Hydrogen Fueling Stations: A Business Case for Clean Transportation in Connecticut

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May 7, 2018

Introduction:

Government and private sector stakeholders are now developing commercial models for the use of hydrogen and renewable energy as a replacement of hydrocarbon fuels in the transportation sector, which accounts for 30.3 percent of Connecticut's total energy consumption. Fuel cell electric vehicles (FCEVs) have several advantages over conventional vehicles, including:

- Zero emissions with high efficiency and responsive operation that meets or exceeds consumer expectations;
- Energy security with fuel produced using domestic and/or renewable resources;
- Quiet operations with electric motor drive and no internal combustion;
- Economic operation that offers competitive pricing and a hedge against fossil fuel price volatility; and
- Long range operation with short duration refueling that achieves parity with fossil fuel vehicles today.

With the advantages noted above, there is increasing interest by consumers and developers to purchase FCEVs and operate them with fuel from newly developed hydrogen fueling stations. This analysis identifies business options for vehicle refueling to support the strategic deployment of FCEVs within vehicle fleet clusters, identified by the 2017 Northeast Regional Hydrogen Economy, Fuel Cell Electric Vehicle Fleet Deployment Plan. This strategic approach will help to establish hydrogen refueling for fleet vehicles with use of funding from the VW Partial Consent Decree, while providing flexibility for hydrogen refueling developers to address and reduce costs associated with infrastructure, operation, maintenance, and product distribution. The goal is to achieve profit on hydrogen sales that can support the refueling station.

Zero Emission Operation and High Efficiency:

FCEVs use a fuel cell to convert hydrogen fuel carried on the vehicle and oxygen from the atmosphere into electricity for motive power. The by-product is water with zero tailpipe emissions. Zero emission FCEVs could replace existing conventional fleet vehicles in Connecticut providing annual carbon dioxide (CO2) emission reductions of approximately 20,600 pounds per vehicle and NOx emission reductions of approximately 10.8 pounds per vehicle.

Potential annual reductions for 257 FCEVs[1] compared to conventional light duty gasoline vehicles are:

- CO2 emissions = 2,081 tons;
- NOx emissions = 2,182 pounds.

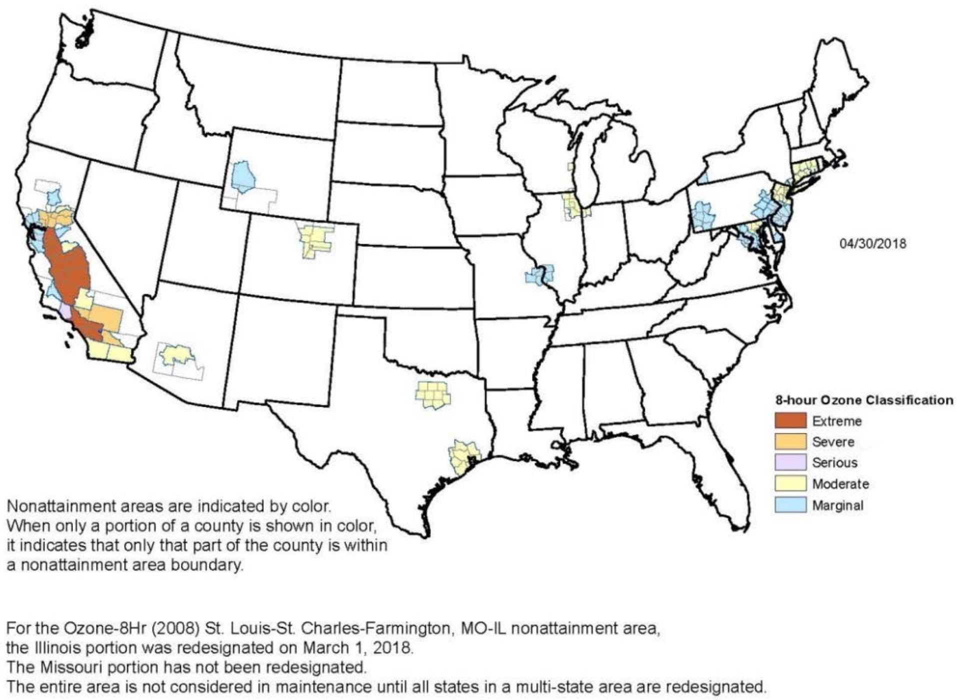
Hydrogen is well suited for fleet and transit operations

- *Hydrogen contributes to energy independence*
- *Hydrogen provides operational flexibility*
- *Hydrogen is ideal for centralized fueling of large fleets*

[1] 257 FCEVs was selected as a minimum number of FCEVs needed to support a 250 kg/day hydrogen fueling station based on vehicle usage of 23,000 miles per year. Based on observations in California, a 250 kg/day hydrogen fueling station could serve approximately 320 vehicles. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references. The 250 kg/day capacity was selected as an option for 33 percent funding from the VW Partial Consent decree.

While there are many reasons and factors for non-attainment of National Ambient Air Quality Standards (NAAQS), the transportation sector releases significant quantities of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx), (and particulates in the case of diesel vehicles)[2]. Vehicles account for over 55 percent of the total NOx emissions in the United States (U.S.), a precursor to the formation of ground level ozone or smog.[3] As shown in Figure 1 below, urban areas in the Northeast U.S., including Connecticut, New York, and New Jersey that are not in attainment of the NAAQS would benefit from the use of zero emission vehicles (ZEV), including FCEVs.

Figure 1: 8-Hour Ozone Nonattainment Areas (2008 Standard)[4]



Energy Security:

Production of hydrogen for use as a transportation fuel is possible using natural gas, renewable energy such as solar energy, or from hydrogen rich compounds such as ammonia and biofuel. Due to the large amounts of these available resources within the U.S., is not likely that the production of hydrogen would be linked to the import of liquid petroleum, crude oil, or diesel fuel. While the price of gasoline and diesel fuel has temporarily stabilized, these liquid fuels are derived from crude oil which is not renewable and subject to price and supply volatility. Hydrogen, as an energy carrier, has value for energy security because it can be sourced from a variety of domestically available feedstocks, including renewable and biofuel energy.

Range and Refueling:

Vehicles fueled with hydrogen offer zero emissions, a fuel efficiency of approximately 65 MPGe, a range over 300 miles or more per fill, and a typical refill time of less than 5 minutes. While cold weather will impact the range of all electric drive vehicles, FCEVs are expected to provide high performance without significant reduction of power and range even with heating and air conditioning.

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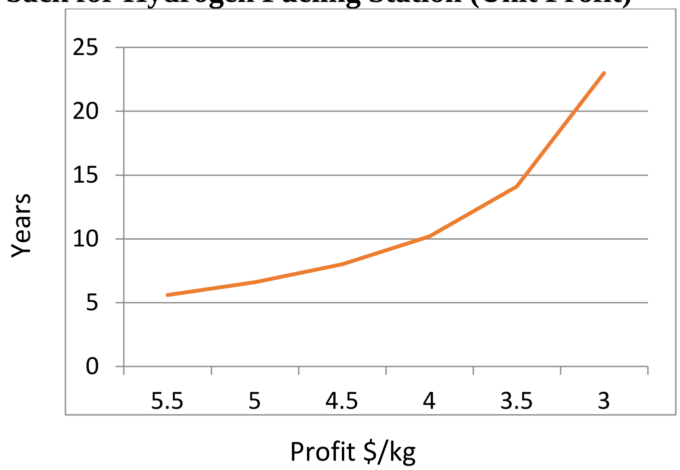
[2] U.S. EPA, Transportation: Mobile Sources; https://www.epa.gov/regulatory-information-topic/regulatory-information-topic-air.
[3] U.S. EPA, About Smog, Soot, and Other Air Pollution from Transportation; https://www.epa.gov/air-pollution-transportation/smog-soot-and-local-air-pollution.
[4] U.S. EPA; "8-Hour Ozone Nonattainment Areas (2008 Standard);" https://www3.epa.gov/airquality/greenbook/map8hr_2008.html; 2016.

Economics:
Hydrogen fueling stations are expected to be developed in Connecticut, Massachusetts, New York, New Jersey, and Rhode Island in the near future to support FCEVs and fuel cell electric buses (FCEBs). The major variables that will impact the economic viability of hydrogen fueling stations include the cost to develop the hydrogen fueling station, operation expenses, and the profit on the sale of hydrogen ($/kg). Consistent with the VW Partial Consent Decree, hydrogen fueling stations with a capacity greater than 250 kg/day would be eligible for up to a 33 percent subsidy. As detailed in Figure 2 below, a hydrogen fueling station with a net cost of $1.675 million and a fueling capacity of 250 kg/day would have a simple payback within approximately 10 years at a profit margin of $4.0/kg[5] or greater.

Figure 2: Simple Payback for Hydrogen Fueling Station (Unit Profit)



As shown in Table 1, hydrogen refueling will have a substantial capital cost. However, station developers are expected to have flexibility to reduce capital costs through scale and standardization of refueling components. In addition, station developers will have high flexibility to reduce operational costs using fully automated systems that address consumer convenience with fast 24/7 refueling without the cost of 24/7 operator service. A favorable economy of scale will come from careful coordination of station size and location within fleet clusters with a known range and refueling needs. The targeted fleet clusters are natural starting places for more widespread deployment of FCEVs by early market adopters, especially in urban areas.

Summary and Conclusion:
Electric drive vehicles appear to be the transportation technology of the future offering highly efficient, powerful, and clean operations for consumers. Without the use of ZEVs, urban areas may be challenged to achieve compliance with air quality standards and without hydrogen fueling stations, FCEVs will not be accepted by consumers and will not be available to reduce air emissions associated with light-duty passenger vehicles. This analysis advocates an incremental approach to accelerate the initial deployment of fleet vehicles, identify which cost parameters require additional attention for cost reduction, and to develop new models to support financing for project development. Strategies that 1) increase awareness[6] of FCEVs and hydrogen fuel, and 2) decrease capital and operating costs for fueling stations and hydrogen fuel will be necessary to encourage private investment and facilitate the development of hydrogen fueling stations.

[5] Net cost after subsidy; includes $200,000 in annual operating expenses, which may include maintenance, taxes, lease, and finance costs.
[6] Strategies to increase awareness and demand for FCEVs, such as group purchasing, finance models, emissions calculators, GHG/Climate calculators, safety analysis programs, fleet purchase database, and ZEV economic analyses could be incorporated into a comprehensive program to aid consumers.

Table 1: Simple Payback for a Hydrogen Fueling Station

Refueling Station Economics		
Marginal Unit Profit ($ / kg)	***$***	***4.00***
Refueling Station Cost ($)	$	2,500,000
Station Incentive (33% per VW)	$	825,000
Net Station Cost	$	1,675,000
Number of Years to Payback		***10.2***
Operating cost		$200,000
Hydrogen Sales Per Year (kg)		***91,054***
H2 Consumption (kg / day / Vehicle)		0.97
Vehicle Use (Miles / Day)		63
Annual Positive Cash Flow ($ / year)	$	364,216
Hydrogen Vehicles Supported Annually		***257***
Average kg dispensed per day		249

Assumptions and Sources	
Mileage	Assumes high mileage fleet use with vehicle operation at 23,000 miles per year
Fuel Economy	Assumes 65 miles per kg (MPGe)
Fueling Station Costs	California Air Resources Board; Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California; December 2015; CEC-600-2015-016
Hydrogen Vehicles Supported Annually	Based on 250 kg per day capacity of the hydrogen station, fuel economy, and mileage.
Operating Cost	Advanced Clean Transit - Cost Assumptions and Data Sources - Update on 10/3/2016,Table 11 - Fueling Infrastructure O&M Costs; www.arb.ca.gov/msprog/bus/tco_assumptions.xlsx.
Finance and Profit	No assumptions have been made regarding the cost of financing and need for profit or return on investment.