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

APRIL 30, 2018 | LONG BEACH, CA | Co-located with Advanced Clean Transportation Expo ACT EXPO

CHBC Hydrogen and Fuel Cells On-Road Freight Workshop at ACT Expo

California Hydrogen Business Council
6/18/18

Acknowledgements

Planning Committee

The 2018 Hydrogen and Fuel Cells On-Road Freight Workshop was planned and organized by members of the California Hydrogen Business Council's Goods Movement, Heavy-Duty Transportation, and Clean Ports Sector Action Group. We particularly thank co-chairs Gus Block and Andreas Truckenbrodt, as well as Cory Shumaker, CHBC Development Specialist. The workshop attracted over 100 people, one of the largest half-day events the CHBC has conducted, an indicator for the interest in this topic.

The CHBC also thanks the organizers of the ACT Expo for allowing the workshop to be conducted at their event.

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The CHBC thanks the following organizations for their financial contributions, without which this workshop would not have been possible

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Executive Summary

To mitigate the devastating effects of global climate change and the harmful effects of local air emissions in the transportation sector, governments around the world have set aggressive emissions reduction goals, began the transition away from the conventional fossil fuels by adopting zero and near-zero emission transportation technologies, primarily through compressed natural gas (CNG), battery electric, and fuel cell electric. One of the areas of focus in California is emissions that are sourced from goods movement in the ports and heavy duty freight sectors, where many disadvantaged communities are in close proximity to those operations and local air quality affects the health of residents. While many of the zero-emission technologies for goods movement are still being developed, fuel cell electric has emerged as the optimal replacement for diesel for heavy duty vehicles both on and off road due to its fast refuel time, long range, and performance under frequent, high demand cycles. In Southern California, the largest potential reduction of emissions would come from transitioning diesel drayage trucks, which account for 12% of total NOx emissions in the South Coast Air Basin, to zero emission, fuel cell electric trucks (FCETs), resulting in local air quality improvements for hundreds of thousands of people.

A wide variety of stakeholders, including several within the hydrogen and fuel cell industry, are developing and investing in the goods movement technologies of the future. Numerous heavy duty FCET demonstration projects are being conducted by Kenworth, Toyota Motor Company, US Hybrid, Transpower, and Peterbilt to replace the diesel trucks in use today. Many of the demonstration projects are being conducted in conjunction with the fleet operators that would like to offer zero-emission options to their customers. The growing interest in the sector is focused on heavy duty fuel cell applications, but there is significant opportunity to expand across all sectors, especially medium duty applications, to increase the impact that zero emission technologies can have on air quality improvements in the near-term.

Infrastructure development is critical to the success of the hydrogen and fuel cell industry. While building a hydrogen fueling station today requires careful navigation of a two-year process in California, this process will become more streamlined and costs will decline as the State government and industry work together to build the necessary fueling infrastructure for fuel cell vehicles. Around the world, electrolyzer costs are rapidly dropping and becoming economically comparable to the SMR method of hydrogen production and station developers are able to generate Low Carbon Fuel Standard (LCFS) credits, and potentially federal RINs, to produce affordable hydrogen.

The path to a zero emission transportation sector is clear, but will require continued, large-scale investments by all stakeholders, including government and industry, to ensue emission reduction goals are met and the health and wellbeing of future generations is guaranteed. The California Air Resources Board (CARB) has created the necessary investment programs to facilitate the transition away from diesel, with billions of dollars in funding available, many of which are focused on activities in the goods movement sector. The violations of some industry players have resulted in penalties and fines that trigger new investment in clean technologies, like the Volkswagen (VW) Settlement and specifically Appendix D of the VW Mitigation Trust for heavy duty and ports applications. In addition, the U.S Environmental Protection Agency's Regions 9 and 10 have formed the West Coast Collaborative to create a regional transition movement and will eventually seek federal funding. Ultimately, the success of these efforts will be placed on the shoulders of consumers to demand government commitment for cleaner, zero-emission technologies, as well as the responsibility of the industry to continue to meet those demands by investing and taking advantage of funding programs that help with the economic burden of early adoption and development of zero emission technologies, primarily through fuel cell electric.

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Introduction

The California Hydrogen Business Council hosted a half-day workshop in conjunction with the ACT Expo in Long Beach on April 30th as a follow up to the workshop by the same name held a year prior. The purpose of the workshop was to continue 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 key drivers of substantive economic and operational benefits. At the workshop, fleet operators and medium/heavy duty OEMs provided presentations, followed by discussion and presentations from hydrogen technology providers on the status of freight demonstrations, future visions, and the available funding options for heavy duty hydrogen fuel cell projects from the California Air Resources Board.

The backdrop for this workshop was that movement of freight and goods from the commercial ports to 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. They also cause significant local air and greenhouse gas emissions, and the medium/heavy duty truck fleets that move goods from ports cause problems well beyond the boundaries of the ports. The environmental footprint is significant, both because of the 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. Areas of California suffer environmental conditions that cause breathing and heart-related health problems and health costs.

Hydrogen-fueled fuel cell electric vehicles are entering the California automobile vehicle market, and hydrogen fuel cell fork lift trucks are commercially purchased by product distribution centers and factories today. More than ever, it becomes noticeable that there are variety of potential hydrogen and fuel cell on and off road vehicles, including cargo handling equipment, that generate zero emissions energy at the point of use, and "well to wheels" zero emission energy when the hydrogen is produced from renewable sources, everyone's long term goal.

Dual Keynote

Dr. Michael Mac Kinnon, Senior Scientist, National Fuel Cell Research Center at UCI

The basic question behind Dr. Michael Mac Kinnon's study "Assessment of the Air Quality and Health Impacts in the South Coast Air Basin" was "If fuel cell electric trucks are used for drayage, how does that affect human health?"

> *"There is significant inequality in exposure to air pollution and related health risks: air pollution combines with other aspects of the social and physical environment to create a disproportionate disease burden in less affluent parts of society" – World Health Organization*

Southern California has the worst ozone and fifth worst particulate matter pollution in the United States, causing numerous health impacts, especially in disadvantaged communities along major freeway corridors and near the ports. In an effort to improve air quality, California has set aggressive emissions reduction goals for the transportation and energy sectors**. The largest potential reduction from emissions in Southern California is transitioning diesel powered drayage trucks,** operating in the Ports of Long Beach and Los Angeles, to zero-emission technologies, like fuel

cell electric. Drayage trucks represent 1% of vehicle miles traveled (VMT), but emit 12% of total NOx in the South Coast Air Basin.

Fuel Cell Electric Trucks (FCETs) offer a complete replacement for diesel drayage trucks, with no sacrifice in performance or equipment durability. In simulations, FCETs penetrations of 45-79% in the total drayage fleet could reduce NOx emissions by 7 to 10 tons per day. Additionally, cleaner trucks' impact can be found in the inland area and around the ports regarding ozone pollution for PM 2.5.

Disadvantaged communities live with the most negative impacts from diesel emissions, especially around the 710 freeway and in the inland empire. These communities will see the biggest health benefits from zero-emission FCETs because of drastically improved air quality. When benefits are monetized in terms of premature mortality, morbidity, lost work days, they have a mean value of $824,610 to $1,310,130 per day.

The adoption of FCETs is a highly effective strategy to reduce pollutant emissions from on-road transportation and meet California's aggressive emissions reduction goals. Furthermore, conversion to zero-emission FCETs will improve air quality for communities throughout California, especially those disadvantaged by their economic standing and geographic proximity to high pollution zones.

John Mikulin, Environmental Protection Specialist, Public Fleet & Trucking Sector Lead, West Coast Collaborative, U.S. Environmental Protection Agency

In 2004, the Environmental Protection Agency (EPA) Regions 9 and 10 established the nation's first regional diesel collaborative as part of the U.S.'s National Clean Diesel Campaign. The West Coast Collaborative (WCC) is a public-private partnership with 1,000 partners from the states of Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, Washington, the Territory of American Samoa, Territory of Guam, Commonwealth of the Northern Marina Islands, as well as partners in Canada and Mexico. WCC's goals are to help meet National Ambient Air Quality Standards, reduce diesel particulate emissions in impacted communities, and support technology advancement and deployment to increase energy efficiency, energy security and economic growth.

To join the West Coast Collaborative in its efforts, interested parties can sign-up at http://westcoastcollaborative.org.

The **WCC will host a biannual partnership meeting from October 16-18, 2018 in Sacramento, CA,** co-produced with the Green Transportation Summit and Expo.

The Fixing America's Surface Transportation (FAST) Act, Section 1413: Alternative Fuel Corridor Designation, provides national funding mechanisms for compressed natural gas (CNG), liquefied petroleum gas (LPG), liquefied natural gas (LNG), hydrogen (H2), and electric vehicles (EVs). Section 1413 directs the U.S. Department of Transportation (DOT) to designate the alternative fuel corridors that identify the near to long-term needs and strategic locations for fueling infrastructure along major national highways.

The Federal Highway Administration (FHWA) nomination package cited $111.38M for planned alternative fueling stations, with a potential $89.1 M in federal cost share. In addition to those funds, the FAST Act outlines numerous national funding programs, including:

- Congestion Mitigation and Air Quality Improvement Program (CMAQ) (~$2.4B/year). More information available at https://www.fhwa.dot.gov/environment/air_quality/cmaq/

- Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE) (~$900M/year). More information available at https://www.transportation.gov/buildamerica/infragrants
- Transportation Investment Generating Economic Recovery (TIGER) (~$500M/year). More information available at https://www.transportation.gov/tiger
- Transportation Infrastructure Finance and Innovation (TIFI) (~$300M/year). More information available at https://www.transportation.gov/buildamerica/programs-services/tifia
- FTA Bus and Facility Competitive Grants (~$300M/year). More information available at https://www.transit.dot.gov/funding/grants/buses-and-bus-facilities-grants-program-5339
- FTA Low-No Bus Grants (~$55M/year). More information available at https://www.transit.dot.gov/funding/grants/low-or-no-emission-vehicle-program-5339c

The **West Coast Collaborative is planning to conduct hydrogen infrastructure stakeholder demand survey** to determine that if sufficient funding were made available, what would the hydrogen, natural gas and battery electric industries **need to establish a corridor of stations**. The eventual end goal of this survey to seek funding from the U.S. DOT. The West Coast Collaborative is beginning by building up multi-state stakeholder engagement. The CHBC responded to this by creating a working group to help facilitate the transfer of information from industry members to government. If you would like to participate in this working group contact Cory Shumaker cshumaker@californiahydrogen.org.

User and Operator Perspectives

Moderator: Andrew Bermingham, CEO, Hydrogen Partners LLC

Hydrogen vehicle fleets are experiencing difficulty obtaining financing**. Industry needs to match supply side partners with demand side partners with offtake contracts to wrap in project financing and management.**

Michael McDonald, Senior Director Maintenance & Engineering, UPS

In the first half of the 20th century, the United Parcel Service (UPS) operated a fleet of electric delivery vehicles. UPS has a history of sustainability, establishing its experience with fuel cell electric vehicles (FCEVs), battery electric vehicles (BEVs), CNG, LNG, ethanol, biomethane, and propane, spending over $750M since 2009 on alternative fuels. In May 2018, UPS began operating two fuel cell electric delivery vans.

With hydrogen fuel becoming widely available in California, expansion of UPS's fuel cell electric delivery van fleet outside of California will remain a challenge until fueling infrastructure opens across the country and economical fuel prices are established. The development of Class 6 trucks has not advanced as quickly as other sectors, with large OEMs focusing on light-duty vehicles and heavy-duty, Class 8 trucks. **The industry needs to create a long-term vision for hydrogen, across all sectors.** To advance the adoption of hydrogen and fuel cells in the Class 6, delivery sector, **UPS is looking at building hydrogen stations at their locations across the U.S.**

Vic La Rosa, CEO, Total Transportation Services, Inc

The Los Angeles area has a significant pollution problem and the shippers and customers must be educated on that significance. To help mitigate pollution and improve air quality, Total Transportation Services, Inc. (TTSI) has set a goal to be responsible stewards of the environment by working towards operating a zero emission fleet for their customers. **TTSI will test eight FCETs that utilize fuel cells from Ballard Power Systems, Hydrogenics, and U.S. Hybrid, with hydrogen fueling from Air Products via a mobile tube trailer with a dispenser**. In the initial

testing of FCETs, drivers were paid a premium to convince them to drive the truck, now they are fighting over the trucks.

TTSI chose to focus on fuel cell technology because the available battery technology cannot handle the heavy duty cycles required for goods movement. Kenworth's FCET will be tested by TTSI, which has decided to experiment with a variety of FCETs to test the longevity of the equipment. TTSI believes the overall benefits of FCETs outweigh the initial investments that must be made to meet California's aggressive emission reduction goals.

With TTSI expanding their FCET fleet in the years to come, hydrogen infrastructure will need to be established to accommodate the transition to zero-emission goods movement. **Most TTSI operations require 200 miles per day, therefore a fuel cell and battery hybrid truck could be feasible.** Hydrogen production primarily comes from steam methane reformation of natural gas, but in the future TTSI wants hydrogen production to be from electrolysis from renewable electricity, mainly solar and wind.

Truck OEM Perspective

Moderator: Nico Bouwkamp, Technical Program Manager, California Fuel Cell Partnership

The success of FCETs will come down to demonstrating the technology to spur additional development, establishing the required fueling infrastructure, and creating a sustainable business model for truck manufacturers. The technology readiness level for FCETs is technology readiness level (TRL) 5-6, system integration and demonstrations. **To reach TRL 9, product launch at high volumes, OEMs will need to continue making large investments in FCETs.**

Bill Kahn, Advanced Engineering Manager, Peterbilt Motors

Peterbilt is looking at a wide range of alternative fuels, including: CNG, LNG, DME, BEV, and FCEVs. Before electrification of fleets became feasible, they were focused exclusively on CNG and LNG technology, primarily for savings on fuel costs due to expensive diesel. With electrification now feasible, **Peterbilt is ready to respond to the market with hydrogen powered FCETs because hydrogen has a high energy density**. Hydrogen has a specific energy of 39 kWh/kg, compared to 13.3 for diesel, 15 for CNG and LNG, and .693 kWh/kg for battery.

Peterbilt and TransPower are building a fuel cell range extender and will utilize a 60kW Loop Energy hydrogen fuel cell. The FCET's onboard storage will hold 10 kg of hydrogen and have a battery capacity of 176 kWh. The total cost of this prototype is $500,000, with a quoted battery cost of $500/kWh. The truck is anticipated to have a 140 kWh consumption at highway speeds.

In the early stages of transitioning away from diesel, Peterbilt believes one truck technology will not be able to do everything, but a fleet consisting of a variety of technologies will. Ninety percent of Peterbilt engineers are focused on emission reductions from diesel trucks. Peterbilt will need a strong business case to move engineers' focus to hydrogen, which would require establishing fueling infrastructure and reducing the cost of hydrogen. **Peterbilt's goal is to have the FCET cost be the same as their CNG trucks, $130,000 up-fit cost with a $200/kWh battery cost.**

Brian Lindgren, Manager, Research and Development, Kenworth Truck Company

Kenworth's FCET is going through demonstration testing, including in the Port of Seattle, and is utilizing an Air Products portable refueler to provide the necessary hydrogen at their test track. The refuler has fast-fill ability of 350 bar, which equates to a 30 kg fill in 6-8 minutes. Kenworth would like to have a 700 bar fast-fill in the future. The weight of the truck frame structure and hydrogen tanks represents the bulk curb weight of Kenworth's FCET.

Kenworth is also improving its shop safety standards for FCETs and has developed a defueler while working on the truck. CNG trucks have defined the safety standards when working with compressed flammable fuels, making maintenance on the FCET familiar. With the right safety valves and equipment, there are no explosions, even if a bullet is fired directly at the tank.

The demonstration projects and testing have revealed some issues that will need to be addressed before mass production occurs. The cable routing will define the final placement of components due to the thick, high voltage cables, which take turning radius considerations into account. The truck has four different cooling loops, creating a major challenge. Communication has also been a challenge, with four different CAN lines.

Reliability will be key before the truck is ready for release to TTSI. A roadworthiness test will be the last major hurdle for the FCET, along with software-in-the-loop testing, hardware in-the-loop testing, and individual components testing**. Before volume production can occur, there will need to be two more years of testing and significant investment.** The truck has a plug-in charge capability for maintenance, but the plug-in capability will be removed. Kenworth would also like to utilize more fuel cells and less batteries as they continue to develop the FCET.

Kohei Masaki, Hydrogen Strategy Consultant, Toyota North America

In April 2017, Toyota started Project Portal, a hydrogen fuel cell system designed for heavy duty truck use at the Port of Los Angeles, which has completed 8,200 miles. Toyota has set a goal to be zero-CO_2 by 2050, producing only FCEVs, BEVs, PHEVs, and HEVs. **Toyota believes hydrogen fuel cells will be optimized in the heavy-duty sector because they have a longer range, quick refueling time, and flexible fueling options.**

There have been significant cost reductions for fuel cell systems from development of the Mirai**. Hydrogen currently costs $3 per mile. Toyota's short-term goal is to reduce that cost to $1.3/mile with 400kg/day for a 10 truck station and a long-term goal of $0.60/mile with 2,000kg/day for a 60 truck station.** Toyota anticipates future partnerships with financing and maintenance companies to ensure a better transition and easy use of fuel cell trucks.

Technology Developer Perspectives

Moderator: Alan Mace, Product Development & Market Specialist, Ballard Power Systems

A hydrogen fuel cell-battery hybrid truck would provide the benefits of both technologies in one vehicle, with batteries providing fast response and brake energy storage and the fuel cell proving constant power generation to maintain the status and health of the battery. The size of fuel cells and batteries could be optimized based on vehicle and route. **A fuel cell electric truck is 6 tons lighter than a battery electric truck.** FCETs hold an

advantage in the heavy-duty and goods movement sectors due to **long-range operation, no roadside charging, fast refueling, and high asset utilization**. China is now deploying FCETs, 500 Dongfeng medium duty trucks are being built and deployed by the end of 2018. The Dongfeng trucks will utilize 30kW fuel cells.

Abas Goodarzi, President & CEO, US Hybrid

Since 1999, Abas Goodarzi has worked with fuel cells, starting with a fuel cell scooter and in 2002, a fuel cell electric bus (FCEB).

FCETs are the future of the heavy-duty and goods movement sector but challenges remain regarding weight and volume. US Hybrid has a battery electric truck (BET) with a range of 80 miles. When the BET was being developed, fuel cells were seen as the way forward to improve the range of the zero emission truck. **Fuel cells are combustion-less engines and have better performance, on a per joule basis, than a diesel engine**. When converting to fuel cell technology, there is no need to worry about the "next trick" or after treatments to reduce emissions, unlike diesel engines.

Fuel cells provide 10 times greater energy density and are 50 times faster to refuel, when compared to battery technology and enable double and triple shifts for commercial fuel cell vehicles. Fuel cells can be utilized for numerous transportation and energy applications, including many in the military. US Hybrid wants to provide enabling for electric traction and propulsion. There is a 17% savings in fueling from CNG compared to hydrogen. US Hybrid has found that **1kg of hydrogen is equivalent to 2kg of diesel.**

Joshua Goldman, Vice President Business Development, Transpower

Development of zero emission, electric trucks begins with the electric motor, everything else is added. TransPower's prototype FCET utilizes a pair of 33kW Hydrogenics fuel cells, totaling 66 kW at full power, 19 kg of onboard hydrogen, and a 140 kWh battery pack with a total tractor weight of 20,500 lbs. The truck is being tested in San Diego, hauling raw metals to a car parts facility. TransPower is learning about fueling through this demonstration project and will eventually look to get the cost of hydrogen in parity with diesel. The next generation of FCETs will likely have larger batteries and more onboard hydrogen storage. To scale up testing and production of FCETs, the **price of hydrogen will need to be less than $8/kg**, otherwise the value of fuel will be hard to see.

Tim Reeser, CEO & Co-Founder, Lightning Systems

Lightning Systems wants to be the global leader for zero emission, vehicle powertrains for commercial fleets. They have developed standard scalable electric propulsion systems for medium duty vehicles through Class 7. Lightning Systems provides two solutions: conversion of new vehicles to zero emission and repower of existing vehicles. With only a Ford transit based FCEV, Lightning Systems has received over 300 orders for the FCEV. The Ford transit FCEV uses a Ballard fuel cell, providing a 200-mile range. StratosFuel will build stations for Lightning and Luxfer-GTM will provide mobile refueling.

Heavy-Duty Hydrogen Refueling

Moderator: Naveen Berry, Technology Demonstration Manager, Technology Advancement, SCAQMD

The South Coast Air Quality Management District (SCAQMD) has a technology neutral and fuel agnostic stance. Right now, hydrogen fueling stations need to expand to the Inland Empire of California, but **challenges for**

fueling include cost, supply chain, CEQA permits, capacity limitations, and fueling protocols. **Hydrogen production from biogas needs to be strongly considered as it is an excellent use for clean fuel**. SCAQMD is beginning to focus on stranded renewables and utilization of power-to-gas (P2G). The California Energy Commission (CEC) Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) have two funding opportunities, which include: GFO 17-602 to renewable hydrogen infrastructure for $4 million and NOPA 17-603 to advanced freight and fleet technologies for $8 million.

Rob Del Core, Director, Business Development, Fuel Cell Power Systems, Hydrogenics

Hydrogenics electrolyzers have been installed at 55 hydrogen stations, 11 out of 13 heavy duty stations, around the world. They commissioned the largest P2G facility in North America, utilizing a 1.25 MW stack, with the highest density and smallest footprint in the world. The Ontario hydrogen station uses Hydrogenics electrolyzers that produces 130 kg/day for the 700 bar station. Hydrogenics has also developed a containerized solution for heavy duty hydrogen fueling using electrolyzers, as well as a 1,000 kg/day configuration concept. New Flyer buses, Freightliner's FCET demonstration, and 17 UPS delivery vans are powered by Hydrogenics fuel cells. **Hydrogen trains are becoming a growing interest with the world's first hydrogen fuel cell train beginning operation this year by Alstrom.**

The long term vision of the hydrogen and fuel cell industry is to have equipment and vehicles throughout the supply chain powered by hydrogen and fuel cells. **The most impactful opportunities are with rubber tired gantry cranes (RTGs), drayage trucks operating around the ports, long distance freight, and locomotives**.

Hydrogenics and StratosFuel have partnered on a project to build a large, centralized renewable hydrogen production facility that will use wind power. From that facility, hydrogen will be trucked to light duty stations across California. The centralized hydrogen production facility will be built near the ports to facilitate fuel cell equipment and vehicles across all applications and reduce the cost of hydrogen by producing it in cheaper, less populated areas. Hydrogenics will need to address challenges and questions before the centralized facility can be built, including: station location, hydrogen production technologies to be used, cost, navigating CEQA, and funding for the facility.

Paul Fukumoto, Director, Business Development Advanced Technologies, Fuel Cell Energy

FuelCell Energy has developed a tri-generation power module that is the utilization of carbonate fuel technology to produce hydrogen, heat, and electricity from biogas. A four-stack module is capable of producing 1.4MW of power and can be scaled up and combined to large fuel cell parks of 50MW+. FuelCell Energy is installing a tri-generation system at the Port of Long Beach to support Toyota's Project PORTAL truck. The system will use landfill gas, "clean" it up onsite, to produce 1,270 kg of hydrogen, 2.3 MW of power, and .5 MMBtu/hr. of thermal energy. **The economics of this system from generating LCFS credits, and potentially federal RINS, will make the most affordable hydrogen available.**

Elán Bond, Project Manager, North America, Nel Hydrogen

Throughout the world, **electrolyzer costs are dropping rapidly and becoming economically competitive** on the CAPEX side with SMR via scale. **Fifty megawatts of electricity produce 25 metric tons of hydrogen per day**. Nel Hydrogen is the first company in the world to have a UL certified hydrogen fueling station.

Nel has developed a concept for a GW sized electrolyzer and is working on a triple fueling solution in Trondheim, Norway for forklifts, trucks, and light duty vehicles, which will use solar and hydropower. They have developed a station with onsite generation at Sunline Transit in Palm Desert, CA using a **PEM electrolyzer to produce 900 kg/day with two dispensers, enough capacity to support 25 FCEBs/day.**

Nel was selected by Nikola to build hydrogen stations for its FCET demonstrations and placed a $9 million order to build two 1,000 kg/day hydrogen production facilities. Nel and Nikola are also looking to collaborate on 16 sites to produce hydrogen and fueling for up to 32,000 kg/day/site. These efforts would support Nikola's Class 8 truck from 2019-2021.

Nel is looking at how to achieve $6/kg of hydrogen from centralized production facilities operating on cheap renewables, which is possible in Northern Europe where cheap renewable energy is available. **Three takeaway concepts for the industry include: perform lean volume manufacturing, be creative by using partnerships and funding, be hungry (how much are you a hydrogen evangelist?).**

Station developers and integrators will now be able to generate Low Carbon Fuel Standard (LCFS) credits, which will help reduce the cost of hydrogen from the $16/kg figure.

Ryan Erickson, Senior Manager Business Development, Trillium CNG

Trillium CNG is focused on having municipalities and transit agencies design, finance, build, and maintain large fueling facilities. California has 50 CNG fueling stations and is looking to provide its customers with the solutions to meet their needs. Due to the CNG industry, mechanics have become highly trained on compressed, gaseous fuels and heavy duty fuels. Trillium is fuel agnostic and will provide the fueling solution its customers need, including EV charging and solar energy.

Trillium is developing its first hydrogen station with Air Products of the Orange County Transit Authority (OCTA). OCTA has 10 FCEBs with plans to expand to 20 FCEBs. The station will have two refueling lanes, filling 30kg in 6-10 minutes per bus, and a capacity of 1,500 kg/day. It is a **liquid hydrogen station that vaporizes and pressurizes the hydrogen onsite.**

Closing Keynote

Leslie Goodbody, Air Resources Engineer, California Air Resources Board

The purpose of regulation is to create and ensure the ideal candidates and environments for zero-emission vehicles and policies are identified. The California Air Resources Board (CARB) is creating a balanced set of investments for zero and near-zero emission solutions. **The funding programs focused on the heavy duty sector, and available for FCETs, are Low Carbon Transportation, Carl Moyer, Community Air Protection, and the Volkswagen (VW) Mitigation Trust.**

Every autumn, the Low Carbon Transportation Program is allocated funds from the Cap & Trade budget. A portion of the funds go toward light duty and heavy duty vehicles. The heavy duty funds enter into a three-year strategy plan. Previous heavy duty projects include, $50 million in 2015 for Zero Emission Drayage Trucks and Multi-Source Facility Demonstration Projects, $34 million in 2016/2017 for On- & Off-Road Freight Demonstration Projects, and $80 million in 2015-2017 to deploy 146 zero emission transit buses, delivery trucks, and infrastructure.

The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) has $122 million available for all technologies plus $14 million for Low NOx engines. 2017-2018 incentives for fuel cell technology include $300,000 for fuel cell buses and trucks and $100,000 per vehicle for infrastructure with 5 or more vehicles per site.

Zero-Emission Off-Road Freight Voucher Inventive Project provides $40 million on a first come, first serve basis with vouchers going towards yard trucks, large forklifts, GSE, RTGs and TRUs. Project lead is Nathan Dean: Nathan.dean@arb.ca.gov

The Carl Moyer Program has funding for hydrogen projects, with the greatest emission reduction per dollar spent prioritized. Program received $69 million annually to fund mobile sources and infrastructure. The air districts determine priority and select projects, such as on and off road vehicles and fueling infrastructure. SCAQMD is accepting applications through June 5, 2018. BAAQMD will accept applications throughout the year.

Community Air Protection Plan, AB 617, received its first year of funding at $250 million to the air districts and is eligible to freight equipment for trucks of all sizes, marine vessels, locomotives, off-road equipment and infrastructure.

VW Mitigation Trust has 4 appendices. Appendix D provides $423 million for NOx mitigation in the heavy duty sector. CARB staff is seeking ARB Board approval for the Proposed Beneficiary Mitigation Plan. The Trust will provide $90 million for zero emission, Class 8 freight and drayage trucks, $70 million for zero emission freight and marine projects (Forklifts and Port Cargo Handling Equipment up to $175,000, Airport GSE up to full incremental cost, Shorepower up to $2.5 million, Zero-emission Ferry Tugboat, and Towboat Repowers up to $2.5 million).

Conclusion

The goods movement sector is responsible for a significant portion of GHG emissions, causing poor air quality and negative health impacts in disadvantaged communities near these operations. The state of California is committed to making a concerted effort to reduce emissions and improve the air quality for all Californians. The State government has made billions of dollars of funding available to develop and demonstrate the zero emission technologies of the future. Fuel cells, powered by hydrogen, is emerging as one of the best possible options to replace diesel and transitioning to zero emission transportation due to its longer range, quick refueling time, and ability to handle high duty demand cycles.

Industry will need to continue to invest in hydrogen fuel cell technology and take advantage of the available funding programs, to assist with the economic burden of new technology development, to establish high volume production and commercialization of medium and heavy duty FCETs to bring down cost and allow for large scale adoption. Supporting FCETs with the required hydrogen fueling infrastructure in the early stages of development is critical to scale-up. Around the world, the cost of electrolyzers are dropping, making 100% renewable, zero emission hydrogen production within reach.

If all stakeholders, led by government action, continue to invest in hydrogen and fuel cell technologies, emission reduction goals can be met and the air quality and health of future generations will be guaranteed.