Geographically-Based Infrastructure Analysis for California

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Acknowledgments

UC Davis Researchers:
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Dr. Marshall Miller
Dr. Chris Yang

USDOE:
Dr. Sig Gronich

Research support: USDOE; H2 Pathways Program sponsors at UC Davis
• Refueling station siting and sizing are key aspects of designing H2 infrastructure during a transition
• Initial H2 stations may be co-located with vehicle fleets
• Wider consumer adoption of H2 vehicles depends on fuel availability and cost (which are related to station number, size and location), + other factors.
• Decision when and where to deploy network of stations depends on scale and growth rate of demand, access to consumers, availability of low cost H2 supply, policy, competition
Factors in consumer decision to buy H2 vehicle

- Vehicle cost
- Vehicle performance
- Fuel cost
- Fuel availability
- Household income
- Number of household vehicles
- “Green” values
- Policies
- Others
UC Davis researchers have employed a variety of GIS-based methods to study scenarios for H2 station deployment.

In this talk we present results from several studies relevant to a H2 transition in California.
Questions:

– How many stations are needed, and where should stations be located for user convenience, for different market stages?

– How we define consumer convenience?
  • Fraction of gasoline stations offering H2?
  • ave. travel time to nearest station?
  • proximity to users?

– For specified station deployment scenario, what is the average travel time to stations, proximity to users?

– For particular demand scenarios, how might the station network change over time?
  • number of stations
  • station locations
  • station sizes
  • station type (H2 supply option)

– What is the cost of different station deployment scenarios to meet growing demand? What are lowest cost H2 supply options over time?
Study 1: How many H2 stations are needed for consumer convenience? Where should they be located? How does this with vary with average travel time and city characteristics?
H2 Station Siting Analysis for Sacramento

- H2 Stations sited to minimize the average travel time to the nearest station for commuters
- Use the existing gasoline network as a baseline for comparison to hydrogen station networks
- Utilize census and traffic data to identify customer locations
Relationship Between Number of Stations and Average Travel Time – H2 offered 10-30% of existing gasoline stations might provide adequate convenience
### HOW MANY STATIONS ARE NEEDED?

#### Characteristics of CA Urban Areas

<table>
<thead>
<tr>
<th></th>
<th>SCAG (LA)</th>
<th>ABAG (Bay Area)</th>
<th>SANDAG (San Diego)</th>
<th>SACOG (Sac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop. (Millions)</td>
<td>15.8</td>
<td>6.5</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Density (people/km²)</td>
<td>1072</td>
<td>997</td>
<td>1059</td>
<td>718</td>
</tr>
<tr>
<td>Time to Nearest Gasoline Sta(min)</td>
<td>1.8</td>
<td>2</td>
<td>2.41</td>
<td>2.43</td>
</tr>
</tbody>
</table>

#### Fraction of Gasoline Stations Needed Varies

<table>
<thead>
<tr>
<th>Time</th>
<th>SCAG</th>
<th>ABAG</th>
<th>SANDAG</th>
<th>SACOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Minutes</td>
<td>1.06%</td>
<td>1.34%</td>
<td>1.80%</td>
<td>2.85%</td>
</tr>
<tr>
<td>6 Minutes</td>
<td>1.55%</td>
<td>1.85%</td>
<td>2.62%</td>
<td>3.86%</td>
</tr>
<tr>
<td>5 Minutes</td>
<td>2.42%</td>
<td>2.80%</td>
<td>4.26%</td>
<td>5.69%</td>
</tr>
<tr>
<td>4 Minutes</td>
<td>4.23%</td>
<td>4.72%</td>
<td>8.03%</td>
<td>9.35%</td>
</tr>
</tbody>
</table>

Source: Nicholas and Ogden, submitted to TRB, 2005
RESULT: Fraction of stations needed varies with required average travel time and population density of city.
Study 2: What is the Average Travel Time to H2 Stations for a Particular Infrastructure Deployment Scenario?
Possible deployment scenario for 0 -> 200 stations in Southern California

- Start with existing and planned H2 stations
- CNG fleet stations
- Municipal agencies with fleets
- Gasoline retail stations sites
1% of stations in LA (40 stations total):
17 planned H2 stations + 23 (of 40 existing) CNG sites
2.5% of stations in LA (100 stations total):
17 planned, 43 from CNG, 40 largest cites
3% of stations in LA (125 stations total):
17 planned, 43 from CNG, 40 largest cites, 25 gasoline locations
5% of stations in LA (200 stations total):
17 planned, 43 from CNG, 40 largest cites, 100 gasoline locations
Average Travel Time to the Nearest Station:
1% ~ 10 min; 3% ~ 6 min, 5% < 5 min
Study 3: How do we site and size stations to maximize number of consumers nearby?
10 stations; 10% of people within 3 minutes
20 stations; 16% of people within 3 minutes
50 stations; 29% of people within 3 minutes
100 stations; 45% of people within 3 minutes
165 stations; 58% of people within 3 minutes
Station sizing

• The analysis allows us to allocate nearby consumers to optimally placed stations

• Knowing the # of consumers served at each station, we develop a distribution of station sizes needed for a given level of market demand
Study 3a: What is the impact of traffic congestion in Southern California on optimized station layout?
60 Stations 1.5%

Legend
- 60 Stations
- 60 Stations Using Congested Network

Travel Time
- Freeflow: 6.4 min
- Congested: 7.0 min

Highways
SCAG Region
Difference Between Freeflow and Congested Networks

Average Travel Time vs. Number of Stations

% Difference (From Freeflow) vs. Number of Stations
Study 4: Infrastructure deployment strategies to meet H2 demand scenarios
DOE’s 3 scenarios for national rollout of H2 vehicles 2012-2025

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<tbody>
<tr>
<td>Scenario 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>2.0</td>
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<tr>
<td>Scenario 2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>700</td>
<td>900</td>
<td>1000</td>
<td>4.9</td>
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<tr>
<td>Scenario 3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>300</td>
<td>500</td>
<td>750</td>
<td>1000</td>
<td>1200</td>
<td>1500</td>
<td>2000</td>
<td>2500</td>
<td>10.1</td>
</tr>
<tr>
<td>HEV + 15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>20</td>
<td>35</td>
<td>48</td>
<td>88</td>
<td>206</td>
<td>281</td>
<td>316</td>
<td>350</td>
<td>458</td>
<td>565</td>
<td>2.4</td>
</tr>
</tbody>
</table>
### DOE’s 3 scenarios for LA rollout of H2 vehicles 2012-2025

#### Estimate H2 Demand in So. California, assuming:

- **H2 Veh. Fuel economy**: 40 mpg (2012) -> 50 mpg (2025)
- **Average annual mileage**: 12,000 miles/yr

<table>
<thead>
<tr>
<th>Year</th>
<th>Scen 1</th>
<th>Scen 2</th>
<th>Scen 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2013</td>
<td>0.8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2014</td>
<td>1.1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2015</td>
<td>5</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>2016</td>
<td>5</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>2017</td>
<td>7</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>2018</td>
<td>20</td>
<td>100</td>
<td>85</td>
</tr>
<tr>
<td>2019</td>
<td>40</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>2020</td>
<td>55</td>
<td>130</td>
<td>160</td>
</tr>
<tr>
<td>2021</td>
<td>70</td>
<td>140</td>
<td>190</td>
</tr>
<tr>
<td>2022</td>
<td>85</td>
<td>150</td>
<td>210</td>
</tr>
<tr>
<td>2023</td>
<td>90</td>
<td>160</td>
<td>250</td>
</tr>
<tr>
<td>2024</td>
<td>100</td>
<td>190</td>
<td>270</td>
</tr>
<tr>
<td>2025</td>
<td>120</td>
<td>205</td>
<td>300</td>
</tr>
</tbody>
</table>
Number of stations: start with 20 stations and grow with demand; set max station size of 2500 kg/d
Estimate number of H2 stations over time from demand and “growth factor”

\[ N_i = \text{Number of stations operating in year } i \]
\[ f_{D,i} = \text{total demand in year } i \]
\[ N_T = \text{total number of stations at full market penetration} \]
\[ \alpha = \text{growth factor (} = 0.1-0.9) \]

\[ N_i = N_T \alpha f_{D,i} \left( 1 - \frac{N_{i-1}}{N_T} \right) + N_{i-1} \]
Number of stations in LA for Scenario 3; estimated by various models

- Scen 3 -set max
- $a = 0.1$
- $a = 0.2$
- $a = 0.3$
- $a = 0.4$
- $a = 0.5$
- $a = 0.6$
- $a = 0.7$
- $a = 0.8$
- $a = 0.9$
Total number of LA H2 stations - Melaina formula, $a=0.15$
Average station size - Melaina method, a=0.15

Station size kg/d

Year

Scen 1 - M
Scen 2 - M
Scen 3 - M
Consider range of station sizes

- Mini 100 kg/d
- Small 250 kg/d
- Medium 1000 kg/d
- Large 2500 kg/d
- Super 5000 kg/d
- Ultra 10,000 kg/d

Use results from GIS analysis of station H2 demand distribution, to estimate mix of station sizes over time
Future work: infrastructure cost evaluation

For various station sizes, select lowest cost supply alternatives:

- Onsite SMR
- Onsite electrolysis
- Central SMR (also depends on geog., and scale)
  - Compressed gas truck delivery
  - LH2 truck delivery
  - Pipeline delivery

Use “steady-state” cost results to guide scenario development
Scenarios for infrastructure deployment

• Divide period 2012->2025 into four 3-year build-out “phases”

• Constraints: supply always exceeds demand expected at end of current build out phase.

• Use steady-state cost results and distribution of station sizes to develop scenarios for each phase
Economic evaluation of Scenarios

- Estimate present value of costs over transition period 2012->2025
  - Capital costs
  - Operation costs
  - Count salvage costs for any equipment that is “retired”
  - Account for capital in place at 2025.

- Estimate levelized cost of H2 ($/kg) over transition period.