# Hydrogen is a Competitive Alternative Fuel, Today!

Docket 10-ALT-1

Air Products is pleased to submit written comments to the 07 March 2011 Advisory Committee Meeting.

Significant technology breakthroughs have advanced the infrastructure deployment forward to make the dispensing of hydrogen cost competitive to existing transportation fuels. Earlier programs sponsored by federal, state and local agencies have provided hydrogen infrastructure developers with the opportunity to gain valuable experience regarding the supply chain associated with the production, distribution, and dispensing of hydrogen for the developing fuel cell electric vehicle (FCEV) market. California has been a key location for this activity, as many auto manufacturers have chosen the state as the site for their U.S. alternative vehicle research/development/demonstration facilities. The auto manufacturers have indicated plans to deploy thousands of FCEVs in 2015, and tens of thousands more through 2017. In addition, system capacity of hydrogen production exists which would serve the fueling needs of over 100,000 vehicles in CA. Given California's efforts to improve local and regional air quality (by reducing emissions of criteria pollutants) and to reduce greenhouse gas emissions in the transportation sector (for example, the Low Carbon Fuel Standard), fuel cell vehicles provide an important pathway to achieve these objectives. Although activities in Europe are focusing on development and deployment of hydrogen infrastructure, the infrastructure requirements to serve the marketplace for refueling and the transportation needs of consumers in California (and the U.S.) will likely need a different approach and result in a different solution.

Since 1995, Air Products has been a key supplier of hydrogen and fueling technology infrastructure to over 130 fueling station projects for light duty vehicles, material handling applications, mass transit and for other markets in 19 countries. The current fueling rate for a variety of vehicles and stationary systems is in excess of 325,000 events per year. Based upon this experience, Air Products has developed advanced fueling station technology for light duty vehicles that meets the following objectives:

- Utilize improved delivery technologies to reduce the cost of transporting low-priced hydrogen from central facilities with high product availability.
- Develop station concepts that are simple, modular, expandable to full-sized station capacities, and reduce capital costs at the point of use.
- Reduced overall site maintenance costs.
- Minimize station footprint to use existing retail gasoline forecourt locations, which significantly lowers the initial cost of infrastructure.
- Utilize renewable resources most efficiently to meet the requirements of CA SB 1505.
- Meet U.S. Department of Energy commercial price targets that are competitive with gasoline today, as well as for hydrogen applications in other emerging fuel cell markets with smaller station capacity than other station configurations.
- More closely match the projected rollout of fuel cell vehicles to serve the market as it grows, as opposed to the installation of large stations that will be underutilized for longer periods of time (which would further suppress a business case for hydrogen fueling).
- Provide a model for national fueling infrastructure, which piggybacks on existing production capabilities. And would provide for energy independence as hydrogen can be produced from domestic sources.

For a delivered hydrogen product and fueling of FCEVs, the current supply chain (shown in Figure 1) includes the steps of (1) production/purification, (2) preparation for transport, (3) distribution, (4) site storage, (5) preparation for fueling, and (6) dispensing.


**Figure 1 – Current Supply Chain for Delivered Hydrogen to Refueling Stations**

As a more detailed depiction of steps 4 through 6 in Figure 1, Figure 2 below shows a conventional fueling station for light-duty vehicles requiring hydrogen at 35 MPa (H35) and 70 MPa (H70). Compression is required for delivery of hydrogen at either pressure (whether from a single compressor or two separate machines as illustrated here), which means station availability is strongly impacted by downtime associated with onsite processing. These types of stations cost between $2 million (for stations integrated with an existing application) and $5 million (for a Greenfield hydrogen fueling station). Onsite generation of hydrogen at the point of use would also add to station costs when compared with delivered product.

Data from hydrogen refueling station operating history worldwide shows that the most downtime and maintenance at fueling stations is attributed to onsite processing systems and specifically those including compressors. Unlike gasoline stations where low pressure fuel pumps are a low-cost and highly reliable means of providing fuel, addition of redundant systems would only increase capital costs and station footprints from today's levels. Station throughput is set by processing capacity, so expansion would require additional compressors, for example, at the fueling station. In order to improve viability of hydrogen refueling stations, this bottleneck can be overcome with a fueling station that is simpler and more robust.

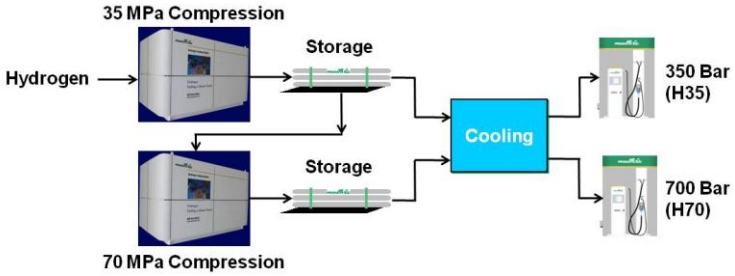


**Figure 2 – Conventional Light-Duty Hydrogen Station (delivered product)**

The new station concept being deployed by Air Products will merge the several steps from Figure 1 into a single operation with a unique cost effective offering by operating from a central production location. Figure 3 depicts the simplification of the supply chain for the proposed station concept. Instead of each station having its own processing system onsite and (in the case of liquid hydrogen) site storage, a single system can be located at a distribution hub. Therefore, the equipment at the hub, which would include all processing equipment, can be sized for larger throughput and utilized for a greater percentage of the time, and its capital cost and product output can be allocated to a number of sites instead of dedicated to a particular station, each of which results in significantly lower cost to each fueling outlet.


**Figure 3 – Proposed Low-Cost Supply Chain for Delivered Hydrogen to Refueling Stations (Patents/Patents Pending)**

A key to the enabling technology for this step-change in delivery/station design is the use of proprietary high-pressure gaseous delivery trailers. Air Products has worked under an exclusive contractual funding arrangement with Structural Composites, Inc. (SCI) (Pomona, CA) in the development and testing of composite vessels that achieve higher operating pressures at a significantly lower weight than steel tubes. Three delivery trailers using this vessel technology have already been deployed for use in the marketplace with patents and pending patents filed related to this technology area.
As shown in Figure 4, utilizing this trailer in a light-duty fueling station eliminates the need for onsite processing systems for H35 fueling, providing a significantly higher reliability for fuel supply than hydrogen fueling systems deployed to date. The H70 equipment can be bolted on as needed for the particular application. This innovative fueling station configuration can cost around $1 million as opposed to the $2 million or more for conventional hydrogen refueling stations, requires 30 to 50% less area than stations using liquid hydrogen as feedstock, and significantly reduces the setback distances from property lines compared to most existing stations.

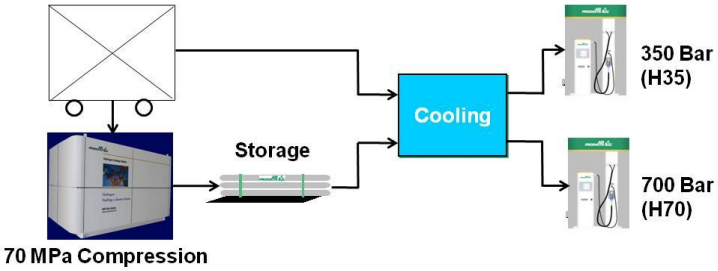


**Figure 4 – Proposed H35/H70 Light-Duty Hydrogen Station (delivered product)**

Capacity at the station is determined by a combination of station footprint (which might limit the size of the trailer) and number of deliveries per unit time. As volumes build at the station, an additional dispenser and associated equipment can be added by a station owner based on the economics of added vehicle traffic (both for fuel and other products/services) through the station. The high-pressure gaseous delivery trailers can be filled either from a central production plant or from a mobile two-phase liquid hydrogen trailer that can supply compressed gas (currently six of these systems are deployed worldwide) in the same fashion that gasoline is delivered today. Duplicating the gasoline model of deliver, store and dispense is the most reliable and lowest cost pathway for hydrogen as it takes advantage of existing station forecourt and existing hydrogen production capability. This model provides the least capital risk to "seed" an early market. Other models which employ larger stations may provide better capital utilization in a fully developed market but at multiples of capital investment to "seed" the market and are beholden to orders of magnitude higher hydrogen demand to reach breakeven.

Under the funding support provided by the Energy Commission during the 2010 solicitation for hydrogen fueling infrastructure (PON-09-608), Air Products will be deploying eight stations (six new

retail locations/two retrofit stations) which will result in hydrogen pricing for early market users of fuel cell vehicles at less than $10 per kilogram based on anticipated demand.

Our analysis indicates that these types of stations can become self-sufficient financially at throughputs as low as 200 kilograms per day. The consumer price decreases as station capacities increase up to 400 kg/day. Further cost reductions are possible with continued technology advancements in storage, compression and distributed production, and also with expected market economies of scale. There are significant opportunities to lower the dispensed fueling costs for hydrogen because hydrogen as a transportation fuel is less mature than traditional petroleum based fuels. A price today with proper demand loading would be approximately $7.00/kg. A cost breakdown based on the latest technology is provided in Figure 5.

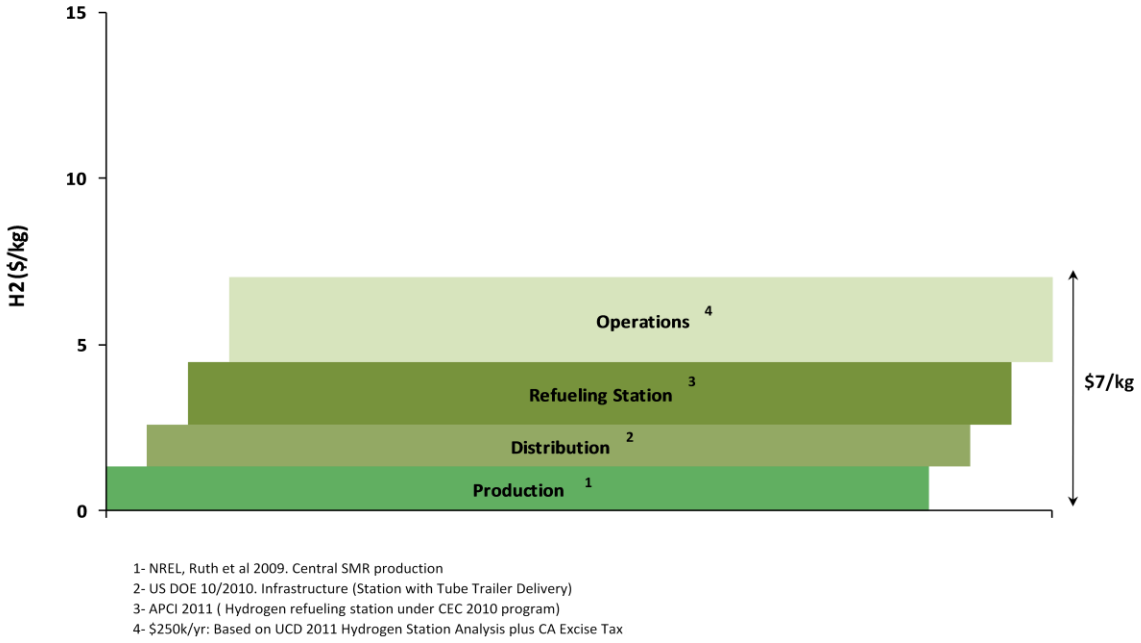


**Figure 5 – Cost Breakdown for Light-Duty Hydrogen Station (delivered product)**

Air Products believes the $40 million funding level in the first CEC Investment Plan released in April 2009 would be sufficient capital to provide for a self-sustaining infrastructure for these small station configurations in southern California. A total of $13.3 million has already been targeted for southern California, and an additional $10.2 million has been allocated for 2011. If another allocation of $16.5 million were made over the next two years, it would allow for 20 more fueling stations using Air Products' latest technology to be installed. We believe at that point with the developing hydrogen fueling station infrastructure in southern California that private investment would consider taking a more active investment role. Air Products would be willing to work with the Commission and the key stakeholders on an optimum hydrogen infrastructure rollout strategy using an analysis tool such as the STREET software being developed at UC Irvine to assist with station site selection. Air Products believes with continued and targeted funding through the AB118 program that hydrogen fueling can be made readily available at the lowest possible cost to stakeholders, can confirm the value proposition for fuel cell vehicles to meet customer requirements for transportation, and provide a domestically available fuel that can move the transportation sector toward significant reductions in greenhouse gas emissions.