

## VIII.F.4 Hydrogen Infrastructure Transition Analysis

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### Objectives

- Understand the benefits and drawbacks of various options for installing refueling infrastructure hardware for a developing hydrogen demand.
- Identify the most economic pathways for successfully meeting emerging hydrogen demand.
- Identify, describe, and quantify options for hydrogen refueling during the transition to hydrogen as a transportation fuel.

### Technical Barriers

This project addresses the following technical barriers from the Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Hydrogen Delivery Barrier A: Lack of Hydrogen/Carrier and Infrastructure Options Analysis
- Technology Validation Barrier C: Hydrogen Fueling Infrastructure
- Systems Analysis Barrier E: Lack of Understanding of the Transition from a Hydrocarbon-Based Economy to a Hydrogen-Based Economy.

### Contribution to Achievement of DOE Technology Validation and Systems Analysis Milestones

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

- *Hydrogen Delivery Milestone 2: Identify cost-effective options for hydrogen delivery infrastructure to support the introduction and long-term use of hydrogen for transportation and stationary power.*  
We are conducting analysis of infrastructure options spatially and temporally using a geographic information system (GIS) as a tool. GIS is a computer-based information system used to create, manipulate, and analyze geographic information. Various scenarios for infrastructure options (including forecourt and central production), delivery options, and renewable options for station configurations are being evaluated.
- *Systems Analysis Milestone 25: Begin a coordinated study of transition analysis with Hydrogen Analysis (H2A) and Delivery models.*  
This analysis is one piece of transition analysis that utilizes H2A and preliminary Delivery model results to identify infrastructure options.

## Approach

- Use GIS to spatially categorize key factors that have an impact on station locations and utilization.
- Utilize GIS data to specify a basic minimal network of refueling stations to facilitate interstate travel.
- Evaluate costs of this interstate network by incorporating H2A capital cost assumptions.
- Evaluate transitional opportunities, such as key partners and resources, in proximity to interstate network of stations.

## Accomplishments

- Identified key resources, including existing hydrogen stations and production facilities, natural gas infrastructure, population, and interstate routes.
- Mapped traffic volumes and identified a subset of key interstate routes.
- Determined that 284 stations (spaced 50 to 100 miles apart) are necessary to support interstate travel along the most heavily traveled east–west and north–south routes throughout the U.S.
- Established that the federal government presents opportunities for transitional activities, with more than 80% of stations on the network within 10 miles of a federal facility.

## Future Directions

- Evaluate network costs using H2A forecourt capital cost assumptions.
- Identify station configuration to support a renewable network of hydrogen production using local renewable resources at each station.
- Identify other potential partners for transitional activities.

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## Introduction

As hydrogen vehicles are introduced, they will be few in number, making it economically difficult to build a substantial number of viable hydrogen fueling stations. Conversely, without adequate fueling options, consumers will be reluctant to purchase hydrogen vehicles. This project was designed to address the “chicken and egg” problem by identifying a minimum infrastructure to support the introduction of hydrogen vehicles. The objective was to determine the locations and number of hydrogen stations that would make hydrogen fueling available at regular intervals along the most commonly traveled interstate roads, thus making interstate and cross-country travel possible. This approach can help lay a foundation for widespread commercial introduction of hydrogen-fueled vehicles across the U.S. and provide an estimate of the infrastructure necessary to bring this new technology to the marketplace.

## Approach

ArcGIS was the primary analysis GIS tool used in this project. A GIS data set consists of two elements: a graphic representation (map) and associated tabular information (data tables) for each graphic element. All information in GIS is linked to a spatial reference used to store and access data, i.e., each point on a map can be queried to view its associated information. This combination of geographic and tabular forms enables analysis and characterization of different phenomena that occupy the same geographic space.

The project was organized under the following tasks:

Task 1: Identify current hydrogen production facilities and alternative fuel stations.

Task 2: Quantify highway traffic volumes throughout the U.S. interstate system.

Task 3: Select specific east–west and north–south corridors as a focus for the project.

Task 4: Incorporate existing hydrogen production facilities, hydrogen and natural gas fueling stations, railroads, traffic volume, and county population data.

Task 5: Place stations on the interstate network.

Task 6: Categorize stations by predicted vehicle and hydrogen throughput.

Task 7: Estimate total costs for construction of the network.

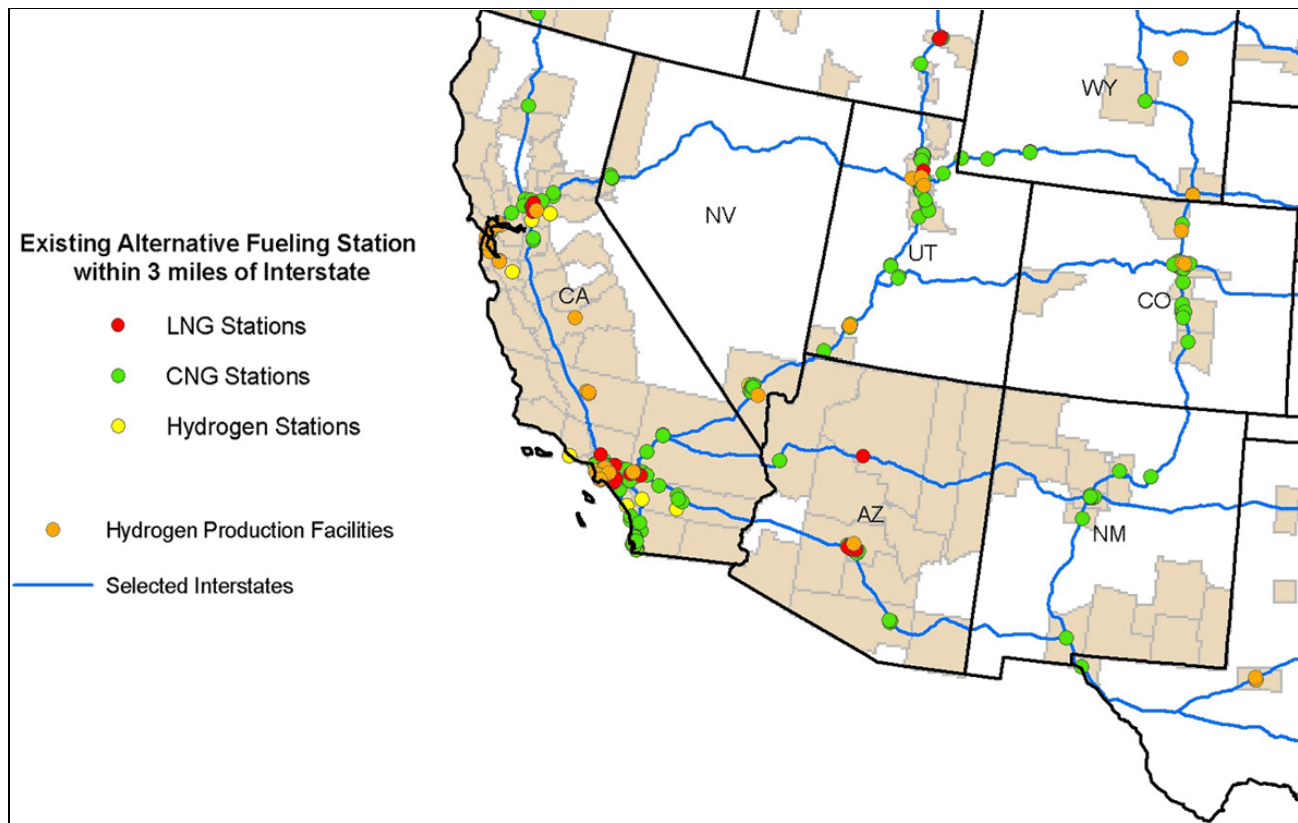
Task 8: Identify federal government partners to improve economics and facilitate construction of infrastructure.

Task 9: Identify other transitional hydrogen distribution options.

## Results

Key resources were identified and mapped (Figure 1). Average annual daily traffic for 2002 was

obtained from the Federal Highway Administration. This was analyzed (Figure 2) and the most heavily traveled interstate routes were selected, which account for 65% of the entire interstate highway system (Figure 3). To cover this distance on the interstate highway system, with stations between 50 and 100 miles apart, a total of 284 stations were selected. Station locations were selected based not only on the distance between stations, but on their proximity to interstate intersections and key resources, such as existing infrastructure and production facilities. Figure 4 shows the stations and their geographical locations. Table 1 lists the stations by interstate, and indicates if they are co-located with other resources. Using preliminary data on station costs from the University of California-Davis, the network is estimated at approximately \$1 billion for capital and construction costs, but these numbers will be updated in the remainder of FY 2005 to include H2A capital cost assumptions.



**Figure 1.** Hydrogen Transition Analysis Base Map (Ref. 1 contains complete maps)

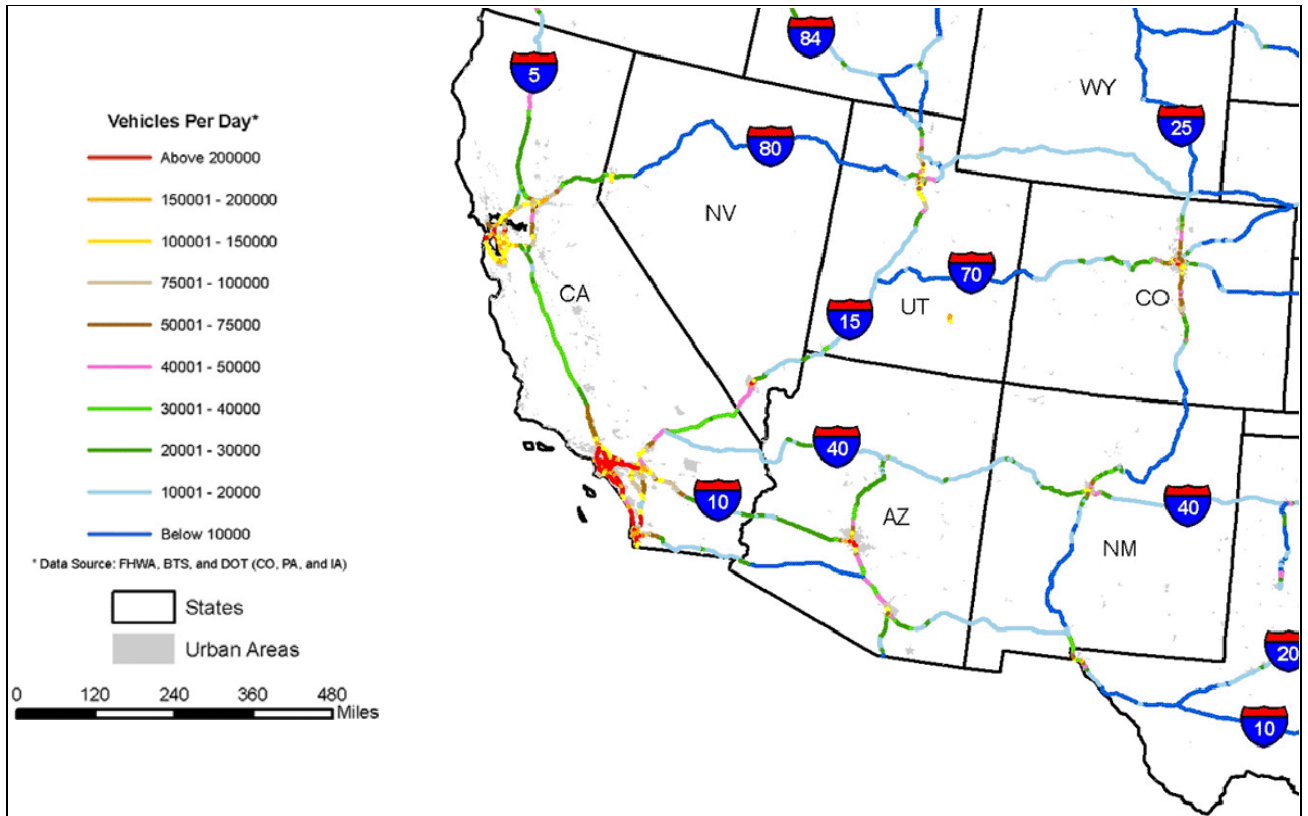


Figure 2. 2002 Annual Average Daily Traffic (Ref. 1 contains complete maps)

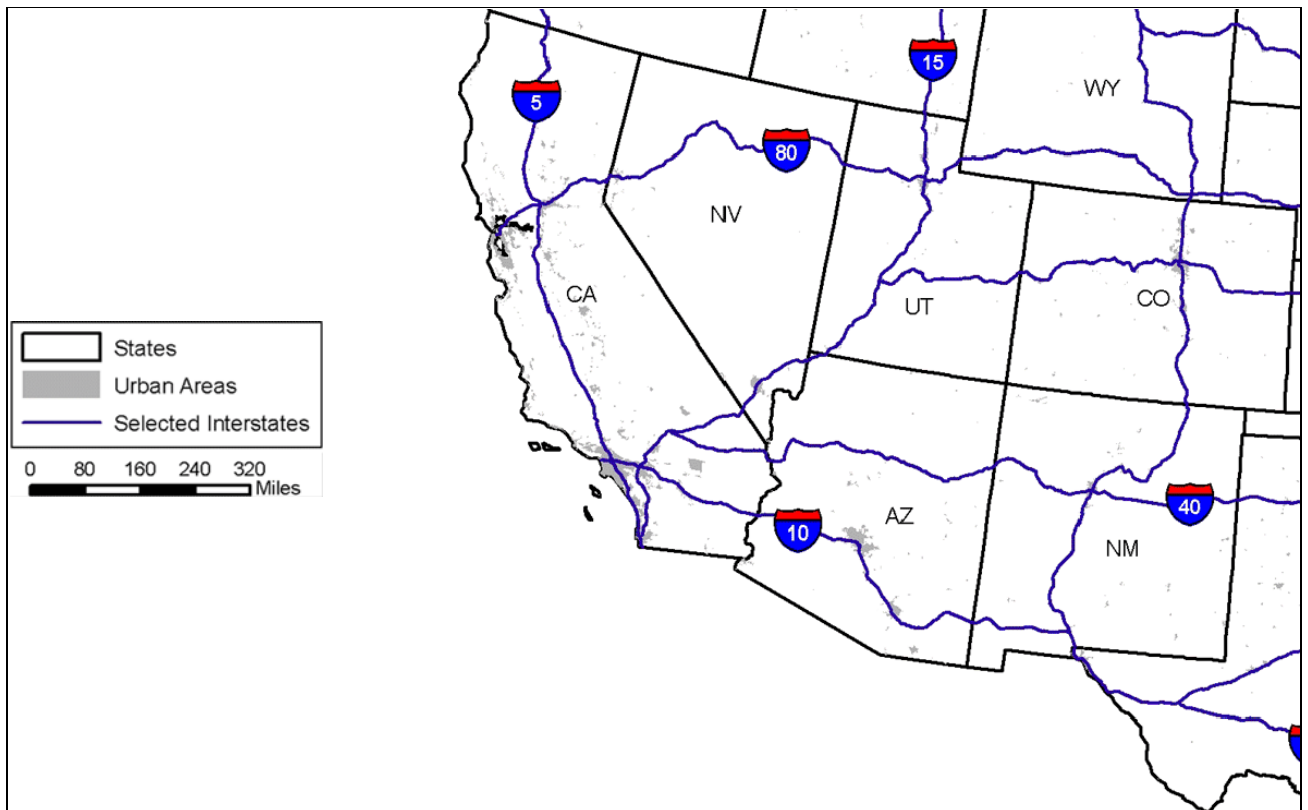
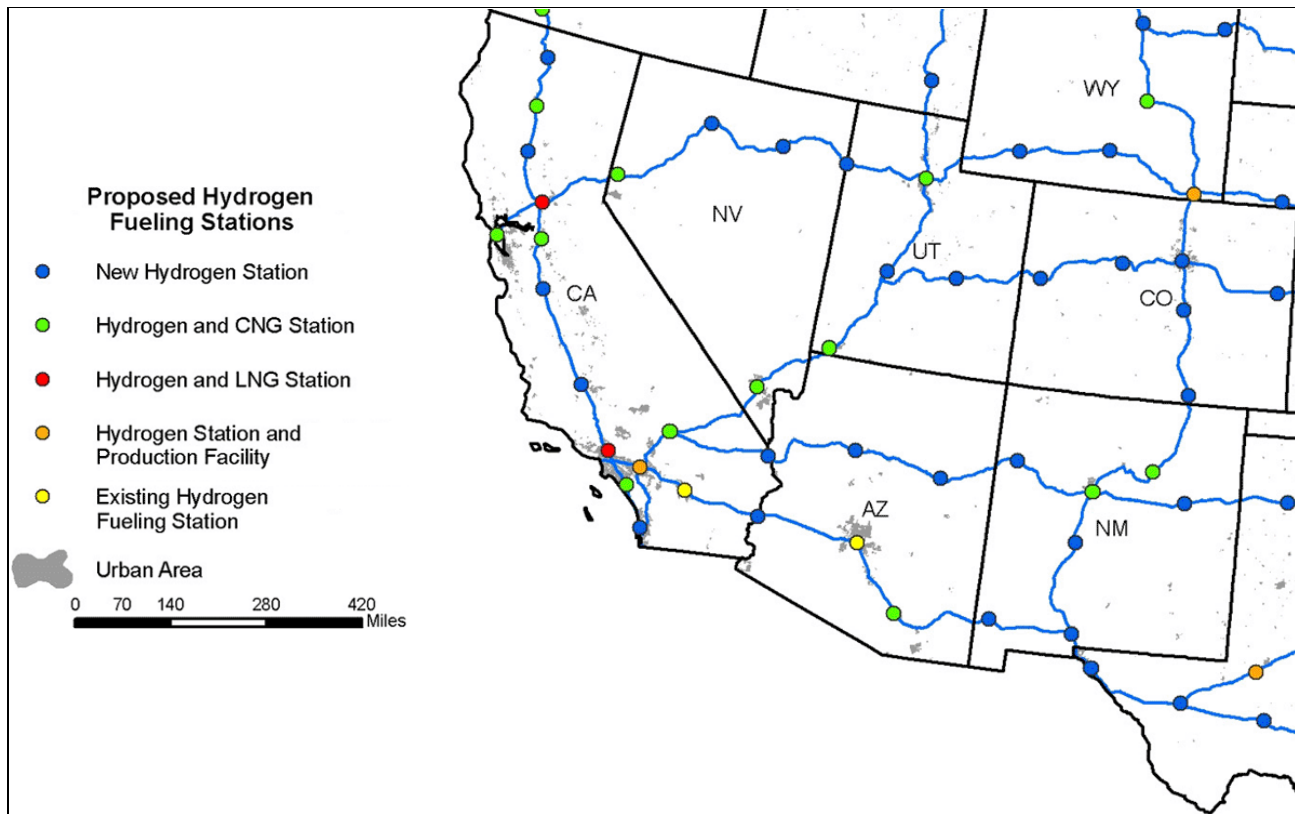


Figure 3. Proposed Interstate Routes for Hydrogen Refueling Infrastructure (Ref. 1 contains complete maps)



**Figure 4.** Proposed Hydrogen Fueling Stations along Major Interstates (Ref. 1 contains complete maps)

**Table 1.** Summary of Proposed Hydrogen Stations along Major Interstates

Interstate	Mileage	Number of Stations	Existing Natural Gas Stations	Existing H2 Stations	Existing H2 Production Facilities	New Stations Needed
5	1,381	20	10	0	2	8
10	2,460	29	1	2	5	21
15	1,434	17	5	0	3	9
20	1,539	18	1	0	2	15
25	1,063	13	3	0	1	9
35	1,568	18	4	0	2	12
40	2,555	28	5	0	0	23
64	938	7	0	0	2	5
65	887	11	1	0	1	9
70	2,153	23	3	0	0	20
75	1,786	19	6	0	1	12
79	343	5	3	0	1	1
80	2,900	33	6	0	4	23

**Table 1.** Summary of Proposed Hydrogen Stations along Major Interstates

Interstate	Mileage	Number of Stations	Existing Natural Gas Stations	Existing H2 Stations	Existing H2 Production Facilities	New Stations Needed
81	855	9	0	0	0	9
89	191	3	1	0	0	2
90	3,021	35	7	0	2	26
94	1,585	16	6	0	0	10
95	1,920	30	13	0	1	16
<b>Total Mileage</b>	<b>28,580</b>					
<b>Total Stations</b>		<b>284</b>	<b>58</b>	<b>2</b>	<b>22</b>	<b>202</b>

### **Conclusions**

- Quantity and costs for refueling infrastructure to minimally support interstate travel are fairly low (284 stations = \$1 billion). These estimates, however, do not consider operation costs.
- There is significant potential to use GIS and spatial analysis to identify solid partners—for vehicles to support stations or facilities to install hydrogen infrastructure.
- The federal government could be a candidate as an early adopter of hydrogen technology to aid in the transition.

### **FY 2005 Presentations**

1. DOE Hydrogen Program Review Poster (May 2005)
2. Society of Automotive Engineers Government-Industry Meeting (May 2005)
3. American Association of Geographers (April 2005)
4. National Hydrogen Association (March 2005)

### **FY 2005 Publications**

1. National Renewable Energy Laboratory (NREL). (2005). *Analysis of the Hydrogen Infrastructure Needed to Enable Commercial Introduction of Hydrogen-Fueled Vehicles*. NREL/CP-540-37903. NREL, Golden, CO.

### **References**

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