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ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

The Port of Los Angeles Everport Advanced Cargo Handling Demonstration Project

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued Grant Funding Opportunity GFO-15-604 to demonstrate freight transportation projects for medium- and heavy-duty vehicle technologies, demonstrate intelligent transportation systems and technologies, and deploy natural gas vehicles. In response to GFO-15-604, the recipient submitted an application, which was proposed for funding in the CEC's notice of proposed awards May 19, 2016 and the agreement was executed as ARV-16-026 on December 13, 2017.

ABSTRACT

The Port of Los Angeles' Everport Advanced Cargo Handling Demonstration Project built upon existing technical demonstrations of zero-emission goods movement technologies by taking the next step toward implementation of a zero emissions pathway for loading and unloading cargo throughout an entire marine container terminal. The project team included original equipment manufacturers Taylor Machine Works, Inc. and BYD Motors, LLC, working together with Everport Terminal Services, Inc. to demonstrate two zero-emission top handlers and three third-generation zero-emission battery-electric yard tractors at the Everport terminal. The Port of Los Angeles installed standard charging equipment from BYD Motors, LLC for the top handlers. The yard tractors are charged by a state-of-the-art Cavotec Smart Plug-In System, the first of its kind to be installed at the Port of Los Angeles.

Keywords: California Energy Commission, Port of Los Angeles, zero-emission, battery-electric, smart plug-in system, petroleum displacement, greenhouse gas, emission reduction

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EXECUTIVE SUMMARY

The Port of Los Angeles' "Everport Advanced Cargo Handling Demonstration Project" demonstrated two types of advanced technology cargo handling equipment in a rigorous port container terminal setting. Everport Terminal Services, Inc., a Port of Los Angeles container terminal operator, tested and evaluated two prototype zero-emission battery-electric top handlers with standard charging equipment and three third-generation zero-emission battery-electric yard tractors with smart charging technology. The top handlers were designed and built by Taylor Machine Works, Inc., with support from BYD Motors, LLC, the supplier of the battery-electric propulsion and charger systems. The battery-electric yard tractors were designed and built by BYD Motors, LLC. These yard tractors were integrated to charge with Cavotec's innovative Smart Plug-In System.

Reconstruction efforts at the Everport terminal presented an opportunity for advanced technology infrastructure development and expanded operation of battery-electric cargo handling equipment. Infrastructure designs for the "Everport Advanced Cargo Handling Demonstration Project" built upon and incorporated power needs and grid capacity from the "Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project," a previous demonstration project. The zero-emission top handlers were charged by two 200 kW electric vehicle supply equipment. The battery-electric yard tractors were each integrated with a vehicle-side charging funnel to connect with the extendable charging arm of the Smart Plug-In System, providing simplified initiation of the charge, consistency of charge, and increased operator safety.

The demonstration achieved significant reductions in key criteria, toxic and greenhouse gas pollutants. The zero-emission fleet achieved 100 percent reduction in all tailpipe emissions. These emission reductions provided a direct benefit to the local disadvantaged communities surrounding the Port of Los Angeles. Key findings include (1) the importance of designing fueling infrastructure to meet local permitting requirements, (2) advanced technology equipment operation should mimic as much as possible existing operations, and (3) the rigorous nature of the port operating environment should not be underestimated.

The "Everport Advanced Cargo Handling Demonstration Project" demonstrated the world's first battery-electric top handlers and an advanced charging system that was the first of its kind to be demonstrated at the Port of Los Angeles. Overall, this project combined technologies that directly reduced emissions at the tailpipe with efficiency improvement strategies to provide an overall benefit to the Port of Los Angeles operators and adjacent communities.

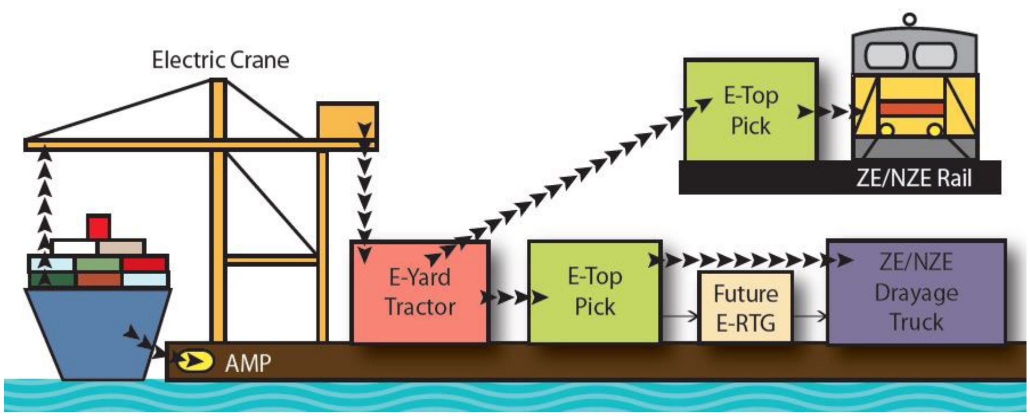
CHAPTER 1: Purpose and Approach

1.1 Purpose of the Project

The City of Los Angeles Harbor Department's (Port of Los Angeles, POLA, Port) "Everport Advanced Cargo Handling Demonstration Project" expands on existing demonstrations of zero-emission technologies by taking the next step toward implementation of a zero-emission pathway for loading/unloading cargo throughout an entire marine container terminal. The project team includes original equipment manufacturers (OEM) Taylor Machine Works, Inc. (Taylor) and BYD Motors, LLC[1] (BYD), working together with the Everport Terminal Services, Inc. (Everport) to demonstrate two prototype zero-emission top handlers and three third-generation zero-emission yard tractors. The top handlers are charged with BYD's standard charging equipment. The yard tractors are charged by Cavotec's state of the art Smart Plug-In System (SPS), a first for POLA.

The Everport zero-emission pathway concept begins at shipside, with an existing all-electric ship to shore crane. After cargo is unloaded, it is moved away from shipside by a battery-electric yard truck and unloaded at container stacks by a battery-electric top handler for stack placement, and eventually loaded by a battery-electric top handler onto either a drayage truck or a train. Figure 1 provides a graphic of this zero-emission pathway concept.

Figure 1: Everport Zero Emissions Pathway Concept



Credit: *Port of Los Angeles*

Targeting top handlers and yard tractors supports increased penetration of zero-emission technology into the cargo handling equipment (CHE) source category. In 2022, top handlers and yard trucks contributed a combined 63 percent of NO_x and 69 percent of PM10 from the

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[1] BYD Motors LLC is an American manufacturing company and a wholly-owned subsidiary of BYD Company Ltd, the largest domestic auto-manufacturer and electric-bus manufacturer in China. Note that BYD is an abbreviation for a marketing phrase "Build Your Dream". However, this acronym is not part of BYD Motors, LLC official company name (the company is not named, "Build Your Dreams Motors, LLC").

CHE category.[2] Many container terminals consider the top handler to be the most important and versatile piece of cargo handling equipment in today's terminal operations and operating zero-emission top handlers is of great interest to terminal operators.

1.1.1 Project Goal

The goal of this project was to enhance market acceptance of advanced zero-emission technology in top handler and yard tractor CHE applications by successfully demonstrating advanced battery-electric technology in two top handlers and three yard tractors, where the yard tractors were fueled using a Smart Plug-In System concept. These technologies were used in equipment that transports freight in the Port of Los Angeles at the Everport terminal. A 12-month in-service demonstration was conducted to collect and analyze real-world operating data to assess effectiveness and cost of the technologies in freight transportation applications. These data document operation costs as well as project benefits including greenhouse gas (GHG) and criteria pollutant emission reductions and reduced petroleum use. These improvements provided a direct benefit to the local disadvantaged communities surrounding the Port, but more importantly provide the foundation for continued transition to zero-emission goods movement at the Port.

1.1.2 Project Objectives

The objectives of this Agreement were to support accelerated market acceptance of zero-emission technology while achieving measurable reductions in port cargo handling equipment petroleum consumption and emissions in accordance with the broader objectives of the California Energy Commission's (CEC) Clean Transportation Program and reducing port impacts on local disadvantaged communities. Specific measurable objectives included:

- Design and build five zero-emission CHE (two top handlers and three yard tractors) for field demonstration in order to verify operational performance and to collect in-use performance data.
- Design and build charging infrastructure to support the daily charging needs of the top handler demonstration units.
- Design and build a Smart Plug-In System that more effectively connects to, and disconnects from, the battery-electric yard tractors. The goal is to eliminate the need for time-intensive connections, support more universal off-road charging standards, and improve safety.
- Document significant reductions in GHG and criteria pollutant emissions compared with conventional diesel CHE performing similar terminal work.
- Document energy cost savings and the reduction in petroleum fuel consumption, compared to cost and fuel used in comparable diesel-powered equipment in operation at the terminal.

1.2 Project Approach

POLA assembled a strong team of advanced technology original equipment manufacturers (OEMs) for the demonstration project. This project expands on existing technical demonstrations of zero-emission goods movement technologies by taking the next step toward

[2] Port of Los Angeles Air Emission Inventory: https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

implementation of a zero-emission pathway for loading and unloading cargo throughout a marine container terminal. POLA's approach to teamwork with OEMs for this project facilitated OEM experience with new zero-emission platforms in order to support the long-term viability of these designs as production equipment in the commercial market.

1.2.1 Top Handler Demonstration

The project team demonstrated two OEM zero-emission top handlers, a first for the Port of Los Angeles, and a first for the world. For this project, Taylor teamed with BYD to integrate BYD's battery-electric propulsion technology to a new application, top handlers. The two OEMs worked together with Everport to integrate this proven technology in a design that would meet terminal operation requirements. The electric vehicle supply equipment (EVSE) to charge the top handlers was produced by BYD. Standard charging infrastructure was designed and installed by POLA Construction and Management (C&M) as match contribution to the project.

1.2.2 Advanced Battery-Electric Yard Tractor Demonstration

This project also developed and demonstrated three third-generation zero-emission yard tractors. The timing of this project compared to earlier demonstrations of the initial BYD yard tractor designs allowed BYD to integrate early demonstration results into the technology's next-generation design. Cavotec provided three SPS units to charge the three yard tractors, designed to simplify the connection process between the equipment and the charger. The goal was to ensure the unit could begin charging upon arrival at the charging location, to ensure a maximum charge could be applied while the yard tractor was not in use. This portion of the infrastructure was designed by POLA Engineering and installed by third-party contractor, Manson Construction, as match contribution to the project.

1.3 Project Tasks

Overall, the project was organized into four key tasks: project administration, design and manufacturing of the project equipment, design and construction of the charging infrastructure, and implementation of the 12-month demonstration with associated data collection and analysis. Below is an overview of each task.

1.3.1 Task 1: Project Administration

Task 1 encompassed Project Administration. During implementation of this project, POLA executed subrecipient agreements and coordinated progress meetings and reports with the project team. This included periodic virtual meetings with the team (weekly or monthly, as needed), monthly virtual meetings with the Commission Agreement Manager (CAM), monthly progress reports to the CEC, two Critical Project Review (CPR) meetings and reports, and development of this Final Report. The first CPR was held on October 31, 2018, and the second CPR was held on October 24, 2019. The CAM approved the project to proceed upon completion of each CPR. POLA's project manager also worked with the project team to monitor the project schedule and ensure that the Schedule of Products and Due Dates was maintained or updated/reviewed with the CAM, as necessary. Overseeing deliverables, such as approved permits and reports – and ensuring their completion – was also included in this task. An important element of the administration task was also to manage project invoicing and payments and document match funding commitments. The project was successfully administered, building and demonstrating five CHE for the in-service demonstration.

1.3.2 Task 2: Design and Build Project Equipment

Under Task 2, the project team planned, designed, built, and shipped two zero-emission top handlers and three next-generation zero-emission yard tractors for demonstration at Everport (see Task 4). Specifically, this task encompassed the following key activities:

- Review equipment build specifications and functional requirements.
- Finalize engineering bill of materials (BOM) and order components for each vehicle.
- Design, fabricate, and build vehicles, components, systems, and subsystems.
- Conduct tests, certifications, quality checks, and validations for vehicle components, systems, subsystems, and safety elements.
- Conduct drivability testing, visual quality assurance, final road or operational test, and pre-delivery test.
- Obtain sign-off authorization to commission the demonstration equipment and deliver vehicles to Everport.

The OEMs successfully completed their Task 2 commitments and delivered the project equipment to Everport for the demonstration in accordance with Task 2 requirements. Figures 2 and 3 depict the project equipment.

Figure 2: Taylor Top Handler Units TH0229 and TH0230

Credit: *Port of Los Angeles*

Figure 3: BYD Yard Tractor Units ET 318, ET 319, and ET 320

Credit: *BYD Motors, Inc.*

1.3.3 Task 3: Design and Construct Charging Infrastructure

The goal of Task 3 was to design and construct charging infrastructure to power five battery-electric CHE during the project demonstration. This effort encompassed the following key activities:

- For the top handlers, standard BYD chargers were modified with dual cables to accommodate the 200 kilowatts (kW) charging capacity.
- Review equipment power requirements and charging specifications for the CHE and ensure sufficient power is available.
- Prepare and provide design calculations, drawings, plans, and specifications to advertise the Cavotec installation project for procurement of materials, equipment, and required labor to install, test, and commission the Smart Plug-In systems as per the bid drawings and specifications.
- Complete installation of all charging equipment.
- Conduct safety and operational testing of the charging equipment for final commissioning.

Figure 4 shows the dual cable 200 kW EVSE installed to charge the top handlers. Figure 5 depicts the SPS, originally designed for 200 kW, with charging arms connected to the yard tractors.

Figure 4: Taylor's Zero-Emission Top Handler and BYD's EVSE

Credit: *Port of Los Angeles*

Figure 5: BYD's Zero-Emission Yard Tractors Connected to Cavotec's SPS

Credit: *Cavotec*

1.3.4 Task 4: Data Collection and Analysis

Task 4 is the heart of the project: to collect operational data from a 12-month demonstration and use these data to assess the environmental and economic impacts of the technology demonstration. For this task, the Data Collection Test Plan that was developed and approved by the CAM was used to guide the demonstration (Appendix A). For 12 months, throughput, usage, and operations data for the project equipment were collected in order to assess the following key metrics:

- Gallons of diesel fuel displaced based on hours of operation of the zero-emission equipment.
- Expected GHG and air pollutant emissions reduction, including carbon dioxide equivalent (CO_2e), diesel particulate matter (PM), oxides of nitrogen (NO_x), and hydrocarbons (HC).
- A quantified estimate of the project's carbon intensity values for life-cycle greenhouse gas emissions.

Task 4 also included the following:

- Develop data collection test plan.
- Troubleshoot any issues identified.
- Maximum capacity of the new fueling system.
- Duty cycle of the current fleet and the expected duty cycle of future vehicle acquisitions.
- Specific jobs and economic development resulting from this project.
- Energy cost savings compared to diesel powered equipment in operation at the Port.
- Identify any current and planned use of renewable energy at the facility.
- Identify the source of the alternative fuel.
- Describe any energy efficiency measures used in the facility that may exceed the Title 24 standards in Part 6 of the California Code Regulations.
- Provide data on potential job creation, economic development, and increased state revenue as a result of expected future expansion.
- Compare any project performance and expectations provided in the proposal to the Energy Commission with actual project performance and accomplishments.

CHAPTER 2: Top Handler Demonstration

2.1 OEM Manufacturing Overview

Taylor Machine Works, Inc. is an OEM specializing in heavy-duty lift trucks for the worldwide material handling market. Celebrating 90 years of customized lift products for customers, Taylor specializes in application-driven solutions optimizing productivity and efficiency while following the company mantra, "We Engineer and Build what You Need". Taylor manufactures over 80 models of heavy lift trucks that range in capacity from 16,000 to 125,000 pounds and includes a comprehensive product line of container handling equipment. Taylor was instrumental in the development of container handlers over 50 years ago leading to the development of the first dedicated container handling industrial trucks. Presently, Taylor has accepted the challenge of meeting zero-emission goals for top-handlers while providing industry leading service and support. A comprehensive network of local dealer sales and service support enables Taylor to provide the technical support and expertise necessary to support customer focus on uptime and productivity. The Taylor brand is backed by engineering expertise, intermodal and container handling market experience, and service support of the material handling market.

For this project, Taylor designed and built two zero-emission top handlers (Model ZLC-976) for demonstration at Everport. The two top handlers have identical functional capabilities and technical design specifications. Project identifiers are as follows:

- Unit ID# E-TH-29(THO229), Serial Number 42332, delivered May 23, 2019
- Unit ID# E-TH-30(THO230), Serial Number 42333, delivered July 12, 2019

The preliminary design and build specifications were combined with essential safety and functional requirements defined by industry standard practices, design and safety standards, and comprehensive safety reviews. The ZLC Series was designed to meet or exceed all requirements outlined in Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations 1910.178 for use, American National Standards Institute / Industrial Truck Standards Development Foundation B56.1 for use and design, and Underwriters' Laboratories (UL) 583 for electrical safety and fire prevention. The ZLC series also met customer performance requirements, which was confirmed during the demonstration, ensuring that the zero-emission equipment performance was equivalent to conventional diesel-fueled top handlers. Key performance specifications for the demonstration equipment included:

- Travel Speed: 14.5 mph (forward and reverse; loaded and unloaded)
- Lift Speed: 48 feet per minute loaded and 60 feet per minute unloaded
- Lowering Speed: 61 feet per minute (loaded and unloaded)
- Gradeability: 18 percent loaded and 30 percent unloaded
- Tractive Effort: 50,000 pounds maximum
- BYD Motors, Inc. Lithium Iron Phosphate battery technology, rated at 922 kilowatt-hours (kWh), and a charge time of between five and six hours

The demonstration units were built off of the main production line in Taylor's research and development facility due to the prototype nature of the builds. Taylor Machine Works is a vertically integrated manufacturer and not just an assembly plant. A large portion of all components are machined and built on site. Over the course of this prototype build process for the ZLC zero-emission top handlers, thousands of labor hours and tens of thousands of individual parts and processes were invested into the success of these units.

The ZLC zero-emission top handlers build sequence began with the chassis, to which the running boards were added. Next was assembly and installation of the drive axle followed by the steer axle and tires. The hydraulic tank was installed along with the valves and associated hoses, followed by the wiring. The drivetrain was then installed followed by the batteries, cab platform, and cab assembly. Once the truck had power, the mast and attachment were installed and tested, then sent to paint and final rigout before shipping to Everport.

Major challenges encountered during manufacturing and the approaches used to address these challenges are summarized below.

- Challenge #1: Bronze couplings purchased for the demonstration unit did not correctly mesh as expected. Taylor's approach to resolve this issue was to undertake a research and development (R&D) effort to improve the assembly, since components did not assemble to Taylor's standards. Taylor's use of an end mill to correct this proved challenging because the end mill would flex and create a slight taper from one end to the other. Ultimately, a different design was chosen, eliminating the coupling altogether, and updates were made to the project demonstration equipment at Everport after they had been placed in service.
- Challenge #2: A second challenge was that machining the dual motor mounts proved to take several iterations before the motors were correctly aligned. During this iterative process, the design was optimized, and the parts were replaced in production.

These are two specific examples of common manufacturing challenges. Experienced OEMs are often presented with inconsistencies from suppliers. Taylor's robust process of manufacturing, fabrication, assembly and testing for its wide range of components was used to address these issues. Feedback from the customer from the units' in-service operation as a result of these two approaches was positive.

2.2 Infrastructure Overview

Project infrastructure was designed to integrate with existing operations at Everport, specifically; these units would not require opportunity charging to meet daily shift requirements. POLA engineering worked with its local electric utility, Los Angeles Department of Water and Power (LADWP) to ensure sufficient power was available for the project units. Design specifications were developed to match project equipment charging and operational requirements. The power interface for the top handlers is 200kW, with approximately 5-6 hours to obtain a full charge.

Figure 6 summarizes key design specifications for BYD's 200 kW chargers designed to interface with the Taylor top handlers.

Figure 6: BYD 200 kW Charger Specifications

Specification	Details
Charging Mode	AC
Input Voltage	480V 3-phase
Operating Voltage Range	432V-528V 3-phase
Input Current	240A
Recommended Circuit Breaker Rating	400A
Input Power	200kW
Frequency	60Hz
Output Current	240A
Output Power	200kW
Charging Coupler Type	IEC62196-2
Wires	3 hot; 1 neutral; 1 ground
Length x Width x Height	19.69 x 15.75 x 78.74 (in)
Number of Coupler(s)	2
Charging Cable Length	118.11in
Mounting Method	Floor-mounted
Short-circuit Protection	Yes
Overheat Protection	Yes
Lightning Protection	Yes
Certification	TUV
Reference Standard	IEC61851/IEC62196
Enclosure Protection	IP55
Operating Temperature	-22 to +122 deg F
Surrounding Humidity	5-95%

Credit: *BYD Motors*

2.3 In-Use Demonstration Experience

The Taylor Zero-Emission ZLC-976 top handlers were manufactured and delivered to Everport mid-2019. Due to electrical component certification and permitting issues with the BYD battery EVSE units, the top handlers were placed in service several months later than originally scheduled. BYD intended for the EVSE to be third-party field certified by Technischer Überwachungsverein[3] (TUV), although Underwriters Laboratories (UL) certification is more common in the United States and at the Port complex. The City of Los Angeles Department of Building and Safety (LADBS) required corrective actions for the EVSE, which BYD engineers and technicians addressed. In this instance, the combination of new technology, parts manufactured in China, and a less familiar certification entity, TUV, added to the lengthy certification and permitting process. The certification and permitting issues were resolved to the satisfaction of LADBS and the final permit was issued for the charging equipment on February 27, 2020. Once the EVSE were energized, some minor functional issues were identified and ultimately resolved by BYD technicians mid-March 2020. These issues and other on-going EVSE challenges are discussed in Section 2.3.3. Figure 7 shows an operating top handler.

[3] English translation: Technical Inspection Association. TÜV Rheinland of North America is accredited as a Nationally Recognized Testing Laboratory (NRTL), by OSHA (The Occupational Safety and Health Administration) in the United States, and as a Product Certification Body by SCC (Standards Council of Canada) in Canada.

Figure 7: Top Handler Lifting a Cargo Container at the Terminal

Credit: *POLA Media Relations*

2.3.1 Operational Experience

During the 12-month demonstration, Taylor's zero-emission top handlers generally performed well once early issues were resolved. Initially upon commissioning, both units experienced a problem with locking beams that could not be extended to the full 40-foot position, requiring mechanics to unlock the beams. Operators also detected a problem with the beams catching against the containers upon release and a slowness during the hoisting process. The Taylor team visited the Everport terminal on March 13, 2020, to work closely with Pacific Crane Maintenance Company (PCMC) mechanics to correct these functional issues. The problems were corrected within the next week and the equipment began test runs the following week. One of the units then experienced an issue with pump system failure, but once this was resolved, both units were placed in service and began accumulating in-service hours in April 2020.

From April through June 2020, both EVSE remained functional, with minor intermittent issues. On July 24, 2020, both top handler EVSE stopped functioning. The top handler on-board charger tripped three circuit breakers on the EVSE and the main breaker on the Port side, causing both EVSE to shut down. On August 7, 2020, POLA Engineering determined the issue was not related to the sub-station; the tripping cause appeared to be within the EVSE. A monitoring system was installed at the substation. EVSE functionality was moderately repaired, rendering one charger at 60 percent capacity, the other was not functioning during August 2020. EVSE were functional during September 2020. During October, November, and December 2020 the breakers tripped frequently, and the equipment failed to fully charge. Only one of the four charging cables remained functional. Diagnostic cables were ordered by BYD in November 2020; the cable arrived December 22, 2020. The top handlers were able to charge, but the charging time was doubled. On January 25, 2021, a BYD technician monitored the diagnostic cables from Everport while on the phone with engineers in Shanghai in order to make a determination of the charging issues. Software updates were installed and the charging issues were resolved in February 2021, with the chargers fully functional in March 2021. Demonstration hours were limited, due to issues with the top handler battery system and eight months of semi-functional EVSE.

The most important issue that continues to be addressed after the demonstration is that Everport mechanics identified a key design concern: when the top handler breaks down, it is unable to be moved to the repair shop, compared to standard diesel equipment, which is placed in neutral and towed back to the shop. The battery-electric unit is frozen in place until repaired, which in the case of Unit #TH230 occurred for two weeks, impeding the flow of terminal operations at the rail yard. This was not acceptable to Everport and was a valuable lesson learned for Taylor's future design generations. Taylor developed a resolution for the ZLC model at Everport. Specifically, Taylor designed a gasoline powered device that can be attached to the stranded top handler, allowing movement of the equipment to the maintenance shop, when the battery system stopped functioning.

2.3.2 Operator Surveys

Everport collected seven operator surveys at the beginning and end of the top handler demonstration period. These operator surveys were conducted to document equipment operator feedback regarding their experience with the project equipment. Generally, feedback was positive from operators when the equipment was reliable. Nearly every survey category indicated that the units were the same or better than the diesel counterparts, noting in particular the decreased noise inside the cab. One operator survey commented, "Love the machine. Should have more."

The feedback provided valuable lessons learned for Taylor's future generations of battery-electric top handlers. One survey reported a blind spot caused by the front visor. Two operators reported on the stiff connection to the container, slow up and down hoisting, and slow acceleration with a container. Another reported that when the landing light is activated, the spreader cannot be manipulated. One operator indicated several issues with slow response times and delays, reporting "much worse" than the diesel counterpart in seven of the fifteen categories. However, this operator utilized the e-top handlers only a few times and the dissatisfaction may be attributed to unfamiliarity with the equipment. "Worse" was indicated a total of four times overall – two in the acceleration with container category and two in the connection to container category. Several operators reported on the lack of air conditioning in the cab, which is a common complaint for most CHE. Once the operators became more accustomed to the equipment, responses were generally positive.

Figure 8 represents a compilation of the operator survey results collected during the demonstration.

Figure 8: Compilation of Operator Surveys

OPERATOR SURVEY – Taylor Battery-Electric Top Handler – End of Demo Compilation

** If no answer was provided listed as N/A

Duty Cycle Assignment: Ship Rail **1** Yard N/A **6**

How does the battery-electric top handler compare to a diesel top handler? (check one)	Much Better	Better	Same	Worse	Much Worse	Does Not Apply	Comments/Notes (use back to expand notes)
Cab Entry and Exit		2	4			1	
Inside Cab Noise Level	1	3	3				
Outside Noise Level	1	3	3				
Heating and A/C System (cabin air comfort, odor, breathing comfort)			2			5	☐ Install AC. ☐ No AC.
In-Cab Controls (function and access to switches/controls)		2	4		1		
In-Cab Visibility (blind spots, rear view)			7				☐ Front visor should be removed.
Maneuverability		2	4		1		
Connection to Container		1	3	2	1		☐ Stiff. Needs to be more precise. ☐ Locks up.
Acceleration with No Container	1	4	1		1		
Acceleration with Container	1	1	3	2			
Lifting Power with Full Container		1	5	1			
Smoothness of Shifting During Acceleration		1	5		1		
Braking (quickly/smoothly stops load)	1		5		1		
Ride Comfort (seat, vibration, shocks, etc)		1	6				
Overall Unit Rating			1		1	5	☐ It's ok.

How many times have you operated the battery-electric top handler?

- ☐ 1-3 = **1;** 4-7 = **2;** 8-10 = **1;** 10 or more = **3**

Did you experience any unusual incident or safety issue?

- ☐ Blind spot, remove the front visor.

Do you have additional feedback you wish to provide about this clean emissions demonstration equipment?

- ☐ I would like to manipulate the spreader while the landing light is activated.
- ☐ Love the machine. Should have more.
- ☐ Hoisting up and down slow!!!
- ☐ Yes, its response is slow to controls and to accelerate. They do not turn as well and buttons have a delay which slows down operation. It also doesn't respond when you hit the gas, has a delay.

Credit: *Everport Terminal Services*

2.4 Data Collection and Analysis

Below are the project results from the zero-emission top handler demonstration. The demonstration period began on April 1, 2019 and ended on March 31, 2020. The top handlers accrued a total of 2,512 hours of operation for this demonstration.

2.4.1 Top Handler Key Specifications and Duty Cycle

Top handlers are rider-controlled industrial trucks used specifically for the purpose of lifting, transporting, and stacking containerized cargo. Top handlers are OSHA Powered Industrial Truck Class I, Electric Motor Rider Truck, off-highway cargo handling equipment designed specifically for the handling of freight containers. These industrial container handling trucks are equipped with attachments that engage the containers on the upper surface via four twistlock operated locking mechanisms. These twistlock corner casings enable handling of containers that are loaded up to rated container capacity, which can be up to 50 tons.

Top handlers in use at Everport are designed to meet the following key requirements:

- Dedicated load handling attachment specifically designed for handling 20-foot and 40-foot freight containers.
- Taylor OEM spreader attachment, planetary wheel end heavy-duty drive axle and drivetrain components, and container handling controls with diagnostics.
- 160,000-pound gross vehicle weight (GVW) (empty)
- Duty cycle to meet two 8-hour shifts without opportunity charging, seven days per week, with a five to six hour charging cycle time depending on state of charge.
- Future acquisitions of zero-emission top handlers will require the capability for the zero-emission equipment to meet this standard top handler duty cycle.

2.4.2 Equipment Operation

The top handlers averaged 1,256 hours of zero-emission operation during the demonstration, with the fleet accruing 2,512 demonstration hours. Monthly operation is documented below in Table 1. Everport's gearmen are responsible for charging the equipment and collected the data by recording hour-meter readings on a paper log after charging each unit.

Table 1: Zero-Emission Top Handler Operation (Hours/Month)

Month, Year	Unit TH0229	Unit TH0330	Total Monthly Hours
Pre-Commission	118	124	242
April, 2020	43	68	111
May, 2020	42	23	65
June, 2020	38	8	46
July, 2020	37	62	99
August, 2020	205	84	289
September, 2020	99	67	166
October, 2020	116	172	288

Month, Year	**Unit TH0229**	**Unit TH0330**	**Total Monthly Hours**
November, 2020	101	151	252
December, 2020	98	114	212
January, 2021	89	162	251
February, 2021	96	134	230
March, 2021	104	157	261
Total:	**1,186**	**1,326**	**2,512**

Source: *Everport Terminal Services*

2.4.3 Petroleum Fuel Displaced

As is common practice at port terminals, Everport does not track diesel fuel consumption for each unit in their fleet on an individual basis because diesel fuel is purchased in large bulk orders to supply its CHE fleet's wet-hose fuel truck. The wet-hose truck drives around the terminal to fuel the parked equipment, instead of the equipment driving individually to a fueling station. To estimate the diesel fuel displacement for the zero-emission top handler demonstration, the CO_2e emissions from the Port of Los Angeles 2015 Inventory of Air Emissions were used to back-calculate the reduction in diesel fuel consumption from the top handlers. The project team estimates that a total of 53,347 diesel gallons would be reduced based on 5,000 operational hours in the 12-month demonstration. As a result of the reduced operation experienced in this project and documented in Section 2.3, actual hours of operation totaled 2,512 for both top handlers, resulting in an estimated diesel fuel consumption reduction of 26,802 diesel gallons. Table 2 provides step-by-step documentation of this back-calculation methodology.

Table 2: Top Handler Diesel Fuel Displacement Calculation

Calculation Step	**Value**	**Units**
Diesel top handler fleet (192 units @ 2,259 hours each) total annual CO_2e metric tonnes per POLA 2015 Emissions Inventory[4], Tables 5.1 & 5.6	47,145	metric tonnes/year
Convert to short tons CO_2e (1 short ton = 0.907185 metric tonnes)	51,968	tons/year
Calculate tons CO_2e per hour (divide total tons by 192 units and 2,259 hours)	0.1198	tons/hour of diesel operation
Convert to pounds per hour (multiply by 2,000 pounds per ton)	239.6	pounds/hour of diesel operation

[4] 2015 Port of Los Angeles Air Emissions Inventory, Tables 5.1 & 5.6: https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

Calculation Step	Value	Units
Apply CO_2e Emissions Coefficient for diesel[5] (22.46 pounds of CO_2e per gallon of diesel) to calculate the gallons per hour of a baseline diesel yard tractor.	10.67	diesel gallons/hour
Multiply gal/hr by 2,512 total top handler hours of operation to estimate the reduction in diesel fuel consumption for the demonstration from the operation of two Taylor units.	**26,802**	**diesel gallons displaced**

Source: *Port of Los Angeles*

2.4.4 Criteria Pollutant and Greenhouse Gas Emissions Reduced

Table 3 summarizes the projected and actual GHG and air pollutant emissions reduction, including carbon dioxide equivalent (CO_2e), diesel particulate matter (DPM), oxides of nitrogen (NO_x), and hydrocarbon (HC) emissions. The projected emission reductions were provided in the original GFO application and based on a total of 5,000 hours of operation using emissions reported in POLA's 2015 Emissions Inventory. The actual demonstration emissions reduction estimates are based on 2,512 hours of zero-emission top handler operation, and they are about 50 percent below projections due to the reduced operation achieved during the demonstration.

Table 3: GHG and Criteria Pollutant Emission Reductions for the Top Handlers

Scenario	CO_2e (metric tonnes)	DPM (tons)	NO_x (tons)	HC (tons)
Originally projected emission reductions (based on 5,000 hours of operation)	592	0.021	4.52	0.28
Estimated emission reductions based on actual hours of operation (2,512 hours)	301	0.011	2.27	0.14

Source: *Port of Los Angeles*

2.4.5 Energy Efficiency Measures

There are no energy efficiency measures used in the facility that may exceed Title 24 standards in Part 6 of the California Code Regulations.

2.4.6 Job Creation and Economic Development

For this project, Everport tracked the specific labor assigned to the demonstration equipment. The job counts provided are based on individual union employees that were hired for a single

[5] Energy Information Agency, Carbon Dioxide Coefficients, Release Date September 16, 2021. https://www.eia.gov/environment/emissions/co2_vol_mass.php

shift. Jobs at the Everport site can consist of a single, 1-day shift or run for multiple consecutive days.

The top handler demonstration utilized 296 individual jobs/shifts. The number of top handlers used at Everport site can dramatically change on a day-to-day and shift-to-shift basis. Some days there may be no labor working at all, and, on other days, Everport may employ 40 top handlers over the course of two shifts.

Early in the transition to a zero-emission top handler fleet, job growth is not anticipated as a direct result of this demonstration. Due to space restrictions on the terminals, and the assumption that Everport is currently operating at capacity, expansion is limited. The expectation is that the zero-emission equipment will replace the diesel counterparts on a one-to-one basis. If there is an opportunity to add new units to the fleet, then job growth to operate additional zero-emission units would be possible. Of course, as the transition to a zero-emission fleet continues, the skill set required by the maintenance and operations staff at the terminal will grow beyond that required for internal combustion engine-equipped units, with staff gaining experience with electric powertrain technology, EVSE, and other specialized technology. Even if the jobs count does not increase, the skill and experience of the staff will develop well beyond today's diesel engine to ensure effective zero-emission fleet operation.

Translating this shift labor count to a traditional, fixed labor force, Everport estimated the following job creation to manage the demonstration and ongoing operation of the two zero-emission top handlers on an annual basis:

- Two (2) Operator positions
- One (1) Mechanic position
- One (1) Management position

For design and manufacturing of the ZLC units, Taylor added one dedicated engineer to the electric vehicle (EV) team, and created one other job, due to transfer into that group. These new positions were located in Mississippi. Additionally, they plan to add one manager job for EV in 2023. Taylor Sudden Service, the aftermarket parts and service arm of the Taylor Group of Companies, added a dedicated EV specialist to the aftermarket support team. As the commercialized units come on board, Taylor expects additional production and service personnel to be added. Cal Lift, Taylor's Dealer in Southern California, will also gear up with additional personnel to meet future service demands. Taylor's additions to the EV team:

- One (1) Engineer position
- One (1) EV position (transfer)
- One (1) EV Manager position
- One (1) EV Specialist (aftermarket support) position

As California transitions to a zero-emission goods movement economy, Everport's early introduction and experience with the Taylor zero-emission top handlers will position the terminal to grow its fleet to process more throughput using a zero-emission pathway. This will ensure the terminal remains competitive with companies that strive to minimize their carbon footprint.

2.4.7 Alternative Fuel and Renewable Energy Use at Everport

The Port of Los Angeles' electrical power is provided by the LADWP. According to LADWP's Power Content Label for 2021[6], 35.2 percent of the utility's power is from eligible renewable sources. Solar provides 14.3 percent, wind and geothermal provide a combined 20.3 percent with hydroelectric and biomass/biowaste covering the balance. Any growth in the renewable energy content of Everport's electricity is solely dependent on LADWP's ongoing efforts to increase its renewable energy content.

In addition to the renewable energy content of the electricity consumed by Everport, the terminal also operates 20-yard tractors that are fueled with liquefied natural gas provided by Clean Energy Fuels. This fuel is Clean Energy's REDEEM, 100 percent renewable.

2.4.8 Carbon Intensity Improvement

California's Low Carbon Fuel Standard (LCFS) regulation[7] provides the benchmark for the average diesel fuel carbon intensity of 92.92 grams (g) CO_2e/mega-joule (MJ) for the year 2020. This year was selected as the benchmark because the demonstration was conducted a majority of the time during 2020.

Per CARB's grid electricity pathway ELC000L00072021[8], the current certified carbon intensity for grid electricity is 75.93 gCO_2e/MJ. This is an 18.3 percent reduction in carbon intensity for this project's zero-emission cargo handling equipment. As California's electricity grid increases its renewable fuel source mix, the use of zero-emission port terminal equipment will continue to improve (i.e., lower) its carbon intensity.

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[6] https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-powercontentlabel?_adf.ctrl-state=wgufh5clh_4&_afrLoop=179676638453161

[7] https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf, Table 2: LCFS Carbon Intensity Benchmarks for 2011 to 2030 for Diesel Fuel and Fuels Used as a Substitute for Diesel Fuel. (accessed October, 2021)

[8] Per the excel database link titled "Current Fuel Pathways", found at https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities (accessed October, 2021)

CHAPTER 3: Advanced Battery-Electric Yard Tractor Demonstration

3.1 OEM Manufacturing Overview

BYD is a global OEM of battery, consumer product, and vehicle technologies with more than $61 billion in revenue, more than 40,000 patent applications, 28,000 authorized patents, and 70,000 engineers worldwide. BYD's North American headquarters and manufacturing facilities are in Los Angeles County, and the company has the financial resources, technology, and organizational depth to continuously design, refine, and manufacture a variety of products for the global markets that they serve. The company was founded on the strength of its battery products—BYD manufactures approximately 16 percent of the world's rechargeable batteries for technologies ranging from consumer products to vehicles. BYD's iron phosphate battery was purpose built for vehicle electrification and has gained a 7-8 percent increase in energy density year over year, for the last five years. More than just a battery company though, BYD is the world's largest producer of battery electric buses, with more than 80,000 buses in operation around the globe. As the worldwide leader in battery-electric buses, BYD has accumulated more than 740 million miles of revenue service around the world. The company recently expanded into battery-electric trucks and equipment, with an emerging product line that includes demonstration or commercial products for local delivery, drayage, refuse trucks, and yard truck markets supported by over 1,000 research and development engineers. BYD is a vertically integrated manufacturer that produces every major component of its vehicles, starting with the batteries and battery management system as well as inverters and traction motors.

For this project, BYD produced three third-generation Class 8 yard tractors (model Gen 3 8Y). Starting in 2017, the first generation of tractors was deployed at various locations in Southern California, including rail yards, distribution centers, and marine terminals. Five first-generation units were deployed at Everport terminal under POLA's earlier "Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project." Although the five yard tractors were not utilized beyond the demonstration period, the project was successful in demonstrating the many challenges associated with operating in an active marine terminal environment. Subsequently, in 2019, BYD introduced its second-generation yard tractors, building on lessons learned from operating the first-generation trucks.

The Gen 3 8Y represents further refinement of the second-generation trucks. Accordingly, BYD did not employ a lot of project-specific production in the initial truck builds. The exception was installation of the Cavotec charging inlet, which required working with Cavotec to design a solution similar to previous collaborative projects. Although information regarding some of the engineering changes to the third-generation yard tractors, such as the change from alternating current (AC) to direct current (DC) platform described in Section 3.2, was unfortunately communicated relatively late in the process (June 2020), BYD and Cavotec had a pre-existing partnership that enabled both teams to work together on a solution that would physically fit into and integrate into the Gen 3 8Y. For BYD, this work mostly required software integration and some modifications to the front curbside of the Gen 3 8Y's cab.

The three Gen 3 8Y yard tractors have identical functional capabilities and technical design specifications. Project identifiers are as follows:

- Unit ID# ET #318, VIN LA9TYG885M1LC0279, delivered June 2, 2021
- Unit ID# ET #319, VIN LA9TYG883M1LC0300, delivered July 23, 2021
- Unit ID# ET #320, VIN LA9TYG885M1LC0301, delivered August 27, 2021

The preliminary design and build specifications were combined with essential safety and functional requirements defined by industry standard practices, design and safety standards, and comprehensive safety reviews. Specifications for the Gen 3 8Y deployed for this project are provided in Table 4 and a list of compliance certifications are provided in Table 5.

Table 4: Gen 3 8Y Yard Tractor Specifications

Chassis	**BYD Gen 3 8Y**
Model Year	2021
Length	203.7
Width	101.6
Height	136.0
Wheelbase	118.1
Curb Weight	19,800 lbs.
GVWR	102,000 lbs.
Top Speed	32 mph
Max Gradeability	15 percent
Wheel Rim	22.5 x 8.25
Tires	11R22.5 16PR ** 11 inch wide radial tire with a 22.5 inch rim diameter and a 16 Ply Rating load capacity
Suspension	Front: Leaf Spring
Brakes	Front/Rear Air Drum Brakes
Max Power	241 horsepower
Max Torque	1,106 ft lbs.
Specified Battery Capacity	217 kWh
Charging	Cavotec: 40kW

Source: *BYD*

Table 5: Gen 3 8Y Yard Tractor Compliance Certifications

Federal Motor Vehicle Safety Standards	Standard Name
101	Controls and displays.
102	Transmission shift position sequence, starter interlock, and transmission braking effect.
103	Windshield defrosting and defogging systems.
104	Windshield wiping and washing systems.
106	Brake hoses.
108	Lamps, reflective devices, and associated equipment.
111	Rear visibility.
119	New pneumatic tires for motor vehicles with a GVWR of more than 4,536 kilograms (10,000 pounds), specialty tires, and tires for motorcycles.
120	Tire selection and rims and motor home/recreation vehicle trailer load carrying capacity information for motor vehicles with a GVWR of more than 4,536 kilograms (10,000 pounds).
121	Air brake systems.
124	Accelerator control systems.
125	Warning devices.
136	Electronic stability control systems for heavy vehicles.
205	Glazing materials.
207	Seating systems.
208	Occupant crash protection.
209	Seat belt assemblies.
210	Seat belt assembly anchorages.
302	Flammability of interior materials.

Source: *BYD*

Although BYD anticipated that the Gen 3 8Y would function sufficiently as designed, several modification and repairs were necessary before the yard tractors could be effectively deployed. Challenges with the AC/DC charging platform alterations, modifications to the funnel box housing, and the height differential in the charging funnel installation resulted in engineering redesigns for both the yard tractors and the SPS. The project partners worked together to overcome these challenges with the system integration. These challenges are detailed throughout this section.

BYD completed the integration of the funnel with the three yard tractors in June 2021. The first yard tractor underwent debugging and was delivered to Everport on June 2, 2021. Upon delivery, Everport requested modifications to the yard tractor, including installation of a headache rack and beaver tail. As a safety measure, all yard tractors operating at Everport are required to have a headache rack installed. Moreover, the modifications to the beaver tail are required to accommodate the lower trailer height used at Everport. BYD fabricated the headache racks and beaver tails at their Lancaster, CA facility; however, long lead times for procurement of materials needed for the modifications caused a delay in the completion and delivery of the remaining yard tractors to Everport.

In July 2021, Everport requested additional modifications to the yard tractors, including mirror adjustments and a louder backup signal. The second fully integrated and modified yard tractor, including the headache rack, beaver tail, and louder backup signal, was delivered to Everport on July 23, 2021. The mirror adjustment on the second yard tractor was completed at the end of August 2021. The fully integrated and modified yard tractors #ET 318 and #ET 320 were delivered to Everport on August 31, 2021 and August 27, 2021, respectively.

In September 2021, the yard tractors and the connection to the Cavotec SPS were tested onsite. Communication issues between the yard tractor and charging units were detected. In October 2021, BYD U.S. engineers, in conjunction with the BYD China team, resolved the communication issue by updating the software installed on the three yard tractors.

Everport requested further modification to the beaver tail installed in third quarter of 2021 to address issues with picking up chassis. BYD engineers completed the design for the modification. In November 2021, BYD procured the necessary raw materials and their fabrication team completed fabricating pieces for the modification. BYD transported one of the yard tractors to their Lancaster facility for modification on November 23, 2021. During the modification process, BYD also made improvements to the door to make it sturdier and painted the window mesh to prevent rust.

Upon validation testing, the yard tractor was delivered to Everport on December 20, 2021 and the second yard tractor was taken to BYD’s Lancaster facility for modifications. Everport tested the modified yard tractor with chassis of varying heights. Everport was not satisfied with the positioning of the beaver tail and requested further modifications from BYD. BYD met with Everport at the terminal on December 28, 2021 to review design specifications. To ensure that the strength of the beaver tail was not compromised, BYD reinforced the tail with additional materials.

The reinforcement materials requested from BYD China arrived to BYD’s Lancaster facility in January 2022. A shutdown of BYD’s Lancaster facility from January 17 to January 31, 2022, due to COVID-19, resulted in delays to complete the modification. During the facility shutdown, BYD engineers prepared an updated design for the beaver tail expected to minimize damage to the tail when detaching from a chassis. The first fully modified yard tractor was delivered to Everport on February 22, 2022 and was placed in service on February 23, 2022. The second and third fully modified yard tractors were delivered to Everport on March 8, 2022 and March 14, 2022, respectively. As of March 15, 2022, all three yard tractors were placed in service.

3.2 Infrastructure Overview

POLA Engineering produced design specifications for the infrastructure development project. POLA issued a competitive bid for infrastructure construction and SPS installation, which was awarded to Manson Construction. POLA Engineering and C&M worked closely with Manson Construction throughout the project.

This portion of the grant project focused largely on installation and utilization of the innovative Cavotec SPS. The core purpose of the SPS is to ensure safe and reliable charging connections. By utilizing remote connection, the system promotes greater safety, a key concern for terminal operations. Manual connection involves heavy equipment, power sources, and potential exposure to the elements, which may pose safety concerns to the gearmen. Another key function of the system is to ensure charging time is maximized. The unit plugs in to the yard tractor immediately upon arrival and disconnects at the last moment to ensure as much charge as possible while parked. This allows the operator to achieve more consistent charge levels and not be concerned with undercharging scenarios. Table 6 summarizes the technical specifications for the Cavotec SPS.

Table 6: Cavotec SPS Charger Specifications

Specification	**Details**
System Voltage (max):	1,000VAC
System Amperage (max):	250A
Power Cables / Plug Configuration (AC)	3ph + N + G + 2p ** Three-phase power + Neutral + Conductance + Single-phase 2-pole circuit breaker
Connection Time:	< 10s
Maximum Arm Reach:	1,000 millimeters (mm)
Operating Range:	200 – 750mm
Horizontal Compensation:	+/- 250mm
Vertical Compensation:	+/- 50mm

Source: *Cavotec*

The power interface for the BYD yard tractors was originally designed to meet Cavotec's 200 kW charging capacity on an AC platform. Due to the design change implemented by BYD China and described in Section 3.1, the charging platform for the BYD Gen 3 8Y yard tractor was altered to utilize higher kW capacity DC charging, with AC at a lower capability. The AC platform is generally used for high-power applications and long-distance power transmission, and is currently used by power plants and the electrical grid. The DC platform is better suited for storing power in batteries, which is the basis for BYD's change. Originally, this project was expected to benefit from previous collaboration between BYD and Cavotec on a similar project at the Port of Long Beach. For that project, both the chargers and the yard tractors utilized an AC platform. By the time the team was notified of BYD's platform change, Cavotec did not have the time to redesign their equipment to accommodate the DC platform. In order to interface with the Smart Plug-In System on the AC platform, the yard tractors were only able to accept a maximum 40 kW charge, which greatly increased charging time and limited the effectiveness of opportunity charging. POLA Engineering modified the infrastructure designs to accommodate the lower electrical output.

Additional challenges were presented regarding the height of the charging funnel and the extended footprint of the charging funnel box housing. Concerns regarding the adaptability of the charging interface between the Cavotec arm and the BYD funnel resulted in design modifications. Engineers at Cavotec and BYD collaborated to resolve these design and engineering issues.

On April 22, 2021, all three SPS units were delivered to Everport Terminal. One of the three SPS units was damaged in transit. All three units were inspected by a Cavotec technician, and the damaged charging unit underwent repairs at a Cavotec facility. The repaired unit was delivered to Everport Terminal on May 19, 2021.

The charging units underwent initial Underwriters Laboratories (UL) inspection in an unenergized state on June 16, 2021. The inspection resulted in a list of corrective actions that needed to be resolved prior to moving forward. The Cavotec team resolved all corrective items by mid-August 2021. The second UL inspection of the charging units to verify that all list items were corrected took place on August 26, 2021. At this second UL inspection, the inspector conducted a rain test to ensure that the charger housing had a watertight seal. During the rain test, the UL inspector noticed water droplets inside the human-machine interface (HMI) covers. As a result, the inspector requested the replacement of the gaskets on the inside of the HMI covers. Overall, the inspection resulted in the approval of the initial corrective actions and a second list of corrective items. At the follow-up UL inspection on September 1, 2021, the HMI covers passed the rain test, and all remaining corrective actions were approved by the UL inspector. With this approval from UL, the LADBS electrical inspector conditionally approved energizing the SPS units for the purpose of testing and UL inspection, which required the chargers to be in an energized state.

Cavotec completed software upgrades to the SPS and commissioned the charging units on September 14, 2021. Additionally, in order for the Cavotec Italy team to communicate remotely with the SPS, Cavotec temporarily set up a wireless fidelity hotspot and later installed subscriber identity module cards in each of the charging units. The WIFI connection ensured data communication between the chargers and the Cavotec engineers in Italy.

The engineering and construction teams worked together to install striping and signage near the charging units. These safety measures improved operator visibility of the designated locations to stop and park the yard tractors. Speed bumps were also installed to control access to the charging area.

In September 2021, Cavotec and BYD conducted internal testing of the SPS with the yard tractor. Communication issues between the charging units and yard tractors were detected. In October 2021, BYD U.S. engineers, in conjunction with the BYD China team, resolved the communication issues by updating the software installed on the three yard tractors. Communication testing following the BYD software upgrade revealed an error message displayed on the charging unit. Cavotec coordinated with BYD engineers on this issue. Cavotec technicians conducted mock charging tests and the issue was resolved on October 20, 2021.

On October 22, 2021, the UL inspector conducted an inspection of the charging units in an energized state. The chargers passed the UL inspection and were UL certified. The UL Field Evaluation Report was received on October 26, 2021 with a request from the UL inspector to revise the nameplates on the charging units with additional information. A copy of the complete UL Field Evaluation Report was emailed to the CAM on October 26, 2021. A permitting inspection was conducted on October 26, 2021, by the LADBS inspector. The LADBS inspector issued a list of corrective actions, including additional safety labels, updated nameplates, and revised UL Field Evaluation Report.

In November 2021, the Cavotec team addressed and resolved all corrective items. On November 16, 2021, Cavotec installed the required nameplates and safety labels. On November 18. 2021, the revised UL Field Evaluation Report was released to the LADBS inspector and project team. A copy of the revised UL Field Evaluation Report was emailed to the CAM on November 18, 2021. On November 29, 2021, the LADBS inspector conducted a second inspection, where the charging units passed inspection and were approved. LADBS issued partial approval of the electrical permit for the Cavotec charging systems, and a copy of the permit was emailed to the CAM on November 30, 2021. The partial approval allowed full operation of the Cavotec SPS, temporarily electrified as described below, and did not impact operations.

On December 16, 2021, Cavotec conducted training with Everport staff. The Cavotec technicians reviewed the charging stations operations and procedures with Everport staff. However, the technicians were unable to conduct a charging demonstration as the yard tractors could not be moved, due to depleted battery charge. A joint training session was held on January 25, 2022 where a charging demonstration was conducted. Subsequent training sessions for gearmen were held by Cavotec on May 9, 2022.

In April 2022, the Cavotec Italy team recommended the installation of an additional hardware communication device in each of the three charging units. The device was intended to serve as a more sophisticated method to gather data for analysis and was referred to as the Internet of Things (IOT) device. The IOT device was ordered and delivered to Cavotec's office in Europe, where it underwent various software installations and testing. The modules were then shipped to the U.S. and installed onto the three charging units on May 17, 2022.

POLA Engineering worked closely with Manson Construction on execution of the infrastructure development. The SPS units were installed in June 2021 and were anchored to the foundation in July 2021. POLA and Manson Construction engaged and coordinated with LADWP on providing permanent power to the site. As an interim solution for energizing the chargers, power was diverted from the EVSE from a previous CEC yard tractor demonstration. The temporary power connection to the chargers was completed on September 7, 2021. As of March 10, 2022, the chargers were switched to the new permanent power from the substation.

Completion of the infrastructure construction project was delayed by installation of the final electrical distribution equipment vault, which houses the transformer and switchgear, due to a resurgence in COVID-19 cases. The vault was surveyed on June 28, 2022. Vault installation was completed by August 23, 2022. Due to delays at LADBS, the final construction permit was issued on April 24, 2023 and submitted to the CAM.

3.3 In-Use Demonstration Experience

The first fully modified yard tractor was delivered to Everport on February 22, 2022 and was placed in service on February 23, 2022. The second and third fully modified yard tractors were delivered to Everport on March 8, 2022 and March 14, 2022, respectively. As of March 15, 2022, all three yard tractors were placed in service.

BYD and Cavotec collaborated on equipment commissioning and operator training. BYD and Cavotec conducted a successful joint training session on January 25, 2022. Yard tractor operators, terminal management, and mechanics were in attendance. BYD and Cavotec provided hard copy and electronic copy of the training materials.

3.3.1 Operational Experience

On April 27, 2022, Everport staff noticed that the brackets holding the funnel charging connection were broken on yard tractor #ET 319 and cracked on yard tractor #ET 320. Both units were removed from service. Cavotec determined that the brackets were manufactured by BYD. In May 2022, BYD's engineering team finalized a plan for the solution and acquired necessary materials from BYD China. Upon completed validation testing of the received materials on June 10, 2022, BYD determined that the shipment from China was missing some materials. On June 21, 2022, with all the needed materials in hand, BYD's fabrication team began fabricating the new design for the brackets. In June 2022, yard tractors #ET 319 and #ET 320 were transported from Everport to BYD's Lancaster facility to undergo repairs. Fabrication of the brackets was completed in mid-July 2022. At the end of July 2022, the repairs on yard tractor #ET 320 were completed. Yard tractor #ET 320 was delivered to Everport and placed into service in early August 2022. The repairs on yard tractor #ET 319 were completed in August, and the yard tractor was delivered to Everport in late August 2022. At the time of #ET 319 delivery, BYD picked up yard tractor #ET 318 for preemptive replacement of the brackets. #ET 318 was delivered to Everport on October 3, 2022. As of October 4, 2022, all three yard tractors were being utilized at the terminal.

On October 30, 2022, Everport reported an issue with the Cavotec truck side charge receiver, the pin would not engage. As a result, yard tractor #ET 319, unable to be charged, was removed from service. The pin required special materials for manufacturing, delaying acquisition of the part. Cavotec sent a technician to repair the pin on January 13, 2023. There were no additional repair issues.

3.3.2 Operator Surveys

Four Operator surveys and five Gearmen surveys were gathered in April 2023 towards the end of the demonstration period. Based on operator surveys, the responses were mostly positive, especially regarding the cab comfort and quite performance. Room for improvement was noted in regard to the lack of maneuverability. For the SPS chargers, the challenge noted was operational consistency related to the need to reengage the charging arm multiple times to initiate the charge. As expected, the Gearmen that indicated more frequent use of the SPS provided more positive feedback than those with less experience. Survey responses are presented as a compilation in Figures 9 and 10.

Figure 9: Compilation of Yard Tractor Operator Surveys

OPERATOR SURVEY – BYD Battery-Electric Yard Tractors – End of Demo Compilation

** If no answer was provided listed as N/A

Duty Cycle Assignment: Ship Rail Yard **3** N/A **1**

How does the EV Unit compare to a Diesel unit? (check one)	Much Better	Better	Same	Worse	Much Worse	Does Not Apply	Comments/Notes (use back to expand notes)
Cab Entry and Exit	2	2					
Inside Cab Noise Level		3	1				
Outside Noise Level	1	1	2				
Heating and A/C System (cabin air comfort, odor, breathing comfort)	3	1					
In-Cab Controls (function and access to switches/controls)	1	3					
In-Cab Visibility (blind spots, rear view)	1	3					
Maneuverability		1	1	2			□ Machine is wider □ Wide turns
Connection to Container		2	2				□ Fan tail too wide
Acceleration with No Container	2	2					
Acceleration with Container	1	2	1				
Pulling Power with Full Container	2	2					
Smoothness of Shifting During Acceleration	1	3					
Braking (quickly/smoothly stops load)		4					
Ride Comfort (seat, vibration, shocks, etc.)	1	3					
Overall Unit Rating	1	3					

How many times have you operated the EV yard tractors? 1-3 = **1;** 4-7 = **1;** 8-10 = **1 ;** 10 or more = **1**

Did you experience any unusual incident or safety issue?

- □ Difficult to park with wide cab

Do you have additional feedback you wish to provide about this clean emissions demonstration equipment?

- □ None

Credit: *Everport Terminal Services*

Figure 10: Compilation of SPS Gearmen Surveys

Cavotec SPS Charging Gear Survey – End of Demo Compilation

** If no answer was provided listed as N/A

How many times have you used the Cavotec Smart Plug-In System (SPS) to charge the yard tractors?
1-3 **(1 Gearmen)** 8-10 **(1 Gearmen)** more than 10 **(3 Gearmen)**

Have you used other electric vehicle charging systems, such as standard plug-in (CCS-1)?
Yes - **2** No - **3**

If yes, how did the SPS compare overall to other electric vehicle charging systems?
Much Better Better About the Same - **1** Worse Much Worse
N/A – **4**

Did you experience any unusual incident or safety issue with the SPS?
Yes No – **1** N/A - **4**

If yes, please explain: ____

____

Please, rate the following from 1 to 5 by circling the number (1 is the lowest and 5 is the best).

Easy to use	1	2 - **1**	3 - **1**	4 - **3**	5
Easy to connect	1	2 - **1**	3 - **1**	4 - **1**	5 - **2**
Simple instructions	1	2	3 - **2**	4 - **1**	5 - **2**
Efficient charging	1	2	3	4 - **4**	5 - **1**
Operational consistency	1 - **3**	2	3	4 - **2**	5

Do you have any additional feedback about the clean emissions demonstration equipment?

- Chargers working more often

Credit: *Everport Terminal Services*

3.4 Data Collection and Analysis

Data collection for the Cavotec SPS and the next generation BYD yard tractors commenced upon commissioning of the first yard tractor in late-February 2022. The SPS contains an internal data collection system and GeoTab data loggers were pre-installed on the yard tractors. In March 2022, tests were conducted to ensure collection of the necessary data.

In March and April 2022, BYD shared raw data from the GeoTab loggers, confirming that data were collected and that #ET 318, #ET 319, and #ET 320 were utilized. As detailed under section 3.3.1, two of the yard tractors (#ET 319 and #ET 320) were taken out of service for repairs on April 27, 2022. Additionally, unit #ET 318 lost connection with the logging device for 27 days. BYD submitted an internal request to troubleshoot the issue, which was resolved on May 23, 2022. The data collected for April 2022 revealed challenges that were addressed in the subsequent months. BYD's attempt to format and analyze the data highlighted several issues, indicating that some expected data may not be accessible through the GeoTab loggers. Further complicating matters, a BYD team member contracted COVID-19 the last half of May 2022, returned to work in early June 2022, and had a serious relapse in late June 2022. The team collaboratively tackled several challenges with the data in May and June 2022 and continued refining in July and August 2022, to determine any lacuna between the data and the Data Collection Test Plan. The team worked directly with GeoTab to resolve data collection challenges.

SPS data were received in a file download with unconverted second-by-second data for March 2022. Cavotec agreed to format the data into comprehensive information, as outlined for the charging mechanism in the project's Data Collection Test Plan. This involved purchasing three pieces of communication hardware, IOT IPC (Internet of Things Inter Process Communications), which were installed on May 17, 2022. Charger data from March 15, 2022 to IOT IPC installation were rendered inaccessible, so the project team and the CAM agreed to start the demonstration clock on May 17, 2022.

Due to charging equipment wireless fidelity connectivity issues, data transmission was interrupted in mid-February 2023 and reestablished in May. POLA Engineering worked with the Cavotec team to provide a data download for the months of February, March, April, and May. All data were retrieved. The SPS chargers continued to function properly.

As of the end of May, based on data from the GeoTab loggers, the yard tractors operated a cumulative total of 1,273 hours from March 2022 through May 2023. Yard tractor #ET 318 logged a total of 541 hours. #ET 319 logged a total of 212 hours. #ET 320 totals 520 hours. Based on data from the yard tractor hour meters, the yard tractors operated a cumulative total of 1,466 hours through May 2023. Unit #ET 318 accumulated a total of 645 hours. #ET 319 indicates a total of 282 hours. #ET 320 totals 539 hours. These total hours differ from data logger demonstration hours and are representative of the overall operational equipment time, including testing and commissioning activities, which aids in understanding overall performance metrics.

3.4.1 Battery-Electric Yard Tractor Key Specifications and Duty Cycle

The project objective was to demonstrate advanced technology yard tractors that would perform identically to a typical diesel-powered yard tractor. The range, lifting capacity, and maximum speed requirements were the same as a comparable diesel-powered terminal tractor. The battery-electric yard tractors, as well as future vehicle acquisitions, are expected to match the operational standards of the diesel-powered counterpart, capable of completing two shifts and meeting equivalent performance metrics. Specifically, the following minimum duty cycle performance metrics were targeted:

- One 8-hour shift (no opportunity charging/fueling assumed)
- Two 8-hour shifts with opportunity charging/fueling
- 70,000 freight load capacity (loaded container plus chassis)
- 25 mph at 0 percent grade
- Gradeability at vehicle launch: 20 percent grade at 81,000 GCW
- Gradeability at vehicle launch: 15 percent grade at 81,000 GCW

3.4.2 Equipment Operation

The yard tractors averaged 488 hours of zero-emission operation during the demonstration and additional hours logged, with the fleet accruing 1,466 total hours. Monthly operation is documented below in Table 7. Due to challenges documented throughout Chapter 3, the equipment operated for several months prior to beginning the 12-month demonstration. Table 9 indicates monthly hours of operation, as recorded by the GeoTab data loggers installed on each yard tractor. Additional hours are registered on the hour meters and assumed to be from factory testing and validation, and pre-demonstration operation.

Table 7: Zero-Emission Yard Tractor Operation (Hours/Month)

Month, Year	Unit 318	Unit 319	Unit 320	Total Monthly Hours
Additional Hours	224	151	144	519
June, 2022	50	0	0	50
July, 2022	146	0	0	146
August, 2022	47	3	112	162
September, 2022	10	1	97	108
October, 2022	6	19	40	65
November, 2022	30	0	6	36
December, 2022	18	0	19	37
January, 2023	66	29	39	134
February, 2023	36	28	35	99
March, 2023	1	11	8	20
April 2023	11	33	28	72
May, 2023	0	7	11	18
Total:	645	282	539	1,466

Source: *Port of Los Angeles*

Table 8 summarizes operational data from the Cavotec SPS units. Note: May 2022 is a partial month beginning May 17th.

Table 8: Cavotec SPS Energy Provided (kWh/month)

Month, Year	Total Number of Charges	Total Charge Time (minutes)	Total Energy Transfer (kWh)
May, 2022 (partial month)	9	891	169
June, 2022	9	1,253	285
July, 2022	15	1,385	314
August, 2022	39	3,741	849
September, 2022	35	2,732	601
October, 2022	23	1,676	380
November, 2022	6	673	154
December, 2022	12	1,230	280
January, 2023	29	2,921	645
February, 2023	32	2,940	647
March, 2023	20	2,230	447
April 2023	7	1,720	234
May, 2023	13	1,324	301
Total:	249	24,716	5,306
Average:	19	1,901	408

Source: *Port of Los Angeles*

3.4.3 Petroleum Fuel Displaced

As noted in Section 2.4.3, Everport does not track diesel fuel consumption for each unit in their fleet on an individual basis because diesel fuel is purchased in large bulk orders to supply its CHE fleet's wet-hose fuel truck. The wet-hose truck drives around the terminal to fuel the parked equipment, instead of the equipment driving individually to a fueling station. In order to estimate the diesel fuel displacement for the zero-emission yard tractor demonstration, the CO_2e emissions from the Port of Los Angeles 2015 Inventory of Air Emissions were used to back-calculate the reduction in diesel fuel consumption from the top handlers. The project team estimates that a total of 22,641 diesel gallons would have been reduced based on the 4,500 operational hours that were projected for the 12-month demonstration. As a result of the reduced operation experienced in this project and documented above, actual hours of operation totaled 1,466 for the three yard tractors, resulting in an estimated diesel fuel consumption reduction of 7,376 diesel gallons. Table 9 provides step-by-step documentation of this back-calculation methodology.

Table 9: Yard Tractor Diesel Fuel Displacement Calculation

Calculation Step	Value	Units
Diesel yard tractor fleet (813 units @ 1,752 hours each) total annual CO_2e metric tonnes per POLA 2015 Emissions Inventory[9], Tables 5.1 & 5.6	73,011	metric tonnes/year
Convert to short tons CO_2e (1 short ton = 0.907185 metric tonnes)	80,481	tons/year
Calculate tons CO_2e per hour (divide total tons by 813 units and 1,752 hours)	0.0565	tons/hour of diesel operation
Convert to pounds per hour (multiply by 2,000 pounds per ton)	113	pounds/hour of diesel operation
Apply CO_2e Emissions Coefficient for diesel[10] (22.46 pounds of CO_2e per gallon of diesel) to calculate the gallons per hour of a baseline diesel yard tractor.	5.03	diesel gallons/hour
Multiply gal/hr by 1,466 total yard tractor hours of operation to estimate the reduction in diesel fuel consumption for the demonstration from the operation of three BYD yard tractors.	**7,376**	**diesel gallons displaced**

Source: *Port of Los Angeles*

[9] 2015 Port of Los Angeles Air Emissions Inventory, Tables 5.1 & 5.6: https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

[10] Energy Information Agency, Carbon Dioxide Coefficients, Release Date September 16, 2021. https://www.eia.gov/environment/emissions/co2_vol_mass.php

3.4.4 Criteria Pollutant and Greenhouse Gas Emissions Reduced

Table 10 presents the projected and actual GHG and air pollutant emission reductions, including CO_2e, DPM, NO_x and HC emissions. The projected emission reductions were provided in the original GFO application and based on a total of 4,500 hours of operation using emissions reported in POLA's 2015 Emissions Inventory. The actual demonstration emissions reduction estimates are based on 1,466 hours of zero-emission yard tractor operation from the time the units were commissioned through May 2023, and they are about 67 percent below projections due to the reduced operation achieved during the demonstration.

Table 10: GHG and Criteria Pollutant Emission Reductions for the Yard Tractors

Scenario	CO_2e (metric tonnes)	DPM (tons)	NO_x (tons)	HC (tons)
Originally projected emission reductions (based on 4,500 hours of operation)	230	0.005	0.543	0.035
Estimated emission reductions based on actual hours of operation (1,466 hours)	75	0.0016	0.1769	0.0114

Source: *Port of Los Angeles*

3.4.5 Energy Efficiency Measures

There are no energy efficiency measures used in the facility that may exceed Title 24 standards in Part 6 of the California Code Regulations.

3.4.6 Job Creation and Economic Development

Job creation and economic development were estimated for the demonstration project itself and for the State's broader transition to zero-emission terminal equipment. The following metrics were used:

- Jobs created
- Employment income effects
- Increased local and State sales tax revenues
- Macroeconomic impacts

To estimate jobs created for this demonstration project, Everport tracked the specific labor assigned to the demonstration equipment, and BYD tracked manufacturing/engineering jobs.

For Everport, the job counts provided are based on individual union employees that were hired for a single shift. Jobs at the Everport site can consist of a single, 1-day shift or run for multiple consecutive days. The yard tractor demonstration required approximately 212 individual jobs/shifts. The number of yard tractors can dramatically change on a day-to-day and shift-to-shift basis. Some days there may be no labor working at all, and, on other days, Everport may employ 120-150 yard tractors over the course of two shifts. It is not anticipated there will be job growth as a direct result of this demonstration. This is due to space restrictions on the terminals and the assumption that Everport is currently operating at capacity. If there is an opportunity to add new units to the fleet, then job growth to operate additional zero-emission units would be possible.

For the demonstration, there were no observed employment income effects. Of course, as the transition to a zero-emission fleet continues, the skill set required by the maintenance and operations staff at the terminal will grow beyond that required for internal combustion engine-equipped units, with staff gaining experience with electric powertrain technology, EVSE, etc. Even if the number of jobs does not increase, the skill and experience of the staff will expand well beyond today's diesel engine to ensure effective zero-emission fleet operation.

For design, manufacturing, and aftermarket support of the zero-emission yard tractors, BYD added one dedicated engineer, one manager, one aftermarket support specialist, and one additional position to the electric vehicle team. These new positions were located at BYD's Lancaster, California factory. Additionally, they plan to add one more dedicated engineer, one manager, one aftermarket support specialist, and one additional position to accommodate anticipated market expansion. BYD's additions to the EV team:

- One (1) Engineer position
- One (1) EV Manager position
- One (1) EV Specialist (aftermarket support) position
- One (1) EV position

For future design and manufacturing of the zero-emission yard tractors, BYD's planned additions to the EV team:

- One (1) Engineer position
- One (1) EV Manager position
- One (1) EV Specialist (aftermarket support) position
- One (1) EV position

No sales tax was paid for the demonstration equipment.

Due to the small nature of the demonstration, macroeconomic effects were not expected nor observed.

It becomes more difficult to quantify the impacts of a Statewide transition to zero-emission terminal equipment without conducting a fairly rigorous economic analysis. Thus, this report relies on published studies and comparable analyses of zero-emission heavy-duty drayage trucks.

Overall, the transition to zero-emission terminal equipment is not expected to result in a significant change in the number of permanent jobs. The California Air Resources Board found that employment effects for a required transition to zero-emission drayage trucks would not exceed 0.2 percent of baseline California employment across the entire regulatory horizon.[11] Some sectors, such as petroleum and coal products manufacturing and natural gas distribution, saw significant job losses (-2 percent to -4 percent), but these losses were offset

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[11] California Air Resources Board, "Original Standard Regulatory Impact Assessment (SRIA) Submitted to Department of Finance for the Advanced Clean Fleets Regulation," 2022.

by gains in sectors such as electric power generation, transmission and distribution (nearly 7 percent increase in jobs). The overall predicted impact was -0.15 percent change in California employment. Similar effects, although smaller in magnitude, are expected for a transition to zero-emission terminal equipment as electricity replaces diesel as a primary fuel.

Although there is no anticipated change in the number of permanent jobs, the transition to zero-emission terminal equipment is expected to generate temporary construction jobs from building electric-charging infrastructure. The Ports previously estimated that terminal-related infrastructure could result in 21,650 temporary construction jobs at the San Pedro Bay complex, which is the State's largest port complex.[12] Similar projects at other California ports would add modestly to this number.

Despite minimal change in job growth, a shift to zero-emission terminal equipment could result in higher quality jobs with positive employment income effects. As noted in the Port's previous analysis of workforce impacts: "…the existing workforce will acquire the necessary skills to operate and maintain this equipment as has been the case during previous introductions of new technologies, such as shore power and diesel engine retrofits. This shift would not require additional labor, only different skills for that labor. A more highly skilled workforce could result in more highly paid workers, which would impose additional costs on employers but generate positive economic effects for the workers."[13]

Significant new purchases of zero-emission equipment are expected to increase local sales tax revenue due to higher prices (two to three times more expensive than diesel today).[14]

In terms of macroeconomic effects, the transition to zero-emission terminal equipment is expected to be similar to, but smaller in magnitude than those predicted for zero-emission drayage trucks. CARB found negligible change in Gross State Product as a result of a full transition to zero-emission drayage. GSP is the market value of all goods and services produced in California and is one of the primary indicators of economic growth. It is calculated as the sum of the dollar value of consumption, investment, net exports, and government spending. Similar to zero-emission trucks, zero-emission terminal equipment is expected to have a negligible impact on GSP: "The results trend negative, as the decrease in consumer and government spending in California would outweigh the increase in investment resulting from the proposed regulation."[15]

3.4.7 Alternative Fuel and Renewable Energy Use at Everport

The Port of Los Angeles' electrical power is provided by the LADWP. According to LADWP's Power Content Label for 2021, 35.2 percent of the utility's power was from eligible renewable sources. Solar provided 14.3 percent, wind and geothermal provide a combined 20.3 percent with hydroelectric and biomass/biowaste covering the balance. Any growth in the renewable energy content of Everport's electricity is solely dependent on LADWP's ongoing efforts to increase its renewable energy content.

In addition to the renewable energy content of the electricity consumed by Everport, the terminal also operates 22-yard tractors that are fueled with liquefied natural gas provided by Clean Energy Fuels. This fuel is Clean Energy's REDEEM, 100 percent renewable.

[12] San Pedro Bay Ports, "Economic and Workforce Considerations for the Clean Air Action Plan Update," 2017.
[13] Ibid.
[14] California Air Resources Board SRIA, 2022
[15] California Air Resources Board SRIA, 2022

3.4.8 Carbon Intensity Estimate

California's Low Carbon Fuel Standard (LCFS) regulation[16] provides the benchmark for the average diesel fuel carbon intensity of 90.41 g CO_2e/MJ for the year 2021. This year was selected as the benchmark because the demonstration of the next generation yard tractors was conducted a majority of the time during 2022.

Per CARB's grid electricity pathway ELC000L00072021[17], the current certified carbon intensity for grid electricity is 75.93 gCO_2e/MJ. This is a 16 percent reduction in carbon intensity for this project's zero-emission cargo handling equipment. As California's electricity grid increases its renewable fuel source mix, the use of zero-emission port terminal equipment will continue to improve (i.e., lower) its carbon intensity.

[16] https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf, Table 2: LCFS Carbon Intensity Benchmarks for 2011 to 2030 for Diesel Fuel and Fuels Used as a Substitute for Diesel Fuel. (accessed October, 2021)

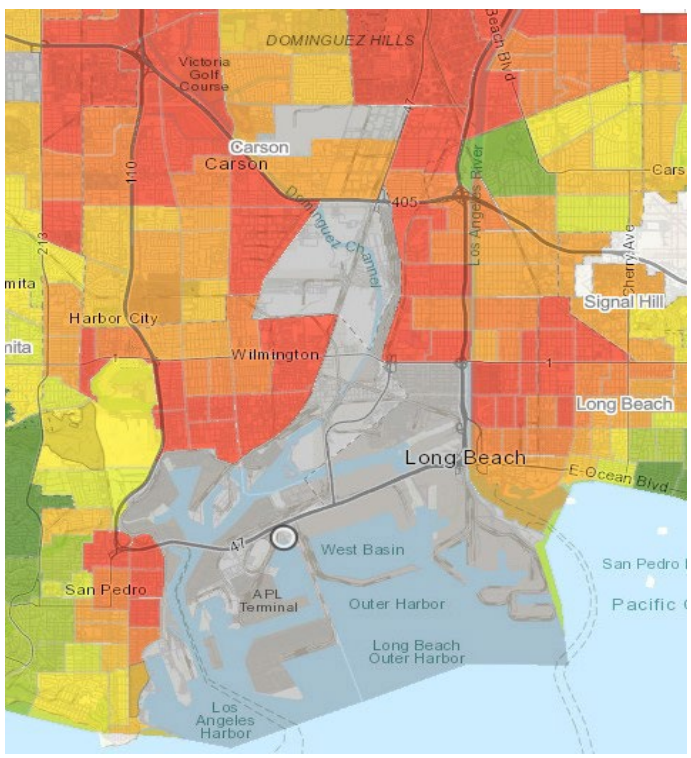
[17] Per the excel database link titled "Current Fuel Pathways", found at https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities (accessed October, 2021)

CHAPTER 4: Findings and Recommendations

4.1 Summary of Results

Overall, the project had a positive health impact by helping to reduce harmful diesel emissions at the Port and the surrounding local community. The zero-emission CHE performed similar duties to diesel equipment already routinely utilized at the Everport terminal, resulting in a net emissions reduction at the Port, which benefits adjacent neighboring communities. Further, the emission reduction benefits of this project have a direct positive impact on the Everport terminal employees and adjacent neighbors. According to the Office of Environmental Health Hazard Assessment's CalEnviroScreen4.0[18] tool, the communities closest to the Port have the highest (i.e., worst) cumulative impacts, or exposure, from all pollution sources in the geographic area. Using this tool, geographic areas are "scored" using a combination of pollution indicators such as ozone and PM2.5 concentrations, traffic density, drinking water quality, etc. and sensitivity or vulnerability of a population to the effects of the local pollution. High scoring communities are indicated by color shading from red (worst) to green (best); the worst communities are designated as the most adversely impacted disadvantaged communities. Figure 11 depicts the ports of Los Angeles and Long Beach and the surrounding communities. Port property is shown in gray, since there is no population residing on the port property.

Figure 11: CalEnviroScreen4.0 Results for Port of Los Angeles Geographic Area



Source: *CalEnviroScreen3.0, California Office of Environmental Health Hazard Assessment*

[18] https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

4.1.1 Top Handler Demonstration

The project team considers the Taylor top handler demonstration a success based on the important design and operation lessons learned throughout the demonstration. The most important project outcome is that Everport took over title of the demonstration equipment and continues to operate the zero-emission top handlers in regular revenue service while the key issue of concern continues to be resolved (i.e., need to be able to move a disabled unit to the maintenance facility when the battery system is "down"). Notwithstanding that issue, the demonstration units worked side-by-side with conventional diesel-fueled models, completing the demanding duty cycle requirements of a port terminal operation. As discussed in Section 2.4, the following direct benefits accrued from the demonstration of zero-emission top handlers for 2,512 hours are estimated below. Note that emission and fuel consumption reductions estimates reflect that the demonstration hours accrued by the top handlers were approximately 50 percent below projections for reasons addressed in Section 2.3.1.

- Reduction in diesel fuel consumption of 26,802 diesel gallon equivalents (DGE)
- Reduction of 301 metric tonnes of CO_2e
- Reduction of 0.011 tons, or 22 pounds of DPM
- Reduction of 2.27 tons of NO_x
- Reduction of 0.14 tons of HC

In addition to the above direct benefits, Everport gained valuable experience from its participation in this demonstration, including:

- Gearmen and operators that worked 296 shifts with the zero-emission top handlers in regular port terminal operation, gaining critical experience in both the operation and maintenance of the all-electric CHE as well as the EVSE infrastructure to support the equipment.
- Everport now has experience with this new zero-emission technology from an OEM and the high quality of this Taylor advanced technology equipment.
- The understanding that as the zero-emission fleet grows, Everport's staff and union labor will need to monitor the charge on the units to ensure uninterrupted operations.
- Mechanics will need additional training to overcome temporary breakdowns/failures when the units are no longer supported by the demonstration team.

The Taylor top handlers successfully demonstrated their ability to operate in a demanding terminal environment, although the project did not prove the concept of a consistent two full work shift capable battery system. During this demonstration, the team learned that opportunity charging was not able to be easily implemented at the terminals. The project team assumed during the design phase that opportunity charging at breaks and lunch would supply the extra power boost for longevity of battery charge. As is now understood, due to regulations, this is not possible at the terminals unless a truly hands-free system, such as inductive charging, is employed. It is likely that future models will prove capable of meeting the average duty cycle of two-full work shifts once the battery system and EVSE challenges are rectified.

Additionally, the project revealed heavy duty cycles for terminal operations which require more energy than can be provided in a single charge. This additional energy requirement in the heaviest duty cycles will require extended run times provided through several options. The options include: 1) higher system efficiencies to provide longer operating time using the same total stored energy; 2) higher efficiencies to provide more work with less total energy; and 3) the consideration of modular stored energy to allow the matching of the appropriate stored energy to minimize cost.

Additionally, infrastructure remains as the consideration with the highest impact on operations. BEV equipment and the fundamental differences from liquid fuels in delivery, storage, and refueling will require an iterative infrastructure development process. This is true due to the scale of both expense and total energy required. Taylor continues to investigate and offer creative charging solutions using single point charging for flexibility, multi-point charging for cost effectiveness, and energy storage solutions. Logistics, labor considerations, maintenance, and installation permanence are all challenges which will require continuous development.

Based on Everport's experience with this demonstration project, the company is actively considering the purchase of additional Taylor battery-electric top handlers and EVSE compatible CHE. Although the incremental cost of zero-emission equipment over diesel counterparts remains high at this time, incentive programs increase the affordability of adding zero-emission equipment to the fleet. The cost of infrastructure continues to be another hurdle which could benefit from incentive assistance. As recognized on this project and others, infrastructure development costs often exceed initial estimates.

4.1.2 Advanced Battery-Electric Yard Tractor Demonstration

The project team found the BYD demonstration to be very challenging, due to the many issues that arose during the demonstration, as discussed in detail in Chapter 3. However, the team still believes the project was a success based on the important lessons learned throughout the demonstration. The most important project outcome is continued product improvement towards developing battery-electric yard tractors capable of meeting the rigorous demands of marine terminal operations. Notwithstanding the issues encountered, when operational, the units worked side-by-side with conventional diesel-fueled models, with the demanding requirements of a port terminal operation.

As discussed in Section 3.4, the following direct benefits accrued from the demonstration of zero-emission yard tractors for 1,466 hours are estimated below. Note that emission and fuel consumption reduction estimates reflect that the demonstration hours accrued by the yard tractors were approximately 67 percent below projections for reasons addressed in Chapter 3. Additionally, Everport's diesel fleet consists of on-road engines rated at Tier 4 or better. As baseline engines become cleaner, emissions reduction amounts become smaller, even when transitioning to zero-emission equipment. Cleaning up the last few tons of emissions will have a higher cost effectiveness.

- Reduction in diesel fuel consumption of 7,376 DGE
- Reduction of 75 metric tonnes of CO_2e
- Reduction of 0.0016 tons, or 3.2 pounds of DPM
- Reduction of 0.1769 tons of NO_x
- Reduction of 0.0114 tons of HC

In addition to the above direct benefits, Everport gained valuable experience from its participation in this demonstration, including:

- Gearmen and operators that worked approximately 212 shifts with the zero-emission yard tractors in regular port terminal operation, gaining critical experience in both the operation and maintenance of the all-electric CHE, as well as the innovative Cavotec SPS infrastructure.

- Everport now has experience with a simplified and safer charging system potentially capable of opportunity charging.
- The understanding that as the zero-emission fleet grows, Everport's staff and union labor will need to monitor the charge on the units to ensure uninterrupted operations.
- The knowledge that Everport will need to explore ways to encourage staff to utilize the advanced technology equipment.
- Mechanics will need additional training to overcome temporary breakdowns/failures on zero-emission CHE once OEM warranties expire.

The BYD yard tractors demonstrated their ability to operate in a demanding terminal environment, although the project did not prove the concept of a consistent two full work shift capable battery system. During this demonstration, the team learned that opportunity charging was not able to be easily implemented due to the power limits required by the BYD design changes (i.e., the 40 kW charge limit). The project team assumed during the design phase that opportunity charging at breaks and lunch would supply the extra power boost for longevity of battery charge. As is now understood, due to regulations, this is not possible at the terminals unless a truly hands-free system, such as inductive charging, is employed. It is likely that future models will prove capable of meeting the average duty cycle of two-full work shifts once the battery system and EVSE challenges are rectified. Everport plans to continue utilizing the project equipment in daily operations beyond the demonstration period.

4.1.3 Energy Cost Discussion

<u>Top Handlers</u>
According to Everport's 2020 and 2021 diesel fuel purchase records, the average price paid for diesel was $2.02 per gallon and $2.80 per gallon, respectively. The weighted average for diesel fuel purchased during the top handler demonstration was $2.69 per gallon.

The Taylor zero-emission top handler demonstration offset 26,802 diesel gallons (Table 2) that were not purchased/consumed as a result of this project. Had the demonstration equipment operated on diesel fuel instead of the electric power, Everport would have spent $72,097 on diesel fuel. Also, per Table 2, the average fuel consumption for the conventional diesel-fueled top handler fleet is 10.67 diesel gallons per hour. At $2.69 per gallon, the baseline fleet fuel cost would have been $28.70 per operating hour. Unfortunately, the top handler charging units were not independently metered, so Everport was unable to track electric power provided to the top handlers. However, based on the analysis of the yard tractor data presented below, it is reasonable to project that the electricity cost of the top handlers was well below the cost to do the same work with diesel fueled top handlers - especially during the demonstration when diesel fuel prices were on the lower end.

<u>Yard Tractors</u>
According to Everport's 2022-2023 diesel fuel purchase records during the demonstration period, the average price paid for diesel was $3.91 per gallon. During the year, the price ranged from a high of $5.22 to a low of $2.91. For the purpose of this cost comparison, $3.91 per gallon was used to estimate diesel fuel costs during this demonstration.

The BYD zero-emission advanced yard tractor demonstration offset 7,376 diesel gallons (Table 9) that were not purchased/consumed as a result of this project. Had the demonstration equipment operated on diesel fuel instead of the electric power, Everport would have spent $28,840 on diesel fuel. Also, per Table 9, the average fuel consumption for the conventional diesel-fueled yard tractor fleet is 5.03 diesel gallons per hour. At $3.91 per gallon, the baseline fleet fuel cost would have been $19.67 per operating hour.

For the yard tractor demonstration, the Cavotec system was tracking charging individually to each unit, allowing the team to estimate the electricity costs to power the BYD yard tractors with the Cavotec system. Everport electric utility costs indicate an average of $0.23 per kWh of electricity purchased to power the Cavotec SPS. Per Table 8, 5,306 kWh of electricity were consumed during the limited battery-electric yard tractor demonstration, for a total estimated cost of $1,220 or $0.83 per operating hour, well below the cost of diesel yard tractor operation.

4.2 Lessons Learned

Overall, the project team learned a number of valuable lessons from this demonstration. First and foremost is not to underestimate the time needed to secure permit approvals and electrical component certifications (i.e., UL Certification).

- Field certification of infrastructure may be a time-consuming process. If possible, factory certify eligible components.
- Equipment utilizing proprietary charging does not provide flexibility over time. The movement towards standardized charging is essential to equipment integration for continued operational use.
- OEMs familiar with producing equipment utilized in terminal operations are generally better prepared to produce advanced technology equipment for terminal operations.
- Appropriately integrated data collection tools provide more reliable robust data than gearmen tasked with manually reporting data, which is outside of their normal duties.

4.2.1 Top Handler Demonstration

The Taylor top handlers were successfully integrated into Everport's fleet, accruing increased operating hours once the infrastructure issues were resolved and as experience was gained. Compared to the expectation that the units would accrue operational hours at the level of their diesel counterparts (~2,250 hours/year), the zero-emission demonstration units fell short at 1,256, on average. Reasons for this include:

- Challenges with the EVSE and battery system (detailed in Section 2.3.1)
- Challenges with infrastructure installation and grid capacity
- COVID-19 pandemic restrictions and operating protocols

Considerations for next-generation equipment and infrastructure include:

- CHE duty cycles will require more energy and extended run times
    - Higher system efficiencies to provide longer operating time using the same total stored energy are required.
    - Higher efficiencies to provide more work with less total energy are needed.
    - Consideration of modular stored energy to allow matching of the appropriate stored energy to minimize cost by using stored energy during times of peak utility rates.

- Infrastructure remains the consideration with the highest impact on operations. Specifically, the following infrastructure issues should be addressed in order to optimize zero-emission CHE operation:
  - Expense and total energy required
    - Existing power at the terminals is insufficient to handle a full conversion to battery-electric CHE
    - Pulling power to the sites is time consuming, expensive, and impacts the flow of terminal operations
  - Charging flexibility, cost effectiveness, and energy storage solutions
    - Peak-shaving battery storage systems are currently being tested as components of demonstration projects at other terminals
  - Logistics, labor considerations, maintenance, and installation permanence.

Overall, the Taylor zero-emission top handler demonstration is considered by the project team to be a meaningful success, providing Everport with real-world operating experience that shows zero-emission CHE has the potential to operate in a rigorous port operating environment.

4.2.2 Advanced Battery-Electric Yard Tractor Demonstration

The BYD yard tractors were challenging to integrate into Everport's fleet and experienced decreased operating hours as the demonstration progressed. Compared to the expectation that the units would accrue operational hours at the level of their diesel counterparts (~4,500 hours/year), the zero-emission demonstration units fell short at 1,466. Reasons for this include:

- COVID-19 pandemic restrictions and operating protocols.
- Challenges with yard tractor repairs and modifications.
- Initial operator hesitancy, due to ongoing equipment design changes, needed to assure operator safety.

Considerations for next-generation equipment and infrastructure include:

- CHE duty cycles will require more energy and extended run times.
  - Higher system efficiencies to provide longer operating time using the same total stored energy are required.
  - Higher efficiencies to provide more work with less total energy are needed.
  - Consideration of modular stored energy to allow matching of the appropriate stored energy to minimize cost by using stored energy during times of peak utility rates.
- Equipment safety modifications to meet the rigorous demands at the terminal.
  - Battery protection to prevent possible "thermal events."
  - Door and window safety modifications.
- Infrastructure remains the consideration with the highest impact on operations. Specifically, the following infrastructure issues should be addressed in order to optimize zero-emission CHE operation:
  - Expense and total energy required

        - Existing power at the terminals is insufficient to handle a full conversion to battery-electric CHE.
        - Pulling power to the sites is time consuming, expensive, and impacts the flow of terminal operations.
    - Charging flexibility, cost effectiveness, and energy storage solutions.
        - Peak-shaving battery storage systems are currently being tested as components of demonstration projects at other terminals.
    - Logistics, labor considerations, maintenance, and installation permanence.

Although BYD had challenges collaborating with Cavotec during initial stages of the project and neglected to communicate fundamental changes to the charging platform, both OEMs eventually devised a solution to keep the demonstration project moving forward. An important lesson learned by project management was to implement weekly team meetings to hold project partners accountable for designated tasks, especially during early stages of the project. Once established, regular weekly meetings enabled the flow of communication and collaboration.

It is important for the terminal to address employee concerns surrounding electrification. Informational and safety training sessions were implemented as an important part of this project, to familiarize operators with the equipment and review safety protocols. Training is challenging to accomplish with casual workers, who may only be onsite for a single day, limiting the number of operators qualified to drive the equipment. Additionally, many terminal workers are uneasy about electrification, equating it with automation and loss of employment. Addressing these issues and finding practical resolutions is critical to the success of technology advancement.

Overall, the BYD zero-emission yard tractor and SPS charging demonstration is considered by the project team to be a meaningful success, providing Everport with real-world operating experience that shows zero-emission CHE and innovative charging technology has the potential to operate in a rigorous port operating environment.

4.3 Significant Challenges

During initial stages of the project, the team considered the most challenging aspect to be third-party certification of the various electrical components and systems associated with the BYD chargers, as detailed in Section 2.3. The challenging certification process resulted in equipment demonstration delays of nearly eight months.

Intermittent functional issues with the EVSE continued throughout 2020 and 2021, resulting in lower than anticipated operational hours for the top handlers. With only one functional charge cable, the top handlers took up to 12 hours to reach a full charge, impacting operating cycles. Battery system failures including the on-board charger, drive motor controller, tripping the main breaker, and software interface issues continued to require maintenance and repairs throughout the demonstration, as detailed in Section 2.3.1.

Additionally, a key design concern identified by Everport involves a battery system shutdown. When the top handler battery system fails, the equipment is rendered immobile and unable to be moved to the mechanic’s shop. In the case of Unit #TH230, this occurred for two weeks, impeding the flow of terminal operations at the rail yard. Two similar incidents happened during the demonstration. The impact to terminal operations is not acceptable to Everport and was a valuable lesson learned for Taylor's future design generations. A potential resolution for the ZLC model at Everport is under development by Taylor, as described in Section 2.3.1.

In addition, there were intermittent functional issues with the EVSE that continued throughout 2020 and into 2021, resulting in lower than anticipated operational hours for the top handlers. Although the chargers continued to have issues, the team experienced several other challenges throughout 2020 and 2021 and in 2022, due to the COVID-19 pandemic, that adversely impacted the project timeline. Quarantine restrictions caused a myriad of limitations on various stages of project implementation.

The team experienced several other challenges throughout 2020 and 2021, due to the COVID-19 pandemic, that adversely impacted the project timeline. Quarantine restrictions caused a myriad of limitations on various stages of project implementation. BYD experienced closures at their facility in China, causing materials, parts, and software delays. BYD's facility in Lancaster was closed for several months, due to the State of California's Safer-at-Home orders. Cavotec, with their engineering facility located in Italy, was hard-hit by the COVID-19 pandemic, with many Cavotec employees personally affected. The situation added limitations to collaboration between BYD and Cavotec on the SPS integration strategy. In Q3 2020, when facilities began to reopen and the project partners resumed collaboration, the project faced several challenges with the BYD charging interface for the Cavotec Smart Plug-In System. During Q4 2020, with a renewed spike in COVID-19 cases, some Cavotec engineers were unable to return to Italy from other parts of the European Union, due to travel restrictions. Extended lead times and difficult parts acquisition occurred, as factories once again closed and halted production. This challenging global situation continued through 2021 and into 2022.

BYD's China facility experienced closures and the facility in Lancaster was closed for several months, due to the State of California's Safer-at-Home orders. Cavotec, with their engineering facility located in Italy, was hard-hit by the COVID-19 pandemic, with many Cavotec employees personally affected. The situation added limitations to collaboration between BYD and Cavotec on the SPS integration strategy. In Q3 2020, when facilities began to reopen and the project partners resumed collaboration, the project faced several challenges with the BYD charging interface for the Cavotec SPS as described under Chapters 3.1 and 3.2. During Q4 2020, with a renewed spike in COVID-19 cases, some Cavotec engineers were unable to return to Italy from other parts of the European Union, due to travel restrictions. Extended lead times and difficult parts acquisition occurred, as factories once again closed and halted production.

The project team anticipated some relief from restrictions during Q2 2021 and beyond, as California fully reopened on June 15; however, the second half of Q3 2021 and Q4 2021 saw a spike in COVID-19 cases. The COVID-19 pandemic's significant impact to the demonstration project continued during Q1 2022 with facility closures as well as extended lead times and precautionary measures. Extended lead times, precautionary measures, and additional outbreaks of COVID-19 were experienced during Q2 2022 and Q3 2022.

Onsite UL certification of the SPS presented additional challenges. Each component in the SPS was thought to be UL certified, which led the Cavotec team to anticipate simple certification of the unit as a whole. The Cavotec SPS units were UL certified six months after delivery. A valuable lesson learned is to provide ample time for certification and permitting. When possible, pre-certification at the manufacturer's facility will expedite the process.

Challenges with design modifications to the BYD yard tractors, necessary for Everport terminal applications, continued to cause demonstration delays, as detailed under Chapter 3.1

As detailed under Chapter 3.4, data collection presented several challenges. As a lesson learned for future projects, data collection should be coordinated with the project partners as early as possible. The challenge is that the data collection interface can only be tested once the equipment is commissioned. For this project, devices were tested, as much as possible, prior to commissioning the equipment; however, the reality on the ground proved to entail an additional 2-3 months to work through various issues. The team streamlined the data acquisition and analysis process to provide information beneficial to the development of advanced technology and to meet obligations set forth in this grant.

Another project challenge is the lack of battery-electric yard tractor utilization in daily operations. Monthly and cumulative hours of operation were lower than anticipated. Yard tractor modifications and repairs account for part of the equipment downtime; however, when the yard tractors were fully functional, usage continued to be minimal. Project management requested that Everport facilitate more continuous usage of the demonstration equipment; however, the terminal indicated that the operators tend to choose the diesel or LNG yard tractors over the battery-electric units.

4.4 Conclusions and Recommendations

The Taylor top handlers were successfully integrated into Everport's fleet and are currently accruing operating hours in regular terminal service. Compared to the expectation that the units would accrue operational hours at the level of their diesel counterparts (2,500 hours/year), the demonstration units fell short. The challenges with functionality and operating consistency of the EVSE, COVID-19 pandemic restrictions and operating protocols primarily contributed to this shortfall.

The BYD yard tractors have the potential for integration into Everport's fleet once operators become more comfortable with the equipment. Compared to the expectation that the units would accrue operational hours at the level of their diesel counterparts (4,500 hours/year), the demonstration units fell short. BYD's challenges with lengthy parts procurement and limited personnel for yard tractor repairs, COVID-19 pandemic restrictions and operating protocols contributed to this shortfall.

Overall, the Taylor top handler and BYD yard tractor demonstrations were considered by the project team to be a meaningful success, providing Everport with real-world operating experience that shows advanced technology CHE has the potential to be compatible with a rigorous port operating environment. The team looks forward to demonstrations involving next-generation zero-emission CHE, with evolution of design based on lessons learned from this, and other, advanced technology demonstration projects.

The demonstration of the Cavotec SPS was considered a success, and once certified and operational, the system performed consistently well. The system's efficiency was not measured to the full extent, due to lower-than-expected use of the yard tractors and the need to reduce kilowatt capability to match BYD's changes to the charging platform. The team looks forward to expanded use of the SPS and other Cavotec charging equipment for terminal operations.

Altogether, when considering the operating cost of electricity compared to diesel, especially in a time of fluctuating prices, this project demonstrated the opportunity for meaningful savings and potential insulation from petroleum fuel price volatility. Additionally, the project reduced

210 metric tonnes of CO_2e and provided a meaningful step towards global greenhouse gas reduction. Zero-emission technology is progressing at a rapid pace, largely due to demonstration projects funded by public agency grants and supported by partnering OEMs. The project team considers the "Everport Advanced Cargo Handling Demonstration Project" as a successful demonstration providing valuable lessons for future development and lasting collaboration.

GLOSSARY

ALTERNATING CURRENT (AC)—Flow of electricity that constantly changes direction between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

BATTERY ELECTRIC VEHICLE (BEV)—Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

CALIFORNIA ENERGY COMMISSION - The state's primary energy policy and planning agency. The agency was established by the California Legislature through the Warren-Alquist Act in 1974. It has seven core responsibilities:

- Developing renewable energy
- Transforming transportation
- Increasing energy efficiency
- Investing in energy innovation
- Advancing state energy policy
- Certifying thermal power plants
- Preparing for energy emergencies

CARBON DIOXIDE EQUIVALENT (CO_2e) -- The amount of carbon dioxide by weight that would produce the same global warming impact as a given weight of another greenhouse gas, based on the best available science, including from the Intergovernmental Panel on Climate Change.

CARGO HANDLING EQUIPMENT (CHE) -- Mobile cargo handling equipment is any motorized vehicle used to handle cargo or perform routine maintenance activities at California's ports and intermodal rail yards. The type of equipment includes yard trucks (hostlers), rubber-tired gantry cranes, container handlers, forklifts, etc. (https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment)

DIRECT CURRENT (DC) -- A charge of electricity that flows in one direction and is the type of power that comes from a battery.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) -- Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including BEVs and PHEVs.

FREIGHT -- Merchandise hauled by transportation lines.

GRAM (g) -- A metric unit of mass equal to $^1/_{1000}$ kilogram and nearly equal to the mass of one cubic centimeter of water at its maximum density. (https://www.merriam-webster.com)

GREENHOUSE GAS -- Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs). (EPA)

GROSS VEHICLE WEIGHT (GVW) -- The maximum operating weight/mass of a vehicle as specified by the manufacturer including the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers and cargo but excluding that of any trailers.

HYDROCARBONS -- Compounds containing various combinations of hydrogen and carbon atoms. They may be emitted into the air by natural sources (e.g., trees) and as a result of fossil and vegetative fuel combustion, fuel volatilization and solvent use. Hydrocarbons are a major contributor to smog.

INTERNET OF THINGS INTER PROCESS COMMUNICATIONS (IOT IPC) -- The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. Inter-process communication (IPC) are the mechanisms provided by an operating system for processes to manage shared data. (https://www.oracle.com/internet-of-things/what-is-iot/ and https://en.wikipedia.org/wiki/Inter-process_communication#:~:text=In percent20computer percent20science percent2C percent20inter percent2Dprocess,processes percent20to percent20manage percent20shared percent20data.)

KILOWATT (kW) -- One thousand (1,000) watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon a typical home, with central air conditioning and other equipment in use, might have a demand of four kW each hour.

KILOWATT-HOUR (kWh) -- The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

LOS ANGELES DEPARTMENT OF BUILDING AND SAFETY (LADBS) -- The mission of the Department of Building and Safety is to protect the lives and safety of the residents and visitors of the City of Los Angeles and enhance the quality of life, housing, economic prosperity, and job creation citywide. Through a timely, cooperative, and transparent process, the department advises, guides, and assists customers to achieve compliance with the Building, Zoning, Plumbing, Mechanical, Electrical, Disabled Access, Energy, and Green codes and local and State laws to build safe, well, and fast. (https://www.ladbs.org/our-organization/messaging/a-few-facts-about-us)

LOW CARBON FUEL STANDARD (LCFS) -- A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore, reduce greenhouse gas (GHG) emissions. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

MEGAJOULE (MJ) -- A Joule is a unit of work or energy equal to the amount of work done when the point of application of force of 1 newton is displaced 1 meter in the direction of the force. It takes 1,055 joules to equal a British thermal unit. It takes about 1 million joules to make a pot of coffee. A megajoule itself totals 1 million Joules.

MILLIMETER (mm) -- One-thousandth of a metre, equal to 0.03937 inch. Symbol mm. (https://www.oed.com/search/dictionary/?scope=Entries&q=millimeter)

NITROGEN OXIDE (NO_x) -- A general term pertaining to compounds of nitric oxide (NO), nitrogen dioxide (NO_2) and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. NO_2 is a criteria air pollutant and may result in numerous adverse health effects.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) -- With the Occupational Safety and Health Act of 1970, Congress created the Occupational Safety and Health Administration (OSHA) to ensure safe and healthful working conditions for workers by setting and enforcing standards and by providing training, outreach, education and assistance. (https://www.osha.gov/aboutosha)

ORIGINAL EQUIPMENT MANUFACTURER (OEM) -- refers to the manufacturers of complete vehicles or heavy-duty engines, as contrasted with remanufacturers, converters, retrofitters, up-fitters, and re-powering or rebuilding contractors who are overhauling engines, adapting or converting vehicles or engines obtained from the OEMs, or exchanging or rebuilding engines in existing vehicles.

PARTICULATE MATTER (PM) –- Unburned fuel particles that form smoke or soot and stick to lung tissue when inhaled. A chief component of exhaust emissions from heavy-duty diesel engines.

PORT OF LOS ANGELES (POLA) -- The Port of Los Angeles is America's Port®, the nation's premier gateway for international commerce and the busiest seaport in the Western Hemisphere. Located in San Pedro Bay, 25 miles south of downtown Los Angeles, the Port encompasses 7,500 acres of land and water along 43 miles of waterfront.[19]

RESEARCH AND DEVELOPMENT (R&D) -- Research is the discovery of fundamental new knowledge. Development is the application of new knowledge to develop a potential new service or product. Basic power sector R&D is most commonly funded and conducted through the Department of Energy (DOE), its associated government laboratories, university laboratories, the Electric Power Research Institute (EPRI), and private sector companies.

SMART PLUG-IN SYSTEM (SPS) -- Smart Plug-In System connects and charges electrical trucks and enables battery charging on the vehicle itself, without having to remove the battery pack. (https://www.cavotec.com/en/your-applications/industry-mining/e-charging)

UNDERWRITERS LABORATORIES (UL) -- Underwriters Laboratories is a nonprofit organization dedicated to advancing the UL public safety mission through the discovery and application of scientific knowledge … conduct rigorous independent research and analyze safety data, convene experts worldwide to address risks, share knowledge through safety education and public outreach initiatives, and develop standards to guide the safe commercialization of evolving technologies. (https://www.ul.com/news/ul-helps-develop-new-global-fire-safety-common-principles)

[19] https://www.portoflosangeles.org/about

APPENDIX A – DATA COLLECTION TEST PLAN

The Data Collection Test Plan will guide the monitoring of key project metrics to inform conclusions from this demonstration project. The data collected under this plan will be analyzed and reported in the project Final Report.

Below are activities planned in anticipation of the demonstration phase:

- Provide training and support to demonstrators, maintenance and operations staff, data collectors, and key project participants, as applicable.
- As part of the initial equipment commissioning, the units will be placed in service to test operability over Everport's duty cycle, including load capacity, maneuverability, range, initial time between charges, charger/equipment interface, etc. for the zero-emission cargo handling equipment (CHE), consisting of two top handlers and three next generation yard tractors.

Below is a list of data that will be collected and activities that will be tracked during the 12-month demonstration:

- Troubleshoot and document resolution of any issues identified throughout the demonstration.
- For project infrastructure, document the maximum capacity and design capabilities of the two charging technologies at the beginning of the demonstration. The two charging technologies include:
    - BYD charging system for the Taylor top handlers
    - Cavotec Smart Charging System (SCS) for the next generation yard tractors.

  This baseline information will be used as a basis of comparison to operation of the charging technologies at the end of the demonstration.
- Document the initial performance expectations of the five zero-emission CHE at the beginning of the demonstration so that actual performance may be compared back to these expectations. This will include an operator survey after the first 4 to 6 weeks of the demonstration, and a repeat of the survey during the month prior to the end of the demonstration.
- Collect one year of monthly throughput and operations data from the project including, but not limited to:
    - Hours of operation per day.
    - Electric power consumed by the demonstration units, on a per unit basis (kWh/hour of operation). Data collected will include daily per-charge energy transfer, average operation time between charges, relevant battery state of charge information and associated time to charge the batteries, and average power output per charge event from the chargers to the zero-emission equipment.
    - These consumption data will be used in conjunction with energy conversion factors to calculate monthly gallons of diesel fuel displaced.

Below is a list of information that will be documented for this demonstration:

- Description of the charging protocol and documentation of any changes to that protocol that may be implemented during the demonstration.
- Expected air emissions reductions will be calculated using average operational metrics of a diesel-fueled top handler and yard tractor as reported in the 2015 POLA Emissions Inventory[20] (as the baseline) and Carl Moyer Program emission reduction calculation methodologies for reactive organic gases (ROG), oxides of nitrogen (NO_x) and particulate matter (PM10). A quantified estimate of the project's carbon intensity values for life-cycle greenhouse gas emissions will be calculated based on CEC and ARB GHG methodologies published under the ARFVTP. No emissions testing is planned.
- Duty cycle of the demonstration fleet and the expected duty cycle of future vehicle acquisitions (i.e., what changes would be needed for future purchases, based on the experience with the demonstration units).
- Documentation of all routine and non-routine maintenance conducted on the units during the demonstration period.
- Documentation of monthly electricity costs for each of the test units (two top handlers and three battery-electric yard tractors).

[20] This approach mirrors that of the original project application for CEC funding for this project.