CALIFORNIA HYDROGEN BUSINESS COUNCIL
Hydrogen and Fuel Cell On-Road Freight Workshop

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HYDROGEN AND FUEL CELL ON-ROAD FREIGHT WORKSHOP REPORT

May 1, 2017

ABSTRACT

For the movement towards zero emission freight to materialize, as mandated by the Clean Air Action Plan created for the San Pedro Bay Ports, a variety of new technologies will need to be commercialized. Hydrogen fuel cell technologies are a way for traditionally high-polluting heavy and medium duty on-road freight vehicles to become zero emission. This report outlines the discussions and conclusions from a CHBC hosted workshop held on May 1, 2017.

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Hydrogen and Fuel Cell On-Road Freight Workshop Report

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Executive Summary

For the movement towards zero emission freight to materialize, as mandated by the Clean Air Action Plan created for the San Pedro Bay Ports, a variety of new technologies will need to be commercialized. Hydrogen fuel cell technologies are a way for traditionally high-polluting heavy and medium duty on-road freight vehicles to become zero emission. During the workshop a number of challenges to this industry were identified, which are as follows:

The ports of Los Angeles and Long Beach have made gained recent negative experiences in demonstration projects with alternative fueled trucks, stifling their enthusiasm to adopt new unproven technologies. In addition, the news of those negative experiences were widely shared in the trucking community. Consequently, any new technology seeking to make inroads with this community need to take these experience into consideration. In the example of hydrogen fuel cell trucks, companies with experience in “beta testing” need to develop a positive track record to establish confidence in the technology. Once the technology is proven to be technologically feasible, there must be a viable business case for drivers and fleet operators to buy in.

Truck manufacturers (OEMs) are cautious about developing hydrogen fuel cell trucks. Only Kenworth has ventured into developing projects with fuel cells, mainly to gain valuable experience in electric drive systems to implement them into faster arriving hybrid trucks. Other Class 8 truck OEMs such as Daimler and Volvo are waiting for regulations to force them to start development.

Hydrogen technology developers can utilize their experience gained from fuel cell buses and are leveraging that knowledge by integrating fuel cell trucks. The high price of fuel cell components are expected to follow a similar price reduction that batteries have experienced. Fuel cell trucks need to find solutions for the space constraints related to fuel cell and hydrogen components and storage.

Education and training for fuel cell truck technicians is severely lacking. Learning institutions and curriculums need to be developed in order for new classes of zero emission vehicles to be properly serviced.

Dedicated heavy duty hydrogen fueling infrastructure is the key issue for further commercialization. Until now, only temporary solutions exist for the six Class 8 fuel cell demonstration trucks. Instead, there will need to be (renewable) hydrogen stations on port land and near distribution centers.

The fuel cell truck industry sector can learn from the commercialization of fuel cell forklifts. Some major lessons include the need for bundling fleet and fueling solutions; developing a sound business case for hydrogen based on economics; providing hydrogen infrastructure that can fuel multiple types of vehicles at one location; and the need of customers to be familiar with the vehicle chassis for full adoption.

Immediate key actions that follow from this workshop include this report, a webinar presenting the findings, and a guidance document for the CHBC Advocacy Committee to become vocal in agency and legislative discussions.

Introduction

The overall purpose of this workshop, co-located at the ACT Expo at the Long Beach Convention Center, was as follows:

- to build awareness and hear from a diverse group of panelists on the ability of hydrogen and fuel cell technologies to enable commercial customers to meet sustainability and regulatory compliance objectives,
- address the technical and non-technical challenges with transitioning hydrogen and fuel cells into fleets, and
- understand the substantive economic and operational benefit drivers.

This workshop was designed to bring the stakeholders in on-road freight to the table with the goal to speed up the pace of commercialization. At the workshop, fleet operators and medium/heavy duty OEMs presented, followed by discussion and presentations from hydrogen technology providers on the status of freight demonstrations, the vision for this sector, and lessons learned from other fuel cell products that have reached commercialization.

Context

The movement of freight and goods from the commercial ports to distribution centers and the consumers represents a vital component of U.S. transportation infrastructure and the U.S. economy. Seaports and distribution networks are economic drivers for jobs and development, and entry points for goods used throughout the country. As medium and heavy duty truck fleets move goods from the ports, they cause significant local air and greenhouse gas emissions. The environmental footprint of the sector is significant, both because of the sheer volume of activity and because ports/distribution centers tend to be located in areas that already experience heavy automobile and truck traffic that create smog, particulate matter, and ozone pollution.

Zero emission hydrogen fuel cell electric vehicles are entering the California automobile vehicle market, and hydrogen fuel cell forklift trucks are commercially purchased by product distribution centers and factories today. There is a great potential for hydrogen and fuel cell on-road vehicle technology to address these challenges, not only because the technology generate zero emissions at the point of use, but also when hydrogen is produced from renewable sources, it’s “well to wheels” emission profile is also zero.

Discussion Topics – Summaries

Zero Emission Fuel Cell Technologies for Freight and Goods Distribution

Pete Devlin, Market Transformation Program Manager, Fuel Cell Technologies Office (FCTO) of the U.S. Department of Energy (DOE), provided a high-level overview of the various fuel cell activities DOE has been involved in. There has been great improvement in reduction of cost for fuel cell membranes and the amount of platinum required, resulting in a unit cost reduction from $275/kW in 2002 to $53/kW in 2016. With further increases in volume, prices will continue to decline. Fuel cells are a reliable solution, and can provide essential support, as showcased during Hurricane Sandy in 2012 when batteries and diesel generators failed.

Pete was excited to have industry taking a lead on heavy duty truck applications with the unveiling of the Toyota fuel cell truck and the announcements from Nikola Motors. Implementing fuel cells into auxiliary power units (APUs) and both medium and heavy duty fleets are steps in the direction of wider commercialization of fuel cells in goods movement. Fuel cells already have a proven, successful track record in forklifts with over 5 million hours of operation. Hydrogen infrastructure remains a key hurdle to mass adoption of fuel cells in general. However, with the growing network of warehouses using fuel cell forklift trucks around the country, DOE analyzed these locations along major highway corridors and determined that a national network of hydrogen stations could be built along these corridors. Every state has the potential to produce hydrogen renewably, with biogas offering a great opportunity that was demonstrated at the BMW plant in South Carolina with the first ever fueling of a forklift truck from hydrogen generated from landfill gas. This June, US Hybrid and Transpower will be testing fuel cell Class 8 trucks as part of the DOE Zero Emission Cargo Transport (ZECT) II demonstration.

In conclusion, medium and heavy duty fleets can help address the issue of lack of hydrogen infrastructure with multiple vehicles sharing stations, increasing throughput and decreasing fuel cost. Furthermore, with the adaptation of multiple fuel cell applications across the board, volume manufacturing can be achieved and further reduce fuel cell unit costs.

User and Operator Perspectives on Hydrogen Fuel Cell On-Road Freight

Jim Petrecky, Vice President of Business Development, Plug Power, moderated a panel of fleet operators sharing their thoughts on using hydrogen fuel cell electric vehicles in their fleets. Mike Britt, Maintenance & Engineering International Operations for Ground Fleet, UPS, stated that his company is “drinking the hydrogen cocktail” and that electric propulsion is the way to go. It is much more reliable than internal combustion engines, and battery technology has not come far enough in their duty cycle without recharging during the day. UPS is very bullish on hydrogen for their Class 6 trucks and plans to develop routes in cities with existing hydrogen stations such as Sacramento. What they develop in the U.S. will be implemented around the world, believing that eventually fuel cell trucks will be cheaper to operate than conventional diesel trucks. UPS does their own service and will be putting their service people through 30 days of high voltage training. Mike spoke of the easiness in integrating components into a Class 6 truck which has more real estate than a Class 8 truck and requires everything to be in the engine compartment or behind the cab. UPS long range trucks have a more difficult duty cycle for fuel cells, with a gross vehicle weight of 105,000lbs traveling 600 miles daily; compared to a port drayage gross vehicle weight of 80,000lbs traveling 200 miles daily.

Vic LaRosa, President and CEO, TTSI, talked about his company's experience with fuel cell trucks from testing the Vision Industries Corp Tyrano Class 8 truck; this proved to them that trucking with fuel cell technology could be done. TTSI is excited to test six fuel cell Class 8 trucks from different vendors in 2017 and 2018. This will allow them to gain experience in fuel cells as they have familiarity with and confidence in the electric motor. TTSI has always believed zero emission trucks are the future. Vic acknowledged that these demonstrations are pre-commercial and can be considered a "beta test", designed to work out the kinks. TTSI is not large enough to own their own service center and outsources to local truck shops and dealers when necessary. TTSI is working on a new 100-acre facility with 88 acres dedicated to 12.5 MW of solar; they are interested in generating their own hydrogen.

Fred Johring, President, Golden State Express Inc., talked about the negative perception any new truck technology will have in the port due to the failure of LNG trucks. He compared it to fishing in a pond: a fisherman will think twice about casting a line into disturbed waters that were recently fished since the fish know there's a hook behind the bait; the port is a disturbed pond. When the LNG trucks came out they were sized for 60,000lbs gross vehicle weight, not the typical 80,000lbs gross vehicle weight. Fred stated any truck in the port should be built to handle up to 125,000lbs as the drivers think can get away with hauling more weight. His recommendation is to make sure the technology is ready for primetime and will not fail in service. There are about 10,000 port drivers that communicate well about these sorts of issues. Cost and performance of fuel cell trucks need to be better than diesel for drivers to buy in.

All operators want better prices for hydrogen and for it to be renewable, and for it to be produced on port property. Terminal operators want a 2-3 time price reduction in fuel to change to alternative technologies. One of the hurdles experienced by all fleet operators is training people to maintain fuel cell trucks and to work on high voltage. The industry needs to invest in training facilities and schools for fuel cell truck technicians. Diesel trucks have about 2,200 parts compared to about 200 for electric vehicles. A big advantage for using fuel cell trucks is the reduction in required maintenance, specifically no oil changes and fewer brake jobs, resulting in less money spent on service. Terminal automation will be a game changer for the port drayage trucking industry, and will result in quicker turnaround times down to 30 minutes from 90 minutes currently. That will make the case for using hydrogen fuel cells over battery electric vehicles; the miles per day will increase, making it difficult for battery electric trucks to get the job done. Currently there are two fully automated terminals with plans for more terminals to consolidate and automate. However, due to the exorbitantly high cost of automating a terminal, and union resistance, it may be a slow process.

Truck OEM Perspective on Hydrogen Fuel Cell On-Road Freight

Nico Bouwkamp, Technical Program Manager, California Fuel Cell Partnership (CaFCP), presented findings from the CaFCP Heavy Duty Truck Action Plan published last year. He stated the need for continued funding to demonstrate fuel cell trucks to spur development. Heavy duty hydrogen fueling infrastructure is required and needs to be established for trucks; it is not possible for trucks to fuel at passenger car stations. The lessons learned by transit agencies in fueling buses with hydrogen, usually at their own facilities, serve as excellent examples for this sector. The goal of the demonstrations is to create a sustainable business case for truck manufacturers so they will buy in and show that the total cost of ownership is competitive with diesel and natural gas.

Brian Lindgren, Manger, Research and Development, Kenworth Truck Company, presented what large OEMs are thinking when developing and implementing a new technology such as hydrogen fuel cells.

Brian stated that Kenworth does not know what the right technology is but is moving forward with hydrogen fuel cells for emissions reasons. Kenworth believes that, by 2025, drayage trucks will be required to be zero emission in the Southern California ports, and that Houston and New York/New Jersey will follow. The expected market for fuel cell trucks is 500-1,000 vehicles per year, relatively small compared to diesel truck production. Government incentives are required today to justify investment in developing fuel cell trucks, which have a current cost of $1.5M compared to a $150,000 for diesel. Kenworth is building a battery electric truck with an onboard fuel cell range extender. The battery size is 100 kWh with a 85 kW Ballard fuel cell and 25 kg of hydrogen storage behind the cab, with an expected range of 110-150 miles. The fuel cell truck project is out of the DOE ZECT II program with help from South Coast Air Quality Management District (SCAQMD) and the California Energy Commission (CEC). The Kenworth fuel cell truck is scheduled for completion in 4Q 2017, demonstration begins in 2018.

Brian went over the multiple challenges with developing a fuel cell truck: complex cooling systems with many parameters, limited space for hydrogen storage (leading to higher pressures in the future) and high cost of hydrogen tanks, and an immense amount of electrical wiring. Other factors challenging hydrogen truck proliferation is the lack of heavy duty hydrogen fueling infrastructure, which leads to range anxiety. Furthermore, concerns include the energy required to create and reform hydrogen and the emissions associated with the production of nonrenewable hydrogen.

Kenworth is motivated to work on fuel cell trucks to learn more about electric drive systems since they plan on releasing hybrid trucks in the near future, and want to compete in zero emission heavy duty vehicle markets. Kenworth will focus on renewable natural gas and hybrid configurations as they try to move away from petroleum all together and push the fuel cell truck concept forward. They expect battery advances to occur but still do not see them getting the weight to where it needs to be to go all electric. He mentioned that Peterbuilt is developing an all-electric truck.

During the open discussion, Ash Corson of Toyota commented on the recent announcement of testing of a hydrogen fuel cell truck using two Toyota Mirai fuel cell stacks and two Mirai electric motors. Ash stated Toyota believes in the scalability of fuel cells and the company has been asked to step forward to help address the freight emissions in the Southern California region.

Technology Developer Perspectives on Hydrogen Fuel Cell On-Road Freight

Alan Mace, Product Manager, Ballard Power Systems, discussed the value proposition of hydrogen fuel cells for material handling equipment, medium/heavy duty trucks, transit buses, and light rail applications. The benefits of using hydrogen are increased range, scalability, zero emissions, and total life cycle affordability. One of the challenges of a Class 8 truck is limited space, which drove Ballard to create fuel cell sub-modules for flexible integration. Ballard has overcome the vast challenges with operating a fuel cell in extreme environments of heat and cold by successfully demonstrating Ballard powered vehicles in Scandinavia and the California desert. For the commercialization of fuel cell trucks, Ballard is leveraging its successful track record with fuel cell buses.

Rob Del Core, Director, Fuel Cell Power System and Hydrogen Infrastructure, Hydrogenics, presented the Celerity fuel cell module, purpose-built for Class 8 trucks and other heavy duty applications. Hydrogenics is part of a CEC drayage truck demonstration project using a Daimler Freightliner chassis, Siemens electric drive, and an ACTIA battery pack. The truck will be operated in the Port of Long Beach by TTSI. Rob talked about the DOE ZECT drayage truck project they are also involved with, supplying two HD30

fuel cell modules to TransPower for a 2-year demonstration in San Pedro Bay Ports. Hydrogenics is also supplying the fuel cell for a UPS delivery van project funded by DOE, CEC, and SCAQMD. In addition to fuel cells, Hydrogenics is an electrolyzer manufacturer. They just entered into an agreement to provide a fleet and fuel package for Sunline Transit supplying a Celerity Plus fuel cell module to five New Flyer buses and an electrolyzer for on-site hydrogen production. They envision the same type of on-site hydrogen production fueling solution for heavy duty freight. Rob stated the technology is here and ready for mass adoption; however, service training and supply chain are issues need to be addressed.

Dr. Abas Goodarzi, President and CEO, US Hybrid, discussed the similarity between a conventional ICE engine and a "fuel cell engine". Both have similar parts for operation including air intake, cooling, low voltage power requirements, and supply of on-board fuel. In the challenging environment of freight vehicles in stop and go traffic, electric propulsion is the solution. Advantages of fuel cell engines are increased efficiency, less maintenance, quick refueling, 24/7 operation, and no range compromise. US Hybrid has developed a Class 8 fuel cell truck with an 80kW fuel cell developed in house, alongside a 26 kWh battery pack, which will be demonstrated in the Port of L.A. in June 2017. US Hybrid is also developing a battery dominant fuel cell bus and a shuttle bus, in addition to a fuel cell street sweeper.

Dr. Andreas Truckenbrodt, Board Chair, Loop Energy, spoke of the need for zero emissions for heavy duty transport. Loop is developing a fuel cell terminal tractor to be demonstrated in 2Q 2017 in the US ports and in 3Q 2017 in China. Andreas believes that the total cost of ownership for heavy duty vehicles can be technology neutral within 10 years and compete with diesel.

In the discussion, the panel responded to a question of the expectation of dropping battery cost, with agreement that battery costs have not come down but will in time, which will benefit fuel cell electric vehicles. Abas stated his fuel cell component costs are coming down, the key to that being volume. When asked about the operational differences between fuel cell trucks and buses, Abas stated drayage trucks have higher power demand while transit buses have lower average power. US Hybrid is interested in the larger goods movement market, rather than the transit bus market. Rob mentioned both applications have high utilization, consume a lot of fuel, and have dynamic operating cycles. When asked when the panel sees hydrogen becoming mainstream, Andreas answered saying it will be sooner than later in California with the help of regulations; with fueling infrastructure remaining the biggest hurdle.

Heavy-Duty Hydrogen Refueling

Naveen Berry, Technology Demonstration Manager, Science and Technology Advancement, South Coast Air Quality Management District, began the discussion of hydrogen refueling with a map of the 67 hydrogen stations, almost all light duty, in various stages of development in California, with 27 currently open to the public. The challenge with heavy duty fueling stations is they are difficult to co-locate with light duty stations and there is currently no protocol for heavy duty hydrogen refueling. Also, higher capacities with more throughput are needed for heavy duty vehicles; a Class 8 fuel cell truck will need about 20 kg/day. The California Sustainable Freight Action Plan and the CaFCP Heavy Duty Fuel Cell Truck Action Plan both call for hydrogen fueling infrastructure dedicated to heavy duty vehicles which will need to be optimized for truck applications: located by ports and goods movement corridors, and have various forms of hydrogen production or generation. Hydrogen logistic options are onsite production from an SMR or electrolysis, liquid delivery, gas delivery, and connecting to an existing hydrogen pipeline. SCAQMD is interested in collaborating for fueling of Class 8 trucks in the ports and will be doing a heavy duty station feasibility study with CaFCP.

Jason Hanlin, Director of Technology Development, Center for Transportation and the Environment (CTE), discussed managing the fueling of all 6 Class 8 fuel cell trucks to be demonstrated in the San Pedro Bay ports, all operated by TTSI for a period of two years. CTE put out a request for proposals and received an array of fueling solutions proposed for the temporary station to supply hydrogen for the demonstration trucks. The challenge was addressing the risks related to each solution concerning the uncertainty of demand. The demand for the station over the three-year period is a bell curve with a peak of 8 fills/day.

Nitan Natesan, Business Development Manager, Linde LLC, talked about the various ways they provide hydrogen for fueling from both renewable and conventional sources. Pipeline transport, trailer transport, and onsite production are all options. Pipelines are expensive at around $2 million/mile. Every station application is different and requires different hydrogen production, transportation, and fueling technologies. The goal is to transition away from conventional hydrogen production from fossil fuels. Linde has developed expansion pathways for both liquid and gas hydrogen production.

Michael Koonce, President, Luxfer-GTM Technologies, talked about their specialty in bulk hydrogen transport systems with double and quadruple tube trailers for 458 kg and 871 kg of storage respectively at 450 bar. Luxfer-GTM also makes ground storage units for 642 kg of hydrogen storage at 450 bar. Luxfer-GTM also produces hydrogen tank systems for transit buses. They have found a niche market in small mobile refuelers providing emergency roadside assistance for fuel cell vehicles. These small mobile refuelers fit inside the back of a pickup truck and can dispense over 6 kg of hydrogen; the average fuel cell car has 4 kg of hydrogen storage. Michael presented their temporary heavy duty fast fill hydrogen station that involves delivered hydrogen at 200 bar, compressed and stored at 450 bar, then dispensed at 350 bar with a total system cost of $525,000 for 42 kg of dispensed hydrogen.

In the discussion, the panel was asked where to find good resources to explore carbon footprint and other environmental issues. The panel suggested the CaFCP website, Argonne's GREET Model, SCAQMD data, information from the California Governor's Office of Business and Economic Development office, and National Renewable Energy Laboratory (NREL). To meet the 33% renewable hydrogen requirement, more solar and wind power to hydrogen will have to be utilized. Nitin commented that the future for heavy duty trucking is liquid fuel.

Lessons Learned from Fuel Cell Forklift Commercialization and Applicability to Hydrogen Freight

Jim Petrecky, Vice President of Business Development, Plug Power talked about the success of fuel cell forklifts, their commercialization, and the lessons that can be applied to other goods movement vehicles including heavy duty fuel cell vehicles. To date, Plug Power has delivered 14,800 fuel cells at 43 sites with over 130 dispensers totaling 6 million hydrogen fills with over 98% uptime. Their plan it to apply this vast experience to the freight sector. Fuel cells provide extended range in applications such as the UPS Class 6 truck where batteries can't perform the duty cycle. Commercial vehicles from forklifts through all truck classes need hydrogen to achieve zero emissions due to heavy utilization, high energy density, and inability to pause operations to charge. Jim's nine lessons learned from the success of fuel cell forklifts are:

1. Need to offer the appropriate suite of vehicles; customers do not want to deal with multiple fuel types.

2. Hydrogen fuel and infrastructure must be part of the freight solution; customer wants “one throat to choke” and is not familiar with hydrogen.
3. Being “green” alone does not sell; it needs a clear value proposition based on economics, which can include a lower cost of environmental compliance.
4. Customers do not understand the impact of demand charges on the total cost of ownership of electric equipment; demand charges can be a huge consumption cost.
5. The more hydrogen used, the cheaper it becomes; the higher number of fills results in a better value due to the infrastructure site being amortized over more hydrogen throughput. This can result in cheaper hydrogen for freight that uses the same distribution center.
6. Both the OPEX and CAPEX model needs to be looked at to make a business case for hydrogen.
7. Sufficient high voltage training needs to be put in place for each customer.
8. Bring the hydrogen to customers, making it easy for the fuel to fit into their work processes.
9. The hydrogen assets (equipment) should use customer preferred chassis vendors so it looks and feels the same as what the customer is used to.

Open Discussion, Outcomes and Action Items

Discussion

Education is a key issue across the board; there needs to be dedicated technical learning centers for servicing high voltage and fuel cells. Some transit properties such as SunLine Transit and AC Transit have developed their own fuel cell vehicle education programs. The California Air Resources Board is working with those agencies to identify an academic curriculum going forward. At Rio Hondo College, Professor Frala has developed a technical education program that can be deployed right now. Currently technicians, system designers, and engineers at universities look down on hydrogen; they need more critical thinking and education.

Truck OEM manufactures do not see the necessary market pull from consumers that they need to start producing fuel cell trucks. There needs to be more consumer demand to affect the supply chain. More PSAs and media attention could broaden the messaging that fuel cells are here and ready. How do we market an odorless, invisible gas? Hydrogen can meet health needs on a local and macroclimate basis. Partnering with hospitals and working with first responders to provide solutions in emergency areas could drive forward the positive perception of hydrogen.

Outcomes

A lot of information was learned and shared in the workshop. An increase in the volume of fuel cell trucks will drive the development of the infrastructure. The value proposition of hydrogen fueling will increase substantially when multiple fuel cell vehicles are fueled at a single location. Bundled solutions of vehicles and fueling make the most business sense for the customer. The customer needs to know the full value proposition of hydrogen and how it makes sense for their business. There needs to be a focus on technical courses for fuel cell vehicles that covers high voltage.

Action Items for the CHBC

1. Develop the Workshop report
2. Perform a webinar summarizing Workshop findings
3. Create an addendum to the Workshop report giving guidance to the CHBC Advocacy Committee on how they can help push forward fuel cell trucks and heavy duty hydrogen infrastructure.