Hydrogen Fuel Cell Vehicles in California

Assembly Select Committee on California’s Clean Energy Economy

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Timothy Lipman, PhD
Co-Director – TSRC
telipman@berkeley.edu

Key Points

• Hydrogen fuel cell technologies have evolved greatly in recent years and UC Berkeley research is finding high potential consumer acceptance of FCVs and hydrogen

• Consumers seem attracted to these vehicles partly due to their green attributes but also because they are **better cars** (in terms of overall “driveability”) not just green cars

• Hydrogen FCVs offer considerable emission reduction advantages near-term, with potential for major reductions in the future

• In addition to hydrogen infrastructure supports $s, additional “market pull” efforts would be helpful to help reduce adoption costs for early consumers/fleets (buses, port vehicles, etc.)
Brief History of the UC Berkeley Program

- Program started in late 2005 with receipt of Daimler “A-Class” F-cell with ~100 mi. range with hydrogen stored at 5,000 psi
- FCV program grew in 2008 with delivery of 3 Toyota Highlander FCHVs – 160 miles range with 5,000 psi storage
- From 2008-2011 a 700-bar hydrogen fueling station was planned, built, and commissioned at the UC Berkeley Richmond Field Station
- The UC Berkeley hydrogen station has now been in operation since May 2011 – with many lessons learned
- Current fleet of 8 vehicles being tested from 3 manufacturers, all operating at 10,000 psi with 240-300 miles range

TSRC Hydrogen Fuel Cell Vehicles
Hydrogen Fuel Cell Development History

FCV Progress
Hydrogen Fuel Cells – Cost Improvement

Fuel Cell Cost Reductions Enabled by R&D

Fuel Cell Cost Reductions

- 50% from 2006
- 30% from 2008
- 5X Platinum Catalyst

Fuel Cell Cost Status and Goal

- $55/kW* for high volume
- ~$280/kW+ for low volume
- $40/kW by 2020 is the goal

*4A, bottom few percent of rehab systems. Catalysis cost, 35% of total price with reactant delivery technology. TOSN, Top-down analysis based on CEM input, 2010 only, with current technology.

Catalyst accounts for >45% of total system cost.

Catalyst remains key challenge and opportunity to lower cost.

HYDROGEN FUEL CELL TECHNOLOGIES OFFICE

Emeryville in 2015 – Commercial Reality

MY 2015 Hyundai Tucson FCV
UC Berkeley TSRC – FCV Test Program

• UC Berkeley TSRC is conducting technical and social/behavioral research with several hydrogen FCVs
• Drivers drive the vehicles for 2 to 4 weeks at a time, filling out “before” and “after” surveys about their attitudes, demographics, and experiences with the vehicles
• Drivers are trained to refuel by themselves after a few assisted fills
• By the end of June, 50 drivers will have completed 1-month test drives in the Toyota Highlander FCHV-adv vehicles
• UC Berkeley findings/results paper coming soon

TSRC FCV Program – Driver Response

Overall, how has the FCHV met your expectations? (Please select one response)

Source: TSRC
Hydrogen Fuel Cell Buses – Great Progress

- Fuel cell buses in operation at AC Transit since 2005
- Current fleet of 12 buses (240 miles range)
- Lead fuel cell bus with 16,500+ hours of operation
- Nearly one million miles of service for AC Transit and over 3 million passengers carried
- Emeryville station has dispensed over 100,000 kg of fuel
- Oakland station now online
FCV Bus Driver Study

- Survey conducted of AC Transit and Golden Gate Transit fuel cell bus drivers during Summer 2013
- Approximately 140 surveys issued and 47 returned (total “n”=47) for 33% response rate
- 3-page written survey with last page for “open ended” responses
- No incentive except drivers paid 15 minutes of overtime for completing survey
- Questions asked about bus performance, perceived safety, and demographics / attitudes

Fuel Cell Bus Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Fair</th>
<th>Poor</th>
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<tbody>
<tr>
<td>Handling (n=46)</td>
<td>15</td>
<td>10</td>
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<td>Ride Quality (n=46)</td>
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<td>Quiet Operation (n=47)</td>
<td>30</td>
<td>5</td>
<td>0</td>
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</tbody>
</table>

Source: TSRC
Fuel Cell Bus Characteristics

Number of Responses

Excellent
Good
Average
Fair
Poor

Acceleration (n=47)
Braking (n=46)

Characteristics

Source: TSRC

Overall, how do you like the new fuel cell bus compared to other buses you have driven? (n=47)

Number of Responses

5: Much Better
4
3: The Same
2
1: Not as Well

Source: TSRC
Overall Impacts Incl. Vehicle and Plant

Overall, Emissions from Plant Construction Are Negligible Compared to Fuel- and Vehicle-Cycle Emissions

T. Lipman - UC Berkeley – June 2015

Emissions Impacts – California Case

Source: CaFCP
Where Does California Go From Here?

- Support for initial hydrogen fueling infrastructure is filling a critical need – the eyes of the world are on California!
- Support for light duty FCV purchases through the CVRP ($5K/vehicle) is likely to be helpful, especially as more vehicles become available on the marketplace
- But unfortunately the $7,500 U.S. federal incentive has expired at an awkward time...Japanese gov’t is offering $20K/vehicle to bring the cost from ~$60K to ~$40K
- Complementary programs would include additional efforts to pull fuel cell trucks, buses, and delivery vehicles into commercial and government fleets through incentives/pilots
- Additional market readiness efforts also needed – training for key safety officials and responders, mechanics, etc.

Source: NRC 2013

FIGURE S.2. Estimated U.S. LDV GHG emissions in 2050 under policies emphasizing specific technologies. All scenarios except the Committee Reference Case (current policies, including the fuel economy standards for 2025) include midrange efficiency improvements. Fuel production for these scenarios is assumed to be constrained by policies controlling GHG emissions (low GHG production).
Conclusions

• Hydrogen FCVs appear to have the potential for high consumer acceptance:
  – High ratings for vehicle performance attributes
  – Rapid acceptance of hydrogen fueling (w/5 mins. for 300 mi.)
• AC Transit fuel cell bus drivers also have high acceptance of vehicle attributes, with high levels of avoided emissions
• Hydrogen FCVs offer immediate emission reductions compared with conventional vehicles and with a pathway to near total “decarbonization” in the future
• Additional market development activities are needed including potential incentive programs for more vehicle types (beyond LDVs), worker/safety official training programs, and gov’t/commercial fleet pilot programs
Well-to-Wheels Emissions – 2035 (U.S. DOE)

CA Market Scenario - FCVs