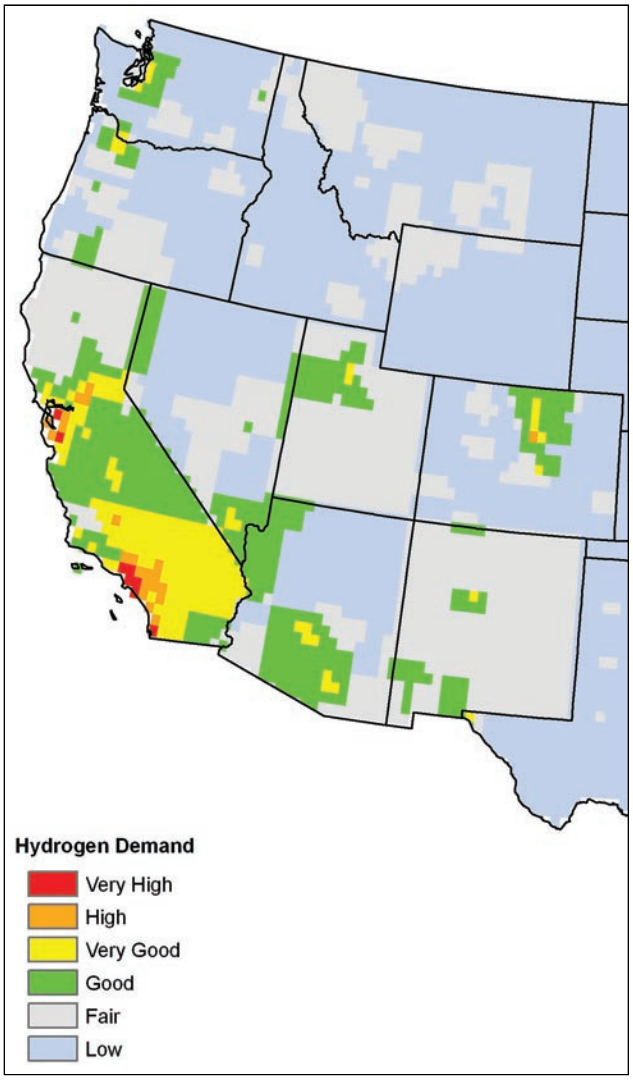

FIGURE 3. Hydrogen Vehicle Demand—Consumer Strategy Policy Scenario (only western states shown)

- Define scenarios for types and quantity of infrastructure at various penetration rates for U.S. infrastructure.
- Identify hydrogen demand on a regional basis for early transition.

FY 2006 Publications/Presentations

Publications

- Melendez, Margo, *Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience*, February 2006.

Presentations

1. 2006 DOE Hydrogen Program Review poster
2. 2006 American Association of Geographers Conference presentation

References

1. Melendez, Margo and Milbrandt, Anelia, *Analysis of the Hydrogen Infrastructure Needed to Enable Commercial Introduction of Hydrogen Fueled Vehicles*, March 2005.