GTI ENERGY

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Zero- and Near Zero-Emission Freight Facilities Project: Zero Emissions for California Ports (ZECAP)

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This Project was part of the California Climate Investments (CCI), a statewide program that puts billions of Cap-and-Trade dollars to work reducing GHG and criteria air pollutant emissions, while strengthening the economy and improving public health and the environment, particularly in disadvantaged communities.

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List of Acronyms

Acronym	Description
CARB	California Air Resources Board
BTMS	Battery Thermal Management System
PIM	Power Interface Module
CHE	Cargo-handling equipment
POLA	Port of Los Angeles
GTM	Gas Transfer Module
HTEC	Hydrogen Technology and Energy Corporation
LADBS	Los Angeles Department of Building and Safety
LAFD	Los Angeles Fire Department
NFPA	National Fire Protection Association
PC	PowerCube
ZECAP	Zero Emissions for California Ports
ZEV	Zero-Emission Vehicles

Executive Summary

The continued development and demonstration of advanced technologies (zero-emission and near zero-emission) is necessary in order to meet California's long-term GHG emission reduction goals, protect public health, and reach attainment with increasingly more stringent federal air quality standards.

This report documents the efforts to develop and demonstrate two zero-emission battery-dominant hydrogen fuel cell yard tractors operating at the Port of Los Angeles (POLA). The trucks were designed to be a direct replacement for the conventional diesel powertrains in operation today. The trucks were designed and built in approximately 1.5 years and were evaluated onsite at TraPac in revenue service throughout the course of one year. An onsite fueler was designed, built, and installed at TraPac's facility to ensure reliable refueling of the vehicles and generate experience for proper evaluation of the impacts of the new technologies on port operations. The researchers credit the future generations of hydrogen fuel cell-powered yard truck designs by Capacity largely to the information gathered from the data received as well as lessons learned by the technical project team. Similarly, the experience with hydrogen station permitting process and fueling operations provided valuable insight into future deployments of the technology in off-highway, industrial and cargo-handling applications.

Local community outreach and education workshops were attended by multiple stakeholders throughout the duration of the project and generated strong interest in the technology and positive feedback from the participants.
The key findings of this project are:

- Hydrogen Fuel Cell Vehicles are capable of operating on the TraPac yard truck duty cycle for up to two shifts when the hydrogen fuel tanks and batteries are at full capacity to start the day.
- The vehicles demonstrated efficiency approximately 2.5 to 3 times that of the conventional diesel powertrains.
- Hydrogen fueling infrastructure deployment and operation requires simplification and performance improvements to ensure operational efficiency.
- Electric powertrains and associated control systems need further improvement, optimization and long-term pre-commercial demonstrations.
- Next generations of technology (fuel cells, e-axles, integrated controls and electrified accessories) developed since the conception of the project have addressed some of the challenges encountered by the project team.
- Data collection from pre-commercial, non-OBD compliant vehicles is challenging and requires dedicated effort.

Introduction

Project background and need

On March 21, 2018, California Air Resources Board's (CARB) issued a solicitation titled Zero- and Near Zero-Emission Freight Facilities (ZANZEFF) under the 2017-18 Funding Plan for Clean Transportation Incentives. The goal of the solicitation was to fund bold, transformative emission reduction strategies that could be emulated throughout freight facilities statewide. Project funding came from two sources: the Cap-and-Trade auction proceeds deposited into the Greenhouse Gas Reduction Fund (GGRF) as part of the California Climate Investments (CCI) and funds deposited in the Trade Corridor Enhancement Account (TCEA). The project was intended to fund a wide array of technologies that further the purposes of AB 32 (Nunez, Chapter 448, Statues of 2006).

The continued development and demonstration of advanced technologies (zero-emission and near zero-emission) is necessary in order to meet California's long-term Greenhouse Gas (GHG) emission reduction goals, protect public health, and reach attainment with increasingly more stringent federal air quality standards. Projects selected under the aforementioned solicitation were required to demonstrate advanced technologies that should be able to provide a significant reduction in GHG emissions and improve air quality for many affected areas within the state when the technology is fully integrated into the marketplace.

A terminal tractor, also called a yard truck, is a heavy-duty tractor designed to quickly couple and uncouple with trailers to move them within a cargo yard. Over 1,800 yard trucks operate at the Ports of Long Beach and Los Angeles, constituting more than half of all cargo-handling equipment (CHE) at the ports. Yard trucks are the single largest source of CHE emissions but are more difficult to convert to fuel cells or batteries because of their variable duty cycles and fundamental requirements for power, versatility, and durability.

Team structure and capabilities

GTI Energy and its team of industry experts proposed to design and deploy two zero-emissions hydrogen fuel cell powered yard trucks. The ZECAP project set the challenge of completing a practical fuel cell yard truck demonstration with onsite refueling. Team members, capabilities and planned responsibilities are outlined below:

GTI Energy: GTI Energy was the prime contractor to CARB and was responsible for overall grant administration, project planning, scheduling, reporting, billing, and for meeting the project goals and deliverables. GTI has managed large, advanced vehicle demonstration projects like this and regularly collaborated with its network of technology partners to bring emerging technologies to commercialization.

Capacity Trucks, Inc. : Capacity has been a leader in terminal truck manufacturing for over four decades. Capacity trucks serve in ports, intermodal, and warehouse & distribution centers in the U.S. and around the globe, including fleet services and governmental agencies. Founded in 1971, Capacity Trucks is headquartered in Longview, TX. Capacity designed and manufactured the vehicle for this project.

BAE Systems: World's leading supplier of electric power & propulsion systems with over 10,000 electric propulsion solutions in service today on 3 continents. BAE defined the performance and subsystem requirements for this project, supplied electric propulsion components and electrified accessories, and was responsible for the integration of the propulsion system.

Ballard: Ballard Power Systems provides clean energy products that reduce customer costs and risks, and helps customers solve difficult technical and business challenges in their fuel cell programs. Ballard supplied the fuel cell and support throughout the demonstration.

ZEN Clean Energy Solutions: Zen Clean Energy Solutions was responsible for the specifications of the fueling solution as well as the permitting and hydrogen safety training. Zen was acquired by HTEC during the project period.

HTEC: Hydrogen Technology and Energy Corporation (HTEC) works across the clean hydrogen value chain, developing, integrating, and operating clean hydrogen energy solutions in strategic North American markets to enable the transportation sector's transition to a low carbon future.

HTEC was Responsible for the development, installation, and maintenance of the hydrogen fueling equipment and as well as the fuel for the ZECAP project. HTEC is focused on making zero-emission travel and transport possible, building the low-carbon future we want to live in and leave behind for future generations.

TraPac: TraPac operates a state-of-the-art container terminal at the busiest container port in North America – POLA. TraPac's involvement in the ZECAP project was to demonstrate the fuel trucks in live, and demanding, heavy duty operation. As part of their commitment to investing in sustainable technologies, the ZECAP project was an opportunity to learn more about fuel cell technology and support a hypothesis that H2 fuel cell hybrid trucks can be a viable, more sustainable option for use at their terminal. Through their participation, TraPac was able to gather further knowledge and experience with the H2 refueling and supply options, technologies and most importantly safety.

Frontier Energy: Frontier Energy is a consulting firm specializing in the development and management of programs to move new technical practices and technologies from R&D into practical commercial use. The firm's emphasis is on fostering energy efficiency and environmental gains in buildings, power supply, and vehicles. The firm has five offices in California. Truck performance and fueling station infrastructure data collection and analysis was handled by Frontier Energy.

Project Goals and Objectives

The ZECAP project team set out with the goal to validate the commercial viability of zero-emissions hybrid fuel cell-electric yard trucks operating in a demanding, real-world cargo-handling application at POLA. The project team was to develop and deploy two hybrid fuel cell–electric yard trucks at the port, operated by TraPac for 12 months. The propulsion technology supplied by BAE and Ballard was to be integrated into TJ9000 yard truck by Capacity of Texas. HTEC designed and manufactured an onsite hydrogen storage and dispensing equipment, and ZEN coordinated the fueler permitting and hydrogen supply. Frontier Energy coordinated training, outreach, data collection and reporting.

Diesel powertrains have been dominant in this application due to the demanding drive and duty cycles of these vehicles in addition to the requirement for 2 shifts of operation before a refueling event. In order to achieve the power and durability requirements, the project opted to use Ballard Power Systems FCveloCity®-HD85 85kW proton exchange membrane (PEM) fuel cell and Nickel-Manganese Cobalt (NMC) lithium-ion battery technology. The onboard vehicle energy storage consisted of 9.1Kg of hydrogen at 350-bar pressure in addition to 85kWh of battery capacity with plug-in charge capability for off-shift or service charging.

To achieve the targeted 12 months of field trials, Capacity leveraged their existing TJ9000 tractor platform design to integrate the fuel cell electric powertrain. Two demonstration units were built and placed into revenue service at TraPac's facilities within the POLA.

To enable quick and cost-effective refueling of the vehicles, the team commissioned an onsite dedicated stationary cascade fill refueling station designed by HTEC with 180 kg of H2 storage at 450-bar.

To educate the various stakeholders about the benefits of fuel cell propulsion, and to ensure that the project has a practical impact in terms of stimulating adoption of targeted technologies, the team planned to hold multiple events to present the project learnings and benefits.

Technology Design and Build

Major Component Descriptions

Based on the project members specific expertise, the following components / systems were selected to meet the objectives of this demonstration. These major components are outlined below.

Capacity TJ9000 Chassis-

A proven, preferred choice for operators of ports, rail yards, and truck terminals, the TJ9000 chassis has been a proven reliable platform for heavy duty use. In order to help reduce the shock loading on the sensitive chassis mounted components, the standard rear suspension was upgraded to Capacity's patented air spring suspension system Dura-Ride. The Dura-Ride system isolates the tractor, cab, and cargo from road shock during use.

Power Unit

Ballard Power Systems FCveloCity®-HD85 85kW proton exchange membrane fuel cell.

Figure 1 - Ballard Fuel Cell Unit

Although the rated output is 85kW, the output for this application was reduced to 50kW to maximize efficiency and reduce colling system needs. The HD85 Fuel cell stack lifetime is expected to exceed 30,000 hours.

Propulsion and Controls

BAE Systems HDS200 HybriDrive® powertrain capable of a peak propulsion power of 200kW (270 hp) and torque of 5200 Nm (3800 ft-lbs). The components included control system, power electronics and driver display. The powertrain and control system are capable of regenerative braking with driver-adjustable braking levels, enabling one-pedal driving (i.e. the truck operation is possible without using the brake pedal – lifting the foot off the accelerator pedal enables regenerative braking adequate for stopping the vehicle).

Energy Storage

Type 4 tanks supplied by Agility Fuel Solutions offer the latest in pressure-vessel technology, employing polymer liner with carbon-fiber composite overwrap. Type 4 tanks advantages include lighter weight due to polymer liner as opposed to the aluminum liner in type 3 tanks.

The batteries supplied by XALT were configured into 85kWh module, which was larger capacity than necessary, however required to achieve the target DC bus voltage of 650VDC, this was one of the design tradeoffs that resulted in increased vehicle weight and reduced real estate for other components.

Mostly due to packaging constraints, the total gross onboard energy storage for this application was approximately 388 kWh (85 kWh battery + 388 kWh H2[1])

Vehicle Design and Packaging

With the operational requirements in mind, the team went through a very difficult design and packaging process due to the complexity, quantity, and space requirements of the new components. Seven iterations of the design were produced, and the final design offered the best compromise between the packaging, commercial component availability, performance, ergonomics, and serviceability. In doing so, several modifications to the cab and the chassis were made, most notable was the modifications to the upgraded suspension in order to accommodate the new drivetrain components as well as dampen out vibrations to protect the more sensitive electronic and fuel cell related components now on the vehicle.

The fuel cell (FC) module was packaged in place of the traditional diesel powerplant while the Battery Thermal Management System (BTMS) and necessary vehicle cooling systems resided along the driver's side frame rail, as shown in Figure 2 below.

With the majority of the electrical and cooling components packed along the driver side frame rail, the passenger side of the frame remained open for the two H2 storage tanks to be mounted. The length and diameter of the tanks were limited by the wheelbase and vehicle width reducing the overall H2 storage from the desired 20 kg to 9.1kg. The space in between the frame rails, normally occupied by a traditional transmission was now filled with the 200kW traction motor as shown below in Figure 3.

1 Equivalent of 32kg of hydrogen with 33.3 kWh/kg energy content

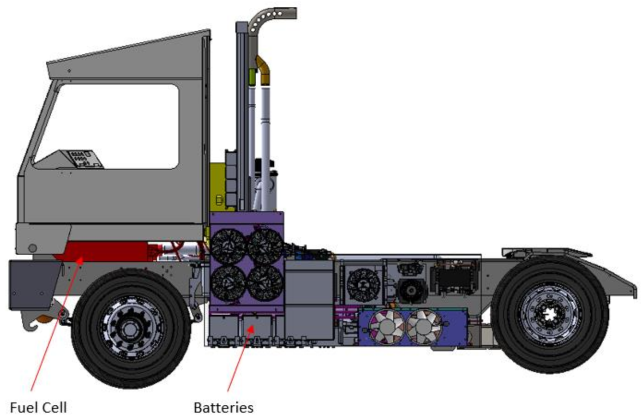

Figure 2 - Left view of final vehicle concept.

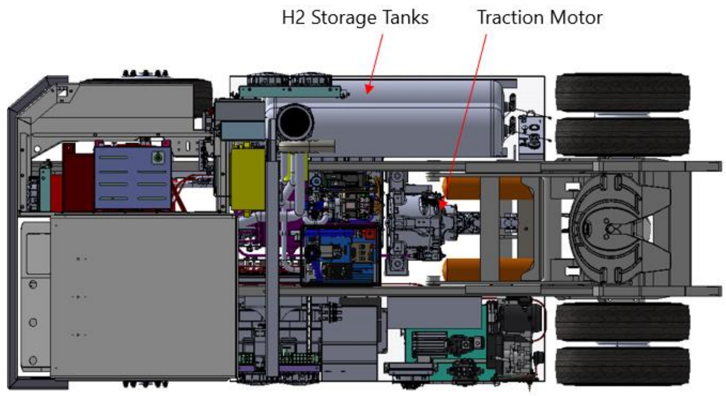

Figure 3 - Top view of final vehicle concept

To accommodate the traction motor, Capacity needed to make modifications to the current Dura-Ride suspension system, in particular, the size of the “A-frame” needed to be reduced. With this, the shear and bending stresses, in the A-frame pivot pin, were found to be higher with the redesigned (shortened) A-frame than with the original A-frame design. This shortened A-frame reduced the mechanical advantage of the A-frame pivot pin. The original A-Frame is shown below in figure 4.

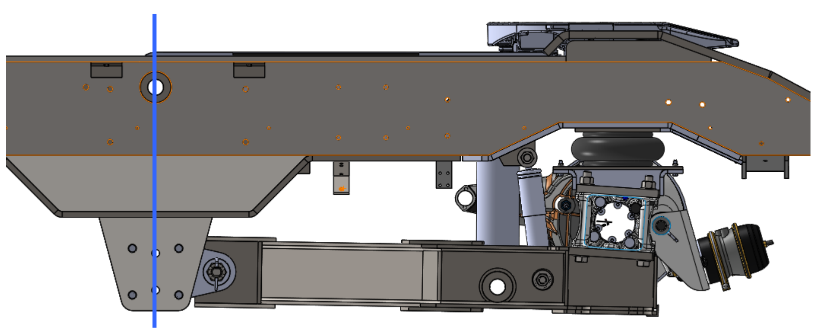

Figure 4 - original A-frame structure free body diagram

In the first iteration of the A-frame redesign, the bending stress, in the pin, exceeded the ultimate tensile strength of the material. Once the A-frame was lengthened and the lower boom cylinder pivot pin was moved closer to the axle, the bending stress on the pin was reduced to below the yield strength of the material. This final iteration is shown below.

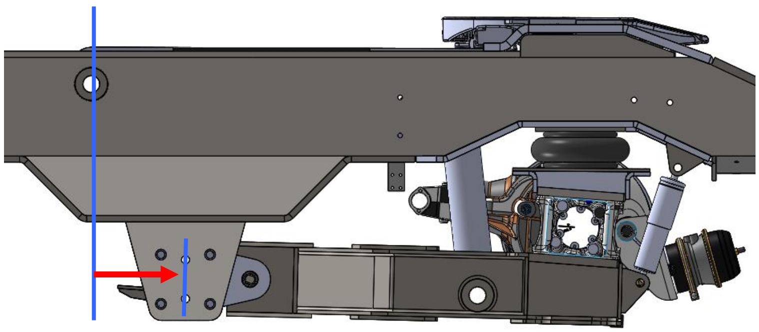

Figure 5 - second iteration of shortened A-frame structure

To further increase the safety factor, for the A-frame pivot pin, the lifting capacity of the boom lift cylinders will be reduced by 15% using 4 inch bore cylinders instead of the typical 5 inch bore cylinders. The reduced lifting capacity is still adequate for the expected loads where the truck will be operating. The reduced bore diameter also reduced the required flow rate of the electrically powered hydraulic pump. Reducing the required flow rate reduces the power required by the system and allows a smaller motor to be used in the hydraulic system.

Vehicle build

With the vehicle design completed, the project team kicked off the long lead components and scheduled the manufacturing of the rolling chassis (glider) which was completed in August of 2020.

Figure 6 - Base platform glider

Additional long lead time components began to arrive throughout the 4th quarter of 2020 allowing a steady flow for the build team to make continuous progress. The hydrogen tanks and batteries were received at the end of October and were installed on the vehicles prior to the custom-built Power Interface Modules (PIM's) and high-voltage cables supplied by BAE which allowed for the HV systems to be completed throughout the 2020 Holiday season.

Figure 7 - Vehicle energy storage systems (H2 tanks and Batteries) installed onto rolling chassis

Figure 8 - Rear view showing Traction Motor during vehicle build

Figure 9 - Rear view of in process vehicle build

With continued progress and the vehicle assembly near complete, BAE scheduled their initial onsite visit in the beginning of January 2021 to perform the integration and preliminary verification testing on the first vehicle. A second visit was planned for February 15, however, Capacity experienced an outbreak of COVID-19 at the end of January. The development progress was further hampered by a one-week facility shut down from a winter storm resulting in widespread power outages across Texas. Capacity and BAE teams met and collaborated virtually, including video walkthroughs and build reviews to keep the progress going. In March of 2021 BAE traveled onsite to Capacity to finish the first high-voltage terminations on the second vehicle and perform commissioning and testing of the first.

First driver impressions on this vehicle were very positive due to the low noise, vibration, and odor compared to the diesel powertrain.

Figure 10 - Front left and right Iso views during vehicle build with cab installed

Figure 11 - Rear view of completed vehicle

Commissioning vehicles

Following the startup of the first vehicle (unit 4067), the onboard storage was purged with nitrogen and filled with hydrogen from a mobile fueler leased for the duration of vehicle development in Texas. The fueler offered 60 kg of fuel onsite to support the commissioning process. Unit 4067 was fueled to 100% and the team performed a variety of tests to ensure component functionality, powertrain performance, and drive characteristics meet the market requirements.

Figure 12 - Initial fill of vehicle for commissioning tests

During the commissioning of 4067, the BAE/Capacity team began working in tandem on both vehicles to maximize the collaboration time. Capacity tested unit 4067 with a 45 ft (30,000 lbs.) trailer loaded with 3 x 15,000 lbs. tractors and concrete blocks as a ballast, bringing the total test weight close to 100,000 lbs. Gross Combined Vehicle Weight – (GCVW). The loaded trailer weight was ~80,000 lbs, which brought the total weight to ~100,000 lbs. Truck curb weight was

~20,000 lbs, approximately 5,000 lbs heavier than a ~15,000 lbs conventional diesel tractors due to the added battery weight.

Figure 13 - First loaded testing during vehicle commissioning

In April 2021, both vehicles were in operation and running series of tests at Capacity facility in Longview, TX. BAE and Capacity continued working on both trucks in parallel to expedite the progress. The 2nd truck (unit 4068) was undergoing commissioning of the subsystems, which was moving faster thanks to the experience with the first unit. In parrallell, Capacity was adding more instrumentation to 4067 to collect additional measurements necessary for the data collection requirements for the project. The truck was performing very well with the 80,000 lb trailer, and although the truck could not be road tested with the trailer on public roads due to axle weight limits, it has been tested with no load on public roads and performed well. Regenerative braking was optimally tuned allowing for driving the truck in “single pedal” mode. Loaded and unloaded endurance testing was conducted throughout the month of May.

Upon successful completion of the testing, and once the team gained enough confidence in the performance of the vehicles, unit 4067 was delivered to TraPac on July 1st of 2021 to await use. Unit 4068 was shipped directly to the ACT Expo in long beach to be put on display as well as a ride and drive event. After the event, it was delivered to TraPac and awaited completion of the permitting process.

Vehicle Specifications

Table 1 - Vehicle Specifications

Attribute	
Manufacturer	Capacity
Fuel Type	Hydrogen
Chassis/Cab	TJ9000 tractor platform
Propulsion System	650V, 200kW
Batteries	85 kWh, 650V, NMC
Axle	Conventional
Plug-in charging	Yes
Onboard charger	Yes
Battery-only range	5 hours*
Fuel Cell	85kWh Ballard, operating at 50kW
Onboard hydrogen storage	9.1 kg @ 5000 psi (350 bar)
Fill Time	10-15 min
Combined Range	16 Hours*

*Based on TraPac use / Duty cycle

Hydrogen Fueling

Design and Specifications

In order to support the demonstration of the vehicles, an onsite, user-friendly fueling solution was needed to maximize uptime and reduce any impact to TraPac's day-to-day operations. To meet this challenge, HTEC set out to create portable, custom PowerCube (PC) modules that could be delivered to the site for final Gas Transfer Module (GTM) assembly. The PC's were intended to be mounted onto the deck of the delivery truck, stacked two high side by side, and secured with twist locks where necessary. The maximum height and width of a PC were thus limited by the maximum dimensions allowed for the truck in accordance with transport regulations as shown below.

Table 2 - Maximum Power Cube Dimensions

Description	Distance (inches)
Max Truck Height	163.3″
Ground to truck deck height (including mounts)	57″
Height of twist locks	1.2″
Maximum allowable PC frame height	(163-57-1.2)/2 = 52.4″
Max Truck Width	102″
Min spacing between PC on truck deck	0.5″
Maximum PC frame width	(102-0.5)/2 = 50.75″

Working within these constraints, along with minimum tank-to-tank / frame clearance requirements, the team went through several packaging studies with various tank quantity and sizes to optimize the amount of H2 Storage capacity. Ultimately, a five-tank per PC configuration was selected giving a total storage of 45 Kg at 450 bar, while allowing four PC's to be loaded onto a single delivery truck as shown below.

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Figure 14 - Completed PC's awaiting delivery

Figure 15 - PC loaded onto delivery truck

Due to the budget limitations, temporary placement of the fueling station in addition to the attempt to simplify the siting and permitting process, a cascade fill mobile fueling system technology was selected whereby the higher-pressure hydrogen in the PC storage system is transferred to the lower pressure compressed hydrogen tanks in the fuel cell yard trucks without the use of a compressor or precooling. In order to sequentially fuel the two hydrogen fuel cell yard trucks daily with up to 9.1Kgs capacity each, the fueler consisted of four PC's for a total of 180 kg of Hydrogen at 450 bar.

The GTM was designed as a stand-alone unit that can be deployed on-site with no permanent infrastructure. This module provides the connection and dispensing ability to allow hydrogen to flow from the HTEC PC's through a dispenser nozzle into the hydrogen fuel tank on the fuel cell yard truck. For installation at TraPac, multiple considerations needed to be taken into account to satisfy all of the codes and permitting requirements. These considerations included proper selection of the installation site to meet setback distances within the facility.

The layout of the site must incorporate various requirements from the codes and standards related to hydrogen installations. The hydrogen specific codes provide specific setback requirements from hydrogen storage areas in order to reduce the risk of these installations/deployments.

Error! Reference source not found.3 provides the minimum setback requirements for h ydrogen equipment according to NPFA 2 Hydrogen Technologies Code (2020). The distances shown in this table are measured from the point of the hydrogen compressed gas system closest to the exposure. It was HTEC's responsibility to verify these values with the latest release edition of National Fire Protection Association (NFPA) 2. In the case of discrepancies, the code takes precedence.

Table 3 - Minimum Distance from Outdoor Bulk Hydrogen Compressed Gas Systems to Exposures - for 350-450 bar system (NFPA 2)

Pressure	**>3000 to ≤ 7500 psig**
Typical maximum pipe size	**ID=7.31mm**
Group 1 Exposures	
– Lot Lines – Air Intakes (HVAC, compressors, others) – Operable openings in buildings and structures – Ignition sources such as open flames and welding	13 ft (3962 mm)
Group 2 Exposures	
– Exposed persons other than those servicing the system – Parked cars	10 ft (3048 mm)
Group 3 Exposures	
– Buildings of non-combustible non-fire rated construction – Flammable gas storage systems above or below ground – Hazardous materials storage systems above or below ground – Heavy timber, coal, or other slow-burning combustible solids – Ordinary combustibles, including fast burning solids such as ordinary lumber, excelsior, paper, or combustible waste and vegetation other that found in maintained landscaped areas – Inoperable openings in buildings and structures – Encroachment by overhead utilities (horizontal distance from the vertical plane below nearest overhead electrical wire of building service) – Piping containing other hazardous materials – Flammable gas metering and regulating stations such as natural gas or propane	10 ft (3028 mm)13

Measurements based on typical maximum pipe size
Source: Excerpt from NFPA 2 2020 Table 7.3.2.3.1.1 (A)(a)

In addition to the NFPA 2 setbacks for bulk hydrogen storage, Section 5809 of the California Fire Code addresses "Mobile Gaseous Fueling of Hydrogen-Fueled Vehicles". This section addresses a vehicle mounted fueling solution which will likely be applicable if the GTM and/or PC's are mounted on a moveable flatbed trailer, and the setback requirements and location restriction information should be considered.

Table 4 - Mobile Hydrogen Fueling Area Limitations (California Fire Code)

Area Limitations	**Setback distance**
5809.4.1 Prohibited Locations	
– Public streets – Public walkways – Inside Buildings – Roof Level of parking structures or other buildings	mobile fueling shall not occur in these areas
5809.4.2 Separations. The point of connection between the roadside hydrogen service vehicle and the following:	
– Buildings – Property lines – Combustible Storage	15 ft (4572mm)

5809.4.3 Sources of Ignition	
– Smoking – Open flames – Other sources, including un-rated electrical equipment	25 ft (7620mm)

Source: Excerpt from Section 5809.4, 2019 California Fire Code, Title 24, Part 9

Based on this, three potential hydrogen fueling locations were identified on TraPac's site. See Figure 16 below. Advantages and limitations of each site were summarized and compared.

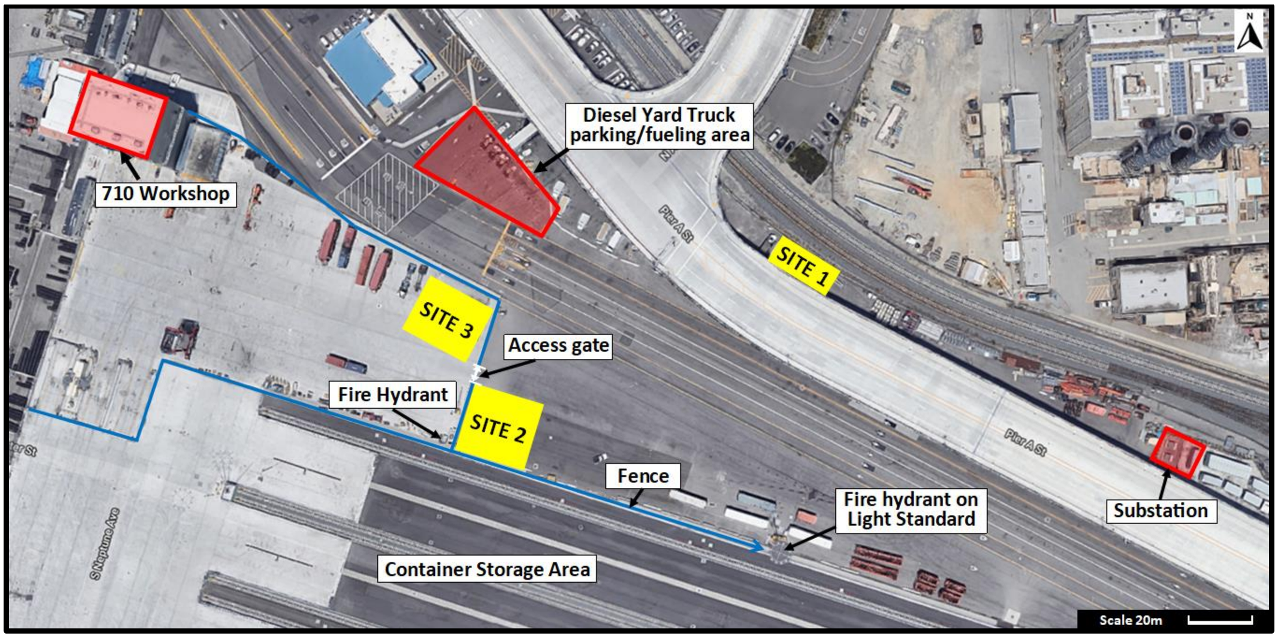

Figure 16 - Site Options for locating Hydrogen Fueling at TraPac's Site

Site 3 was chosen as the recommended site for locating the hydrogen fueling equipment. It had sufficient room for delivery trucks to maneuver, access to power and fire hydrants, no overhead restrictions and the added advantage over the other two sites of having a concrete surface which can be easily bolted into for securing equipment.

Figure 17 - Site 3 – Recommended Hydrogen Fueling Location at TraPac Site

Site 3 was currently being used for temporary storage but was cleared and made available for use during the project. The Site 3 area as shown in Figure 17 is approximately 58 feet deep, extending from the curbed containment area to the access gate opening. The width of the area is approximately 70 feet wide, extending from the east side fence to the end of the curbed containment area. The back of the Site 3 area was just over 15′ from the yellow line defining the edge of the six-lane road, meeting setback requirements from incompatible materials that may travel on this road. The closest fire hydrant is located across the site, approximately 85′ away. Power access is available from the nearby 710 Workshop and TraPac worked on hardwiring a portable light tower in the immediate vicinity of Site 3 which will provide the necessary lighting, near-by power access and a mounting location for a flame detector.

Permitting

Upon site selection the permitting process needed to be completed prior to installation. This process included multiple agencies including the POLA, Los Angeles Fire department (LAFD), and Los Angeles Department of Building and Safety (LADBS).

The POLA (Los Angeles Harbor Department (LAHD)) manages the land in the Harbor District on behalf of the City of Los Angeles and the State of California under the State Tidelands Trust. Any activity on Port property other than visiting areas open to the public requires permission from the LAHD. A project may require multiple permits, and these can all be applied for using the Application for Port Permit (APP). Projects are classified as either Development or Non-development and this classification defines the permit requirements. While the ZECAP fueling station was a temporary solution, it was necessary to drill into the concrete surface at the TraPac site to seismically secure the equipment as well as install a grounding rod for the equipment. The bolts were removed at the end of the project, and the grounding rods were sheared off level with the concrete, leaving the site with no permanent impact from the project. TraPac indicated that with the minimal amount of drilling required to secure the equipment to the existing concrete slab, the project should be classified as Non-Development.

Three permits were ultimately required from the LAHD, LABDS for the installation, and LAFD for operation of the fueler. As part of the permitting process, a complete set of site drawings and equipment plans were prepared, reviewed, and stamped by a California licensed Professional Engineer prior to submittal. Once completed, the permit package was submitted in March of 2021, which started multiple back and forth between Zen and the various departments throughout a 7 month period approving the installation of the fueler in October of 2022.

Fueler installation and partial commissioning was completed in the first week of November. The balance of commissioning tasks was delayed due to several unexpected issues including: component delays, incomplete site inspection by hydrogen supplier caused the delivery hose to be too short and delayed fuel delivery, incorrect k-rail layout, dispenser nozzle incompatibility with the vehicle receptacle, and modification required to the nitrogen control air system to provide a tap for hydrogen delivery tanker. AirLiquide delivered the hydrogen to site and filled the fueler to about 50% with the remainder to be delivered during final commissioning. HTEC ordered the correct dispenser nozzle and remedied the remaining issues in December allowing for the scheduling of the training and first fuel fill. On January 6, 2022, the LA Fire Marshall was onsite to witness the first full fill of the fueler along with the hands-on fueling training of the TraPac staff, signing off on the operation of the unit followed by the LADBS final building inspection on February 2 completing the roughly 11 month long process.

Figure 18 - Fueler installed at TraPac Facility

Figure 19 - Operator control panel

Figure 20 - First hydrogen delivery to the onsite fueler by AirLiqude. Delivery tractor visible on the right

Minimal GTM issues were reported throughout the program, issues that were reported were due to procedural errors that were easily resolved with additional training.

Technology Demonstration

Demonstration of the technology was planned to be carried out over a twelve-month timeframe at the TraPac terminal within the POLA where the hydrogen-powered Utility Tractor Rigs (UTRs) would be put into real world service. Due to delays caused by the factors outlined below, and compounded by an intermittent power steering pump issue, the trucks were operated in practice for about a six-month period. The main challenges encountered by the team were:

Supply Chain issues caused delays in the delivery of the H2 tanks and fueler components.

Delayed fueler assembly due to valve manufacturing defect

Outbreak of COVID19

Winter storm at Capacity causing production delays.

On-site vehicle testing, in addition to operator and maintenance training was conducted at TraPac on November 9 and 10, of 2021. Revenue service commenced on January 6, 2022 when the completion of the first fill. Initial impressions from the operators were favorable with positive comments on the low noise, vibration, and odor but reports of delayed power steering were reported after vehicle startup.

The team has collaborated with two telematics service suppliers who ultimately declined to adapt their systems to this prototype vehicle and to the unique SAE J1939 communications requirements. GTI Energy developed a custom data acquisition/telematics system, which was delayed due to cloud security concerns requiring additional enhancements to the software. Once the updates were completed, the data loggers were shipped to Capacity to run through a series of bench tests simulating an operational vehicle and eventually installed into the vehicles in early March of 2022. The vehicles were available for operation and reported in-use, although limited data was uploaded to the server for the entire month of March indicating an issue with the data logger connectivity to the server. Despite multiple attempts of remote troubleshooting, an onsite visit by GTI Energy was made in May of 2022. Manual review of the data loggers showed that 20 days' worth of data were recorded and stored onto the loggers, but the root cause of the server connectivity issue was unknown. The data loggers were removed from the vehicles and returned to GTI for additional diagnostics with no issues found. This led the team to again suspect the spotty cellular service at the port so the loggers were returned to TraPac for reinstallation requiring a series of onsite visits throughout the remainder of the project to download the data.

In June of 2022, the vehicles were taken out of service due to continued complaints about intermittent delayed power steering functionality. The power steering root cause analysis continued remotely until August when Capacity traveled onsite. During this visit, it was determined that one vehicle would need to be transported back to Capacity for more in-depth analysis. After two additional months of troubleshooting, it was found that a software update was needed from BAE to update the hydraulic pump controller. The software update was received in November and unit 4067 was delivered back to TraPac on November 14th. Unit 4068 was initially planned on being updated with the software onsite at TraPac but later found inoperable due to the extended period of nonuse and required shipment back to Capacity for repair. It was found that with the extended period of nonuse, the State of Charge (SOC) on the battery went below critical level and required specialized maintenance procedures. Upon successful repair, unit 4068 shipped back to Capacity, repaired, and returned to TraPac in January of 2023.

To help offset the delays, TraPac put priority on these trucks within the operators to maximize uptime while the vehicles were in service but was only met with marginal acceptance as the power steering complaints and new technology acted as a deterrent.

Data Collection and reporting

The project team had planned to collect several data streams throughout the program to properly analyze the vehicles performance against the baseline diesel UTR's. Vehicle data was to be recorded and automatically uploaded to a server for further analysis via an onboard vehicle mounted data logger. This proved to be difficult due to a multitude of issues hampering data acquisition, mostly due to cellular data transfer speeds limited by the datalogger firmware updates by the manufacturer, spotty signal coverage at the POLA, unreliable datalogging equipment and control system anomalies. With this, data retrieval was resorted to a manual download through a series of onsite visits to TraPac while the vehicles were in service.

Frontier Energy developed automated data analytics with a web dashboard, breaking down the data into daily usage metrics that included vehicle speed, fuel / energy used, and fuel filled in addition to other parameters used in the analysis. The system was developed with limited data collected during the initial testing of the units and revised throughout the project to account for inconsistencies found within the data files and addition of channels recorded to further enhance the accuracy of the information.

As shown in the figure below, the amount of telematics data collected is much smaller than the actual hours operated (over 180 operational hours vs the 85 recorded). Of the 85 hours recorded, approximately 14 of those hours provided the fuel cell output values that were used to estimate the fuel cell efficiency / overall energy consumption for the remaining hours.

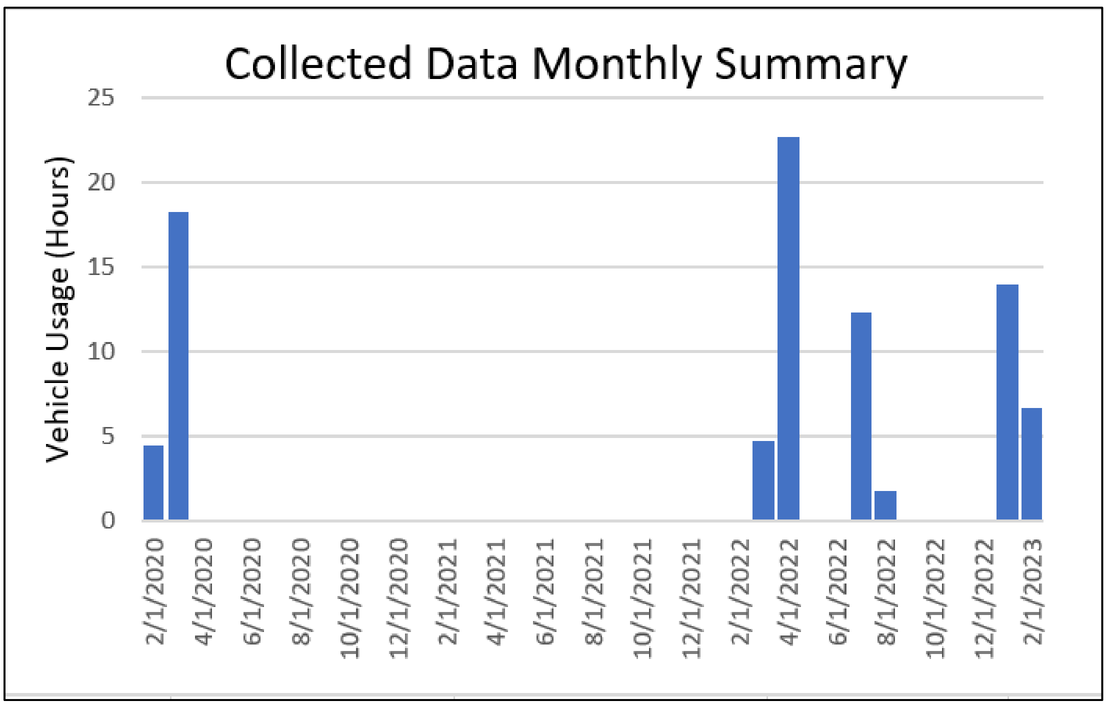

Figure 21 - Recorded hours of operation by month (not total operating hours)

Fueling data

Fueling data consisted of onboard tank pressure sensors and handwritten paper logs from the operators for the estimated fuel consumption in addition to the invoices from Air Liquide on the bulk amount being refilled into the fueler. The total fuel bulk fuel delivered to TraPac for the operation of the vehicles totaled 438 kg over 4 separate deliveries. It is unclear on the actual total vehicle fuel consumption though as the written logs during the refueling events proved to be unusable due to incomplete / inconsistent records. The onboard data loggers managed to capture approximately 59 kg's of usage.

Based on the limited log data and discussion with the gearman during a GTI onsite, time to refuel the vehicle ranged anywhere from ~10 minutes on a full GTM to 30 minutes once the pressure in the BTM decreased reducing the pressure differential to drive the fuel into the vehicles efficiently. This increased time was discussed onsite with the gear man as a disruption to the operations along with their concerns over having to refuel a potential entire vehicle fleet with a fueler requiring the vehicles to be coordinated and individually moved to the refueler. In the current operations, the diesel UTR's are refueled by what is commonly referred to as "Wet Hosing". Wet hosing is where a single tanker vehicle is pulled up to a number of parked vehicles and refueled by a single gearman that can move from truck to truck with an extended fueling hose. This eliminates the logistics of multiple vehicle moves required with a stationary fueler.

Figure 22 below shows the first six refueling events on unit 4067. From these events, the following observations can be made:

Decrease in peak fill pressure can be observed as the BTM pressure decreased, fueling event 1 to fueling event 6 had a decrease in maximum peak pressure of approximately 25%.

Short fills, fueling event number four in particular, can be observed. This type of event can be explained either by lack of following proper procedure to maximize driving pressure of the BTM or insufficient time given to equalize the tank pressure.

In either case, both of these conditions result in the same outcome, decreased operating time and increased fueling events leading to perception of shorter range when compared to baseline diesel units. Another observation was the continued data recording capturing fueling event #3, this indicates that the vehicle electronics were not properly shut down according to the developed fueling procedures highlighting the need for additional safeguards to be put in place for the future to enhance safety.

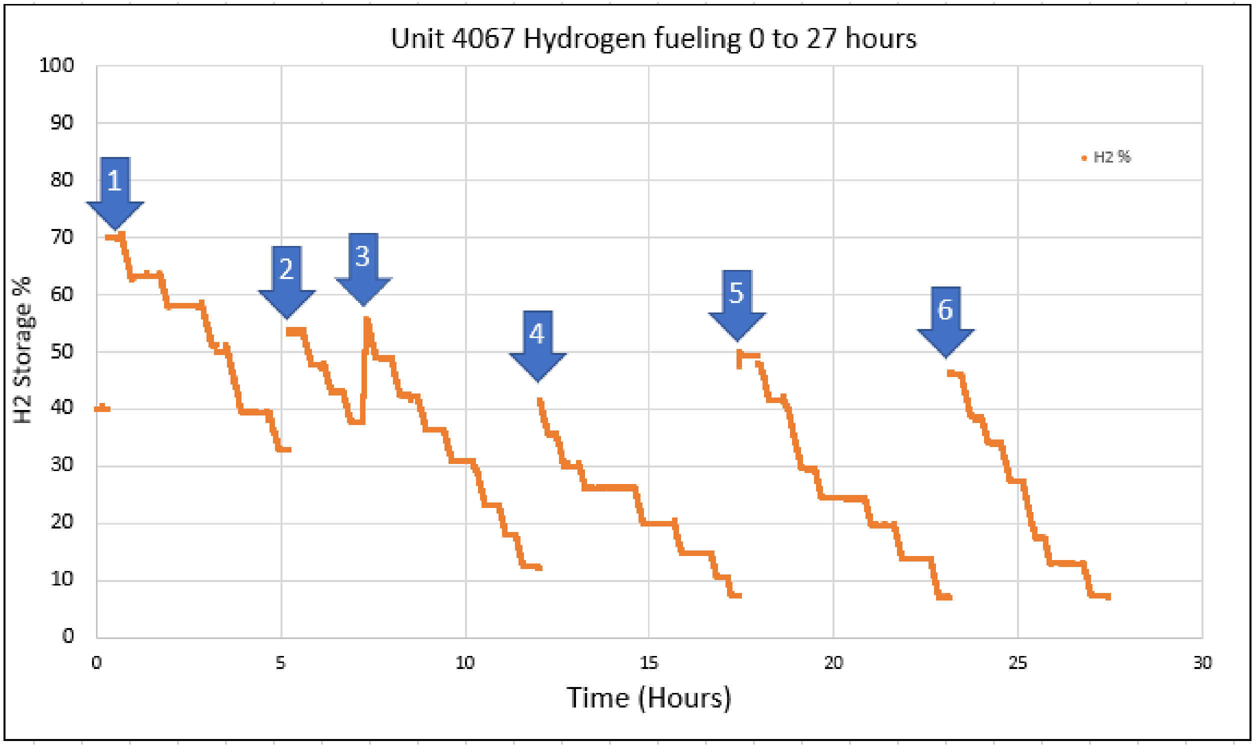

Figure 22 - Vehicle pressure sensor fueling data

Vehicle drive Cycles

Due to TraPac's high level of automated operations, the UTRs are tasked with a support role in the operations, such as moving the container chassis and yard housekeeping within the terminal which ultimately results in a large percentage (64%) of idle time lowering the average speed to approximately 6mph over the 1000 combined miles between the two UTR's.

Outreach and Education

Amid COVID19 challenges at the onset of the project, Frontier energy and the project team planned to host several activities to educate stakeholders about the benefits of Zero-Emission Vehicles (ZEV). The team planned to participate in other events as well to help raise awareness of the project and capabilities of ZEVs.

The planned and conducted activities are listed below:

Community Workshops

The outreach team has originally planned to work with the equipment operators and mechanics, as well as the community groups associated with the terminal workforce to learn about their concerns regarding the new technology. Based on the community comments the team planned to conduct targeted workshops and educations sessions to increase the awareness of the technology and its benefits to the community. Unfortunately, at first outbreak of COVID-19 and then protracted collective bargaining agreement negotiations prevented an open bilateral communication. Instead, the team has produced a video showcasing the project and the benefits to the port environment, which was disseminated in numerous forums, including internal communications to terminal workforce, conferences and webinars.

Safety and Training

Safety training and education conducted with union staff prior to start of operation. Dedicated safety sessions were conducted with drivers, gearmen, supervisors, as well as the first responders. Additionally, operating training sessions were conducted with the drivers and maintenance training sessions were conducted with the mechanics.

ACT Expo (August 2021) in Long Beach CA

The vehicle was exhibited at ACT Expo and was demonstrated in Ride and Drive event.

Figure 23 - Ride and Drive Event at ACT Expo 2021

Project Video shoot – March of 2022 – Frontier Energy

Due to COVID19 restrictions on live events the team agreed to create a promotional video showcasing the project and the technology. The video shoot was onsite at TraPac and the edited footage is available in the following link.

https://youtu.be/MRlyHPCiDrY

Figure 24 - Drone photography at the POLA. Notice the drone in upper left corner.

Figure 25 - Drone photography at the POLA. Note the drone in upper right corner.

ACT Expo (May 2022) in Long Beach CA - Vehicle exhibition - Capacity

ACT Expo is the nation's leading conference about clean trucks. The 2022 events set records for attendance with more than 3,000 attendees and 8,500 industry stakeholders registered for the event. More than 75 vehicles were on display at the 188 booths inside and outside the convention center. Capacity had a large booth with a fuel cell yard truck on display and a steady flow of visitors to the booth throughout the event.

Figure 26 - Fuel cell truck at ACT Expo 2022

Mobilize Summit conference (July 2022) in Temecula CA - Frontier Energy and GTI Energy

The Advanced Transportation and Logistics Sector of the California Community Colleges, in partnership with Workforce Training Associates, helped more than 250 people to collaborate on existing and emerging clean technologies, trends, and training tactics as part of the 2022 Mobilize California Summit.

At the Mobilize Summit event, Frontier Energy and GTI Energy staff worked an exhibit booth with a tabletop display showcasing the ZECAP drone video footage. The ZECAP project was also presented by GTI Energy during a breakout session focusing on transportation electrification at seaports. Goals of attending the event was to understand if fleet operators are considering implementing hydrogen fuel technology into their fleets. The full report for this can be found in appendix B.

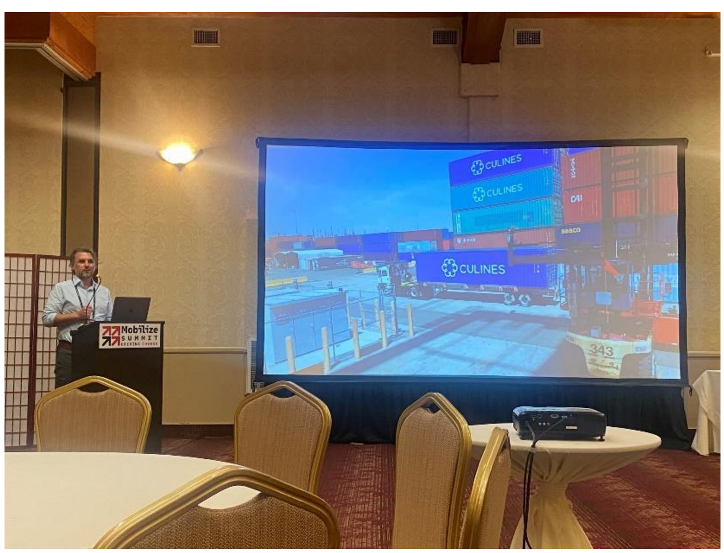

Figure 27 - ZECAP project showcased during Mobilize California Summit

Website launch

To highlight the project and provide background to the public, Frontier energy developed a project website that went live in October of 2022. This website has links to the project video developed as well as the Webinar hosted by GNA.

https://hydrogenyardtruck.com/

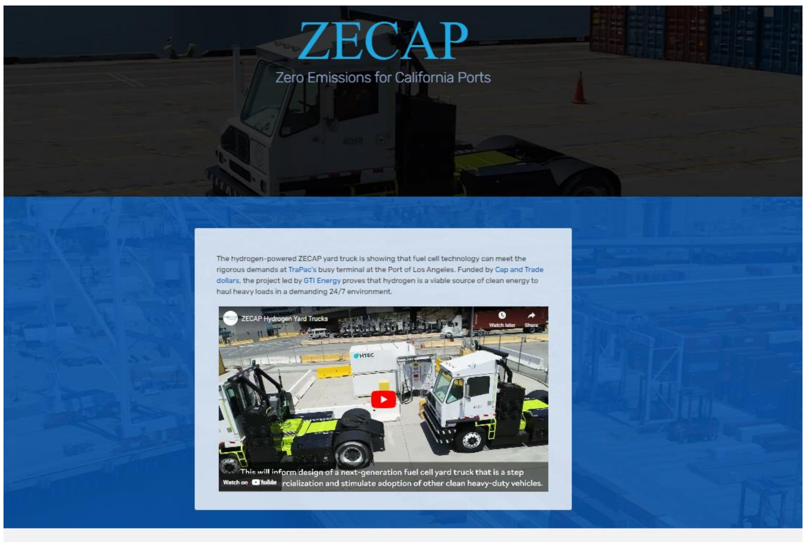

Figure 28 - ZECAP project website screenshot

CHBC Ports Luncheon USS Iowa Event (November 2022) in Long Beach CA – Ballard

The California Hydrogen Business Council's second annual invitation-only informational session on fuel cell port technology for port operators and stakeholders was held in November 2022. This year the event was held in the "war room" aboard the USS Iowa, permanently berthed as a museum at the Port of LA. Presentations were given by CHBC, Ballard, Trillium and Plug Power on fuel cell technology, fueling infrastructure and low carbon hydrogen fuel supply. The attendees represented mostly those responsible for the operations for terminal operators at the Ports of Long Beach and Los Angeles. Those in attendance were highly supportive of hydrogen as a ZEV solution for port equipment but wanted to see evidence of decreasing costs for fuel and vehicles. More than one terminal operator approached the suppliers in attendance about immediate need for vehicles and fuel.

Figure 29 - ZECAP truck at the boarding ramp for the USS Iowa, along with a placard showing project information

GNA webinar (December 2022)

SoCal Gas, TraPac, HTEC, Capacity, and GTI Energy project partners presented the project during a webinar organized by Gladstein, Neandross and Associates (GNA).

GNA webinar was conducted on a December 14th, over 300 people attended with overall positive feedback. Link to the event recording is provided below:

[Hydrogen Yard Trucks – Cap and Trade Dollars at Work]

Figure 30 - ZECAP webinar organized by GNA and Frontier

Fuel Cell and Hydrogen Energy Association (FCHEA) Seminar -GTI Energy presented ZECAP program

The Hydrogen & Fuel Cell Seminar is the most impactful and longest-running conference and exposition for the hydrogen sector in North America, providing insight and connections for almost fifty years. GTI Energy has presented the ZECAP project among the Hydrogen Deployment Case Studies. The event was sold out and featured hundreds of exhibitors and participants from all over the world. GTI Energy has received numerous positive feedback and questions about the project.

Figure 31 - ZECAP project highlighted during FCHEA Seminar 2023

Outreach conclusions

The outreach activities, although significantly disrupted by COVID-19, have been successful and generated great interest from stakeholders and audiences. Due to COVID-19 outbreak, followed by social distancing and limitations on in-person events, as well as the limited access to the terminal workforce, the team had to reassess the planned community workshops and outreach, and instead focused on showcasing the project and technology in public forums, such as conferences and webinars. Moreover, previous team experience has shown that direct outreach to the community, in relation to the technology research and demonstration projects, has rather limited efficacy. Communities are usually concerned with acute issues, such as safety, economy, noise, traffic congestion, and the conversations typically gravitate towards these topics. Air quality is a frequent concern, but is overshadowed by the above issues. Showcasing technology demonstrators does not immediately address the concerns, but rather highlights the pathway to a future improvement of air quality. These forward-looking statements or projections offer little comfort to the community. The team has found value in educating the community members about the differences between battery-electric vehicles and hydrogen fuel cell vehicles, as well as dispelling any preconceived notions about hydrogen safety. A suggested approach for future projects is to organize such educational sessions with community college students, which are not only more receptive to the new technologies, but they also disseminate their newfound knowledge with peers and family members. Another promising target audience are mechanics and technicians working at municipal and transit fleets, or enrolled in continuing education programs at community colleges. These groups were suggested by attendees of Mobilize California conference – fleet managers and community college educators.

Commercialization study

Figure 32 - Capacity Trucks terminal tractor at Port of Los Angeles

Terminal Tractor Market Assessment

Typical Applications and Customers

Terminal tractors have a compact wheelbase that allows them to make tight turns in crowded spaces, making them more maneuverable than other cab tractors and allow the operator to put in less effort in a normal drop and hook operation. Terminal tractors are used for moving semi-trailers across the grounds of distribution centers, warehouses, receiving facilities, intermodal depots, or ports.

Orange EV, a company that builds, sells, and services industrial vehicles manufactures 100 percent electric Class 8 vehicles from California to New York. The customers have included warehouse and distribution centers, manufacturing centers, construction sites, waste management and recycling facilities, rail intermodal yards, LTL (less than truckload freight shipping) freight terminals, and port operations. These demonstrate success in multiple cases of deployed fleets that operate in rigorous duty cycles and varying weather conditions.

Market Size

Due to the Chapter 13 Commercial Vehicle[6] definition of which terminal tractors lie under, terminal tractors cannot be titled, registered, or operated on public roadways in California. Terminal tractors are categorized as off-highway vehicles along with multiple other vehicles and cannot be traced back directly to the term terminal tractors per Chapter 13 in California. This information makes it difficult to predict an exact market growth for yard trucks, but there is some information out there.

According to Industry Growth Insights, the market for yard trucks is globally expected to grow at a compound annual growth rate of 5.5% in the period of 2018 to 2030. The growth is to be attributed to increasing demand for electric trucks, rising adoption of warehouse automation, and growing intermodal transportation. The diesel-powered yard truck market is expected to dominate the overall yard truck market during the forecasted period of 2018 to 2030, owing to its low cost and high efficiency as compared to electric-powered yard trucks. However, as there is an increase for environmental awareness as well as regulations on emissions, electric-powered yard trucks are expected to have higher growth rates over this period. Warehouses account for a majority share of the global market size for yard trucks, with an increase in demand for yard trucks coming from the automotive and manufacturing industries due to the growth of these sectors. The increasing use of yard trucks in warehouses and distribution centers for material handling purposes. Growing demand for electric yard trucks from municipalities and other government organizations due to environmental concerns over emissions from diesel-powered vehicles. There is also an increasing popularity of yard trucks as a replacement for forklifts in many material handling applications. [7]

Current annual hydrogen production in the U.S. is about 10 million metric tons, but recent research suggests a hydrogen demand potential of about 166 million metric tons by year 2050. The significant expansion of existing production, storage and distribution infrastructure will be necessary to meet future hydrogen demand for widescale fuel cell equipment use, including port users. None of the fuel cell equipment provided capital payback potential in 2020 due to their high

[6] Chapter 13: Commercial Vehicles - California DMV

[7] https://industrygrowthinsights.com/report/yard-trucks-market/

incremental capital costs and low operational savings. However, in 2030, reasonable capital payback values were derived for fuel cell equipment types, except for switcher locomotives and ferryboat applications. In 2045, very favorable paybacks were derived for all fuel cell equipment analyzed except for switchers and ferryboats which still must overcome high incremental capital costs. However, based on recent developments the future costs may be reduced such that a favorable payback could come within the tine periods projected. These results suggest that port fuel cell equipment economic benefits will increase in the long-term as equipment capital costs decrease and the hydrogen fuel market matures.

The rise in fuel prices contributes to the demand for electric terminal tractors. Traits like zero emissions and relatively less energy consumption have made them a viable choice among various end users.[8]

Cost Analysis

As illustrated in the tables below, the cost of hydrogen fuel cells with the capital investment costs and operating costs is more than the diesel prices, with capital costs for diesel in the year 2020 being $110,000 as compared to the capital costs for hydrogen fuel cells being $225,000. However, it is estimated that over time the difference in these initial capital costs between diesel and hydrogen fuel cells will decrease. By the year 2045, it is estimated that the capital cost of hydrogen fuel cells will only be $9,089 more than the initial capital cost of diesel, and the annual operating cost for hydrogen fuel cells will be $13,201 cheaper than for diesel, meaning that in the first year of operation after 2045 the hydrogen fuel cells are estimated to be cheaper to invest in and maintain than diesel.[9] This data is taken from an EPA report: Assessment of Fuel Cell Technologies and the costs may become outdated over time, but are representative of cost comparison factors.

Table 5 - Estimated Cost Comparison of Diesel and Fuel Cell Yard Tractors

Diesel Yard Tractor Cost Elements		Fuel Cell Yard Tractor Cost Elements	
Assume 12-yr Lifetime		Assume 12-yr Lifetime	
Calendar Year 2022			
Diesel Fuel Price ($/gal)	$3.33	Hydrogen Fuel Price ($/kg)	$13.00
Total Capital Investment	$110,000	Total Capital Investment	$225,000
Total Annual Operating Costs	$22,981	Total Annual Operating Costs	$38,464
Annual Yard Tractor Fueling Cost	$19,181	Annual Yard Tractor Fueling Cost	$32,966
Annual Yard Tractor Maintenance Cost	$3,800	Annual Yard Tractor Maintenance Cost	$5,498
Calendar Year 2030			
Diesel Fuel Price ($/gal)	$3.76	Hydrogen Fuel Price ($/kg)	$5.00
Total Capital Investment	$134,089	Total Capital Investment	$182,074
Total Annual Operating Costs	$26,314	Total Annual Operating Costs	$17,799
Annual Yard Tractor Fueling Cost	$21,681	Annual Yard Tractor Fueling Cost	$12,679
Annual Yard Tractor Maintenance Cost	$4,632	Annual Yard Tractor Maintenance Cost	$5,120

[8] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1015AQX.pdf

[9] Assessment of Fuel Cell Technologies at Ports – Report (EPA-420-R-22-013, July 2022)

Table 6 - Summary of Fuel Cell Yard Tractor Capital and Operating Cost Results

Parameter	Yard Tractor	
	Diesel	**Fuel Cell**
Lifetime	12	
Year 2020		
Capital Cost ($)	110,000	225,000
Operating Costs ($)	22,981	38,464
Payback (Yr)	None	
Year 2030		
Capital Cost ($)	134,089	182,704
Operating Costs ($)	26,314	17,799
Payback (Yr)	5.7	
Year 2045		
Capital Cost ($)	180,467	189,556
Operating Costs ($)	29,577	16,376
Payback (Yr)	0.7	
*Operating Cost includes annual maintenance costs and fuel costs		

Analysis of Interviews and Focus Groups

Figure 33 - Map of Focus Group Locations

Focus Groups were done in Colorado, Utah, Texas, California, Oregon, Minnesota, North Carolina, and New York in order to gain perspectives about benefits and barriers to ZEVs and ZEV adoption. The focus groups were each consisting of 5-10 people per group, held over a video conference, and audiences were varied, but mostly consisted of local government representatives, especially coming from a fleet background.

Across the focus groups, over half the interviewees were not very informed on vehicle electrification or what the process towards electrification looks like. The ones that were informed on vehicle electrification discussed many barriers towards electrification, mostly stating cost. For government agencies, the budget to transition to ZEVs could not be justified when spending taxpayers' money. There were also issues of reliability, where the agencies that already had ZEVs had run into service issues that put their vehicles out of commission for weeks at a time, which is a huge loss of money no matter what agency type.

Based on the knowledge of ZEVs and what is needed for ZEV adoption based on these focus groups, another large barrier here is education on the matter. Education to drivers, technicians, operators, and fleet owners need to be a priority in order to make a successful introduction to and adoption of ZEV technology. When these individuals are educated on the matter, there is increased awareness of the safety associated with ZEVs, the fueling process and vehicle operation, therefore allowing better acceptance and willingness to adopt.

In order to reduce the costs associated with ZEVs, most participants agreed that having the infrastructure onsite would be beneficial, as long as the buildings could support the infrastructure and there would be enough initial funding to be able to transition to infrastructure that supports ZEVs.

Major Findings

As the e-commerce industry is growing, the typical customers are looking for alternatives to the movement of goods in an efficient and safe manner, increasing their need for more terminal tractors, as well as looking towards safer, cleaner, and more efficient alternatives. Hydrogen fuel cell terminal tractors have quick refilling times of an average of 10 minutes, are quiet in operation, have a reduced maintenance cost, and have zero tailpipe emissions, and as they become readily available to customers become a great choice for efficiency of moving the material goods, as well as safety of the operators.

With continued awareness of and regulations on environmental issues, there will be larger adoption rates of zero- and near-zero emission yard trucks. By 2045, it is estimated that hydrogen fuel cells will be a cheaper investment and maintenance operation to run, making hydrogen more economically and environmentally attractive.

Design Discussion

Drivetrain

A single, 200kW (270 hp) electric motor was paired to a conventional heavy duty Meritor RS24-160 7.17:1 ratio rear axle. This combination of hardware proved to be reliable throughout the demonstration period as no downtime or maintenance of the system was needed. Future improvements would be to combine the two and simplify to an e-axle configuration but due to the high gear ratio of these vehicles, there was not an e-axle configuration available at that time.

E-axles provide multiple benefits to EV and hybrid fuel cell-electric vehicles which may assist with widespread industry adoption. Benefits include higher efficiency in power transfer by elimination of conventional gearboxes, integrated power electronics and controls offering reduced complexity and packaging space requirements, improved Noise Vibration and Harshness (NVH), and improved reliability over conventional powertrains.

Energy Storage

Energy storage selected for the project was a combination of lithium-ion batteries and Type IV composite hydrogen tanks. With a goal of storing enough energy to operate the vehicle for 2 shifts without the need for fueling or charging, the design team has gone over several iterations of hardware configurations and layouts. The most notable challenges and constraints were:

- Availability and lead times of hydrogen tanks that fit the available real estate on the vehicle. The resultant 9.1kg onboard hydrogen storage is not adequate to support 2-shift operation in charge-sustaining mode (keeping the battery fully charged). However, the 85kWh battery has enough energy to keep the vehicle going throughout the remainder of 2^{nd} shift after the hydrogen tank has been depleted. In simplified terms, the 9.1kg of hydrogen is equivalent to 303kWh of energy. With anticipated 55% fuel cell efficiency, the hydrogen would offer 166kWh of energy delivered to the powertrain. The above estimate is a crude approximation, however it demonstrates the amount of energy produced from the onboard hydrogen.

- Availability and lead times of battery packs that could be stringed together to offer a nominal 650VDC bus voltage and discharge current required by the powertrain. The final design utilized more battery capacity (85kWh) than originally intended, which offset the limited hydrogen tank capacity. In practice, the data collected suggested that the vehicles have rarely been operated for two consecutive shifts and was mostly operating in charge-sustaining mode.

Battery Charging

Charging interface provided with the vehicle is a Level2 Combined Charging System (CCS) connector, and is intended only as a service/maintenance feature. The truck operators had no intention of using charging between shifts and there were no chargers or power supplied to the parking area of the trucks.

Cooling System

Cooling system, although a packaging challenge due to limited real estate on the truck, performed without issues in various climatic conditions, in Texas and in Long Beach. Fuel cells can be a challenge to cool due to relatively low operating temperatures (when compared to combustion engines) and narrow temperature operating window, which typically requires large heat exchangers. Thanks to the robust engineering and vehicle packaging, the radiators installed on the vehicle performed without issues.

Electric Accessories

Since the vehicle utilized conventional hydraulic power steering, hydraulic 5th wheel boom and air brakes, electrified hydraulic pump and air compressor were supplied with the vehicle. The hydraulic pump and associated has proved to be somewhat problematic with the operators, who had a difficulty adjusting to a different power steering response, or “feel”. Additionally, the hydraulic pump control system included features that were turning the pump off after extended idle times to conserve energy. The operators were reporting the time required for pump re-start to be excessive, which caused a perceived delay in availability of power steering. Capacity engineering team has reprogrammed the hydraulic pump twice, but the drivers have continued to be apprehensive about the power steering functionality. The team took that as feedback to be incorporated into future designs, but it may also require driver training and managing the expectations, as it is common with all new technologies.

Operator Interface

The operator interface was intended to look familiar to the diesel yard tractor and included typical controls found in Capacity trucks. The key differences were a display displaying the status of electric powertrain and a regenerative braking dial offering adjustment of the amount of energy being recovered during braking. At the maximum setting of “high” the vehicle could be operated in “one pedal” driving mode.

Performance, Efficiency Discussion

After the 2022 ACT Expo and unit 4068 was shipped to TraPac to begin service, both vehicles combined usage based on the vehicle odometers for the project totaled approximately 1086 miles over 179 hours of operation. 85 hours of that usage was recorded by the onboard vehicle data recorders giving insight into the drive cycles and overall performance. Upon review of this data, the average speed for this application was approximately 6 mph with 64% of the operating time spent at idle due. With a large percentage of the operation at idle, the data was reviewed further and determined that over 60% of the overall energy usage was consumed during this time. This led the team to determine that there were significant opportunities for future gen products to improve on this as accessory component (electric air compressor, hydraulic pump, air conditioner compressors, etc.) technologies evolved lower energy consumption.

To determine the operating range of the vehicles, the average H2 consumption was calculated and found to be on average 0.71 Kg/hr. At this rate, 2 full shifts (~16 hours) of usage is possible with a fully charged battery at start of shift and roughly one and a half shifts (~11.75 hours) of usage with a depleted battery at the start of shift. These estimates are based on TraPac's unique drive cycle consisting of the high idle time and average forward speed of 16 mph of mostly lightly loaded operation. Load was not recorded nor could it be inferred from the available data leaving the TraPac duty cycle description to be based on observation only.

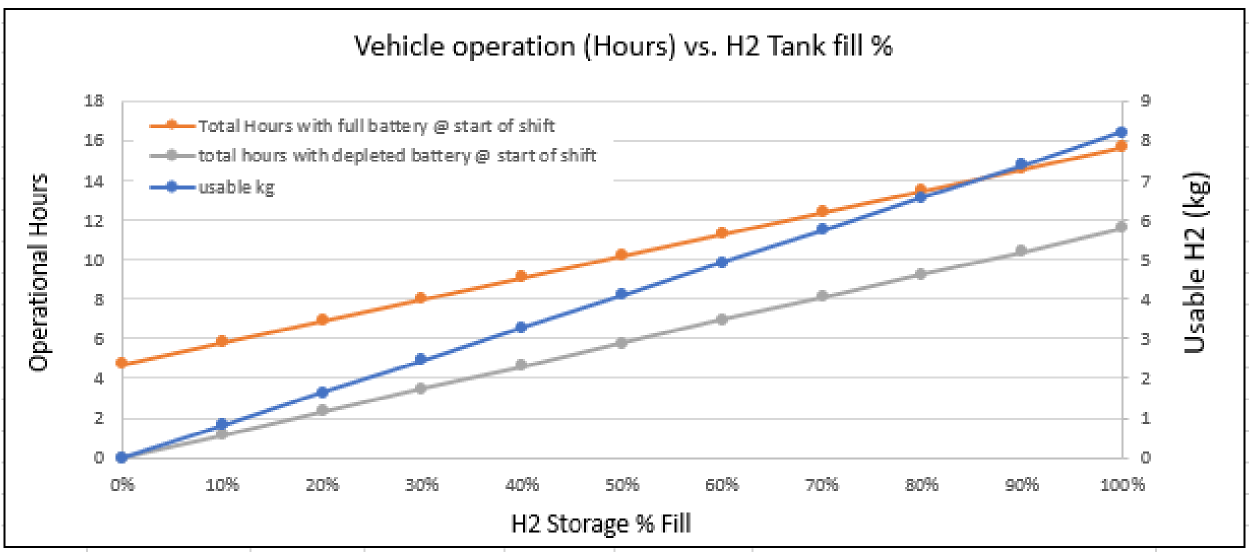

Figure 34 - % H2 Tank fill vs Vehicle operation for full and depleted battery

Comparison to Diesel

When comparing the Hydrogen fuel yard truck to the conventional diesel, we will rely on the operator comments as well as the average diesel usage received from TraPac as no diesel baseline data was available for comparison. According to TraPac, the diesel UTR's consume on average 1.75 gallons of fuel per hour for the same duty cycle that the Hydrogen trucks were subjected to. With one gallon of diesel equivalent to 40.7 kWh of energy, the Trapac duty cycle total gross energy consumption per hour of the diesel UTR comes to 71.2 kWh's. For the H2 vehicle, the average consumption rate over the ~85 hours of operation recorded was approximately .71 kg/hr. With 1kg of H2 equivalent to 33.3 kWh of energy, this put the gross energy consumption per hour of the H2 UTR at 23.64 kWh or a potential 67% improvement over the baseline unit.

Reliability Discussion

Overall, when the vehicles were in service, they performed well. There were no technology drive hardware related failures with the exception of the plaguing power steering issues that ultimately wound up to be a shut off timer for the hydraulic pumps to conserve energy at idle that needed to be increased. Regular maintenance items, such as topping of the Fuel cells deionized water for the cooling system and weekly inspections largely populated the reports.

During the power steering pump root cause analysis downtime, it was found that if the vehicles sit for an extended amount of time (more than a few weeks) without being used, extensive service may be required to bring them back online. This was mostly due to the HV system reaching critical thresholds requiring coordinated recharging and battery maintenance.

Infrastructure and fueling

Feedback from TraPac- fueling needs to be comparable to the diesel fleet, mobile fueling truck with 1-3 minute re-fueling time. Current baseline is 30 vehicles in a ~65 minutes. Having a static fueling station requires vehicle movement between each fueling. Mobile unit with hose allows operator to move vehicle to vehicle very efficiently. Learning curve on the vehicle start procedure.

Onsite fueling station was designed with the consideration of limited funding available, the future decommissioning / removal of the station and limited electrical power at the location. As a result, the team deployed a cascade-fill system with gas transfer module that required manual operation of cascading (switching between the pressure banks during the fill, from the lowest to the highest pressure).

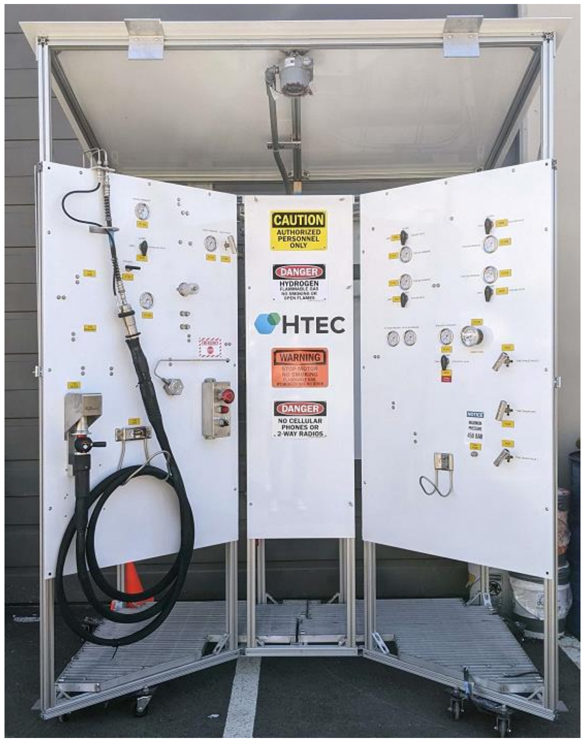

Figure 35 - HTEC GTM Control panel

This has proven to be too complex for the personnel refueling the vehicles, and despite several training session, the vehicles were filled using incorrect procedures where all banks were open at the same time. As a result, the fill duration was increased and the usable hydrogen capacity was reduced from the design assumptions. With the station storage at full capacity the vehicles would fill within ~10 minutes (reported, as the operating logs were inconclusive), however as the storage was partially depleted and the pressure in the storage was lower, the hydrogen flow would slow down, and the operators aborted the fill before completion – resulting with partial vehicle fills.

This solution, although the most cost effective, proved to be somewhat impractical in commercial setting due to complexity. One alternative solution would be a permanent fueling station, similar to stations serving light duty vehicles or transit fleets. Unfortunately, these solutions are cost prohibitive for 2-vheicle operation, as they can cost in excess of $10,000,000. An alternative solution would be a mobile/temporary fueler with automated cascading operation, simplifying the process for the operators. Such fuelers are commercially available and frequently employed by early adopters with few hydrogen vehicles in operation.

Recent technology developments offer promising solutions, such as mobile fuelers utilizing liquified (cryogenic) hydrogen storage onboard and submerged cryogenic pumps, significantly reducing the equipment cost, complexity and power requirements (no need for gas compression or cooling). These solutions are in development / early demonstration stages and are expected to be commercially available in the next 3 years.

Finally, a consideration should be given to the hydrogen use and onsite storage capacity. Onsite storage of gaseous hydrogen, although simpler, is more expensive. Large amounts of onsite gaseous storage (1000s of kgs) are impractical due to the footprint and cost of the pressure vessels. For this project a 180kg of onsite storage was adequate, as it offered approximately 7 days of fuel supply for the two trucks, meaning it required a delivery of hydrogen to the site once a week. This would be impractical for 5 or more trucks, as frequent fuel deliveries would increase cost significantly. An alternative solution found at sites with larger demand (i.e. 200kg/day and more) is liquified hydrogen storage, which offers 1000s of kgs of hydrogen in a comparable footprint. This solution comes with its own drawbacks, such as high cost and complexity, high power requirements for compression and cooling of hydrogen for fast fills, and requires continuous use to avoid hydrogen boil-off (warming up of liquid hydrogen when sitting unused in the cryogenic tank).

Lessons Learned

The project team has learned numerous lessons that will inform future decisions for technology development, commercialization and deployment of fuel cell yard tractors.

Technical:

Capacity team has learned the process of designing and integrating a hybrid fuel cell vehicle, including aspects such as powertrain component selection and packaging, high voltage system design, fuel cell and hydrogen storage integration, and more. Key lessons learned have been implement in 2nd generation of designs, which will be commercially available from Capacity in Q3 2023. The new design will incorporate improved features, including more energy storage, smaller fuel cell and improved driver experience (including power steering operation improvements).

TraPac and HTEC have gained valuable experience with siting, permitting and commissioning a hydrogen fueling infrastructure, working with the Authorities Having Jurisdiction and first responders. TraPac has learned the procedures for handling hydrogen onsite, coordinating hydrogen deliveries with the operating schedules, and operating / maintaining hydrogen-powered vehicles. TraPac also learned that the fueling solution and fueling process must be robust and simple enough to be performed by revolving workforce. The workforce requires frequent, repeat training, to keep the new skillsets fresh and to develop intuition for best practices (such as de-energizing the vehicle during fueling).

GTI Energy and Frontier's data collection team have learned that prototype vehicles with novel electric powertrains do not yield well to commercial off the shelf data acquisition solutions. Although the protocols and interfaces are similar to conventional diesel vehicles, they are not standardized and may change frequently due to the prototype development/improvement cycles. As such, the data acquisition systems must be flexible enough to be capable of remote reprogramming, troubleshooting, failsafe operation, and offer adequate onboard storage to prevent data loss in instances of interrupted wireless connectivity. Finally, the quality of data coming from the prototype vehicles in intermittent operation (as frequently found in technology pilots and demonstrations) can be statistically insignificant and inconclusive. This requires longer data collection periods to gain the statistical significance, or a disciplined test plan, which may be difficult to execute in commercial operation.

Conclusions and future recommendations

- The project is considered very successful as it has **demonstrated the feasibility** of hydrogen fuel terminal tractors in port environment.
- The vehicles will be moved back to Capacity in Texas, and deployed to demonstrations at other prospective Capacity customers, such as **distribution centers, manufacturing facilities** and port terminals
- Lessons learned informed future designs of the vehicle, and the vehicle manufacturer is planning **commercial availability of 2nd generation vehicles** in Q3 2023.
- Despite numerous technical tradeoffs the vehicles demonstrated the capability of **operating for 2 consecutive shifts** without fueling.
- The feedback from operators was very positive, even considering the power steering performance concerns. The drivers liked the **instant torque, responsive acceleration, quiet and vibration-free** working environment, and effective regenerative braking.
- Aspects of deployment, such as permitting and siting the fueling station or interacting with the authorities having jurisdiction has provided a valuable perspective on the logistics, **complexity and lead times** of securing a fueling solution for future implementations. The fueling solution choice informed future plans for fleet size, fueling type choice and overall decision making in adoption of new technologies.
- Workforce **needs to be continuously educated** on the safety aspects of hydrogen vehicles, both to increase safety and to dispel misconceptions and apprehension. If the vehicles are accepted by the workforce, they will be the best advocates of the technology to their peers and community.
- Fueling infrastructure **needs technology development and investment**. It was learned from other alternative fuels, such as compressed natural gas, that inadequate

infrastructure can undermine a very effective vehicle technology. While the fueling stations can be built onsite to support specific fleets, the cost can be prohibitive and needs incentives

- Fuel cell terminal tractors, if adopted at broader scale, can **enable economy of scale and hydrogen adoption** in other difficult to decarbonize cargo-handling applications, such as top handlers, rubber-tired gantry cranes, automated straddle carriers, and more. These applications, difficult to decarbonize due to demanding duty cycles, can benefit from hydrogen fuel cell powertrains and quick refueling. Increased hydrogen consumption will stimulate the economy of scale and reductions of both equipment and hydrogen cost.
- More **demonstrations and incentives are required**, especially for zero emission cargo handling equipment development. Cargo handling equipment is typically designed and produced by smaller specialty manufacturers without financial strength to fund design and development of complex technology that does not have an established market demand and clear business case.

Appendix A

GNA Webinar

Appendix A - GNA Webinar

Milestone 3.04 (Community Workshop as an Open House-style Event)

GNA webinar was conducted on a December 14th, over 300 people attended with overall positive feedback. Each presenter introduced their company and presented their input into the ZECAP project. Presenters of the webinar are detailed below

- Mark Jensen – TraPac
- Mary Fry – HTEC
- Jeff Chase – SoCal Gas
- Jerry Looney – Capacity
- Bart Sowa – GTI Energy

A copy of the webinar has been posted on the project website:

[Hydrogen Yard Trucks – Cap and Trade Dollars at Work]()

Figure 36 - GNA Webinar screenshot

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Appendix B

Temecula Report

Appendix B -Temecula Report

Temecula Outreach report

Community Outreach for ZECAP Project

Figure 37 - GTI Energy and Frontier representation at summit

Outreach at Mobilize Summit

South Coast Winery Resort & Spa

July 21-23, 2022

Submitted by Ben Xiong – Frontier Energy

About Mobilize Summit

The Advanced Transportation and Logistics Sector of the California Community Colleges, in partnership with Workforce Training Associates, helped more than 250 people to collaborate on existing and emerging clean technologies, trends, and training tactics as part of the 2022 Mobilize California Summit.

Dozens of information-packed sessions took place over the 3-day event this summer in Temecula, California, all centered around ways attendees could train a skilled workforce ready to tackle the advanced technologies already permeating many industries.

Mobilize Summit participants were able to learn advanced vehicle safety technologies, practical electrical diagnostic skills, electric school bus high voltage safety, how to calibrate ADAS components, and more. Plenary sessions explored the intersection of transportation, innovation, and entrepreneurship as well as People of Color in green spaces.

Over 250 people from over 150 different organizations attended the 3-day event. A full list of attendees with organization and title can be found in appendix A.

Figure 38 - Picture of Attendees at the beginning of event

At the Mobilize Summit event, Frontier Energy and GTI Energy staff worked an exhibit booth with a tabletop display showcasing the ZECAP drone video footage and had a giveway. The ZECAP project was also presented by GTI Energy during a breakout session focusing on transportation electrification at seaports. Goals of attending the event was to understand if fleet operators are considering implementing hydrogen fuel technology into their fleets. This report is a summary of the interactions at the event through the exhibit booth and speaking sessions.

Exhibitor display

The exhibitor area was located in the South Coast Winery courtyard. Next to the exhibitor area were two sessions – a technical breakout session that took place outdoors and a breakout session in the building behind the courtyard. Of the 250 attendees, 15-20% visited the Frontier Energy booth during the two days that Frontier Energy exhibited. Frontier Energy attributes the low number of visitors on a few factors: location, heat, and audience.

Figure 39 - EV Training booth

While the courtyard did have two sessions next to it, the Main Stage was where the majority of attendees remained and was farther away from the Exhibitor area which resulted in low foot traffic throughout the day as attendees traveled between sessions. The technical session that was next to the Exhibitor area drew in attendees that did visit some of the other booths in the area but were mainly looking for information on classes and resources to improve their technical skills which we referred to the other booths such as Klein Educational Systems and Switch Vehicles Inc.

In addition to the location being separated from the main stage, the courtyard was also outdoors with high heat throughout the event. The Frontier Energy booth did contain an outdoor fan to keep staff cool and there were water stations in the area but the 100+ degree temps deterred attendees from traveling too far from the covered and air-conditioned area near the main stage.

The Frontier Energy/GTI Energy 10x10 booth housed a table with a TV that displayed the ZECAP Hydrogen Yard Truck video showcasing the yard trucks in action at the POLA. The video was downloaded onto a laptop that connected to the TV and looped continuously. The video can also be viewed on YouTube here: https://www.youtube.com/watch?v=MRIyHPCiDrY. There was also a raffle giveaway that was used to draw in attendees. The giveaway was successful in drawing in attendees and getting conversations started.

Figure 40 - Frontier and GTI Energy Booth

Primary questions asked during our conversations included:

- What does vehicle electrification mean to you? Does it include fuel cell vehicles?
- In addition to cars and trucks, do you use yard trucks or other off-road vehicles?
- The ZECAP yard truck runs on hydrogen. It fuels in about 5 minutes and can operate for 12 hours. How would something like this fit into your operation?
- Do you have a timeline for transitioning to ZEVs? What barriers do you face?
- Tell me more about your fleet and your operations

Attendees we spoke to ranged from technicians, mechanics, instructors, and directors. Conversations at the booth with attendees resulted primarily in general overview about hydrogen and fuel cell technology. Attendees had heard of hydrogen and fuel cell technology, but many were not familiar with how it works or what type of vehicles are currently on the road commercially or available for fleets. All of the attendees that we spoke to have some sort of vehicle electrification plan and some already had started implementing electrification into their fleet operations. Most did not have hydrogen fuel cells as part of their plan or in their current fleets. The attendees we spoke to did not use yard trucks or off-road vehicles.
The instructors and directors we spoke to were all interested or already implementing electric vehicle technology in their curriculum. However, they indicated that cost and space requirements to implement a hydrogen fuel cell course are the major barriers to why hydrogen and fuel cell technology is not currently being offered at their institution. In addition, they felt battery electric vehicle technology is here now; whereas they felt hydrogen fuel cell technology is farther out in the future.

Breakout Session

Bart Sowa presented on the Transportation Electrification at Seaports breakout session. The session was moderated by Larry Rillera (California Energy Commission) and had two additional panelists: Lianna Rios (San Diego Gas and Electric) and Renee Yarmy (Port of San Diego). The panel focused on projects and issues associated with electrifying the transport systems at seaports. Mr. Sowa's presentation highlighted the work at the POLA with the ZECAP hydrogen yard trucks.

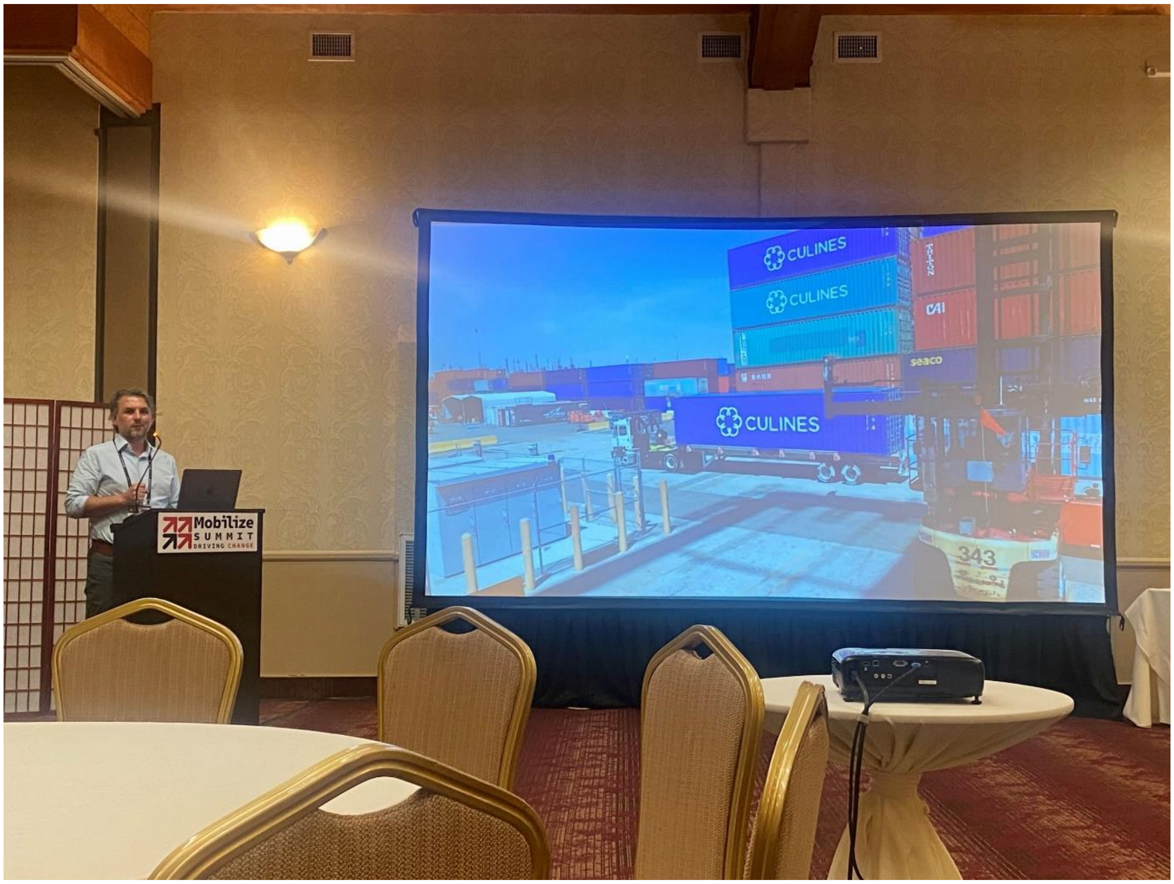

Figure 41 - GTI Energy presenting ZECAP project

Recommendations

Frontier Energy staff found that the sessions at the Mobilize Summit event drew most of the attendees and that the Exhibitor area was lightly attended. The breakout sessions had multiple interesting topics and the main stage was well attended. It is our recommendation that the best method to reach our audience would be to have staff present at the breakout sessions.

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Appendix C

Community Outreach for ZECAP Project at the Port of Long Beach

Appendix C - Community Outreach for ZECAP Project at the Port of Long Beach

About ACT Expo

ACT Expo is the nation's leading conference about clean trucks. The 2022 events set records for attendance with more than 3,000 attendees and 8,500 industry stakeholders registered for the event. More than 75 vehicles were on display at the 188 booths inside and outside the convention center. Capacity had a large booth with a fuel cell yard truck on display and a steady flow of visitors to the booth throughout the event.

Figure 42 - Capacity booth at ACT Expo 2022

Figure 43 - Unit 4068 on display at ACT EXPO 2022

During ACT Expo, hundreds of people who live in and near Long Beach worked at the convention center and nearby hotels and restaurants. Frontier Energy conducted short interviews with a variety of workers to understand the impact that the port has on their lives, their awareness of zero emission vehicles, and if being around the ZEVs at ACT Expo impacted their awareness. This report is a summary of the interviews and additional information from publicly available sources.

About Interviews

- An interview is a one-to-one conversation about a specific topic or issue.
- The purpose is to obtain project-relevant information to understand individual thoughts and preferences rather than measure answers.
- The interviewer does not educate participants or tell participants the topic of the conversation.
- Observing how participants react is important to explore unexpected issues and reveal hidden concerns or ideas.
- Responses can identify issues, concerns, and desired agendas and understand potential consequences of a course of action.
- Diversity is important to collect the range of attitudes, beliefs, and notions.

During ACT Expo, Frontier asked questions to explore four "domains:"

- Their awareness of zero emission vehicles
- Their concerns about the port and any impacts on their lives
- Notions, opinions, and attitudes toward hydrogen-powered vehicles
- Personal interest in owning a ZEV

In exploring the domains, Frontier also asked objective questions to understand the influence that being around the vehicles on display and at the ride-and-drive had on their opinions. Most interviews lasted less than 10-minutes to respect people's time.
Frontier completed 14 interviews, as shown in Table 7

Table 7 - Summary of Participants

Person	Sex	Primary Language	Job at ACT Expo	Long Beach
P1	M	English	Exhibit Temp	Work
P2	F	English	Exhibit Temp	Work
P3	F	Spanish	Catering	Live
P4	F	Spanish	Catering	Live
P5	M	Unknown	Custodial	Live

P6	M	Spanish	Shuttle driver	Live
P7	F	English	Bartender	Work
P8	F	English	Bartender	Work
P9	M	Spanish	Custodial	Work
P10	F	Cambodian	Custodial	Work
P11	F	Unknown	Custodial	Live
P12	M	Unknown	Catering	Live
P13	F	English	Registration	Work
P14	M	English	Registration	Work

High-level Observations

1. **"ZEV" is not known.** No one recognized the terms ZEV or zero-emission.
2. **Proximity made a difference** in awareness of ZEV trucks.
3. **Hydrogen was a surprise** to all participants, even to the people who worked in a hydrogen truck exhibit.
4. **Concern about climate change** was universal, but also out of their control.
5. **High gas prices** were more important than improved air quality.

Interview Comments and Analysis

"I know about Teslas, but didn't know there were electric trucks," the participant said. "Why don't companies buy these?"

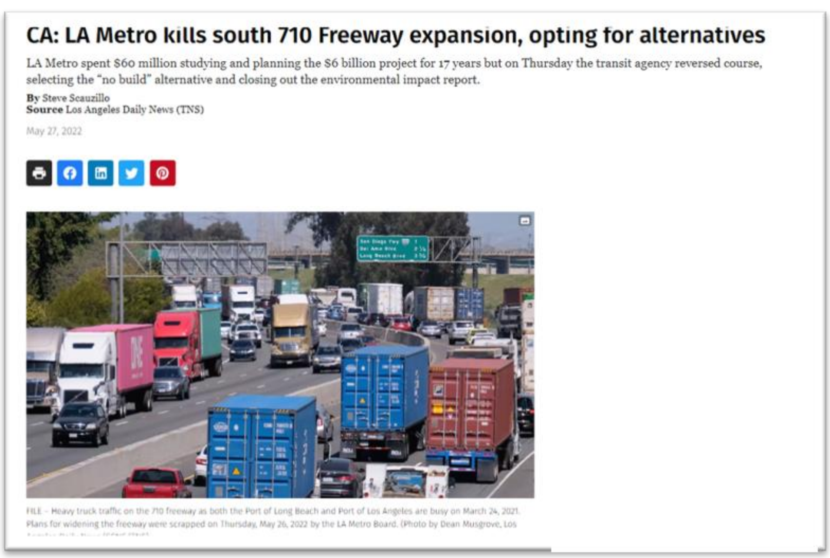
All of the interview participants were aware that the trucks on display included electric trucks. Most the vehicles on display had prominent lettering and signs that said "electric." Participants were less aware of the fuel cell trucks on display. A person who was doing catering in the Hyundai booth didn't know that the trucks ran on hydrogen until I told her. When I asked about hydrogen, others responded "is that they same thing as a hybrid?"

None of the participants knew the phrase "zero emission vehicle." Focus groups that Frontier Energy conducted across the country have the same result. For most vehicle buyers—consumers and fleets—ZEV is an unfamiliar term.

After talking about what zero emissions means, participants answered with "these are a good idea," and "all trucks should be like this."

We transitioned to talking about what they experience with the port, and all participants talked traffic. "There are so many trucks on the 710," one said. "It makes me late to work." Another stated, "I don't feel safe with all the trucks, and expanding the 710 will make it worse."

After ACT Expo, the 710 Freeway expansion was cancelled, as shown in Figure 44[2]


CA: LA Metro kills south 710 Freeway expansion, opting for alternatives

LA Metro spent $60 million studying and planning the $6 billion project for 17 years but on Thursday the transit agency reversed course, selecting the "no build" alternative and closing out the environmental impact report.

By Steve Scauzillo
Source Los Angeles Daily News (TNS)

May 27, 2022

FILE – Heavy truck traffic on the 710 freeway as both the Port of Long Beach and Port of Los Angeles are busy on March 24, 2021. Plans for widening the freeway were scrapped on Thursday, May 26, 2022 by the LA Metro Board. (Photo by Dean Musgrove, Los

Figure 44 - Story from Los Angeles Daily News. Source: Mass Transit News

2 https://www.masstransitmag.com/management/news/21269257/ca-la-metro-kills-south-710-freeway-expansion-opting-for-alternatives

The participants who lived in the Long Beach area talked about dirt and noise from the

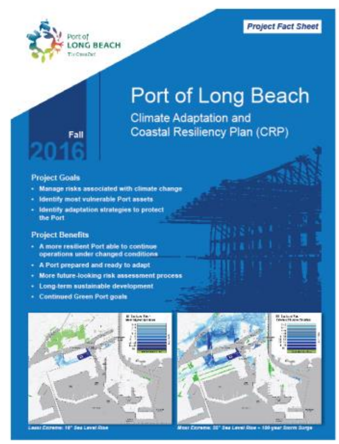
port, and not directly related to drayage trucks. “We hose off the (window) screens every week and they are just black with dirt,” one said. Another answered, “the banging goes on all day and night. It’s hard to sleep sometimes.” Reports Frontier found from ports around the world, including the ports of Seattle, San Diego, Houston, and Dublin (IR) echo the Long Beach residents’ complaints about noise and dirt.

None of the participants mentioned air quality, greenhouse gas emissions, or climate change. I asked them about GHG and air quality, and all agreed that electric trucks would help those issues. **Error! Reference source not found.**summarizes participants opinions about the impacts f rom the port and if a zero-emission truck could help with the issue.

None of the participants:

- Knew about the Port’s Climate Adaption Plan (Figure 45)
- Attended a meeting or event about climate change
- Were aware of the electrification efforts at the Port
- Participated in any outreach events about EVs and ZEVs
- Remembered seeing any advertising or offers about EV incentives
- Knew the name of a local organization that was working on climate change, pollution, or environmental justice

Figure 45: Port Climate Adaption Plan



On June 1, 2022, the Port had its biannual stakeholder meeting with 120 participants. GNA, the meeting host, believes that zero were residents.

Table 8 - Summary of Port Impacts

Issue Cause by Port	Could a ZEV help resolve the issue?
Traffic/Congestion	**No**
Dirt/Dust	**Maybe**
Noise	**Maybe**
GHG emissions	**Yes**
Air quality	**Yes**

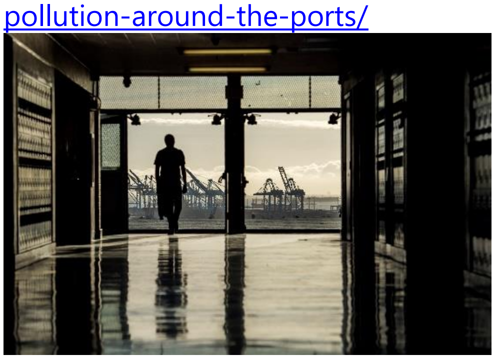
GHG and Air Quality: Literature Review

Several community activities and organizations focus on the effects of poor air quality on Long Beach residents and people who work at the Port, and on climate change and action planning. The follow are from recent publications:

"Longshore workers have to wear two hats in the ILWU," says (Ray) Ortiz, Jr. "One for safer docks and healthier neighborhoods, and the other for good jobs that our communities need." (Tim) Podue told the group he was speaking as a private citizen, not a union representative, but went on to explain how he and other longshore workers have been inhaling diesel exhaust for decades. He said that many of his coworkers have cancer, and that he hates breathing exhaust fumes on the job.

But Podue also said how much he loves his work and how important the good jobs are for thousands of area families who depend on the Port. "I've been poisoned myself by breathing exhaust from the stacks of a ship while I was working in a crane, and you never get over it," said Podue. "But you also can't chase away the work." Podue said he would love to see all the port equipment 'plugged in and green.'"

Seeking solutions to pollution around the ports, https://www.ilwu.org/seeking-solutions-to-pollution-around-the-ports/



"Nick Serrano, a San Pedro High School senior…is more concerned about harder-to-avoid threats from three oil refineries and two freeways within four miles of his home. The POLA's sprawling industrial complex is blocks from his home. It can also be seen from classroom windows at his school."

Reporter collects own data for series on air pollution near LA ports, https://centerforhealthjournalism.org/2018/08/27/reporter-collects-own-data-series-air-pollution-near-la-ports

"On a sunny day in Signal Hill's Hilltop Park with panoramic views of Long Beach, Theral Golden points to a layer of brown smog lining the ocean horizon, as a line of cargo ships sits backed up for miles to Orange County.

He then points to his neighborhood on Long Beach's Westside, an area called the 'diesel death zone' and 'asthma alley' because of its proximity to freeways, oil refineries and the ports of Long Beach and Los Angeles."

'We're breathing this all in,' said Golden, 73. 'You can see it. You can smell it. It's dirty.'"

West Long Beach is choking on air pollution from cargo congestion, https://centerforhealthjournalism.org/fellowships/projects/you-can-see-it-you-can-smell-it-it-s-dirty-west-long-beach-choking-air

Knowledge about Hydrogen

Three participants were assigned to booths that included hydrogen fuel cell and battery electric trucks. They were unaware of FCEVs before ACT Expo.

- "The (fuel cell) trucks seem like a better idea. They can go farther than the battery truck, but where do they get hydrogen?"
- "I saw a few booths with hydrogen trucks. Do they make hydrogen cars, too?"

11 participants were not assigned to booths. All were aware that the trucks at ACT Expo were electric and hydrogen but didn't know what the difference was.

None of the participants expressed concern about hydrogen safety.

Personal Interest in ZEVs

All participants were interested in zero emission vehicles, and most mentioned it was because of high gas prices. "Gas is so high and being around these trucks made me think I should get an EV."

They asked me many questions:

- "Do you know about EVs?
- "I live in an apartment. Could I get an EV? How would I charge it?"
- "Do they make hydrogen cars? Where do I go to charge it up?"
- "(EVs) are so expensive! Are there cheaper ones? I only know about Tesla."
- "I need a van because I have so many kids. Do they make EV vans?"
- "What pickups are EVs?"
- "Do you know how much it costs per gallon?" (it was same question about hydrogen and electricity)
- "You should have the EV cars outside (in the ride and drive). We'd all be driving them!"

Observations

During one of the interviews, the participant and I were outside the convention center and could see vehicles driving through a busy intersection. She said, "I see so many Teslas. Everywhere I look I see one. It's like everyone is buying a Tesla."

I asked her to look for pickup trucks while we talked. When we finished our interview she said, "I can't believe how many pickups there were. Why haven't I noticed that before?"

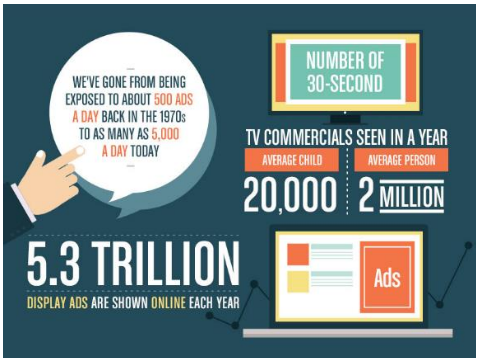


Figure 46 - American Advertising Exposure

1**Selective attention** (sometimes called selective screening) is the process all humans use to select and focus on input and ignore irrelevant stimuli. When you hear about Tesla in the news, on social media, and in advertising, you see Telsa cars "everywhere" when, in fact, you actually see more pickup trucks.

Selective distortion is the tendency to interpret information in a way that will fit our preconceptions. It is the way that all humans justify what they want (e.g., organic cheeseburgers are better for you than regular cheeseburgers) and ignore or refute things that don't fit their beliefs.

Experts believe that American adults are exposed to about 5,000 ads a day, as shown in **Error! Reference source not found.**.3 The more ads we see every day, we become more selective about what we see and share, and advertisers/marketer become increasing clever about how they appeal to people's emotions instead of using rational content.

'Meeting people where they are' has become a common adage in equity and diversity outreach. Originally coined around 2010 for social workers and therapists, it referred to recognizing a client's unique challenges and understanding their needs, desires, responses, worries, and hopes.

Today, in the world of outreach, it means bridging the gap between your expectations and what the other person values and believes. Albeit very limited in scope, the 14 people we interviewed talked about the negative impacts of port-related traffic, dirt, and noise. They acknowledged pollution and GHGs when the interviewer asked them about it. To meet Long Beach residents where they are, community advocacy organizations might reach residents by talking about how zero emission vehicles are quieter that internal combustion engine vehicles and associate zero emission with less dirt and dust in their window screens.

3 https://appliedpsychologydegree.usc.edu/blog/thinking-vs-feeling-the-psychology-of-advertising/

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Appendix D

Summarized Vehicle Operational Data Collected

Appendix D – Summarized Vehicle Operational Data Collected

Date	Operation Hours	Total Miles	Idle Time %	H2 kg consumed
2/4/2020	0.13	0	1	0
2/11/2020	0.15	0	0.94	0
2/18/2020	2.9	3	0.84	1.75
2/19/2020	1.27	7	0.51	0.95
3/4/2020	0.55	1	0.84	0.47
3/7/2020	0.7	3	0.41	0.51
3/8/2020	3.9	18	0.51	3.24
3/9/2020	1.49	9	0.42	1.09
3/10/2020	0.9	6	0.37	1.02
3/11/2020	4.23	11	0.67	2.88
3/12/2020	3.22	8	0.74	1.57
3/15/2020	3.26	11	0.63	2.58
3/23/2022	0.51	2	0.55	1.57
3/24/2022	4.15	17	0.34	4.10
4/1/2022	5.37	14	0.58	3.20
4/8/2022	5.08	18	0.68	4.08
4/13/2022	2.98	7	0.72	2.00
4/15/2022	2.09	8	0.59	1.78
1/17/2023	5.81	16	0.71	2.51
1/18/2023	0.04	1	0	0.04
1/19/2023	5.47	9	0.8	2.98
1/20/2023	0.59	0	1	0
1/22/2023	1.66	14	0.28	2.33
1/25/2023	0.38	2	0	0.58
2/2/2023	5.64	25	0.53	4.77
2/10/2023	0.5	6	0	1.16
2/13/2023	0.07	0	0.5	0
2/17/2023	0.42	0	0.91	0
4/20/2022	6.6	26	0.63	3.09
4/21/2022	0.55	2	0.35	0.91
7/18/2022	0.04	0	1	0.04
7/19/2022	0.2	0	1	0
7/20/2022	4	4	0.91	1.49
7/22/2022	3.42	3	0.93	0.91
7/25/2022	4	6	0.85	1.75
7/26/2022	0.55	0	0.89	0.04
7/27/2022	0.09	0	0	0.25
8/21/2022	1.7	22	0	3.27

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