Comments on proposed support for hydrogen fueling stations by the California Energy Commission

I attended the September 29, 2009 meeting of the California Energy Commission (CEC) on the planning for hydrogen refueling stations. Three recurrent questions posed by the CEC were:

1. Where should these stations be located?
2. What level of support is required?
3. What is an appropriate exist strategy for the need for public funds?

On the first issue, two broadly different responses were provided by the representatives of GM, Alex Keros and Honda, Robert Bienenfield. GM's stated position can best be characterized as build them in reasonable locations and the hydrogen fuel customers would come. They also indicated that they would make efforts with their dealers to sell vehicles where stations were located. Honda's position was to provide for small local stations specifically located to the block as to where their customers were likely to be. The California Fuel Cell Partnership (CaFCP) presented an Action Plan that highlighted the deployment of early stations in four Southern California communities and then considered broadening the location of the stations to other locations and perhaps along freeways. The argument for local stations serving a community is based on the issue of convenience to the customer and avoiding areas of congestion. However, such a strategy would lead to networks of small stations that are not economic. The argument for stations nearer to freeways is that they serve a wider public base and generally have three times the fuel throughput as local stations. The other issue that requires some consideration is the relative number of stations required in Southern California (Los Angeles and Orange County basin) and Northern California (San Francisco and Sacramento). When I was at the Department of Energy, it was assessed at that time (2006) that the major concentration should be in Southern California and New York City where populations to support the early deployment of vehicles and infrastructure existed. In that report, the construction of stations in Northern California would be planned in the post 2016 period.

On the second question, the level of support is going to be variable. The expectation of the industry is that there is likely to be about 4000 Hydrogen Fuel Cell Vehicles (HFCVs) deployed by 2014 and 50,000 HFCVs by 2017. Several of the automobile companies have made public statements about providing commercial vehicles by 2015 which should be interpreted as anywhere from multiple thousands to ten thousand vehicles by 2017 per automobile company. Honda, Toyota, Daimler, Hyundai and GM are all companies with such plans according to public statements made by their company spokesmen. Toyota press releases by several company representatives have been particularly vocal about the comparative cost of battery technology and fuel cells. Considering the recent actions by the Secretary of Energy to attempt to forestall

the HFCV program, those statements seem to be foolhardy. But I want to direct your attention to the first chart of the attached presentation, based on the assessment of the Department's Hydrogen Program and Vehicle Technology staffs presented at the 2009 DOE Annual Merit Review as to when component cost targets are being met to attain the commercial viability of plug-in hybrid vehicles and HFCVs. Hydrogen fuel cell costs have been decreased significantly to $72/kw and are likely to be reported this October as around $61/kw. Storage system costs were reported as $15/kwh for 5000 psi hydrogen tanks and $23/kwh for 10,000 psi tanks. On the other hand, battery costs today are quoted for high power density batteries as around $1,000/kwh to be reduced to $500/kwh by 2012, and $300/kwh by 2014 for the required high energy intensity battery for 30 to 40 mile electric range. Now when those numbers are used to price out electric platform vehicles, the $60/kw fuel cell and the $15 to $23/kwh storage system costs (assuming no further progress on costs) and the $300/kwh battery system cost to be achieved in 2014, both electric platform vehicles are about $5000 more expensive than gasoline vehicles when produced in quantity. Also, achievements by the industry in the production of hydrogen vehicles with 280 to 430 mile range and significant progress in freeze start capability were reported at the September 29 meeting and see figure 2 of my presentation.

The remaining issues are then the cost and the durability of the fuel cell. I maintain that costs have already been reduced to be competitive to other electric platform vehicles and are market ready with some tax credits being required after 2018. At the DOE Annual Merit Review, 3M reported membrane lifetimes in simulated laboratory tests of 7000 hours and the DOE technology validation program reported 2300 hours durability from fuel cells in one manufacturer's vehicles. The durability for the future membranes to be provided in future vehicles should increase based on the new membrane technology and be able to achieve the 5000 hours generally considered to be a cost effective lifetime. The above lifetimes are normally quoted for 10% voltage degradation but it is probably possible to go beyond that degradation before the customer would note any differential in the power characteristics of the vehicle. So can we conclude that the automobile company statements are valid and that commercial quantities of vehicles can be expected from 2015 to 2017. Yes. Does the CEC need to be cautious based on the lack of number of HFCVs on the road today and the prior experience with existing stations being under-utilized? No, a tsunami is coming to meet the infrastructure demand for these vehicles. Now CEC policy is not in place to support regulation, but the regulation and the industry's progress in HFCVs is pivotal in recognizing that an aggressive infrastructure policy is required in 2009 and 2010-2011.

On the third question, in the early phase of infrastructure deployment, smaller stations (i.e., 100 kg/day) and in appropriate local communities (i.e., Santa Monica, South Bay, Irvine and Newport Beach) would be the optimum stratagem as described in the CaFCP Action plan. However, those stations should have the ability to grow to a minimum of 400 kg/day as

demand increases. At the September 29 CEC meeting, Air Products and Linde respectively presented high pressure gas and liquid delivery systems that are improvements to the state of the art and can provide low cost stations for the early program. Air Products is providing such a station as part of the ARB program in South Bay and a liquid station could be provided as an expansion option in Newport Beach. The concepts discussed at the September 29 meeting are important options for the future and should be recognized as such. However, because of the low throughput of 100 kg/day, the revenue to the station owner is going to be minimal and may need up to 90% cost share of the capital investment by the government. At 400 kg/day, at a price of $7/kg, an annual revenue stream close to $1 million dollars could be generated to offset expenditures. Thus, lesser cost share requirements would be necessary for expansion of the initial facility to 400 kg/day. Ultimately, stations of 1500 kg/day size will need up to 25% cost share initially but reduced to zero when produced in quantity. That is difficult to forecast at this time and should be revisited after the second installment of the investment plan. However, it strongly indicates that the CEC contribution is critical in the first two phases and can be phased out during the third phase.

Where do we proceed from here. First of all there is a need to recognize where we are currently. The ARB recently had a very successful result from their recent RFP which should lead to three stations in Southern California with a minimum capacity of 100 kg/day with the capability of expanding to 400 kg/day. They are at UCLA, South Bay and Newport Beach. The latter two are in two of the communities suggested in the CaFCP Action Plan and the third is near but not in Santa Monica and is in a more high traffic area. There are two stations that are due to be online soon as a result of the DOE program in Fountain Valley (renewable option) and Burbank. There are two other applicable stations in Torrance as the result of a Congressional earmark and the station at UCI on Jamboree Boulevard. All these stations should be included in initial plans and upgraded in preparation for traffic demand increases. There next should be a solicitation modeled after the previous ARB solicitation for stations in Santa Monica proper (2), South Bay (1), Irvine (1) and Newport Beach (1). Other sites can be considered in addition to the above but the above have to be accomplished in this procurement. The second procurement being considered for 2010-2011, needs to consider additional stations along freeways and at malls with Costco stores that use forklift trucks to justify larger stations on the order of 400 kg/day to 1500 kg/day. An additional $40 million would be required for this phase. At this stage of infrastructure deployment, there are not sufficient economics to justify a business strategy for a specific fuel provider, but the ARB model that will let the hydrogen equipment suppliers (i.e., Air Products, Linde, Praxair, etc.) to find individual station providers and gasoline distributers to proceed will be the best approach to define the opportunities that will exist. The CEC should not select locations as that will depend on the individual station owner. Something between Honda's and GM's world view is necessary during this phase to succeed.

The CEC funding is critical for the hydrogen vehicle market deployment program to proceed. To not go forth robustly will curtail a burgeoning technology that is essential for meeting the 80% carbon dioxide reductions by 2050. As the ARB representative presented at the September 29 CEC meeting, an aggressive program only achieves a 70% reduction by then. To achieve that target both hydrogen fuel cell and plug-in hybrid vehicles are necessary and the only sufficient options available. The CEC needs to make the necessary resources available to achieve that goal.

Sincerely,

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Infrastructure Needs for Hydrogen Fuel Cell Vehicles

Presented to the California Energy Commission

By Dr. Sigmund Gronich

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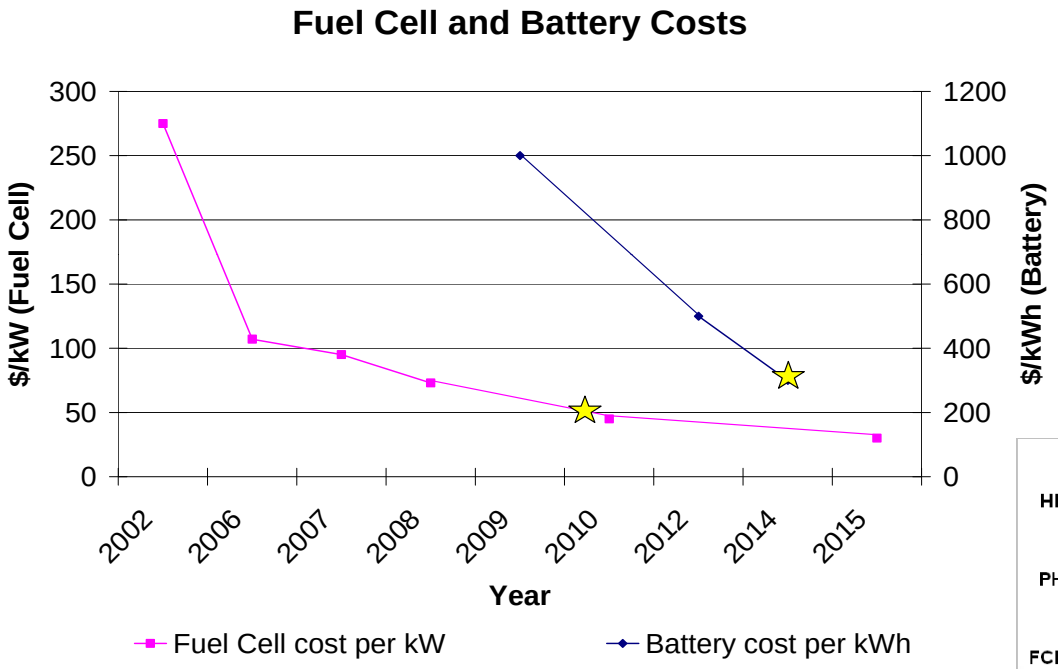
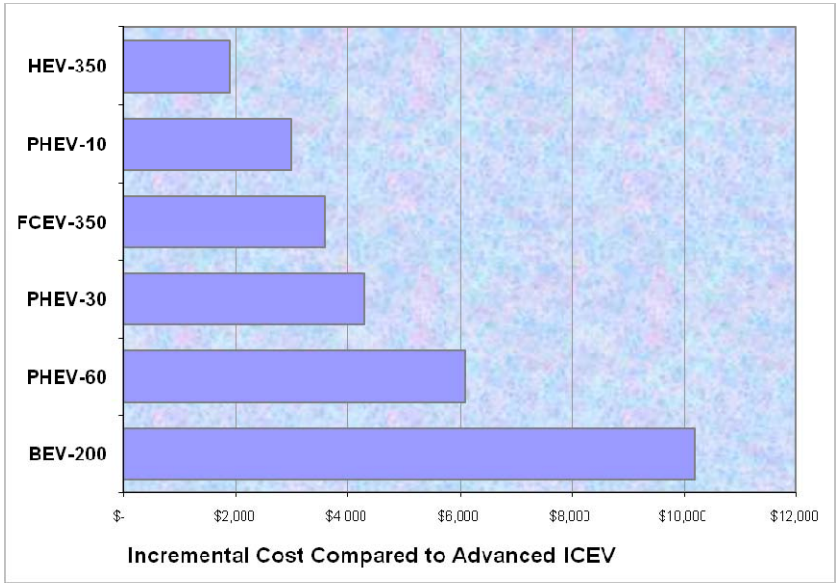
Misconception #1: Fuel cells vehicles (FCV's) are too expensive
Analysis shows: Fuel cell system costs have been reduced substantially and FCV's are expected to be cost-competitive with other advanced electric vehicles.





Papageorgopoulos, D. *Fuel Cell Technologies*. Presented at 2009 DOE Merit Review
Howell, D. *Energy Storage R&D Overview.* Presented at 2009 DOE Merit Review

Misconception #2: Breakthroughs are needed in hydrogen storage
Analysis shows: Compressed hydrogen tanks safely provide adequate range in a reasonable volume

- The Department of Energy has monitored and evaluated real-world performance of 140 fuel cell vehicles which have safely accumulated over 85,000 hours of operation and 1.9 million miles. Second generation FCV's exceeded the 250-mile DOE range target for 2008. Hydrogen storage tanks projected to have 10+ year lives.

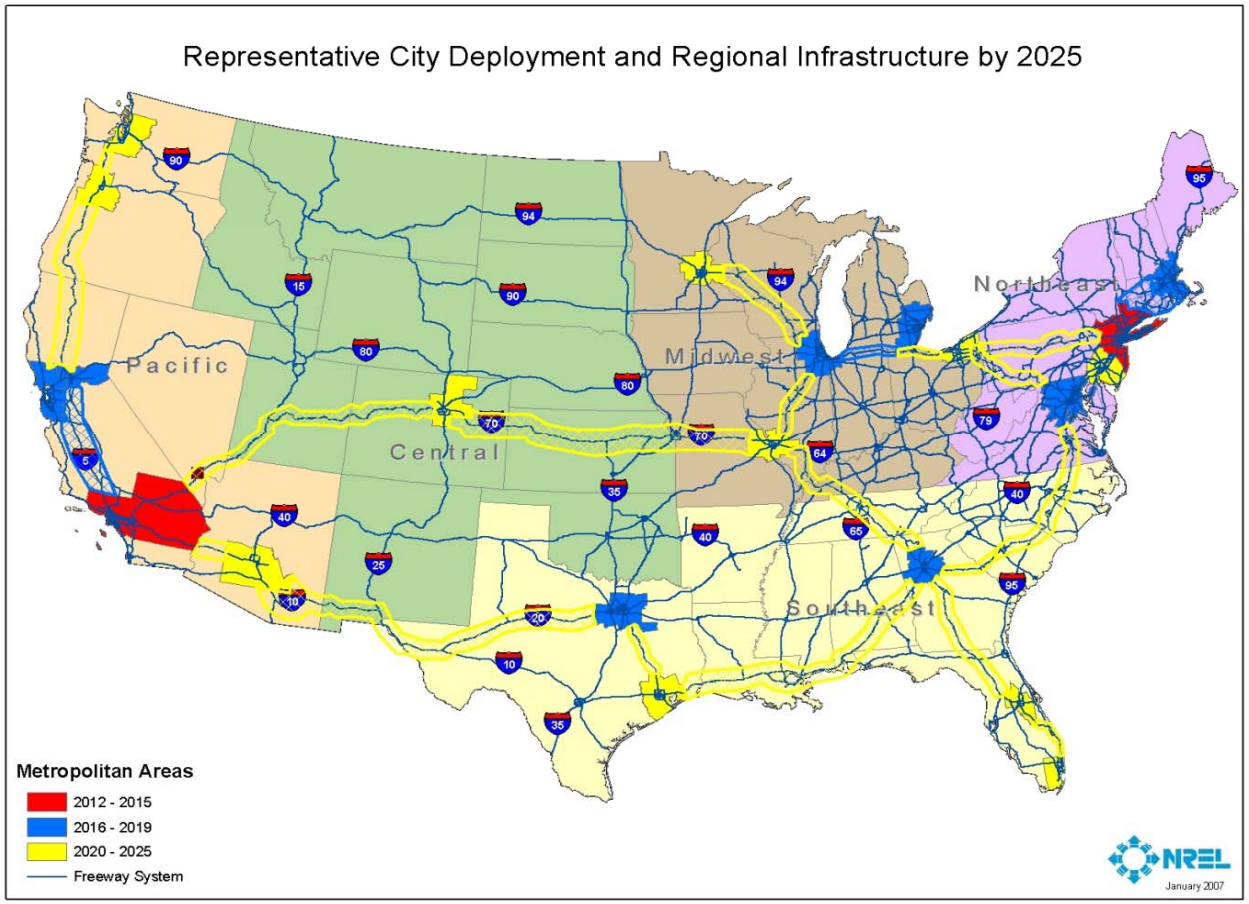
- Current life of 10 mile range electric fuel cell batteries are 3+ years and is targeted to achieve 10+ years by 2012, and 40 mile range battery is targeted to achieve 10+ years by 2014. 40 mile range battery needs to become energy intensive.

Misconception #3: It is inefficient to make hydrogen
Analysis shows: Hydrogen from natural gas, coal and biomass with sequestration is clean, low cost, energy efficient and can be used to transition to renewable .

- The DOE compared "well-to-wheel" emissions of GHGs from various pathways, and the results show that FCVs using hydrogen from natural gas emit 60% fewer GHGs than today's gasoline vehicle, and 35% fewer GHGs than natural gas vehicles. FCVs using hydrogen from biomass emit 60% fewer GHGs than a PHEV running on cellulosic ethanol.
- The National Research Council shows deep reductions in GHG emissions from hydrogen fuel cells with the greatest reductions coming from a 'portfolio' approach. Hydrogen makes significant reductions in vehicle oil consumption.
- Hydrogen produced from coal or biomass with CO2 sequestration can be dispensed for $2-4/kg, comparable to $1.00 to $2.00 per gallon gasoline (untaxed). Per vehicle, hydrogen stations cost about the same as home charging.

Misconception #4: Building a hydrogen infrastructure is too difficult and costly

Analysis shows: Hydrogen can be cost-competitive with gasoline and stations can be deployed using a coordinated cost-effective, regional strategy.



Several studies have shown that it is possible to roll-out infrastructure regionally concurrently with vehicle deployment to maximize utility and minimize costs for early markets. In assessing a transition to hydrogen fuel cell vehicles, the National Research Council modeled a fuel production pathway to supply fuel for 1.8 million vehicles through 2020 and 10 million vehicles through 2025.

What to Concentrate On

- Concentrate on stations in the four Southern California communities indentified in the CaFCP Action Plan (Santa Monica, Torrance, Irvine and Newport Beach).
- Utilize existing stations in those areas for initial deployments
- Santa Monica is the greatest challenge for early vehicle deployments

Technology Options

- Demand for a station needs to be 400 kg/day to decrease the amount of government cost share that is required.
- Use flexible approaches that can be expanded as the demand increases to a minimum of 400 kg/day.
- High pressure gas and liquid delivery, and on-site production are compatible with these demands.
- Continue to pursue options identified in prior ARB solicitations (i.e., start at 100 kg/day but can be expanded to 400 kg/day).

Existing or Potential Hydrogen Fueling Stations

- Burbank
- UCLA station at Kinross
- Torrance at Western & 195th St.
- Torrance at Western & Pacific Coast Hwy.
- Fountain Valley (Irvine) at 405 (renewable)
- UCI station on Jamboree Blvd
- Shell Newport Beach Station

Most Immediate Needs

- Can initially deploy 100 kg/day stations that can expand to 400 kg/day when demand is there (ARB model)
- Two additional stations in the West Santa Monica area are most critically needed
- One new station each in Torrance, Irvine and Newport Beach are required to support a network of operating stations
- Consider expansion of Fountain Valley waste water to hydrogen for renewable resource option

Conclusions

- The demand for new hydrogen fueling infrastructure is pressing and needed to support the expected response of certain OEMs to the ZEV mandate post 2010
- The CEC should immediately address the need for networks of hydrogen fueling stations in Santa Monica, Torrance, Irvine and Newport Beach
- A solicitation similar to the prior ARB solicitation should be the model for early stations that can grow with demand (technology exists to implement this strategy)

References

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- (Kromer & Heywood, "Electric Powertrains: Opportunities & Challenges in the U.S. Light-Duty Vehicle Fleet Report # LFEE 2007-03RP, MIT, May, 2007, Table 53).
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