Where Cars are King: 
The Economics of Transitioning to Hydrogen Fueling Stations in California

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California has a long history of supporting alternative transportation fuels

• 1990: California Air Resources Board mandates Zero Emission Vehicles
• 2007: Executive Order S-1-07’s Low Carbon Fuel Standard requires 10% average reduction in carbon intensity for transportation fuels by 2020
• 2012: Executive Order B-16-2012 to promote rapid commercialization of Zero Emission Vehicles by state agencies

Transitioning to hydrogen ("H₂") fuel presents a “chicken or egg” dilemma

• Coverage/Convenience: Potential fuel cell vehicle ("FCV") owners need to know that adequate H₂ filling stations will be available
• Capacity Utilization/Economics: Potential H₂ filling station owners need to know that low-utilization start-up period losses will be covered

Issue: How many H₂ fueling stations are required and at what is the required support to overcome this early mover dilemma?
Spatially and Temporally Resolved Energy and Environment Tool ("STREET") used to identify robust network of 68 existing, funded, and proposed H\textsubscript{2} fueling stations in California.

Economic analysis of these 68 H\textsubscript{2} fueling stations found:

- A strategically planned H\textsubscript{2} fueling station network can meet driver convenience needs while minimizing economic impact, with little dependence on vehicle adoption rate

- Network analysis provides added portfolio insights based on individual H\textsubscript{2} fueling station economic attributes

- Operation & maintenance and capital costs are the largest contributors to the delivered cost of H\textsubscript{2}. 
68 H$_2$ Station Locations Identified Using STREET

This plan has been adopted by the California Fuel Cell Partnership ("CaFCP") and forms the foundation for two recent CaFCP publications:

- A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles (June 2012)
- A California Road Map: Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State (July 2012)
HY_COST Economic Model: Assumptions

• **General H₂ delivery station assumptions**
  - Debt-equity ratio: 100% debt; 0% equity
  - H₂ pump location: At existing gasoline station
  - Interest rate (100% debt): 7.5%
  - Fixed O&M: $100 K per year
  - Insurance: $20 K per year
  - Electricity rate: $0.105/kWh
  - Maximum station utilization: 90%
  - Natural gas price: $4.50/MMBtu in 2011; escalates at ~1.5% annual inflation rate
  - Gasoline price, reformulated, premium $3.40-6.70/gallon (Source: EIA, 2011 Annual Energy Outlook)

• **Gaseous H₂ delivery station (33 stations*)**
  - Station equipment cost: $1.0 MM
  - Capacity: 180 kg/day
  - Land lease: $24 K per year
  - Upgrade cost: $500 K for an additional 180 kg/day of H₂ station capacity

• **Liquid H₂ delivery station (17 stations*)**
  - Station equipment cost: $2.0 MM
  - Capacity: 400 kg/day
  - Land lease: $36 K per year
  - Upgrade cost: $600 K for additional 400 kg/day of H₂ station capacity

* Remaining 18 stations are one-of-a-kind (e.g., Torrance pipeline, Orange County Sanitation District); tax loss carryover assumed in all cases.
Hybrid electric vehicle ("HEV") adoption rate assumes stagnation at sales of 45,000 HEVs per year beyond 2011.

CaFCP FCV penetration survey results very aggressive vs. actual HEV sales.
FINDINGS: Economic analysis of 68 existing, funded, and proposed H\textsubscript{2} fueling stations in California
Delivered H₂ Costs Vary by Station

- Fixed O&M ("FOM"), capital cost ("debt") are largest factors for new H₂ stations.

- Transportation cost can be significant for geographically isolated connector H₂ fueling stations.

- Fixed O&M ("FOM") is largest factors for existing H₂ stations.

- Transportation cost can be significant for geographically isolated connector H₂ fueling stations.
Case Study: Gaseous H₂ Fueling Station (2014 Build)

Gaseous H₂ Fueling Station

- Income Required to Break Even
- Income if H₂ sold on par with Gasoline

Gaseous H₂ stations provide low-cost market entry and low-cost H₂; cost eventually drops below gasoline on a $ per mile basis

Liquid H₂ Fueling Station

- Income Required to Break Even
- Income if H₂ sold on par with Gasoline

Liquid H₂ stations require more capital, but offer greater profit potential

* Assuming 1/5 HEV adoption rate for FCVs.
Gaseous H$_2$ Station: Operating Cost Comparison

Date for FCV Commercialization

Cost per Mile (NPV $)

ICE $/mi
FCV $/mi, 10% HEV
FCV $/mi, 20% HEV
FCV $/mi, 50% HEV
FCV $/mi, 100% HEV

Date for FCV Commercialization
Required Support per H₂ Fueling Station Varies*

- Proposed gaseous H₂ stations require less support (and have less throughout vs. liquid H₂ stations).
- Capital expense of existing/funded H₂ stations has already been allocated.
- Connector stations experience low throughput and high transportation costs, thereby requiring extra support.

* Represents the negative cash flow that must be offset in the early years of each H₂ fueling station's life; does not consider any potential profits occurring in later years.

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In both the high FCV adoption rate (HEV) scenario, and the low FCV adoption rate (1/10 HEV) scenario, the max $H_2$ throughput is over 20,000 kg/day.

For the low scenario, max is attained just before $H_2$ stations start to reach end of life in 2025.

For the high scenario, max $H_2$ throughput is attained in 2021 and maintained for 6 years.

Max $H_2$ throughput results for all FCV adoption rates; unsatisfied demand “balances” $H_2$ network.
Required Support for 68 H₂ Station Network

- HEV Profit
- 1/2 HEV Profit
- 1/5 HEV Profit
- 1/10 HEV Profit

HEV Support
1/2 HEV Support
1/5 HEV Support
1/10 HEV Support

Maximum yearly level of required support is $15-17 MM regardless of FCV market adoption rate.

Reducing FCV market adoption rate by 50% increases required support at lesser rate of 20-40%.

Total required support:
- 1/10 HEV: $81.4 MM
- 1/5 HEV: $66.3 MM
- 1/2 HEV: $47.1 MM
- HEV: $33.4 MM
Overall Economics of 68 H₂ Station Network

Total required support:
- 1/10 HEV: $81.4 MM
- 1/5 HEV: $66.3 MM
- 1/2 HEV: $47.1 MM
- HEV: $33.4 MM

Total potential profits:
- 1/10 HEV: $150 MM
- 1/5 HEV: $241 MM
- 1/2 HEV: $305 MM
- HEV: $343 MM
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