



# Multi-Source Facility Demonstration Project Green Omni Terminal Project Final Report



**Los Angeles Harbor Department and the California  
Air Resources Board**

**Green Omni Terminal Project  
Project No. 129054**

**Revision 1  
12/6/2023**



# **Multi-Source Facility Demonstration Project Green Omni Terminal Project Final Report**

prepared for

**Los Angeles Harbor Department and the California Air  
Resources Board  
Green Omni Terminal Project  
Wilmington, CA**

**Project No. 129054**

**Revision 1  
12/6/2023**

prepared by

**Burns & McDonnell Engineering Company, Inc.  
San Diego, California**

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Multi-Source Facility Demonstration Project  
Green Omni Terminal Project  
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### Certification

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Date: 12/6/2023

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**LIST OF ABBREVIATIONS**

<b><u>Abbreviation</u></b>	<b><u>Term/Phrase/Name</u></b>
A	Ampere
AB	Assembly Bill
AC	Alternating Current
AQIP	Air Quality Improvement Plan
ATS	Automatic Transfer Switch
BESS	Battery Energy Storage System
BMcD	Burns & McDonnell Engineering Company, Inc.
CAEM	Clean Air Engineering-Maritime
CAL/OSHA	California Division of Occupational Safety and Health Association
CARB	California Air Resources Board
CEC	California Energy Commission
CHE	Cargo Handling Equipment
CO <sub>2e</sub>	Carbon Dioxide Equivalents
DAC	Disadvantaged Community
DC	Direct Current
ECCS	Emissions Capture and Control System
EO	Executive Order
EPA	Environmental Protection Agency
ESS	Energy Storage System
EV	Electric Vehicle
FiT	Feed-in-Tariff
FMVSS	Federal Motor Vehicle Safety Standards

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GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas
GW	Gigawatt
GWH	Gigawatt-hours
Hz	Hertz
ILWU	International Longshore and Warehouse Union
kV	Kilovolt
kVA	Kilovolt Amp
LADBS	Los Angeles Department of Building and Safety
LADWP	Los Angeles Department of Water & Power
LAFD	Los Angeles Fire Department
LAHD	Los Angeles Harbor Department
lb	Pound
LFP	Lithium Iron Phosphate
MSFDP	Multi-Source Facility Demonstration Project
MW	Megawatt
MWh	Megawatt-Hour
NEM	Net Energy Metering
NMC	Nickel Manganese Cobalt
NO <sub>x</sub>	Oxides of Nitrogen
O&M	Operations & Maintenance
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Association
Pasha	Pasha Stevedoring & Terminals, LP
PM <sub>10</sub>	Diesel Particulate Matter

POLA	Port of Los Angeles
PTO	Power Take-Off
PV	Photovoltaic
Q	Quarter
ROG	Reactive Gases
SCAQMD	South Coast Air Quality Management District
SCCR	Short Circuit Current Rating
SOx	Oxides of Sulfur
Tri-Mer	Tri-Mer Corporation
UCLA	University of California, Los Angeles
UCR CE-CERT	University of California, Riverside College of Engineering - Center for Environmental Research & Technology
UL	Underwriters Laboratory
V	Volt

## 1.0 EXECUTIVE SUMMARY

CARB awarded the Los Angeles Harbor Department (LAHD or Harbor Department) a Multi-Source Facility Demonstration Project (MSFDP) at Pasha Stevedoring & Terminals, LP's (Pasha) Wilmington, CA facility in the Port of Los Angeles (POLA). The goal of the MSFDP was to demonstrate multiple types of equipment and vehicles employing zero and near zero-emission technologies at one freight facility located within, or with the project directly benefiting disadvantaged communities (DACs). Projects were intended to reduce greenhouse gas (GHG) emissions and provide economic, environmental, and public health co-benefits to DACs, while synergistically demonstrating the practicality and economic viability of wide-spread adoption of advanced freight technologies for various sources at a single facility.

### 1.1 Project Objective

The Harbor Department in partnership with Pasha established the goal of developing a Green Omni Terminal at Pasha's POLA Terminal in the Wilmington DAC. The goal of the project was to incorporate zero and near-zero emissions cargo handling equipment (CHE) to move goods from ships through the terminal to clean transportation to their final destinations, while making portions of terminal operations more sustainable and resilient through the development of a solar powered and battery storage microgrid.

### 1.2 Approach

Electric CHE and vehicles developed and tested included two (2) BYD battery-electric Generation 1 yard tractors, two (2) Kalmar T2 TransPower-repowered battery-electric yard tractors, three (3) Kalmar heavy-duty TransPower-repowered battery-electric forklifts, two (2) Navistar International TransPower-repowered battery-electric Class 8 trucks, and one (1) commercially-available Kalmar T2E+ battery-electric yard tractor. Two (2) BYD 100-kilowatt (kW) and seven (7) TransPower 70-kW electric vehicle (EV) chargers were installed at the terminal and were connected to upgraded electrical infrastructure designed and constructed by Burns & McDonnell Engineering Company (Burns & McDonnell or BMcD) to integrate a 1-megawatt (MW) solar photovoltaic (PV) system and 1-MW / 2.6-megawatt-hour (MWh) battery energy storage system (BESS), which were intended to serve as the basis of a renewable solar and battery storage microgrid. A mobile dockside emissions capture and control system (ECCS),

referred to as the ShoreKat, was developed by Clean Air Engineering-Maritime to demonstrate the feasibility of capturing and treating vessel auxiliary engine emissions from a shore-based system.

The demonstration project was planned to be completed within a three-year period; however, delays in equipment development, agency approvals, and contract negotiations combined with safety and reliability issues limited the full demonstration of the equipment and microgrid infrastructure and extended the demonstration period until December 2023. Table 1 provides a summary of the levels of development and demonstration achieved for the key project elements.

**Table 1: Development and Demonstration Status of Key Project Elements**

<b>Project Element</b>	<b>Demonstration Period</b>	<b>Development and Demonstration Status</b>
BYD Yard Tractors	Q1 2017, Q3 2017, Q2 2020-Q4 2023	BYD vehicles were developed and delivered on time, but software and mechanical updates were required to place vehicles in service. Use was limited by the extended time when chargers were not in service due to third-party certification process and vehicle reliability issues. The demonstration period totaled approximately 2 years, although reliability issues and slow repair times limited overall use. Yard tractors were able to meet Pasha's operational needs when in service, with adequate battery capacity, and were preferred by drivers. Generation 1 yard tractors were replaced with Generation 2 yard tractors in 2022 to address reliability issues. Generation 2 yard tractors were operated for a combined approximately 2,800 hours.
TransPower Yard Tractors	Q1-Q4 2019, Q1 2022	Vehicle delivery was delayed by TransPower's limited design and delivery capacity. Total duration of use was less than 1 year. Units were out of service for two years because of the Occupational Safety and Health Association (OSHA) documentation issue requiring safety certifications following vehicle modifications. Yard tractors were able to meet Pasha's operational needs when in service, with adequate battery capacity. Units were taken out of service in 2022 following a thermal event that occurred when a mafi trailer struck an energy storage system (ESS) box when a driver was performing a jack-knife maneuver. A second thermal event occurred with the second unit when it was not in operation after moisture was able to enter an ESS that had previously become compromised.
TransPower Forklifts	Q2 2022	Repowering of forklifts took 2.5 years to complete for the first unit due to design challenges. Second and third units were completed within 1 year of the first. Forklifts were not placed in service for over 3 years because of the OSHA documentation issue. Forklifts had equivalent lifting capacity as diesel equivalents. When eventually placed in service, preliminary tests indicated that forklifts were able to meet Pasha's operational needs. The forklifts were taken out of service following the thermal events involving the two TransPower yard tractors.

Project Element	Demonstration Period	Development and Demonstration Status
TransPower Drayage Trucks	Q3-Q4 2020, Q2 2021	TransPower delivered drayage trucks to Pasha in Q2 2018, but units were not placed in service because of the Federal Motor Vehicle Safety Standard (FMVSS) approval process. FMVSS approval was attained in Q3 2020. After initial limited use due to low cargo volumes and lack of power take offs, batteries required replacement. Vehicles were taken out of service permanently because of ground faults that created an unsafe driving condition.
Kalmar Yard Tractor	Q2 2021 – Q2 2022	The Kalmar T2E+ yard tractor is a commercially available unit that was procured with reallocated project funds. The vehicle functioned reliably but was taken out of service because of Pasha’s concern over the potential for a mafi trailer to strike the ESS box, causing a thermal event similar to the TransPower repowered Kalmar T2 units due to the similar location and arrangement of the ESS.
TransPower EV Chargers	Q3 2020 – Q2 2022	Third-party certification delayed the in-servicing of chargers for a period of months. Once in service, chargers performed reliably, but received limited use due to inability to place vehicles in service due to FMVSS and OSHA requirements for drayage trucks and CHE, respectively. Chargers required retrofits to serve different battery types – lithium iron phosphate (LFP) and nickel manganese cobalt (NMC).
BYD EV Chargers	Q1-Q3 2017, Q2 2020 – Q4 2023	One charger was temporarily placed in service and used in 2017. Third-party certification and retrofit delays limited use in 2018-2019. Chargers performed reliably once placed in service permanently. Operators preferred these chargers over those of TransPower because the cables and plugs were lighter and easier to connect to vehicles.
ShoreKat	Q2 2019 – Q2 2020	The ShoreKat was delivered to the terminal in Q1 2018. Once on the terminal, a trailer and dolly had to be fabricated and delivered to support the system and achieve mobility. The ShoreKat was placed in service in Q2 2019 and was demonstrated against four (4) vessels during the demonstration period. Carbon capture pilot demonstrations were not performed due to technical and economic infeasibility.

Project Element	Demonstration Period	Development and Demonstration Status
Microgrid	N/A	Electrical infrastructure upgrades were divided into three phases due to permitting delays. The supporting civil and electrical infrastructure, including switchgear, transformers, conduits, and foundations were completed in 2018. The BESS has not been energized to date due to modifications identified during the permitting and third-party certification process and delays in obtaining a second Interconnection Agreement from the Los Angeles Department of Water and Power (LADWP). LADWP required that a new Interconnection Agreement be obtained due to changes in the solar PV panels resulting in the size of the overall solar PV system changing from 1,006,400 kW direct current (DC) / 800 kW alternating current (AC) to 1,000,080 kW DC / 800 kW AC. The solar PV system was not installed due to delays resulting from lease negotiations between the Harbor Department and Pasha and the need to secure a second Interconnection Agreement. In 2023, LAHD completed additional electrical infrastructure upgrades to increase the functionality and reliability of the microgrid once completed. As of December 2023, the solar PV system has not been installed, the BESS is not energized, and the microgrid is consequently not in operation.

### 1.3 Accomplishment of Project Objectives and Lessons Learned

While not all the elements of the project functioned as envisioned or were completed as of the date of this report, the Green Omni Terminal was successful in demonstrating zero emission and near-zero emission technologies, including EVs, electric CHE, and the ShoreKat ECCS, excluding the carbon capture pilot projects. The demonstration project provided valuable insights into the processes of obtaining approvals, permits, and buy-in necessary to operate pre-commercial and novel technologies at a marine terminal where the terminal operators, unions, agencies, and technology providers must all be aligned to place equipment in service and sustain its ongoing use. Challenges that had to be overcome on the project included:

- Obtaining necessary permits and approvals from agencies for vehicles and charging equipment
- Providing adequate documentation on the safety of equipment
- Training and guidance to support operations and maintenance

- Achieving safe vehicle functionality through iterative software, electrical, and mechanical upgrades, retrofits, and repairs
- Addressing operator concerns and resistance to the use of new technologies that required modifications to existing operational approaches

Through this project, the following lessons were learned that could be used to improve future demonstration projects and progress the state and commercialization potential of these zero and near-zero emission technologies.

**Safety:** Safety-related issues were the most important factor that affected the deployment and use of infrastructure, EVs, and the ShoreKat ECCS. The deployment of the BESS, chargers, and the TransPower-repowered drayage trucks, yard tractors, and forklifts all were delayed by either (1) the lack of safety-related approvals, permits, and documentation or (2) the need for retrofits and repairs to achieve safe operational parameters. Safety issues encountered at every phase of the project undermined the confidence of Pasha and vehicle operators in the technologies, potentially inhibiting future use, purchases, and deployments. Two thermal events involving the two TransPower yard tractors resulted in all models with similarly configured battery packs being taken out of service.

**Permitting and Agency Approvals:** Delays in obtaining permits and agency approvals resulted in years-long delays in the deployment of demonstration equipment. Original equipment manufacturers (OEMs) can greatly enhance the quality and use of their products by designing the equipment with the permitting and certification process in mind and pursuing necessary approvals, certifications, permits, and documentation during the technology development phase to the maximum extent practicable.

#### **1.4 Future Applications of Technologies and Commercialization Prospects**

The assessment of future technology applications and commercialization prospects was based on the demonstrated effectiveness of the technologies during this project, projected need for the technologies, and ability to improve on the technologies to meet operational needs of multi-modal facilities.

**Microgrid:** The inability to install the solar PV system and energize the BESS has delayed the microgrid demonstration at a marine terminal. The BESS has not been energized due to initial delays relating to permitting/third-party certification process and retrofits and the need to obtain a second Interconnection Agreement from LADWP due to changes in the overall size of the solar PV system from 1,006,400 kW DC / 800 kW AC to 1,000,080 kW DC / 800 kW AC due to changes in solar PV panels to be installed. Microgrids that incorporate solar and energy storage have already been designed and constructed at military bases, airports, manufacturing facilities, data centers, industrial complexes, and campuses. Renewable-based microgrids at ports have the greatest potential for smaller terminals with power demands of key infrastructure in the 1-2 MW range. Regardless of whether a microgrid is developed, the individual solar and BESS technologies are commercially available and widely used across California. Lessons learned from this project have been shared with other ports resulting in the successful deployment of solar and storage based microgrids at other California marine terminals, including the Port of San Diego's Tenth Avenue Marine Terminal.

**Electric Vehicle Chargers:** Once third-party certifications were obtained for the EV chargers, they functioned reliably throughout the demonstration. The BYD chargers were preferred over the TransPower units because the charging cables were lighter and easier to use. Consistent with many fleet operators, Pasha staff expressed the desire that chargers have the capability to serve multiple OEM vehicles to provide greater flexibility in updating fleets. Additionally, charging operations for yard tractors would benefit from configurations that allow vehicles to pull through charging stations with the trailers attached. The current consolidated arrangement of the chargers minimizes the footprint of the infrastructure with the tradeoff of requiring trailers to be detached prior to charging multiple vehicles.

**Yard Tractors:** Of the vehicles tested during the Green Omni Terminal Project, the battery-electric yard tractors presented the strongest opportunity for broader commercial adoption. While mechanical and electrical issues reduced the use of the vehicles, OEMs made significant progress in addressing software and mechanical limitations over the course of the project. Additionally, later generation models were placed in service at the terminal and used reliably when delivered to the terminal. Yard tractors were able to meet the operational needs of the terminal during shifts with adequate remaining states of charge, and drivers reported that they preferred electric

yard tractors because they had air conditioning, were quieter, and produced less exhaust emissions. Design improvements are still needed to enhance the safety of the vehicles, including modifying the placement and protection of ESS boxes on Kalmar battery-electric models to better protect the ESS from physical damage that has the potential to result in thermal events.

**Forklifts:** The repowered heavy-duty forklifts, while only in use for approximately two weeks, showed promise for broader use. Pasha reported that the forklifts met the operational needs of the terminal during shifts, completing shifts with approximately 40-50% state of charge.

Additionally, lift testing demonstrated that the battery-electric forklifts had equivalent lifting capacity as diesel-fueled units. Software updates are still required to optimize the operation of the forklifts and future models would benefit from positioning batteries in arrangements that minimize blind spots behind the driver, which are currently addressed with cameras, sensors, alarms, and signs. Heavy-duty forklifts are now commercially available from OEMs, such as Wiggins, Kalmar, and Taylor.

**Drayage Trucks:** The TransPower-repowered battery-electric Navistar International drayage trucks did not meet the operational or reliability needs of the terminal. The trucks were only capable of driving 49 miles on a charge while transporting terminal equipment. Additionally, the trucks experienced repetitive and unresolved electrical and mechanical issues that affected vehicle safety and ongoing use. It is recognized that the state of the technology has progressed beyond these two early TransPower models. Battery electric trucks that provide ranges of 125-350 miles per charge are commercially available from: BYD, Freightliner, Kenworth, Lion Electric, Nikola, Peterbilt, SEA Electric, and Volvo.

**ShoreKat:** The demonstration of the ShoreKat ECCS provided valuable insights into the practicality and limitations of operating a dockside system. The demonstration project showed that shore-based ECCS create potential conflicts with vessel unloading operations that are not encountered with barge-based systems. The dockside unit impacted vessel unloading operations, altering CHE routes and slowing productivity by approximately 30 minutes per shift. The crane-based emissions capture boom had a reach of 150 feet, which limited the ability to reach high stacks or stacks located to the seaward side of the ship. Staffing had to be negotiated with the International Longshore and Warehouse Union (ILWU), initially creating administrative and operational challenges. Lastly, while the ShoreKat and emissions capture boom are mobile and

can be moved around the terminal, the weight and size of the systems make a shore-based system less mobile than barge-based systems. The most likely future application of a shore-based ECCS is at a terminal that has a constrained channel that cannot accommodate an ECCS barge positioned along a berthed vessel. With the expansion of CARB's At-Berth Regulation to additional classes of vessels beyond container vessels, the demand for shore power and ECCS is expected to increase over the next five years. The cost of and timeframe for retrofitting different classes of ships to make them shore power compatible will increase the market demand for ECCS.

## **1.5 Conclusion**

The Green Omni Terminal Project provided valuable lessons learned for the deployment of zero emission and near-zero emission technologies, including EVs, electric CHE, and the ShoreKat ECCS at a multi-modal facility. Pasha served as a test facility for the commercialization of zero-emission technologies that move high-tonnage break bulk and containerized cargo. Through the demonstration, the project provided valuable information on the process of obtaining the proper authorizations to operate battery-electric CHE and vehicles safely and legally, as well as the deployment of supporting charging infrastructure. While the overall demonstration duration was generally less than the two-year target, the process of placing the infrastructure and equipment in service and iteratively modifying, upgrading, and repairing the equipment to achieve operational utility provided valuable data and insights on the reliability and commercial readiness of each of the technologies. Lessons learned from this project have informed follow-on projects being implemented at POLA, as well as other California and U.S. ports. Additionally, configuration, operational, and safety issues have been shared with Original Equipment Manufacturers, resulting in improvements in commercially available, yard tractors, forklifts, and on-road trucks.

## 2.0 INTRODUCTION

In June 2015, CARB solicited proposals from Grantees to implement and administer the MSFDP under the Air Quality Improvement Program (AQIP) and Low Carbon Transportation Greenhouse Gas Reduction Fund (GGRF) Investments, as identified in the Fiscal Year 2014-15 Funding Plan approved by the Board in June 2014. The MSFDP, along with the Zero- Emission Drayage Truck Demonstration Project, is part of a \$50 million allocation for advanced technology freight demonstrations and complements a separate project to deploy early commercial zero-emission trucks and buses. The goal of the MSFDP was to demonstrate multiple types of equipment and vehicles employing zero and near zero-emission technologies at one freight facility located within, or with the project directly benefitting, disadvantaged communities. Projects were intended to reduce GHG emissions and provide economic, environmental, and public health co-benefits to disadvantaged communities, while synergistically demonstrating the practicality and economic viability of wide-spread adoption of advanced freight technologies for various sources at a single facility. CARB awarded the Harbor Department \$14,510,400 to implement a MSFDP at Pasha's Wilmington, CA facility.

### 2.1 Project Goals and Objectives

The Harbor Department in partnership with Pasha established the goal of developing a Green Omni Terminal at Pasha's POLA Terminal in the Wilmington DAC. The goal of the project was to incorporate zero and near-zero emissions CHE to move goods from ships through the terminal to clean transportation to their final destinations, while making portions of terminal operations more resilient through the development of a solar powered and battery energy storage microgrid.

The overarching objective of the project was to demonstrate how multiple zero and near-zero emission technologies can be integrated to enhance sustainable terminal operations and reduce overall environmental impacts, benefiting the surrounding Wilmington DAC. The Green Omni Terminal Project was to serve as the first step in transitioning the Pasha terminal to a zero-emission terminal, while serving as a scalable model that could be replicated at other ports and industrial facilities throughout California, the country, and the world. Specific objectives of the project included the following:

- **Provide GHG, criteria pollutant, and toxic air contaminant emission reduction benefits to the Wilmington DAC.** Through the use of battery electric technologies and the ECCS, this project reduced GHG, diesel particulate matter, oxides of nitrogen (NOx), and reactive organic gases (ROG) emissions in a DAC that is not meeting National Ambient Air Quality Standards.
- **Demonstrate multiple types of equipment and vehicles employing zero and near zero-emission technologies at one port facility.** Pasha served as a test facility for the commercialization of zero and near-zero emission technologies that can move high-tonnage break bulk and containerized cargo.
- **Provide economic, environmental, and public health co-benefits.** The Green Omni Terminal was intended to serve as a catalyst for change at the San Pedro Bay Port Complex, providing a cost-effective and scalable model for sustainable and low-emission terminal operations at thousands of distribution centers and marine terminals throughout the state, nation, and world.
- **Demonstrate the practicality and economic viability of wide-spread adoption of advanced freight technologies for various sources at a single facility.** The Green Omni Terminal was envisioned to go beyond this goal to demonstrate how a sustainable and resilient terminal can integrate electric zero emission equipment into the first seaport terminal microgrid. This microgrid was designed to use renewable power to operate independent of the electric grid in the event of a natural or manmade disaster that causes the electric grid to lose power.
- **Fund technologies on the cusp of commercialization that further the purpose of Assembly Bill (AB) 32.** This project contributed to reductions in the costs of electric drayage trucks and yard tractors and furthered the commercial viability of these zero emission technologies. It will also demonstrate the applicability of a solar-powered microgrid that integrates solar PV system and BESS to enhance operational sustainability and resiliency.

## 2.2 Project Overview

Near-commercial electrified CHE, including yard tractors, 21-ton forklifts, and on-road electric drayage trucks were demonstrated at the Pasha Terminal. It was the intent of the project to power the electric equipment with standardized charging infrastructure that can power different manufacturer's equipment. In addition, an at-berth vessel ECCS was to be integrated into the project to address the largest source of GHG and priority pollutant emissions at the terminal.

A 1-MW rooftop solar PV array was to be added to the terminal to supplement current power usage and help meet resiliency objectives. When combined with a 1-MW/2.6- MWh BESS and microgrid/energy management control system, key elements of the facility were to be capable of remaining operational for finite periods of time when islanded from the electrical grid in the event of power outages caused by unforeseen man-made and natural events.

## 2.3 Final Report Overview

The purpose of the final report is to document the methods and results of the demonstration project and provide a discussion of the level of accomplishment of project objectives, lessons learned, and future applications of the technologies demonstrated and their commercialization prospects. This report provides a summary of the process required to install the supporting infrastructure, manufacture and place the zero and near-zero emission technologies in service, and demonstrate the technology. Most importantly, this report documents the challenges that were encountered and were overcome and the lessons learned throughout the project so that other multi-modal facilities and technology providers can learn from this project and streamline the deployment of zero and near-zero emission technologies moving forward. This report does not provide the results of data monitoring, collection, and analysis tasks as those are separately reported by Ricardo, Inc. for (1) the ShoreKat ECCS and (2) the electrified CHE, on-road drayage trucks, and supporting EV chargers.

### 3.0 METHODS AND RESULTS

The Methods and Results section provides summaries of the planned and implemented approaches for the Green Omni Terminal Project. A comparison is made between the originally planned approach and the demonstration project as implemented in which details are provided on the challenges that were encountered in implementing the project, solutions that were developed, and the overall implications to the project schedule and demonstration period.

#### 3.1 Project Location

The Green Omni Terminal Project is located at the Pasha Omni-Cargo Terminal, which includes Berths 174-181 at 802 South Fries Avenue in Wilmington, California (Figure 1). The terminal is a 40-acre facility that includes 3,300 linear feet of berth space, 180,000 square feet of warehouses, three gantry cranes, and adjacent rail access.

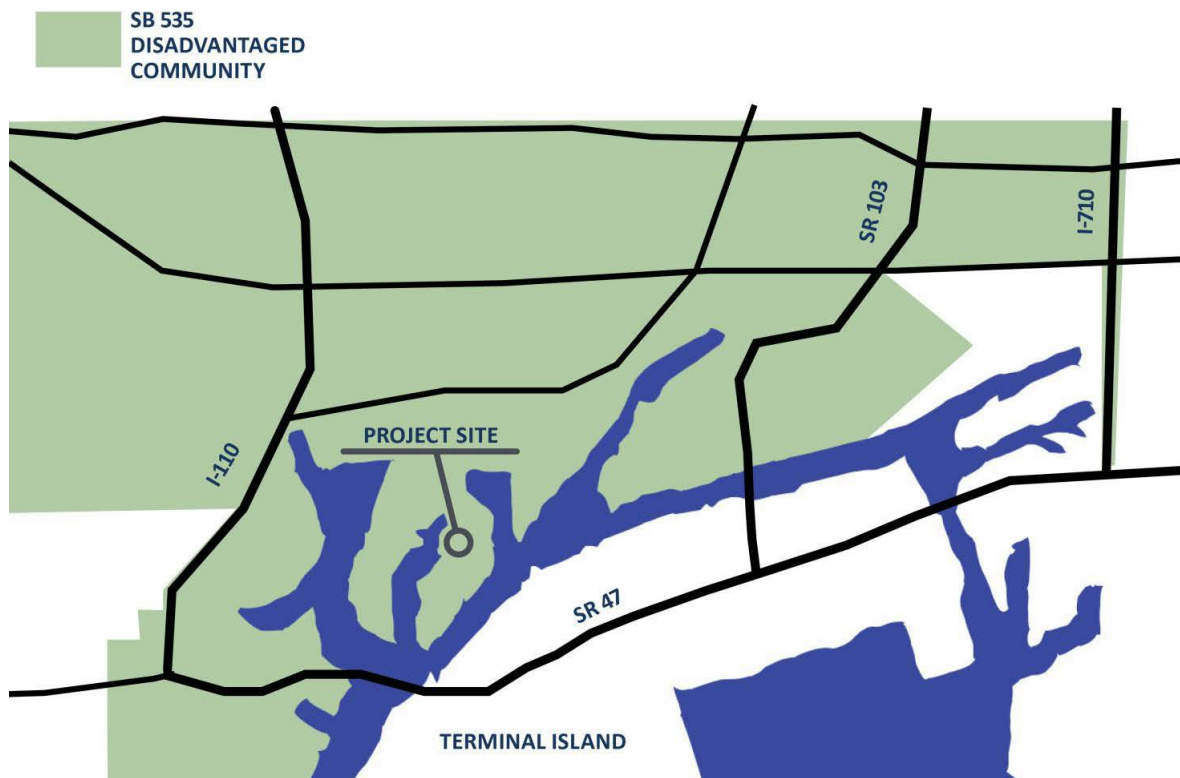


Figure 1: Port of Los Angeles Green Omni Terminal Project Location

The Pasha Terminal’s cargoes include steel products, such as coils of sheet, wire rod coils, square tubing, pipe, and rebar; breakbulk; forest products; heavy machinery and equipment; yachts; rolling stock; project cargoes; steel slabs; and containers.

### 3.2 Project Participants

The Green Omni Terminal Project was led by the Harbor Department, as the grant awardee, working in close coordination with Pasha, as the demonstration facility. The key project participants and their associated roles are listed in Table 2.

**Table 2: Roles of Key Project Participants**

Key Participants	Roles
Los Angeles Harbor Department	Lead Applicant – Project Leadership, Administration, Oversight of Technology
Pasha Stevedoring & Terminals	Multi-Source Facility Operator – Equipment and Vehicle Operation
Burns & McDonnell Engineering Company	Project Management, Design-Build Engineer for Energy Infrastructure
BYD	Technology Provider – Battery Energy Storage System, Charging Equipment, Yard Tractors
Clean Air Engineering-Maritime	Technology Provider – ShoreKat Dockside Marine Emissions Treatment System
TransPower	Technology Provider – Yard Tractors, Drayage Trucks, Charging Equipment
PermaCity	Technology Provider – Rooftop Solar PV Array
Ricardo	Third-Party Data Analysis
University of California, Riverside College of Engineering-Center for Environmental Research & Technology	Technical Advisor – Dynamometer Testing for Yard Tractor, Field Data Collection and Analysis for Forklifts
Los Angeles Department of Water & Power	Technical Advisor – Smart Grid and Utility Integration
South Coast Air Quality Management District	Technical Advisor – Zero and Near-Zero Technology Demonstration and Commercialization
University of California, Los Angeles Luskin Center	Technical Advisor – Sustainability Environmental Benefits, Policy and Economics
Coalition for Clean Air	Disadvantaged Community Advisor

### 3.3 Summary of Planned Approach

The proposed workplan for the Green Omni Terminal Project included the development of a solar-powered, resilient facility that would demonstrate how zero emissions CHE and vehicles could move goods from ships through the terminal to clean transportation to their final destinations. The project was to include a 1-MW rooftop solar PV array to provide renewable energy to the terminal to meet Pasha's current electricity demands. When combined with a 2.6-MWh BESS and microgrid control system, the PV system would allow key elements of the facility to remain operational for a finite period when islanded from the electrical grid in the event of a power outage.

The plan was to develop and demonstrate the following near-commercial electrified equipment and vehicles:

- Two (2) TransPower-repowered Navistar International on-road drayage trucks
- Two (2) BYD battery electric yard tractors
- Two (2) TransPower-repowered battery electric Kalmar yard tractors
- Two (2) 21-ton battery electric TransPower-repowered Kalmar forklifts
- One (1) TransPower-repowered battery electric top handler

The demonstration vehicles and equipment were to be integrated into the existing fleet for in-use testing in the movement of both heavy break bulk and containers. The vehicles and equipment were to be demonstrated in a variety of port operations including intra- and inter-terminal moves and short haul drayage to and from nearby rail facilities.

Electric equipment was to be powered by EV chargers connected to standardized charging infrastructure. An on-dock, at-berth vessel ECCS, referred to as the ShoreKat, was to be integrated into the project to treat at-berth vessel auxiliary engine GHG and criteria pollutant emissions. Lastly, wharf crane drive upgrades were planned to enhance energy efficiency.

The project was scheduled to be completed over a 3-year period. Infrastructure permitting, design, and construction were planned to be completed within one year; vehicles and CHE were to be designed, manufactured, and placed in service within 1.5 years; the ShoreKat dockside

ECCS was to be placed in service within 6 months, and the equipment demonstration was to run for 2 years.

Field data were to be collected by a third-party company contracted separately by CARB. A laboratory analysis of vehicles was to be performed by the University of California, Riverside College of Engineering-Center of Environmental Research and Technology (UCR CE-CERT).

### **3.4 Implemented Approach**

As of December 2023, completed project elements included infrastructure to support the integration of the 1-MW rooftop solar PV array, 2.6-MWh BESS, microgrid controller, and EV chargers (Figure 2). While the infrastructure has been installed, the solar PV system has yet to be procured and installed. The BESS has been procured and installed, and modifications to the units' fire suppression systems have been completed. According to the current Interconnection Agreement with LADWP the BESS can only be energized as a component of the completed microgrid, which requires the installation of a solar PV system. EV chargers were placed in service and were used to charge electric CHE and vehicles. Crane drive upgrades to achieve energy efficiency benefits were also completed.

The following battery-electric CHE and vehicles were delivered and placed in service:

- Two (2) TransPower-repowered Navistar International on-road drayage trucks
- Two (2) BYD battery electric yard tractors, with first generation units being replaced by second generation units in 2022
- Two (2) TransPower-repowered battery-electric Kalmar yard tractors
- Three (3) TransPower-repowered 21-ton battery-electric Kalmar forklifts
- One (1) Kalmar T2E+ battery-electric yard tractor

Electric CHE and vehicles were not fully integrated into the existing fleet for offloading vessels and transporting break bulk materials and containers because of safety documentation, certification, and reliability issues. Ricardo documented that the EVs and CHE were used inconsistently throughout the May 2019 to February 2022 demonstration period. Ricardo's analysis showed that the two BYD yard tractors were in operation for a combined 83 days, while TransPower yard tractors were only operated for a combined 24 days. Additionally, the BYD

Generation 2 yard tractors were operated for a combined 2,800 hours following replacement of the Generation 1 yard tractors. While not included in Ricardo's analysis, the Kalmar T2E+ yard tractor was placed in service following its delivery in the first quarter (Q1) of 2021 and was used consistently and reliably in cargo operations until it was taken out of service following the thermal event involving one of the TransPower-repowered Kalmar T2 yard tractors. Forklifts were placed in service after the demonstration period in April 2022 and were used for 3 days. Forklifts were taken out of service following the initial yard tractor thermal event and were not used again due to safety concerns of Pasha and their equipment operators. The TransPower drayage trucks were only used a very limited basis because of unresolved electrical and mechanical issues that created unsafe driving conditions. Factors affecting the limited demonstration of vehicles included delays in obtaining agency approvals and documentation for safe operation, which delayed the in-servicing of the TransPower CHE and vehicles, retrofits to achieve safe operations, downtime for repairs and maintenance, and two thermal events involving both TransPower-repowered Kalmar T2 yard tractors, as detailed below in Section 3.5.2.

The ShoreKat on-dock ECCS was also used on a limited basis throughout the project. Ricardo reported that the system was used against four vessels during the demonstration period between April and July 2019. The proposed ShoreKat system was to include carbon capture capabilities; however, the technologies assessed were determined to be either technically infeasible or too costly to demonstrate. Further details are provided in Section 3.5.3.

While the project was scheduled to be completed over a 3-year period, from February 2016 through December 2018, the project was extended through December 2023 to allow Pasha and the Harbor Department additional time to complete unfinished project elements and continue the demonstration to further test electrified equipment that had achieved limited use due to the factors described below in Section 3.3.

### **3.5 Comparison of Planned Approach to Implemented Project**

Project challenges not only extended the total planned duration of the project from approximately three years to eight years, modifications to originally planned infrastructure, equipment, and demonstrations also were needed to achieve a successful demonstration. The

following sections detail the approach to project implementation for infrastructure, electrified equipment and vehicles, and the ShoreKat ECCS.

### **3.5.1 Infrastructure Design and Construction**

Preliminary assessments of the terminal's electrical infrastructure were performed prior to the submittal of the grant application. The assessments showed that while the existing electrical switchgear was over 30 years old, it had sufficient capacity to allow for the integration of the solar PV system, BESS, and charging equipment. The assessment of the Berth 181 Warehouse roof identified the need for retrofits and reroofing to make the warehouse solar ready. Upon project initiation, further assessments of the terminal's infrastructure and engagement with permitting agencies identified the need for additional warehouse improvements and modifications to the planned location for the new electrical infrastructure. Warehouse 181 was found to have asbestos, requiring remediation prior to completing retrofits and re-roofing. As-built drawings and ground penetrating radar were critical in identifying underground utilities that required a shift in the locations of the BESS, chargers, and other supporting electrical infrastructure. Figure 2 provides a layout of the charging infrastructure and BESS constructed at the terminal.

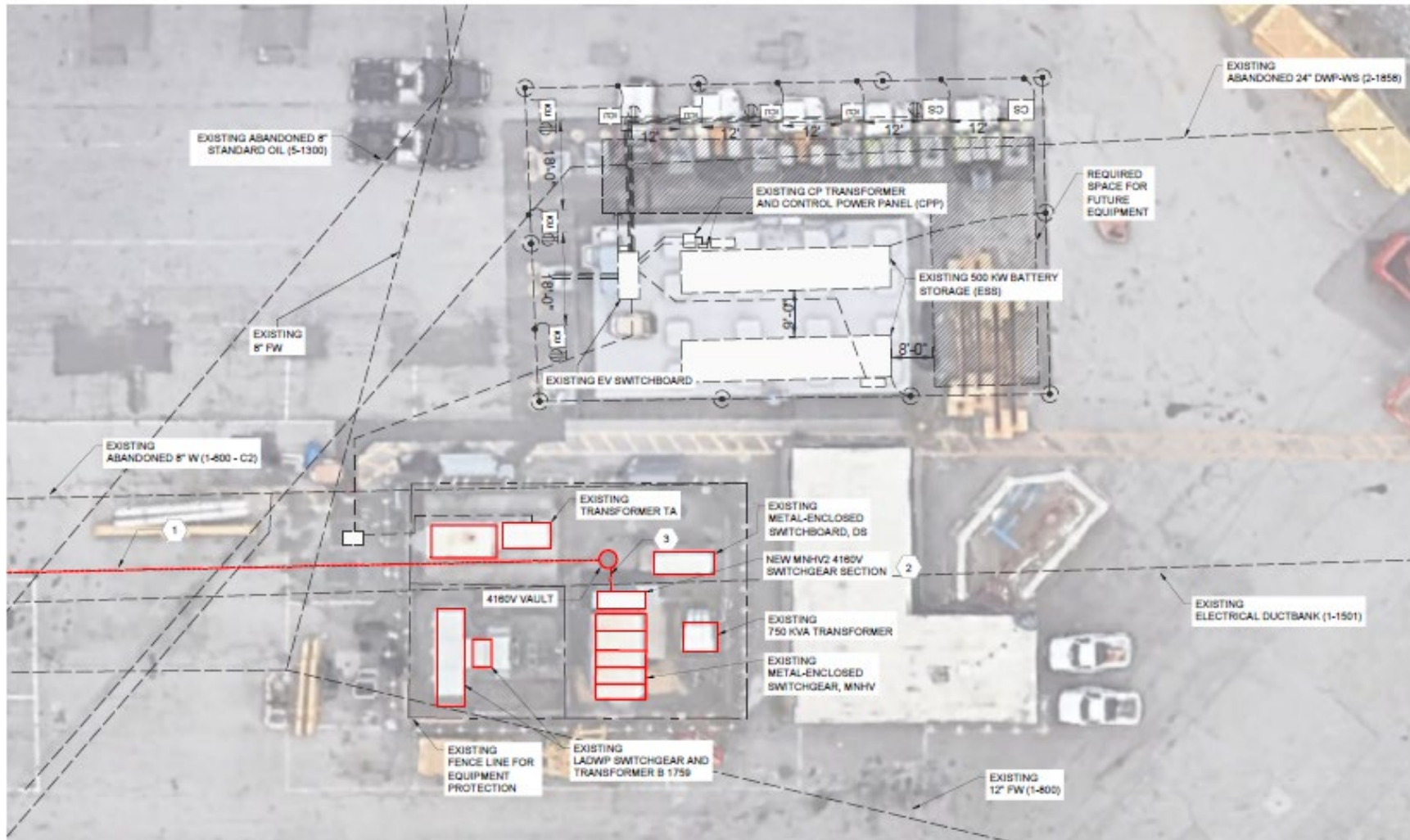


Figure 2: Constructed Electrical Infrastructure Supporting the Battery Energy Storage System and Electric Vehicle Chargers

### 3.5.1.1 Permitting

The Green Omni Terminal Project involved the first application of a solar-battery storage microgrid in the service territories of LADWP, Los Angeles Department of Building and Safety (LADBS), Los Angeles Fire Department (LAFD), and LAHD. The project also required the first permanently permitted installations of heavy-duty EV charging infrastructure for BYD and TransPower. The microgrid components of the projects required approvals from LADBS, LADWP, LAFD, and LAHD in addition to third-party certification of the BESS. The chargers required approvals by LADBS and LAHD in addition to Underwriters Laboratory (UL) listing (or third-party certification). Design and permitting was initiated in 2016, with the first permit applications submitted to LADBS on December 30, 2016. Permits and permissions were obtained in multiple phases for the project over the course of six years, with the final approvals obtained from LAFD to modify the BESS's fire suppression systems in Q1 2022. LADWP would not allow modifications to the existing 1980's era switchgear at the terminal unless the existing gear was brought up to present-day codes. To obtain approvals without incurring millions of dollars of upgrade costs, electrical upgrades needed to leave the existing gear largely unmodified, which resulted in compromises in functionality and the necessity of phasing upgrades.

- **Phase 1:** Installation of EV chargers, BESS, EV switchboard, and microgrid control system, with approvals required by LADBS, LAHD, and LAFD. The completion of Phase 1 would allow the chargers to service the EVs and the BESS to support EV charging when both connected and islanded from the utility grid.
- **Phase 2:** Installation of solar PV system and associated electrical infrastructure upgrades, including upgraded electrical cables between Berth 181 warehouse and addition of a new section to the existing switchgear. Permit approvals were required from LADBS, LADWP, and LAHD. Phase 2 would provide solar energy to offset the terminal's electrical loads, but solar could not be fed directly to the BESS until Phase 3 upgrades were completed.
- **Phase 3:** Upgrade of old switchgear by the Harbor Department, with approvals required from LADBS and LADWP. Completion of Phase 3 would allow the solar to directly feed the BESS while islanded from the grid in the event of a power outage.

Phasing of infrastructure required additional time to navigate the permitting process and delayed ordering of longer lead-time items, such as transformers and switchgear; however, these delays were overshadowed by the challenges in obtaining third-party certifications (equivalent to UL listing) for the precommercial EV chargers and BESS. The third-party inspection and certification process identified required modifications to the chargers and the BESS that had to be implemented prior to energization. This process took two years for the BYD EV chargers and four years for the BESS.

The permitting process for the BESS was the most complex and challenging element of the project because the approval process for these systems was being developed throughout the project by the different agencies. The approval process was particularly challenging because this was the first BESS project within the City of Los Angeles and the agencies rightfully had concerns regarding fire and life safety, as well as limiting the potential of the systems to back-feed into the utility grid. To achieve LADWP approval, the project was broken into phases whereby the automatic transfer switch (ATS) was removed from the design and a power reverse relay was incorporated into the 480-volt (V) switchboard to prohibit the batteries from back-feeding to the grid, limiting their use to only powering the EV chargers. Replacement of the existing 5- kV switchgear in Phase 3 of the electrical upgrades included the removal of the reverse relay and installation of an ATS to connect the solar to the batteries and provide full microgrid functionality. LADBS approval required that the BESS be inspected by an approved third-party certification company and LAFD. The need for retrofits and special approvals involved a multi-year process, with third-party certification obtained in Q3 2020 and approval of fire suppression system plans obtained from LAFD in Q1 2022.

The permitting process for the EV chargers was much less complex than for either the solar or BESS; however, the third-party certification process identified retrofits that substantially delayed the project. Both TransPower and BYD chargers required retrofits to obtain third-party certifications, as identified by inspectors in Q1 2018. TransPower was able to complete retrofits and obtain approvals in Q2 2018, while BYD was able to complete final retrofits and obtain approvals in Q2 2020. The drastic difference in permitting timeframes was the result of BYD delays in sourcing required replacement charging cables and implementing retrofits.

A single Interconnection Agreement was obtained from LADWP for the microgrid, including the solar PV System and BESS because the system was designed to operate with both distributed energy resources in place. This approach was found to be problematic because LADWP would not allow the interconnection of the BESS without the installation of the solar PV system, which has yet to be installed.

### 3.5.1.2 Solar Photovoltaic System

The planned approach for the solar PV system was for Pasha to contract PermaCity to install a 1-MW roof-top solar PV system on the Berth 181 Warehouse following the retrofit and reroofing of the warehouse by the Harbor Department (Figure 3). The PV system was to be connected to a 1500-kilovolt ampere (kVA) pad-mounted transformer at the existing building, which would feed to a 3,000-amperes (A) switchboard with two breakers – 1,200 A for the solar PV system and 400 A for the existing building. A single 5-kV feeder was to be run from the warehouse to the existing substation. Roof retrofits and re-roofing were completed in Q4 2016, structural repairs to warehouse supporting columns were completed in Q2 2018, and supporting electrical infrastructure were installed in Q3 2018.



### Figure 3: Conceptual Layout of the 1-MW DC Rooftop Solar PV System

Upon grant award, Pasha planned to procure the solar PV system under LADWP's Feed-in-Tariff (FiT) program. The FiT program requires solar energy be transmitted directly to the grid to contribute the utility's renewable energy portfolio targets. Special permissions were required from both LADWP and the California Energy Commission (CEC) to allow the incorporation of a FiT system, which would allow solar energy to be directly used by the terminal during a utility outage event. The system was initially designed and achieved approvals from LADWP and the CEC to both participate in the FiT program and support the microgrid. Due to the operational constraints of such a system, Pasha later decided to pursue solar under LADWP's Solar Incentive Program, more commonly referred to as net energy metering (NEM). The supporting electrical infrastructure, including metering arrangement, was redesigned to be consistent with NEM, providing greater operational flexibility. The permitting process for incorporating a solar PV system into the microgrid took approximately two years, with Phase 2 permits obtained from LADBS and LADWP for solar and associated connecting infrastructure upgrades in Q2 2018 and the LADWP interconnection agreement obtained in Q3 2018.

While infrastructure upgrades required to support the solar PV system were more involved than initially anticipated and took over two years to complete (inclusive of permitting), the primary issue that delayed the installation of the solar PV system was the prolonged terminal lease agreement negotiation between Pasha and the Harbor Department. In Q2 2017, it became evident that the lack of a lease between Pasha and the Harbor Department was a limiting factor that did not allow Pasha to enter into a solar PV system lease agreement with the solar provider, PermaCity, to install the system under the LADWP FiT program. Multiple options were evaluated to structure the lease agreement with the solar provider, including agreements between Pasha and PermaCity, as well as a direct agreement between the Harbor Department and PermaCity. In the end, the parties determined that the only acceptable path forward was a direct agreement between Pasha and PermaCity; this outcome required that a long-term property lease be in place that was equal to or greater than the duration of FiT agreement (i.e., 20-years).

In Q3 2017, Pasha determined that it could procure the solar PV system under NEM, which would provide greater microgrid functionality for the terminal, including peak shaving and load

shifting to reduce energy costs and flexibility to test islanding modes of operations that were not possible under the FiT program. The project was redesigned, and permits were obtained for the solar PV system, including the microgrid Interconnection Agreement from LADWP in Q3 2018. While the supporting infrastructure was also completed in the same quarter, terminal lease negotiations were still ongoing as of December 2023. As of the date of this report, Pasha has entered into a contract with the company that acquired PermaCity – Catalyze. Due to changes in the selected solar PV panels, the size of the solar PV system changed from 1,006,400 kW DC / 800 kW AC to 1,000,080 kW DC / 800 kW AC, resulting in LADWP requiring a new Interconnection Agreement for the microgrid. The Interconnection Agreement process is currently in process as of the date of this report.

### 3.5.1.3 Battery Energy Storage System

The planned approach for the BESS was for BYD to manufacture and deliver two containerized units to Pasha that could be connected to the newly constructed electrical infrastructure upon completion. The BESS was to provide a total of 2.6 MWh of capacity and include batteries, power conversion system (PCS), container, and supporting systems. The BESS was to include two 40-foot containers, which were to be positioned adjacent to the existing substation (Figure 4).



**Figure 4: BYD Battery Energy Storage System Containers Installed at Permanent Locations**

BYD delivered the two BESS containers to the terminal in Q1 2017. Since the electrical infrastructure was not complete, the BESS was connected to temporary auxiliary power in Q3 2017 to run the HVAC systems to maintain the units at constant temperatures. The supporting permanent infrastructure was completed in Q2 2018; however, the BESS could not be installed and energized until UL listing or third-party certification of the units was obtained.

In Q1 2017, BYD contracted an LADBS-approved third-party certification company, Intertek, to perform testing of the BESS to determine compliance with UL 9540 Standard for Safety Energy Storage Systems and Equipment, 2016, 1<sup>st</sup> Edition, with reference to 2016 CEC, California Code of Regulations, Title 24 Part 3. Intertek identified 35 non-conformances that required repair, replacements, or additional information/documentation. While most issues could be resolved with relatively minor modifications or by providing additional information, the most challenging items to address were the requirement to have adequate worker clearances within the BESS containers to avoid arch flash issues (36 inches per clause 10.4 of the National Electric Code standards) and the need to upgrade the fire suppression system to meet standards.

The process of resolving the non-conformances took approximately 3.5 years and involved multiple meetings with LADBS, Harbor Department Engineering, LAFD, and Intertek. In addition to making small repairs, equipment replacements, and installing labels and signage, BYD performed more major retrofits, including modifications to raceways, installing plexiglass to limit arch flash risk, rerouting the condensate pipe for the HVAC systems, and modifications to FM 200 fire suppression system. BYD then submitted a formal Safety and Analysis Plan for the BESS that explained how the system would be operated and maintained in a manner that meets the intent of building and safety codes (e.g., safe working clearances). Intertek then used the analysis along with additional documentation, laboratory testing, and other retrofits performed by BYD to develop a final preliminary report that documented that the non-conformances were resolved and the BESS was substantially in compliance with applicable codes and standards.

In Q3 2019, LADBS inspected the BESS infrastructure as a component of their Intertek report review. The report identified the batteries as being rated for 5,000 A to provide a conservative

estimate because no amperage was listed for the systems. This created a problem because this amperage was lower than what is typically found in similar systems or even a common house, creating a potential short circuit current rating (SCCR) issue. Burns & McDonnell worked with BYD to determine the actual amperage of the BESS to identify if further retrofits would be required. In Q2 2020, BYD provided adequate documentation to Intertek to show that the SCCRs for the BESS were adequate to allow direct connection of the systems to terminal electrical infrastructure, resolving this issue. In Q3 2020, Burns & McDonnell installed the BESS at their permanent locations, but the systems could not be energized until the fire suppression system issues could be resolved and anti-islanding testing could be performed.

While Johnson Controls performed retrofits to the FM 200 fire suppression system to address non-conformances identified in the Intertek report, in Q4 2019 the LAFD identified that the FM 200 fire suppression system installed in the BESS was different from the types recommended in BYD's safety data sheets. The Harbor Department, working with Johnson Controls, took the lead to resolve this issue with LAFD. It was determined that the FM 200 system would need to be replaced with a CO<sub>2</sub>-based fire suppression system. The Harbor Department submitted their first permit application to LAFD for the replacement of the fire suppression system in Q1 2021. The plan check review and revision process took over one year, with final permit approval obtained in Q1 2022.

The Harbor Department and Johnson Controls completed retrofits of the fire suppression system in Q4 2022. In Q4 2023, the Harbor Department completed the Phase 3 electrical upgrades of the 5-kV switchgear. Upon installation of the solar PV system by Catalyze, the BESS will be integrated into the microgrid, which will allow the batteries to be charged by the solar PV system and provide power to the terminal when islanded from the LADWP grid. As of the date of this report, a revised Interconnection Agreement is being pursued to meet LADWP's requirements for placing the BESS in service.

#### **3.5.1.4 Microgrid Controller**

In Q3 2017, BMcD began construction of Phase 1 infrastructure to support the installation of the microgrid controller / energy management system. The controller was installed in Q1 2018, and third-party certification of the controller was obtained in Q3 2018. A Siemens SICAM

Microgrid Controller was installed that has the capability to interface with the 5-kV main switchgear consisting of one main breaker and four distribution breakers with SEL protective relays on a common ethernet network, which will be used by the microgrid controller to command the relays to trip/close breakers. The controller also was designed to have the ability to interface with the solar PV system with a 5-kV ATS to allow it to supply power to either the utility (normal conditions) or the microgrid (islanded operation). The controller is capable of interfacing with the solar inverters when in islanded mode. Lastly, the controller also has the capability to interface with the 480-V switchboard that connects the EV chargers and the 1-MW/2.6-MWh BESS.

#### **3.5.1.4.1 Grid-Tied Mode**

The microgrid controller's primary function when grid tied is to accumulate data on the state of the electrical system and provide general SCADA functionality for the controlled devices. When the utility is available, the solar power will be directly connected to the serving utility via the ATS and will not supply power to the microgrid. The controller will provide a desired charge/discharge rate and power factor (or reactive power set point) to the BYD batteries to manage the peak power demand of the site. At no point should the battery be allowed to discharge below 33% State of Charge while grid connected in order to have some power available for islanded operation. The microgrid controller will not disconnect any EV while grid tied. The BESS is to serve as the only method for peak shaving control.

#### **3.5.1.4.2 Islanded Mode**

When the utility source is lost, the BESS will isolate itself from the distribution system and change mode of operation to provide voltage and frequency. The microgrid controller will trip the breakers in the 5-kV switchgear and then command the battery to connect to the microgrid. This will immediately re-energize the 480-V switchboard, which supplies the batteries and EV charging equipment. The two battery storage containers are expected to function as a single entity to hold 480 V and 60 hertz (Hz) on the switchboard's bus without direction from the microgrid controller. The microgrid controller will then close the breaker on the 5-kV breaker serving the battery switchboard's transformer to energize the 5-kV switchgear. It will then close the breaker to supply the "emergency" source to the ATS and then the transformer for the office building. Next, the microgrid controller will close the breaker supplying the transformer for

general power around the terminal. Next, it will close the breaker supplying the transformer for the warehouse and 1 MW of solar power. Finally, the microgrid controller will close the breaker that supplies power to the cranes. Each step in the re-energization process will be based on the available capacity of the BESS. If the actual load on the system is too high to proceed to the next step, then only a portion of the microgrid will be re-energized.

While islanded, the BESS will maintain the 480-V switchboard's voltage and frequency while allowing loads to cycle and the solar array to generate power. The microgrid controller will limit the maximum power generated by the solar array based on the BESS's reported state of charge (full solar output at 70% and below, no output at 85%, linear ramp between). If the battery's state of charge goes below 25%, the microgrid controller will trip the breaker serving the cranes. If the state of charge goes below 20%, it will trip the general power. If the state of charge goes below 15%, it will trip the office building. If the state of charge goes below 10%, it will trip all breakers in the 5-kV switchgear and then reclose the main breaker to await power restoration by LADWP.

If power is restored while the battery is supplying power to the microgrid, the microgrid controller will send a signal to the BESS to synchronize back to the utility. The battery controller will look at the voltage on both sides of the 5-kV main breaker and adjust the output of the BESS to be synchronized with the utility. The controller will then send a close command to the main breaker. Once the breaker is closed, the system will return to grid-tied operation. If, for any reason, the BESS is unable to complete a synchronized return to the utility, the microgrid controller will alert the operator and await a command to perform an open transition to utility. Once this is confirmed, the controller will trip each of the load breakers in the 5-kV switchgear, command the solar inverters to turn off, trip the 480-V breakers in the EV switchboard, and command the BESS to disconnect from the microgrid. As soon as the inverters show that they have shut down, the microgrid controller will release the ATS to return to its utility source and then re-enable the inverters. When the 5-kV switchgear shows 0 V, the microgrid controller will reclose the main breaker and then restore all loads.

### 3.5.1.5 Charging Equipment

The plan was to install standardized electrical infrastructure to connect two BYD chargers and seven TransPower chargers to support the charging of electric CHE and vehicles within six months of project initiation. BYD chargers installed are 100-kW units and TransPower are 70-kW chargers (Figure 5). Significant differences in the design of the manufacturers' vehicles precluded the potential use of a common standardized charging system.



**Figure 5: BYD and TransPower Chargers**

BYD delivered charging units to the terminal in 2016. One charger was temporarily installed at the maintenance building to allow demonstration of the BYD yard tractors until such time as the permanent location of the chargers was completed.

Prior to the permanent installation of the EV chargers, LADBS required equipment to be UL listed or approved by an authorized third-party certification entity. The charging infrastructure provided by both BYD and TransPower were not UL listed, requiring that they undergo certification prior to being placed in service. In Q1 2018, the inspection process identified

retrofits for each of the manufacturers' equipment. In Q2 2018, TransPower obtained third-party certification of their chargers, and BMcD installed the seven TransPower units and one BYD charger in their permanent locations. In Q3 2018, TransPower EVSE were placed in service. BYD chargers required ordering parts and cables that were not readily available. It was not until Q2 2020 that both the BYD chargers were retrofitted, obtained third-party certification, and were approved for use by LADBS.

Chargers were not only specific to the manufacturer, but they could also only be used to charge specific types of batteries. TransPower chargers were originally configured with fixed grounds to support the charging of lithium iron phosphate (LFP) batteries. Chargers need to be modified from fixed to floating ground configurations to be able to charge the new nickel manganese cobalt (NMC) batteries. For an interim period, there were three different types of chargers on the terminals – BYD chargers, TransPower chargers with fixed grounds for vehicles with LFP batteries, and TransPower EVSEs with floating grounds for vehicles with NMC batteries. This required special labeling of the chargers and the vehicles to avoid plugging TransPower vehicles into the wrong charger, which would damage the vehicle. Eventually, all TransPower vehicles were transitioned to NMC batteries and all chargers were configured with floating grounds.

Once BYD and TransPower chargers were placed in service, the units functioned reliably and did not require regular maintenance and repairs to maintain operational readiness.

#### **3.5.1.6 Wharf Crane Drive Upgrades**

The original project approach scheduled wharf crane drive upgrades to take place within six months of project initiation. Pasha planned to upgrade the electrical drives and crane control systems for two of the gantry cranes to increase the energy efficiency of cargo handling operations. In Q3 2017, Pasha performed an assessment of the useful lifespan of their electrical cranes and determined that cranes would need to be replaced within three years. This determination led to a decision to forego drive upgrades due to the limited return on investment. Pasha later determined in 2022, that they will continue the use of the cranes into the foreseeable future. Wharf crane drive upgrades were initiated and completed in 2023.

### **3.5.1.7 Testing and Commissioning**

Once the solar PV system, BESS, chargers, and supporting electrical infrastructure were installed and in service, the plan was for BMcD to commission the microgrid. The commissioning effort was to test and optimize the system for grid-tied and islanded modes of operation. The commissioning procedures were to be documented in a commissioning report.

Due to delays in the installation of the solar PV system and the energization of the BESS, commissioning has not been performed as of December 2023.

### **3.5.2 Vehicles and Cargo Handling Equipment**

Electric CHE and vehicles were planned to be developed in two phases over approximately a 1.5-year period. During Phase 1, TransPower was to manufacture and deliver the two drayage trucks, two yard tractors, and one 21-ton forklift; and BYD was to manufacture and deliver two yard tractors. In Phase 2, TransPower was to manufacture the second 21-ton forklift and top handler to build on the lessons learned during the manufacturing and commissioning of the Phase 1 forklift. Following delivery, the vehicles were to be placed in service and demonstrated for two years.

While all the planned vehicles were delivered to the terminal, other than the top handler, which was replaced with a third forklift, the timeframe for delivery, modification, and certification was so prolonged that all vehicles were demonstrated for less than one year as of the date of this report. The following sections provide details on the manufacturing, delivery, modification, and certification process for the different manufacturers and classes of vehicles that limited the demonstration time for EVs and CHE.

#### **3.5.2.1 Yard Tractors**

BYD and TransPower each delivered two battery-electric yard tractors, and Kalmar provided a commercially available yard tractor near the end of the project. While overall use of the vehicles fell far short of the intended two-year demonstration period as of the date of this report, the yard tractors achieved the greatest amount of use at the Pasha terminal.

### 3.5.2.1.1 BYD Yard Tractors

BYD delivered two yard tractors in December 2016, and the yard tractors were placed in service and used against two vessels in Q1 2017 (Figure 6). Upon initial testing of the BYD yard tractors it was determined that the trailers could not be safely connected and disconnected from the units, requiring modifications prior to placing the vehicles in service again. The location of the fifth wheel was 12-15” further forward towards the cab than a standard yard tractor. The mafi trailers were found to slide off the units, creating a safety issue. The position of the access panel toward the rear of the vehicle did not allow the fifth wheel to be moved further back. This design limitation required BYD to redesign the back end of the units. Additionally, the fifth wheel could not be raised and lowered while the vehicle was moving, and acceleration/deceleration issues were also identified that limited the units’ ability to creep at low speeds.



**Figure 6: BYD Generation 1 Battery-Electric Yard Tractor**

As a consequence of these issues, the vehicles were taken out of service so that retrofits and software upgrades could be performed. Pasha initiated discussions with union operators to support safe operations in light of operational differences in the BYD electric yard tractors with standard diesel-powered yard tractors. Pasha also specified the need for BYD to develop and provide an operational training manual for the yard tractors, as well as operational safety stickers to be placed inside vehicles, and perform training for operators prior to in-servicing of vehicles.

In Q3 2017, BYD returned the yard tractors to the terminal after making initial retrofits and installing operator signage. Pasha attempted to place the vehicles in service again, but the retrofits to the fifth wheel trailer hitch did not solve the initial mafi trailer sliding issue nor did they address the inability of the fifth wheel to be raised or lowered while the vehicle is in motion. Additionally, repairs and retrofits to the steering system and fifth wheel were required before vehicles could be placed in service again.

In Q3 2018, BYD retrofitted one of their yard tractors by adding guides to the fifth wheel trailer to resolve issues related to the safe loading and offloading of mafi trailers (Figure 7). Similar modifications were required for the second yard tractor. While the guide plate retrofit was successful, the yard tractors did not decelerate when the accelerator was released when being operated in reverse. This creates a safety issue at the terminal and union operators and representatives informed Pasha that they will not operate the vehicles until the issue was resolved. In Q4 2018, BYD completed a software update that allowed the yard tractors to decelerate once the accelerator was released; however, the update created other acceleration-related safety issues, which required further software updates.



**Figure 7: BYD Yard Tractor Fifth Wheel Retrofitted with Guides**

In Q1 2019, repairs and retrofits to the steering system and fifth wheel were completed, retrofits to the trailer hitch and associated plates were completed for the two yard tractors, and software updates were completed that corrected poor backup operation. By 2019, both BYD chargers had been installed in their permanent locations; however, delays in resolving third-party certification issues for the chargers did not allow the BYD yard tractors to be used until Q2 2020.

BYD yard tractors and chargers were placed in service in Q2 2020 and were used against vessels as long as maintenance and repair issues did not take the vehicles out of service. When operational, the BYD yard tractors were reported to perform well, maintaining adequate charge to complete shifts, and received positive responses from drivers. The drivers stated that they liked that the vehicles had air conditioning, were quiet to operate, and did not produce diesel exhaust and fumes.

Throughout the remainder of the demonstration, the combination of low shipping volumes and maintenance issues limited the total demonstration of the BYD units to 39 days for unit Y-262 and 44 days for unit Y-263. By the end of 2020, software updates were able to resolve low-speed operation issues (i.e., ability to creep) and the ability to raise and lower the fifth wheel while the vehicles were in motion. Maintenance and reliability issues were an intermittent problem, with Y-262 having a consistent issue with the low-voltage battery draining, resulting in the vehicle not starting.

Due to the reliability issues, BYD committed to replace the Generation 1 yard tractors with Generation 2 units, which have been found to be more reliable and require less maintenance based on other demonstration projects. BYD delivered the Generation 2 units to Pasha in Q1 2022. Pasha has found these units to function well and has reported no major maintenance and repair issues through the date of this report based on a combined 2,800 hours of operation.

### **3.5.2.1.2 TransPower Yard Tractors**

In Q2 2018, TransPower delivered two yard tractors to the Pasha terminal, and in Q1 2019 demonstrations were initiated (Figure 8). The yard tractors were used to offload multiple vessels throughout 2019, and units were generally found to complete shifts with approximately 50% state of charge, as reported by Pasha.

In Q4 2019, Pasha determined that due to compliance issues related to Occupational Safety and Health Association (OSHA) and California Division of Occupational Safety and Health Association (CAL/OSHA) standards, the TransPower yard tractors could not be used because the repowering of the Kalmar T2 yard tractors by TransPower was a modification that required approval by the original manufacturer, Kalmar, to avoid a potential violation. If modifications affect the capacity or safe handling of vehicles, OSHA CFR Section 1910.178(a)(4) and Cal/OSHA Cal. Code Regs Title 8 Section 3650(e) require either prior written approval of modifications by the manufacturer or verification after the modifications are complete that the modifications were designed, manufactured, and installed in accordance with recognized good engineering and manufacturing principals. Documentation could be provided either by the manufacturer or by a qualified, registered, professional engineer. In addition, labels or plates must be updated to describe the capacity, operation, and maintenance instruction for the modified vehicle.



**Figure 8: TransPower Battery-Electric-Repowered Kalmar T2 Yard Tractors**

The process of obtaining certifications and adequate documentation that met Pasha legal requirements took approximately two years to complete. While TransPower initially planned to self-certify the safety of the vehicles in Q2 2020, upon acquisition of the company by Meritor, the Meritor legal department determined that self-certification would be possible contingent upon the outcome of a review by a professional engineer. In Q1 2021, TransPower contracted the services of a qualified, registered, professional engineer who determined that the vehicles as

modified were safe for operation. After additional months of negotiation on the documentation language and following the replacement of battery cells that had degraded from lack of use, Pasha reinitiated the demonstration of the yard tractors in Q1 2022.

Later that same quarter on March 17, 2022, a driver while performing a jack-knife maneuver while backing up the yard tractor with a trailer drove the front of the trailer into one of the ESS boxes on the yard tractor damaging the unit and initiating a thermal event. A second thermal event occurred on May 31, 2022, involving the second TransPower yard tractor while the unit was parked and the ignition switch was in the off position. This event appeared to be the result of moisture entering a compromised ESS box. After the thermal events, Pasha stopped the demonstration of all TransPower-retrofitted equipment and vehicles, including the Kalmar Ottawa T2E+ yard tractor. None of the units were placed back in service.

#### **3.5.2.1.3 Kalmar Yard Tractor**

A commercially available Kalmar Ottawa T2E+ electric yard tractor was purchased with reallocated funds from the ShoreKat carbon demonstration project component and was delivered to the terminal in Q2 2021 (Figure 9). The yard tractor was placed in service and was found to be reliable, functioned well, and completed shifts with more than 50% state of charge, based on project update reports from Pasha.



**Figure 9: Kalmar T2E+ Yard Tractor**

Due to the thermal event following a trailer striking the ESS boxes on the Kalmar unit repowered by TransPower, Pasha also took the new Kalmar T2E+ yard tractor out of service because its ESS boxes are also susceptible to being struck when a driver performs a jack-knife maneuver. As of the date of this report, the Kalmar yard tractor is out of service due to this safety concern. Pasha is engaging the vehicle provider to assess options for protecting or repositioning the ESS boxes to minimize the potential for the trailer to collide with and damage the ESS boxes. No viable options were identified, and the unit was not placed back in service. Kalmar Ottawa was notified of the safety issue and based on this feedback the company reported that it was in the process of redesign of future battery electric yard tractor models to better protect the ESS.

### **3.5.2.2 On-Road Drayage Trucks**

In Q2 2018, TransPower delivered two Navistar International LT625 6X4 battery electric-repowered drayage trucks (Figure 10). The vehicles lacked the agency approvals for on-road operation, including National Highway Safety Agency Federal Motor Vehicle Safety Standards (FMVSS) alterer approvals, CARB Experimental Permit. The vehicles also required a CARB Executive Order and United States Environmental Protection Agency (EPA) Certificate of

Conformity to allow for the transfer of title of the vehicles from TransPower to Pasha. An Experimental Permit was obtained in Q4 2019 and FMVSS alterer stickers were obtained in Q3 2020, which was the final approval required to place the vehicles in service.



**Figure 10: TransPower Repowered Battery Electric Navistar International Drayage Truck**

The International trucks were placed in service after TransPower obtained the FMVSS alterer stickers for the vehicles. PST reported that they have had few opportunities to use the vehicles because the trucks do not have power take-offs (PTOs), which provide the ability to raise and lower the trailers' beavertails. Due to the extended period that the vehicles sat on the terminal unused, the original batteries were no longer holding a sufficient charge and required replacement. In Q1 2021, TransPower replaced the batteries, allowing the vehicles to be placed in service.

In Q2 2021, the vehicles were placed in service for approximately one week before one of the trucks (T-614) stalled due to ground fault issues when transiting the local bridges while pulling a loaded trailer, creating an unsafe operating condition. During the time that drayage trucks were in service, Pasha was able to operate the vehicles for 49 miles under a load before the batteries

were depleted. Pasha took both vehicles out of service because their drivers were unwilling to drive the vehicles until the ground fault/stalling issue was resolved.

TransPower attempted to identify the causes of the ground faults and stalling over the course of 2021 and extending into 2022. Software upgrades and replacement of key components were performed, but as of Q1 2022, the operational reliability issues were not resolved. Following the two thermal events involving the two TransPower yard tractors, Pasha discontinued the use of all TransPower-retrofitted vehicles based on safety concerns.

### **3.5.2.3 Top Handler**

In Q3 2017, Pasha determined that its Wilmington terminal operations no longer required the use of a top handler so electrification of the unit would not result in regular use. CARB approved the development of a third electric forklift in its place.

### **3.5.2.4 Forklifts**

Pasha provided three used 2008 Kalmar 21-ton forklifts to TransPower to be converted to battery-electric drives (Figure 11). The initial plan was for the first forklift to be completed and delivered as a component of the phase 1 vehicles; however, limitations in TransPower's engineering and manufacturing capacities combined with the challenges of completing a first of its kind re-power of a heavy-duty forklift delayed the delivery of the first forklift until Q1 2019, following initial testing and commissioning.

There were several safety concerns related to visibility, stability, and overall operational limitations raised by Pasha that delayed the in-servicing of the forklifts for three years. Pasha initially did not place the first forklift in service because union operators requested that additional signage and a back-up sensor be applied to the vehicle to account for the reduced visibility resulting from the placement of the battery packs. TransPower provided the requested signage and installed the back-up sensor in addition to the back-up camera that was previously installed.



**Figure 11: TransPower Repowered Battery-Electric Heavy-Duty Kalmar Forklift**

TransPower and Pasha performed lift testing of the battery-electric forklift to determine if it had the same lifting capacity as a diesel equivalent and assessed the stability of the forklift while performing lifts. The battery-electric forklift was able to pick up 34,500 lbs. The electric forklift's weight distribution was heavier toward the rear of the vehicle compared to a diesel equivalent. Kalmar rates the forklifts at 36,000 lbs. Following the lift testing, Pasha expressed concerns regarding capacity, visibility, braking, and stability.

Pasha requested a letter from the OEM, Kalmar, indicating that the modifications to the vehicle would not hinder its safe operations. Kalmar provided a letter indicating that the modifications, as reported by TransPower, would not impact the vehicle's weight distribution or lifting capacity; however, they could not certify that the modifications would not impact operational safety because they were not directly involved in the modifications. Pasha requested additional

documentation that specifically addressed OSHA and Cal/OSHA requirements prior to placing the unit in service, as detailed above in Section 3.3.2.1.2 TransPower Yard Tractors.

In Q4 2019, TransPower delivered Forklifts 2 and 3, completing delivery of all Phase 2 vehicles. These vehicles could not be placed in service until the OSHA issue was resolved. The process of obtaining certifications and adequate documentation that met Pasha legal requirements took approximately three years to complete from the time the first forklift was delivered. While TransPower initially planned to self-certify the safety of the vehicles in Q2 2020, upon acquisition of the company by Meritor, the Meritor legal department determined that self-certification would be possible contingent upon the outcome of a review by a professional engineer. In Q1 2021, TransPower contracted the services of a qualified, registered, professional engineer who determined that the vehicles as modified were safe for operation. After additional months of negotiation on the documentation language and following the replacement of battery cells that had degraded from lack of use, Pasha initiated the demonstration of the forklifts in Q2 2022.

The forklifts were only used against two ships, and while there were some minor maintenance and software issues reported, the forklifts were able to finish the day shift with approximately 40% state of charge. Following the two thermal events involving the TransPower yard tractors, Pasha discontinued the use of all TransPower-retrofitted vehicles and equipment, including the forklifts.

### **3.5.3 ShoreKat Emissions Capture and Control System**

The planned approach was for CAEM to manufacture the ShoreKat ECCS over a 5-month period followed by a 1-month period for delivery, at-berth assembly, and commissioning. Emission testing was to be conducted over a month period to validate system performance, after which demonstration would proceed through the end of the project.

Primary design considerations were the ability of the system to operate as a self-contained unit for a minimum duration that is equivalent to one vessel call. The system was also to be designed to accommodate a wide variety of auxiliary engine stacks. Additional design improvements were to include increased NO<sub>x</sub> removal efficiency, improved energy efficiency, non-methane volatile organic compounds (VOC) and oxides of sulfur (SO<sub>x</sub>) reduction, and CO<sub>2</sub> capture.

The primary focus of fabrication was to greatly reduce construction time and level of effort in the field and reduce shipping costs from the factory. This was to be accomplished by focusing on a modular type of design that incorporated many elements into a single integrated component. The goal was to shift labor delivered in the field to being delivered at the factory.

The proposed approach for the ShoreKat was for CAEM to develop an ECCS that integrated carbon capture capabilities with core treatment system, which captures and controls criteria pollutant emissions. Shortly after project initiation, CAEM reported that they would be unable to accomplish this integration. Instead, CAEM proposed and CARB approved pilot tests of two carbon capture systems that would be connected to the ShoreKat and demonstrated for 6-month periods.

### **3.5.3.1 Core Emissions Capture and Control System**

Pasha entered into an agreement with CAEM to develop the ShoreKat ECCS in March of Q1 2017. The core ECCS included a Grove crane modified to serve as an emissions capture boom and two stackable, modular units that were approximately 60 ft long, 10 ft wide, and 20 ft high (Figure 12). The core ECCS was to be placed on a trailer to allow the system to be towed distances up to 5,000 feet at 10 miles per hour. Factory assembly of the ShoreKat core system was completed in Q3 2017 by Tri-Mer at their Michigan manufacturing facility. CAEM delivered the ShoreKat core treatment system to Pasha in Q1 2018; however, CAEM did not provide a trailer that could support the system when assembled.



**Figure 12: ShoreKat Emissions Capture and Control System**

In Q2 2018, the Grove crane was delivered to the terminal. The crane and extraction system was retrofitted by the manufacturer so that the system could be considered to be an emissions capture device rather than a crane. This involved changing out counterweights, modifying the software, and updating labels and name plates. In addition, the manufacturer provided a letter indicating that modifications to the crane would not impact the safe operation of the unit in compliance with OSHA and Cal/OSHA regulations.

In Q4 2018, CAEM completed the assembly of the ShoreKat ECCS on a custom-built Greenfield trailer. The combined weight of the ShoreKat system on the trailer was too heavy for on-site yard tractors to move the unit safely. In Q1 2019, CAEM ordered a dolly from Greenfield that would reduce the weight of the trailer on the towing yard tractor or truck, with the goal of allowing the trailer to be pulled by a standard yard tractor. The ShoreKat without the dolly placed 42.5 tons

of weight on the 5<sup>th</sup> wheel. The dolly was installed on the ShoreKat trailer in Q3 2019, and testing confirmed that the unit could be towed by a yard tractor. The total weight of the ShoreKat was 240,000 lbs, which required that the Harbor Department issue a heavy lift permit to place the system along the wharf. The heavy lift permit requires an analysis of the wharf's capacity to support the system without causing damage or creating an unsafe condition.

The ShoreKat was placed in service and was connected to the first vessel in April 2019. Throughout the demonstration period, which ran from April 2, 2019 – March 31, 2020, the ShoreKat was successfully used to treat emissions from four vessels. ShoreKat use was limited by low numbers of vessel calls at Pasha due to the impacts of steel tariffs, refusals by ship owners to allow ShoreKat use, incompatible orientations of vessels that did not allow the emissions capture boom to reach and connect to auxiliary engine stacks, and inoperability of the ShoreKat in Q1 2020 when the ShoreKat was found to have approximately 40 broken filters.

### **3.5.3.2 Carbon Capture Systems**

The carbon capture component of the ShoreKat demonstration was to include evaluation and selection of two technologies that would each be deployed over six-month periods to demonstrate the feasibility of capturing and treating GHG emissions. CAEM technology partner Tri-Mer Corporation (Tri-Mer) evaluated CO<sub>2</sub> capture and conversion technologies in the following categories:

- Conversion
- Chemical Sequestration
- Bio Sequestration
- Photo-electrochemical
- Artificial Photosynthesis
- Nano Structured Materials

Tri-Mer determined that conversion, chemical sequestration, and bio sequestration technologies have the greatest commercial viability and were evaluated in greater depth. Upon completing their evaluation, Tri-Mer selected a CO<sub>2</sub> conversion technology and chemical sequestration technology for pilot project development (Table 3).

In Q1 2019, CAEM and Tri-Mer determined that the two carbon capture and treatment technologies could not be demonstrated at a pilot scale because of technical and financial feasibility constraints. The CO<sub>2</sub> conversion technology being developed by GST LLC was reported to not function as specified and the pilot unit could not be delivered for demonstration. The chemical sequestration technology developed by Carbon Clean Solutions was shown to be technically feasible, but the cost of developing a pilot unit was estimated at \$1.5 million. Due to the determination that the carbon capture and treatment technologies were not feasible, funds were reallocated from the carbon demonstration to the purchase of the commercially available Kalmar T2E+ electric yard tractor.

**Table 3: Evaluation of Carbon Capture and Treatment Technologies**

Approach	Company	C.O.O.	Technology	Substrate	Status & Scale	Demo Unit Availability	Demo Feasibility
<b>Technologies Selected for Demonstration</b>							
CO <sub>2</sub> Conversion	GST LLC	USA	Non-Thermal Plasma	Plasma	Pilot	5	5
Chemical Sequestration	Carbon Clean Solutions Pvt. Ltd.	U.K.	CDRMax™ Column Absorption Tower	Reformulated - Proprietary Solvent	Full Scale Commercialization	2	5
<b>Technologies Considered, but NOT Selected for Demonstration</b>							
CO <sub>2</sub> Conversion	Carbon Conversion Intl	USA	Non-Thermal Plasma	Plasma	Lab	1	1
Chemical Sequestration	Climeworks AG	Switzerland	Direct Air Capture (DAC)	Chemically Bound Proprietary Solvent Filter Bed	Full Scale Commercialization	5	5
Chemical Sequestration	Tecno Project Industrialnale (TPI)	Italy	Column Tower Absorption Tower	Reformulated - Proprietary Solvent	Full Scale Commercialization	5	4
Chemical Sequestration	Matoon Power LLC	Sweden Norway USA	Pressurized FBC/PFBET	Pressurized K <sub>2</sub> CO <sub>3</sub>	Pilot   Small Scale	4	2
Chemical Sequestration	Noram E&C Ltd. BC Research Inc. Carbon Capture & Conversion Institute	Canada USA	Optimized Column Absorption Tower	Reformulated - Proprietary Solvent	Pilot   Full Scale	3	3
Chemical Sequestration	LLNL   ARPA-E   Center for Carbon Removal	USA	Core-Shell Microcapsules	Polymer Encapsulated Na <sub>2</sub> CO <sub>3</sub>	Lab/Bench Scale	5	3
Chemical Sequestration	Westec Environmental Solutions LLC	USA	Co-current, Micro-Froth Absorption	Reformulated - Proprietary Solvent	Pilot   Small Scale	4	3
Bio Sequestration	HY-TEK Bio LLC	USA	Algae Photo Bioreactor (APB)	Algae	Lab/Bench Scale	3	1
Bio Sequestration	Phyco2 LLC Michigan State University	USA	Algae Photo Bioreactor (APB)	Algae	Lab/Bench Scale	3	1

### 3.5.4 Demonstration and Data Collection

The demonstration phase was planned to extend for two years, with the goal of showing how multiple zero and near-zero equipment can operate together to sustainably move break bulk and container cargo through the terminal to clean transportation. Field data on the vehicles, CHE, and ShoreKat were collected and analyzed by CARB's third-party contractor, Ricardo, to monitor, collect, and analyze the data from the Green Omni Terminal Project. Laboratory dynamometer

data for the TransPower repowered Kalmar Ottawa T2 yard tractor was collected by UCR CE-CERT. Field data for the forklifts were also collected and analyzed by UCR CE-CERT.

While the overall duration of the project was extended from three years to seven years to provide more time for project elements to be completed and demonstrated, the demonstration periods for project vehicles, the ShoreKat, and the microgrid were impeded by reliability issues, extended timelines for retrofits, certifications, regulatory approvals, safety documentation requirements, and terminal lease negotiations. Due to the various challenges described for the different project elements in the above sections, the project was not able to demonstrate how the various project elements work together to perform zero emissions and near-zero emissions cargo handling operations. Table 4 provides a summary of the demonstration durations for the different project components.

**Table 4: Demonstration Periods for Green Omni Terminal Project Equipment and Vehicles**

<b>Project Element</b>	<b>Demonstration Period(s)</b>	<b>Comments</b>
BYD Yard Tractors	Q1 2017, Q3 2017, Q2 2020- Q2 2022	Total duration time of over 2 years. Use limited by retrofits/repairs and extended time when chargers were not in service due to third-party certification process.
TransPower Yard Tractors	Q1-Q4 2019, Q1 2022	Total duration of use was less than 1 year. Units were out of service for 2 years because of OSHA documentation issue. Units were taken out of service following thermal event.
TransPower Forklifts	Q2 2022	Units not placed in service for over 3 years because of OSHA documentation issue.
TransPower Drayage Trucks	Q3-Q4 2020, Q2 2021	Units were not placed in service because of FMVSS approval process. After initial limited use due to low cargo volumes and lack of power take off, batteries required replacement. Vehicles were taken out of service permanently because of ground faults that created unsafe driving condition.
Kalmar Yard Tractor	Q2 2021 – Q1 2022	Vehicle functioned reliably but was taken out of service because of Pasha’s concern over potential for trailer to strike ESS box, causing a thermal event.
TransPower EV Chargers	Q3 2020 – Q2 2022	Chargers received minimal use due to inability to place vehicles in service due to FMVSS and OSHA requirements.
BYD EV Chargers	Q1-Q3 2017, Q2 2020 – Q2 2022	One charger was temporarily placed in service and used in 2017. Third-party certification and retrofit delays limited use in 2018-2019.
ShoreKat	Q2 2019 – Q2 2020	The core emissions treatment system was demonstrated for one year against 4 vessels.
Microgrid	N/A	The BESS and solar PV system were not placed in service.

### 3.5.4.1 Field Data Collection

Ricardo conducted field data monitoring and collection for the project from May 2019 to February 2022. Data were collected for the BYD and TransPower yard tractors, TransPower drayage trucks, TransPower forklifts, associated reference vehicles, and the ShoreKat. Detailed methods and results of the field data collection efforts are presented in Ricardo’s Final Reports for the ShoreKat ECCS and electric vehicles.

### 3.5.4.2 Laboratory Data Collection

UCR CE-CERT evaluated the Kalmar T2 Yard Tractor repowered by TransPower with NMC batteries at their Heavy-Duty Chassis Dynamometer facility in Riverside, CA in Q1 2022. The yard tractor was tested over cycles designed to represent typical yard tractor operations. The test

cycles included cycles representing operations with a light and a heavy load. Energy consumption, state of charge usage, and average power were measured/calculated. Details on Laboratory Data Collection are provided in the UCR CE-CERT report entitled Performance Evaluation of a Battery Electric Equipment and Vehicles at the Pasha Terminal – Yard Tractor Testing.

## 4.0 DISCUSSION

The following sections describe the extent to which the project accomplished key project objectives, lessons learned, technological readiness, and future applications of tested technologies, including commercialization prospects.

### 4.1 Accomplishment of Project Objectives

The goal of the Green Omni Terminal Project was to incorporate zero and near-zero emissions CHE to move goods from ships through the terminal to clean transportation to their final destinations, while making portions of terminal operations more resilient through the development of a solar powered and battery storage microgrid. The objective of the project was to serve as the first step in transitioning the Pasha terminal to a zero-emission terminal, while serving as a scalable model that could be replicated at other ports and industrial facilities throughout California, the country, and the world.

While not all the elements of the project functioned as envisioned, the Green Omni Terminal Project was successful in demonstrating zero emission and near-zero emission technologies, including EVs, electric CHE, and the ShoreKat ECCS. The demonstration project provided valuable insights into the processes of obtaining approvals, permits, and buy-in necessary to operate pre-commercial and novel technologies at a marine terminal where the terminal operators, union, agencies, and technology providers must all collaborate to place equipment in service and sustain its ongoing use. Challenges that had to be overcome on the project included obtaining necessary permits and approvals from agencies for vehicles and charging equipment, providing adequate documentation on the safety of equipment, training and guidance to support operations and maintenance, and addressing operator concerns and resistance to the use of new technologies that may require modifications to existing operational approaches.

The resiliency goal for the project and the associated microgrid has yet to be achieved as of the date of this report. While much of the electrical infrastructure has been installed at the terminal, the solar PV system has not been installed and the BESS has yet to be energized. As the first solar and battery storage microgrid in the LADWP service territory and under the jurisdiction of LADBS and LAFD, navigating the permitting process has been exceedingly difficult. The process required extensive meetings with agencies, design modifications that resulted in

intermediate limitations on microgrid functionality, and extensive modifications to the BESS to obtain third-party certification and agency approvals. The Harbor Department and Pasha are committed to completing the microgrid project elements. It is anticipated that all the elements of the microgrid will be in place in 2024.

The accomplishment of specific project objectives is discussed as follows.

**Provide GHG, criteria pollutant, and toxic air contaminant emission reduction benefits to the Wilmington DAC.** The project was projected to reduce approximately 3,200 tons per year of CO<sub>2e</sub> per year, as well as criteria pollutants and toxic air contaminant emissions. The project fell well short of this target because two major contributors of emissions reductions were not accomplished through the project. The ShoreKat carbon capture demonstration was not completed, negating approximately 1,500 tons per year of CO<sub>2e</sub>. Additionally, because the solar PV system has yet to be installed, the project is forgoing approximately 800 tons per year of CO<sub>2e</sub>. It is anticipated that the solar PV system will be installed in 2024, providing emissions reduction benefit moving forward.

**Demonstrate multiple types of equipment and vehicles employing zero and near zero-emission technologies at one port facility.** Pasha served as a test facility for the commercialization of zero and near-zero emission technologies that move high-tonnage break bulk and containerized cargo. In demonstrating the technologies, the project provided valuable information on the reliability and commercial readiness of each of the technologies. Electric yard tractors showed the greatest promise for commercial use at terminals, followed by forklifts, and lastly by on-road drayage trucks. This assessment was based on vehicle reliability once they were properly commissioned, the ability to meet the operational needs of the terminal with adequate state of charge, and positive operator feedback. A more detailed discussion of the state of the technology is provided in Section 4.3.

**Provide economic, environmental, and public health co-benefits.** The Green Omni Terminal Project and other grant-funded demonstration projects have served and continue to serve as a catalyst for change at the San Pedro Bay Port Complex, providing a cost-effective and scalable model for sustainable and low-emission terminal operations at thousands of distribution centers and marine terminals throughout the state, nation, and world. The technologies that have been

deployed during this project have laid the foundation for ambitious goals for transitioning port operations to zero emissions by 2030 for CHE and 2035 for drayage trucks at the San Pedro Bay Ports. Other ports have followed suit in California, Washington, New York, and Texas among others, with ports increasingly establishing 100% zero emission and net zero goals with target dates ranging from 2025 to 2050.

**Demonstrate the practicality and economic viability of wide-spread adoption of advanced freight technologies for various sources at a single facility.** The Green Omni Terminal was intended to go beyond this goal by demonstrating how a sustainable and resilient terminal can integrate zero and near-zero emission equipment into the first seaport terminal microgrid. While the microgrid component of the project is currently incomplete, the Port and Pasha are committed to completing this project component to provide sustainable and resilient power to the terminal. Pasha has also secured additional funding from the United States Maritime Administration to add project components, such as wind turbines, to augment the microgrid.

The project provided valuable insights into the practicality and economic viability of the different technologies. As previously noted, the electric yard tractors were determined to be the most practical technology followed by the forklifts and drayage trucks. The ShoreKat ECCS was found to be less practical to operate compared to barge-based ECCS. The placement of an ECCS on the terminal created operational constraints and conflicts that are not encountered with a barge-based system, such as limitations on the crane-based emissions capture boom to reach stacks and conflicts with vessel loading and offloading operations.

The project did not provide strong evidence for the economic viability of the demonstrated technologies. The capital costs of heavy-duty EVs and CHE, as well as their associated charging infrastructure were approximately three times higher than diesel-fueled equivalents. This price differential, which totals hundreds of thousands of dollars per unit is not likely to be offset based on the lower cost of electricity relative to diesel fuel. Additionally, the vehicles demonstrated in this project required regular repair and maintenance over and above their diesel equivalent reference vehicles, minimizing any projected O&M savings of EVs.

**Fund technologies on the cusp of commercialization that further the purpose of AB 32.** This project helped continue the process of increasing the commercial viability of these zero emission

technologies. While still more expensive than diesel equivalents, EV costs continue to improve as does the reliability and functionality of the vehicles. Throughout the course of the project, the costs of the first units developed were higher than subsequent units. For example, the first forklift cost \$1,210,000, partially due to \$500,000 in one-time engineering costs, while the second and third forklifts cost \$490,000 each. The price of electric yard tractors did not decrease substantially over the course of the project. In 2016, the TransPower electric yard tractor cost \$410,000, while the commercially available Kalmar electric yard tractor cost \$397,939 in 2020. Further progress is needed to close the cost differential between EVs and diesel-powered units.

## **4.2 Lessons Learned**

The Green Omni Terminal Project provided valuable lessons learned for the deployment of zero emission and near-zero emission technologies, including EVs, electric CHE, and the ShoreKat ECCS at multi-modal facilities. The demonstration project provided insights into the processes of obtaining approvals, permits, and buy-in necessary to operate pre-commercial and novel technologies at a marine terminal where the terminal operators, unions, agencies, and technology providers must all be aligned to place equipment in service and sustain its ongoing use.

### **4.2.1 Safety**

The biggest and most important challenge to implementing new technologies at a port terminal is safety. This was true for the infrastructure, vehicles, and ECCS. Safety starts with ensuring that the different equipment is designed to meet industry and agency standards as well as the specific operational requirements of a multi-modal facility. Operations and maintenance staff must be trained adequately to safely use the equipment and the equipment must function with a level of consistency and reliability to maintain a safe working condition. More than any other factor affecting the project, it was safety, including associated liability concerns, that was the root cause of many project challenges and delays.

#### **4.2.1.1 Equipment Design and Operations**

The safety and associated liability of the demonstration technologies were the two interrelated concerns that Pasha expressed for all project components. Vehicles and equipment were often delivered to the terminal lacking necessary placards, stickers, and signage. Many of Pasha's concerns were shared by the International Longshore and Warehouse Union (ILWU) operators

and representatives. The use of vehicles and equipment was halted on several occasions due to safety concerns.

The BYD yard tractors' fifth wheel was designed in such a way that a mafi trailer could slide off the vehicle because of a lack of guides. Additionally, the software programming of the vehicles initially resulted in acceleration and deceleration issues, including the vehicle continuing to accelerate when in reverse when the accelerator was not depressed. TransPower vehicles also were delivered in a condition that required repeated software refinements to achieve desired safe functionality. Repeated mechanical and electrical issues, such as ground faults, caused one of the drayage trucks to stall on a bridge and have difficulty restarting. The wide variety of design and operational issues combined with the iterative and generally slow approach to resolving problems, undermined the confidence of Pasha and the ILWU equipment operators in the demonstration vehicles.

The locations of ESS boxes impacted the safe operation of the forklifts and the yard tractors. The configuration of the battery packs on the repowered Kalmar forklifts resulted in reduced visibility behind the driver. To address the issue, a back-up camera, sensor, alarm, and signage were added to the units. Additionally, Pasha also expressed concerns about the stability of the forklifts while lifting heavy loads. This concern was addressed by performing lift tests and measuring the weight distribution of the axles to demonstrate that there were no significant differences with their conventional units.

The most notable safety issue encountered during the project was the thermal event that occurred when a mafi trailer struck the ESS box of a TransPower yard tractor. Pasha was already concerned about the potential fire risk of lithium-ion batteries, and while the fire was contained to one ESS, the amount of time it took the Fire Department to put out the fire raised additional safety concerns. This incident resulted in a safety stand-down that temporarily halted the use of all battery-electric vehicles. Pasha compared the positioning of the ESS boxes to the fuel tanks on diesel-powered yard tractors and reported that the ESS boxes are positioned higher, increasing the potential for the mafi trailer to strike the ESS at an earlier angle when performing a jack-knife maneuver as compared to a diesel-fueled equivalent unit.

Safety concerns were also raised regarding the ShoreKat and the associated emissions capture crane. These concerns included the stacked configuration of the core emissions treatment system that may create a tipping risk when transporting the system, the stability of the crane when extended, the number of trained staff needed to safely operate and monitor the ECCS when connected to a ship, and overall weight of the system and potential to damage the wharf and limit the safe towing of the system around the terminal. These concerns were evaluated and addressed through the demonstration process.

While the above list of items is not intended to serve as a comprehensive list of the safety issues related to the design and operation of the demonstration technologies, it illustrates the concern voiced repeatedly by Pasha staff and union operators regarding the safety of new equipment and technologies on a terminal. The prevalence of design and operation issues heightened the concerns of Pasha staff and union operators regarding the safety and reliability of zero and near-zero emission technologies.

Demonstration projects provide valuable information to CARB, project partners, and the overall industry about the operational safety and readiness of the vehicles and equipment. The design and operational challenges encountered during this project if addressed can greatly benefit the designs and performance of future models.

**Recommendation:** Original equipment manufacturers (OEMs) need to take additional time to test, commission, and resolve functional issues before vehicles are delivered to a terminal. While the purpose of the demonstration is to test the viability of the equipment and vehicles, critical safety issues should be resolved prior to delivery to an operating terminal to the extent practicable. One downside of placing vehicles in service too early is that repeated problems undermine the trust of operators in the technologies, potentially inhibiting future purchase and use by other terminals that hear about negative experiences.

#### **4.2.1.2 Training**

Operational training was provided by TransPower and BYD, and O&M manuals were provided for vehicles. In addition, TransPower provided O&M training to the Pasha mechanics. These were generally one-time training events and they occurred around the time that vehicles were delivered to the terminal. Due to the extended timeframes between when vehicles were

delivered and when they could be used, the project could have benefited from repeated training opportunities immediately before vehicles were placed back in use.

**Recommendation:** While the one-time O&M training was valuable, additional maintenance training of the terminal's mechanics would support knowledge transfer that would support the ongoing maintenance and use of the vehicles and CHE beyond the demonstration period.

#### 4.2.1.3 Commissioning

For nearly every piece of equipment or vehicle that was placed in service at Pasha, there was a period of weeks, months, and sometimes years where the vehicles underwent software updates, physical modifications, and retrofits to improve safety and performance. The vehicles and equipment were said to have undergone a commissioning process at their respective factories and this created an unrealistic expectation that the units should be ready for full demonstration when delivered to the terminal.

**Recommendations:** It would be beneficial if projects schedule an extended commissioning period when the technology provider actively works with the operator to test the vehicles and equipment and make modifications and improvements until the vehicles and equipment can be safely and reliably used. This would help set more realistic expectations at the terminal that pre-commercial demonstration equipment will require a period of modification and optimization to achieve the desired performance (i.e., commissioning) rather than expecting that the vehicles will be ready for demonstration upon delivery. Additional time would need to be scheduled for this interim period before the official demonstration begins. OEMs would need to build this effort into their budgets and assign staff to be on site regularly at a terminal until the vehicles and equipment are functioning properly. In addition, the OEMs may need to have available facilities and parts to make modifications in a timely manner. In this project, some modifications took months and even years to accomplish because OEMs appeared to have underestimated the iterative approach required to place vehicles safely in service.

#### 4.2.2 Permitting and Agency Approvals

While it is recognized that pre-commercial and early commercial products may not have all the permits and approvals that are required to place them in service, a demonstration project cannot

safely and legally proceed unless the necessary certifications, permits, and approvals are obtained.

#### **4.2.2.1 OSHA Compliance for Cargo Handling Equipment**

If modifications affect the capacity or safe handling of vehicles, OSHA CFR Section 1910.178(a)(4) and CAL/OSHA Cal. Code Regs Title 8 Section 3650(e) require that the original equipment manufacturer provide either prior written approval of modifications or verification after the modifications are completed that the modifications were designed, manufactured, and installed in accordance with recognized good engineering and manufacturing principals. If the manufacturer is unable or unwilling to certify the modifications are safe, then a qualified, registered, professional engineer can do so. These regulations are in place to protect workers from unsafe conditions resulting from modifications that have unintended safety consequences. An employer in violation of these regulations could be subject to civil and criminal penalties in addition to fines.

Pasha determined that the TransPower forklifts and yard tractors and the Grove crane were modified, as defined by the OSHA regulations, and thus required certification by the OEM or a professional engineer to legally and safely place the vehicles in service. While TransPower's primary business was the repowering of conventionally fueled vehicles to battery electric drives, this was the first project where they encountered this requirement. The process of resolving the issue of providing adequate documentation to satisfy Pasha safety and liability concerns took over two years. It involved the process of engaging the OEM, Kalmar; obtaining written documentation that Kalmar could not certify the modifications as safe because they were not involved in designing, implementing, or reviewing the changes; hiring a professional engineer to review and certify the modifications as safe; correcting issues identified in the engineering review; and legal negotiations of the specifics of the documentation between Pasha and TransPower. In contrast, when the Grove crane was modified to serve as an emissions capture boom, the OEM, Grove, was involved in the modification process and was able to provide adequate documentation within months of the issue being identified.

**Recommendation:** For future projects that involve the use of modified vehicles, all parties should be aware of OSHA regulations and requirements at the outset of the project, the OEM

should be engaged throughout the process to obtain its review and approval of modifications, and adequate time should be allocated to address this requirement.

#### **4.2.2.2 On-Road Vehicle Permits**

The two Navistar International battery-electric drayage trucks repowered by TransPower also required agency approvals for on-road operation, including FMVSS alterer approvals and CARB Experimental Permit. The vehicles also required a CARB Executive Order and EPA Certificate of Conformity to allow for the transfer of title of the vehicles from TransPower to Pasha. While the vehicles were delivered in Q2 2018, the process of obtaining the required approvals took an additional two years. TransPower is a registered vehicle manufacturer with the U.S. Department of Transportation and a licensed vehicle manufacturer in California. It self-certifies its vehicles in accordance with FMVSS; however, it appeared that in this project the certification process to obtain an alterer sticker was not initiated until after the vehicles were delivered.

**Recommendation:** The agency approval process for on-road vehicles should be initiated during the vehicle design and manufacturing phase to minimize demonstration delays.

#### **4.2.2.3 Infrastructure Permitting and Third-Party Certification**

Infrastructure elements of the multi-source demonstration project, including solar, EV chargers, BESS, and the supporting electrical infrastructure required approvals by multiple agencies, including LADBS, LADWP, LAFD, and LAHD. Each agency had a separate review process that addressed different safety concerns. Design and permitting was initiated in 2016, and permits and permissions were obtained in multiple phases for the project over the course of six years.

The BYD and TransPower EV chargers and the BYD BESS all lacked UL listing when delivered to Pasha. The LADBS permitting process required that the equipment undergo a third-party inspection and certification process prior to installation. The third-party inspections identified non-conformance items for the BYD and TransPower chargers and the BESS. Resolution and certification of the equipment ranged in time from months to multiple years due to the lack of availability of required parts and the complexity of resolving numerous non-conformance items for the BESS.

The permitting process for novel technologies or technological applications, such as the first microgrid in the LADWP service territory, required significant investment in meeting and coordination, retrofits to new technology to obtain certification, and upgrades to existing aged infrastructure to allow the safe integration of the new infrastructure. To navigate the permitting process, the project was broken into phases to allow permits to be obtained and the project to proceed as permits and approvals were obtained.

**Recommendations:** While each agency has its own independent review process, complicated projects would benefit from regular meetings with representatives from all agencies having jurisdiction to streamline the permitting process and avoid performing retrofits of equipment and infrastructure more than once.

Priority should be given to equipment that already has UL listing or third-party certification. Obtaining approvals for equipment installation/energization must be considered a significant milestone with a significant portion of the equipment reimbursement tied to successfully obtaining required listings and permits for installation. This will incentivize technology providers to resolve issues in as timely a manner possible.

### **4.3 Future Applications of Technologies and Commercialization Prospects**

The future applications of technologies were assessed based on the demonstrated effectiveness of the technologies tested, the projected need for the technologies, and the ability to improve upon technologies to meet operational needs of multi-modal facilities.

#### **4.3.1 Microgrids**

As of the date of this report, the solar PV system has yet to be installed the BESS has not been energized. All other infrastructure upgrades supporting the systems have been completed, including the Harbor Department's replacement of the 1980's era 5-kV switchgear, which was implemented to allow the full functionality of the microgrid (i.e., power generated from the solar PV system once installed will be able to charge the BESS). The completion of these components will enhance resiliency by allowing the terminal to power operations when both connected and islanded from the grid. When grid connected, the terminal will be able to use solar energy to offset energy use at the terminal and battery storage to reduce peak demand. When islanded, the

terminal will be able to use solar power and batteries to keep key elements of the facility operational.

The constraints on the completion of this project element were not technological; rather they were the challenges of navigating the permitting and approval process and contractual lease negotiations between the Harbor Department and Pasha. The City of Los Angeles permitting process has required retrofits to the BYD BESS that have not been required in other jurisdictions. The same BESS models have been safely and successfully deployed at the University of California, San Diego for more than seven years without incident. This is not to say that the required retrofits do not enhance the safety of the system, but it is to say that the permitting process and required retrofits vary greatly from one location or jurisdiction to the next. Additionally, the California Fire Code standards for BESS have been updated throughout the duration of this project, and those updates have changed the way that a BESS is manufactured today. For example, containerized BESS no longer includes walk-in units. All unit components (e.g., inverters and battery cells) can be accessed from the exterior of the containers without requiring entry to avoid arc flash safety concerns.

The commercialization prospects of microgrids and their component technologies are strong. Microgrids have been successfully developed and demonstrated at a wide range of facilities, including military installations, airports, manufacturing facilities, data centers, industrial complexes, and campuses. Many microgrids incorporate renewables and energy storage, so there is a high degree of confidence that microgrids can be used to serve Pasha and other smaller terminals with moderate power requirements (e.g., 1 MW). As far as large container terminals are concerned that have substantially larger power requirements (e.g., 5-10 MW), it is unlikely that solar and energy storage alone can meet the terminal's power needs as a microgrid.

The individual project components of the microgrid will continue to be used commercially in the future, especially as California moves to a 100% renewable future. According to the California Energy Commission (CEC), solar PV and solar thermal power plants produced 29,450 gigawatt-hours (GWh) of energy or 15.43 percent of California's in-state generation portfolio in 2020<sup>1</sup>. Additionally, the utility-scale battery storage capacity in California was 1.438 gigawatts (GW) as

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<sup>1</sup> [https://ww2.energy.ca.gov/almanac/renewables\\_data/solar/index\\_cms.php](https://ww2.energy.ca.gov/almanac/renewables_data/solar/index_cms.php)

of June 2021<sup>2</sup>. Additionally, solar and battery storage microgrids are currently being developed at terminals at the ports of Long Beach and San Diego and ports across the country are expressing interest in developing more on-site renewable energy and storage. Despite permitting challenges that can be encountered in various jurisdictions, the commercial prospects of solar and battery storage microgrids are strong.

### **4.3.2 Electric Vehicle Chargers**

Once the EV chargers were placed in service, they had very few reliability issues. One area of focused improvement in the heavy-duty EV charger realm is the standardization of chargers among different vehicle manufactures. Even for the TransPower vehicles, the chargers needed to be modified (i.e., fixed ground to floating ground) to support batteries procured from different battery manufacturers. At a minimum, the standardization of the electrical service to the chargers will facilitate the changing of chargers, which may be required to serve new vehicles.

The layout of the chargers at Pasha consolidated the nine chargers around the BESS to minimize the amount of space required for charging vehicles on the terminal. Trailers must be removed from the vehicles so that multiple vehicles can be charged at the same time. This creates an operational constraint that is not encountered with diesel yard tractors. To support opportunity charging, it may be beneficial to arrange chargers to serve as pull through charging stations, which do not require a trailer to be removed from the vehicle for charging. In addition, the use of inductive charging could also minimize the impact of charging on operations.

### **4.3.3 Yard Tractors**

Of the vehicles tested during the Green Omni Terminal Project, the electric yard tractors presented the strongest opportunity for broader commercial adoption. Once the yard tractors were configured properly and initial electrical and mechanical reliability issues were resolved, the vehicles were able to meet the operational needs of the terminal. Yard tractors were able to complete shifts with 40-50% state of charge. Drivers appreciated the comfort of vehicles, including having air conditioning, the quietness of vehicles, and absence of exhaust emissions.

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<sup>2</sup> <https://insideclimatenews.org/news/02092021/inside-clean-energy-california-energy-storage-visstra-corp/>

The process of placing the BYD Generation 1 vehicles in service required a period of years to resolve design and software issues that resulted in operational safety issues (e.g., the lack of guides on the BYD fifth wheel that could cause a mafi trailer to fall off when unloading and loading, the initial inability to raise and lower the fifth wheel while the BYD vehicles were in drive, and acceleration and deceleration issues that required software upgrades). Once the issues were resolved, Pasha and their drivers reported that the vehicles met the operational needs of the terminal. Additionally, drivers preferred to drive the electric yard tractors over diesel-powered units because the electric yard tractors had air conditioning, were quieter, and produced less emissions.

For TransPower yard tractors, the process of optimizing vehicle performance was accomplished via software updates over a period of several months. The yard tractors were found to function well for nearly a year before Pasha required that the vehicles be taken out of service until documentation of OSHA compliance could be attained. The TransPower yard tractors were able to complete a shift without the need to perform opportunity charging. Later generation vehicles, such as the BYD Generation 2 yard tractors and the Kalmar T2E+ yard tractor, did not require software updates or retrofits to achieve the desired functionality. The demonstration of these vehicles showed that OEMs are making progress in developing commercially available yard tractors.

Design enhancements are still required to enhance the safety of the vehicles. The current position of the ESS boxes along the sides of the Kalmar yard tractors, including the TransPower repowered T2 models and the commercially available T2E+ model, increases the probability that a driver could drive the trailer into the ESS boxes when performing a jack-knife maneuver. The diesel models have fuel tanks in a similar position, but they provide greater clearance. In those models, if a driver were to perform a jack-knife maneuver and fail to stop in time, the trailer would strike the cab of the vehicles. Ongoing design improvements, including increases in the energy density of batteries, will support broader adoption of electric yard tractors.

The thermal event at Pasha created a heightened concern over the safety of EVs for the Pasha staff and union representatives. The terminal experiences a high turnover of union drivers from day to day making it more difficult for drivers to learn the operational differences between diesel

and battery electric models. Continued improvements to the EVs that enhance safety will be necessary to support the broader acceptance and use of EV models. Moreover, additional training is needed at terminals and at fire departments to train personnel in best practices for addressing thermal events.

#### **4.3.4 Forklifts**

The heavy-duty electric forklifts, while only in service for approximately two weeks as of the date of this report, also showed promise for broader use. Electric forklifts were demonstrated to have equivalent lifting capacities as diesel equivalents and were able to complete shifts with approximately 40-50% state of charge. Software updates are still required to optimize their operations (e.g., increase the speed in which the forklifts transition between forward and reverse), but with ongoing optimization through software updates it is anticipated that this issue will be resolved similar to the issues that previously were successfully resolved for the TransPower yard tractors with iterative software updates. Given that the electric forklifts were repowered 2008 Kalmar units, it is anticipated that a newly designed forklift would improve the placement of the batteries and minimize visibility restrictions.

Three OEMs have developed and are selling battery-electric heavy-duty forklifts, including the Kalmar DCE160-12 model, Wiggins Yard eBull, and Taylor ZH-360L. These models have lift capacities of 36,000 lbs. Deployments of these units are underway at ports, and initial reports indicate that that these commercially available units are meeting operational needs.

#### **4.3.5 Drayage Trucks**

The TransPower electric drayage trucks did not meet the needs of Pasha's operations because of their limited range and the inability to overcome electrical and mechanical issues. The approximately 49-mile range of the drayage trucks while under load presented the greatest impediment to commercialization and wider use. Additionally, the lack of a power take-off for the fifth wheel limited the vehicles' use. Pasha staff reported that the overall perception of the drayage trucks was that they were unreliable and unable to meet the terminal's operational needs. It is recognized that the state of the on-road electric drayage trucks has improved beyond the limitations of these early repowered Navistar International models. TransPower battery electric drives have been installed in Peterbilt 579 trucks, and these trucks were reported by TransPower

to have greater ranges and improved reliability. The commercialization prospects of on-road drayage trucks would improve with increases in operational ranges, improved reliability, and a more robust charging network to support operations in and around ports.

#### **4.3.6 Shore-Based Emissions Capture and Control Systems**

The ShoreKat was developed to test the viability of a shore-based ECCS. The ShoreKat uses a modified crane with an emissions capture system to collect and funnel emissions from an auxiliary engine exhaust stack to a mobile emissions treatment system that rests on a heavy-duty trailer. The crane can be driven independently of the trailer and a yard tractor can be used to move the core treatment system along the wharf front and to different areas of the terminal.

The dimensions (70 ft L, 10 ft W, 20 ft H) and weight of the trailer-mounted ShoreKat (123,000 lbs) require that the system be moved slowly around the terminal, especially when conducting turns because of the unit's high profile. Additionally, the emissions capture boom weighs 102,000 lbs. Due to the substantial weight of the system, a heavy lift permit was required from the Harbor Department to assess and document that the capacity of the wharf could accommodate the weight of the system.

The reach of the emissions capture boom is 150 ft. The ShoreKat can reach exhaust systems that are positioned on the shore-side of the vessel, but it is less likely to be able to reach stacks that are located on the channel-side of the vessel due to its reach limitations. The emissions capture hood is only able to treat one stack at a time; therefore, if a vessel runs more than one auxiliary engine that feeds two or more stacks, the ShoreKat is not capable of achieving targeted emissions reductions. The limited reach of the emissions capture boom combined with the ability to treat emissions from one exhaust stack limits the utility of the system.

A shore-based ECCS creates potential conflicts with vessel offloading operations that are not encountered with a barge-based ECCS. The footprint of the ShoreKat on the trailer is 10 ft by 70 ft and the dimensions of the emissions capture boom when outriggers are deployed measures 23 ft by 23 ft. By placing the system on the wharf, CHE operating routes must be modified to avoid the system. Pasha estimated that changes in the driving routes of CHE slowed vessel unloading operations by approximately 30 minutes.

A shore-based ECCS also created ILWU staffing issues. The issues initially halted the use of the system but were later resolved through multiple meetings that Pasha held with union representatives, an arbitrator, and CAEM. In the end, it was determined that the system can be operated by a crane operator and a mechanic. A third mechanic must be available to provide breaks. These issues are not encountered with the use of a barge-based system.

The ShoreKat ECCS uses filtration and chemical scrubbing to remove criteria air pollutants. To qualify as a CARB approved emissions capture system, the ShoreKat must achieve emission rates less than 2.8 g/kW-hr for NO<sub>x</sub>, 0.03 g/kW-hr for PM 2.5, and 0.1 g/kW-hr for ROG for auxiliary engines. Additionally, for ECCS approved after 2020, the power source for the ECCS must have GHG emissions that are grid-neutral using the grid emission rate for the year that the technology is granted an Executive Order (EO). The treatment system itself is not required to reduce GHG emissions from the vessel exhaust as there are no CARB-approved ECCS that capture/treat GHG emissions.

While the ShoreKat did not consistently achieve the emissions capture goals for criteria pollutants for each of the four vessels it was tested, it appeared that with additional testing and calibration emissions reduction targets for criteria pollutants could be achieved. Unlike shore power, the ShoreKat does not have the ability to reduce GHG emissions. While the plan was to test the integration of carbon capture technologies with the ShoreKat, CAEM and Tri-Mer were unable to identify carbon treatment systems that were both technically viable and cost effective. Consequently, the planned 6-month carbon capture demonstrations were not conducted.

The most likely future application of a shore-based ECCS is at a terminal that has a narrow channel that cannot accommodate an ECCS barge positioned along a berthed vessel, while allowing another vessel to transit the channel. Additionally, shore-based ECCS could be used at terminals where vessels can be oriented along the wharf so that the exhaust stacks are reachable by the shore-based emissions capture booms. ECCS providers have reported that liquid bulk terminals may be strong candidates for shore-based systems.

With the expansion of California's at-berth regulation to additional classes of vessels beyond container vessels, the demand for shore power and ECCS is expected to increase over the next five years. Most roll-on roll-off vessels have yet to be outfitted with shore-power compatible

ship-board systems and the timeframe for vessel replacements and/or retrofits indicates that even if shore power is the desired technology to comply with At-Berth Regulation, an interim solution, such as an ECCS, will be required.

Currently, there are a limited number of ECCS providers. CAEM is the only provider that offers CARB-approved barge-based ECCS. Currently, there are no providers that have a CARB-approved shore-based ECCS because CARB invalidated the Executive Order issued to CAEM when ownership of the ShoreKat was transferred to Pasha. While there is a regulatory driver that is creating a commercialization opportunity for this technology, the lack of approved options raises questions regarding the commercialization potential and viability of this strategy. The limited number of potential ECCS providers also raises questions about whether there will be enough systems to meet the projected demands created by the expanded at-berth regulation.

In summary, spatial conflicts of a shore-based ECCS combined with the use of an emissions capture boom located on the same side of the vessel where unloading operations are taking place may limit the utility of these systems at container and breakbulk terminals. Additionally, wharfs where mobile ECCS are to be used must be sufficiently robust to accommodate the weight of the core treatment system and emissions capture boom. Shore-based ECCS will likely have the greatest utility at terminals that serve smaller vessels that can be positioned so their stacks are located along port-side of the vessel. Shore-based ECCS may be preferable at ports with narrow channels that cannot accommodate an ECCS barge tied alongside, while still allowing other vessels to safely transit the channel. Additionally, one of the major benefits of a shore-based ECCS is the lower capital cost of the system than a barge-based system. With no need for a barge, shore-based ECCS cost approximately 50% of barge-based ECCS, potentially providing a more cost-effective solution for the right terminal.



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