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California Energy Commission
Clean Transportation Program

FINAL PROJECT REPORT

San Diego Port Sustainable Freight Demonstration Project

Prepared for: California Energy Commission
Prepared by: San Diego Port Tenants Association

Gavin Newsom, Governor
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PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual *Clean Transportation Program Investment Plan Update*. The CEC issued GFO-15-604 to fund projects that demonstrate freight transportation projects for medium- and heavy-duty vehicle technologies, demonstrate intelligent transportation systems and technologies, and deployment of natural gas vehicles. In response to GFO-15-604, San Diego Port Tenants Association submitted an application which the CEC proposed for funding in its notice of proposed awards on May 19, 2016, and the executed the agreement as ARV-15-068 on December 1, 2016.

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ABSTRACT

The Port of San Diego is one of the most prominent hubs for commerce, navigation, recreation, and fisheries, dedicated to protecting and enhancing its future success as a thriving and working port. Seaports face unique constraints when deploying zero-emission vehicles and equipment, including high energy demand, restrictive duty cycle requirements, and diverse tenant and operational interests. Led by the San Diego Port Tenants Association, the San Diego Port Sustainable Freight Demonstration Project served as a critical step toward reducing emissions from port vehicles and equipment. The project deployed 10 medium- and heavy-duty, battery-electric freight vehicles for port operations as well as an intelligent transportation system. The San Diego Port Tenants Association designed the project to accelerate both the advancement of zero-emission technologies on the path towards commercialization and the adoption of these technologies by port tenants.

The 10 zero-emission vehicles provided an annualized emission reduction of nearly 125 metric tons of oxides of nitrogen, reactive organic gases, particulate matter, and greenhouse gases.

The trucks used during the demonstration of the intelligent transportation system application freight averaged 70 one-way runs per month on the corridor with signal priority. Freight signal priority showed effectiveness in each performance measure category, reducing emissions by about 27 percent per run.

Keywords: San Diego Port Tenants Association, Port of San Diego, Zero-Emission, Medium- and Heavy-Duty, Pre-Commercial, Yard Tractors, Drayage Trucks, Forklifts, Intelligent Transportation System, Freight Signal Prioritization, Disadvantaged Community

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EXECUTIVE SUMMARY

The California Energy Commission awarded $5,903,652 in grant funds to the San Diego Port Tenants Association in 2016 to demonstrate 10 zero-emission vehicles, such as drayage trucks, yard tractors, and forklifts, and the intelligent transportation systems application freight signal priority at the Port of San Diego. San Diego Port Tenants Association and project partners designed the project to align with the CAP, with goals to reduce noise, traffic jams, and emissions from traffic in the port and the nearby areas.

Three technology vendors designed and built the 10 zero-emission freight vehicles: BYD Motors made three yard tractors and four drayage trucks, Cummins repowered two World-Lift forklifts, and Transportation Power, LLC repowered one Kalmar forklift.

STC Traffic designed and installed the freight signal priority application, which uses vehicle-to-grid technology to control traffic signals and the flow of traffic in order to reduce wait times at intersections. This results in less time spent idling, reduced fuel use, and improved air quality at the port and surrounding communities.

The San Diego Port Sustainable Freight Demonstration Project occurred in and around the disadvantaged communities next to the Port of San Diego, such as the community of Barrio Logan, the City of National City, and the City of Chula Vista, and it reduced greenhouse gas and criteria pollutant emissions in all of these areas.

As part of this project, The Greenlining Institute drafted California's first port freight equity plan. This plan included workforce and supply chain diversity workshops, conducted public outreach, and evaluated the equity effects of the freight signal priority application. Another partner, GC Green, a Disabled Veteran Business Enterprise, performed outreach to expand chances for veteran and disabled-veteran businesses to take part in the planning, design, and use of zero-emission vehicles.

Project Goals & Objectives

Between 2016 and 2021, the project helped enhance market acceptance and deployment of freight transportation technologies, reduced GHG emissions, reduced petroleum use, and provided measurable benefits to priority populations. The project achieved all measurable objectives, including:

- Removed more than 5,100 gallons of petroleum during the project and an estimated 12,000 gallons per year in the future.
- Reduced greenhouse gas emissions by more than 52 metric tons of carbon dioxide equivalents during the project and an estimated 124 metric tons of carbon dioxide equivalents per year in the future.
- Reduced criteria pollutant emissions by nearly 0.07 tons during the project and an estimated reduction of 0.4 tons of criteria pollutant emissions per year in the future.

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CHAPTER 1: Introduction

In May 2016, the California Energy Commission (CEC) awarded the San Diego Port Tenants Association (SDPTA) grant funding for the San Diego Port Sustainable Freight Demonstration Project (project). The SDPTA developed this project to align with the San Diego Unified Port District's *Port of San Diego Climate Action Plan 2013* (CAP). This plan included the goal of a 10 percent reduction in greenhouse gas (GHG) emissions by 2020 and emphasized the transportation sector as the most significant source of emissions in the port region.

Figure 1: Port of San Diego

Credit: San Diego Port Tenants Association

The project demonstrated 10 new or repowered zero-emission drayage truck and port vehicles and the intelligent transportation system (ITS) application freight signal priority (FSP) in and around the Port of San Diego (POSD, or port). The goal of the project was to reduce freight traffic impacts by decreasing GHG emissions, improving air quality, and providing health benefits to the port and surrounding communities.

The project purchased battery-electric drayage trucks, yard tractors, and forklifts from BYD Motors (BYD), Transportation Power, LLC (TransPower), and Cummins Electrified Power NA, Inc. (Cummins), respectively, and port tenants Dole Food Company (Dole), The Pasha Group (Pasha), Terminalift, and Marine Group Boat Works (MGBW), carried out the vehicle demonstrations. Additionally, Build Momentum, Inc. (Momentum) provided project management services and alternative fuel consultant carbonBLU, LLC (carbonBLU) performed data collection on each vehicle to analyze performance emission reductions.

In addition to demonstrating the 10 battery-electric freight vehicles, SDPTA partnered with STC Traffic, Inc. (STC Traffic) to deploy an innovative ITS technology that employs vehicle and intersection communications to establish the FSP application, which gave specially-equipped freight trucks the right of way at intersections along Harbor Drive to reduce congestion and the negative freight traffic impacts at the port.

SDPTA and the project stakeholders participated in outreach activities to the local communities, with an emphasis on disadvantaged communities, which are disproportionally impacted by port emissions and traffic impacts. POSD employs many residents of these communities, and having the community's awareness of the project and input were valuable factors contributing to the success of this project and the overall transition to a cleaner economy.

The project concluded in April 2021 and overcame multiple challenges to demonstrate the 10 medium-duty and heavy-duty (MDHD) battery-electric freight vehicles and the FSP system. Challenges included stakeholder withdrawals, company acquisitions, pre-commercial technology flaws, and a global pandemic.

CHAPTER 2: Project Background

POSD's CAP projected port GHG emissions to reach nearly 855,500 megatons (MT) of carbon dioxide equivalents per year (CO_2e/year) by the year 2020 in the absence of any intervention. Through the CAP, the port sought to reduce overall port-related GHG emissions by at least 10 percent by 2020 and by 25 percent by 2035, in comparison with the 2006 baseline levels. Because more than 60 percent of the projected 2020 port emissions are from the on- and off-road transportation sectors, many of the proposed reduction measures focused on transportation. To achieve the lowest emissions possible, these measures included supporting and promoting a mix of alternative fuels, electric, or hybrid technology vehicles and vessels owned by port tenants. It also included implementing traffic and roadway management strategies to improve mobility and efficiency and reduce associated emissions at maritime facilities. In support of these emissions reduction goals, SDPTA and the project team developed and executed this project to implement some of the port's first zero-emission MDHD and ITS demonstrations, including 10 zero-emission MDHD vehicles and a FSP traffic system. The project also directly aligned with other CEC goals, including enhancing the market acceptance and deployment of advanced vehicle technologies that will reduce GHG emissions, reduce petroleum use, and benefit disadvantaged communities.

2.1 Project Scope

Diesel-powered MDHD trucks and equipment at ports and industrial areas are a major source of pollution and harmful emissions. The truck market is powered predominantly by diesel fuel. Decreasing vehicle emissions by transitioning to electric vehicles is a promising solution but not a simple process. Critical barriers exist that hinder the widespread adoption of advanced MDHD vehicles. These barriers included a lack of familiarity with these technologies, operator inexperience with all-electric MDHD vehicles, and a higher cost per vehicle.

This project took a broad approach to tackling the electrification problem by providing the funding and resources needed for 1) proper manufacturing of electric vehicles and systems to meet port operation standards, 2) education and training of stakeholders, 3) collaboration with disadvantaged communities that surround the port, and 4) data collection and analysis to quantify project impacts.

2.1.1 Project Development

SDPTA worked with a diverse group of strategic partners in developing and supporting the project and included: POSD, San Diego Association of Governments (SANDAG), City of San Diego, City of National City, San Diego Gas and Electric (SDG&E), California Department of Transportation (Caltrans), and Naval Base San Diego. Many of the partners were instrumental in supporting the ITS component of the project and working with the project team on the installation of the FSP system. Of particular mention are POSD and SANDAG, both of which leveraged existing connections and budgets to fortify the project team and reduce risk. For example, POSD contributed money to the project to cover a temporary budget shortfall and SDG&E leveraged SB 350 funding to install chargers at the Tenth Avenue Marine Terminal.

Project success would not have been possible without the support these critical partnerships provided.

SDPTA also partnered with several of its port tenants to demonstrate some of the port's first zero-emission vehicles. Original participating port tenants included Dole, MGBW, Pasha, and Terminalift, Cemex, Harborside Refrigerated Services and Cold Storage (Harborside), and Continental Maritime[1]; however, Cemex, Harborside, and Continental Maritime pulled out of the project prior to deploying the vehicles. Cemex decided not to renew its lease at the port, thereby losing eligibility to participate in the demonstration; Continental Maritime had concerns about the reliability of the prototype battery system designed by TransPower and decided the technology was not a good fit for its operations; and Harborside chose to end its participation in the project during the process of developing the second project amendment. The remaining demonstration partners took over the demonstration of the vehicles associated with the departed participants, ensuring that no vehicles were removed from the scope of the project. Together, participating port tenants successfully demonstrated 10 zero-emission MDHD vehicles, including three battery-electric yard tractors, four Class 8 battery-electric drayage trucks, two 12,000-lb battery-electric forklifts, and one 40,000-lb battery-electric forklift.

Table 1 shows the associated technology vendors and the tenants that demonstrated the technologies.

Table 1: Electric Freight Vehicle Demonstration Overview

Technology Demonstrator	Vehicle Type	Technology Vendor	Units
Dole Food Company	Class 8 Electric Yard Tractor	BYD	2
Marine Group Boat Works	Class-6 Electric Forklift	Cummins	2
Pasha	Class 8 Electric Yard Tractor	BYD	1
	Class 8 Electric Drayage Truck	BYD	2
Terminalift	Class 8 Electric Drayage Truck	BYD	2
	40,000-lb Electric Forklift	TransPower	1

Source: Momentum

In addition to the vehicle deployments, this project demonstrated the FSP system. The FSP route, shown in Figure 2, spans the South Harbor Drive corridor located between the Tenth Avenue Marine Terminal and POSD's National City Distribution Center. The route designated by the blue line is South Harbor Drive that local truck drivers frequently use and who regularly experience traffic congestion along the route. By providing a traffic signal priority, commercial vehicles could reduce the number of stops within the project bounds. Fewer stops lead to reductions in idling, reduced fuel consumption, improved travel time reliability, traffic safety at intersections, and improved air quality in areas categorized as disadvantaged communities.

[1] During the course of this project, Continental Maritime went through two acquisitions. After the first, by Huntington Ingalls, it became known as HII-San Diego. Later Titan Acquisition Holding purchased it and returned to the name Continental Maritime. For simplicity, it will be referred to as Continental Maritime throughout this report.

Project partner STC Traffic managed the planning, deployment, and data collection associated with this FSP system, and STC Traffic and SDPTA engaged local fleets to demonstrate the system.

Figure 2: Map of Project Area and Surrounding Disadvantaged Communities

Credit: San Diego Port Tenants Association

Throughout the project, carbonBLU provided data collection support. carbonBLU was responsible for installing and monitoring data loggers that tracked the performance of the demonstrated vehicles. The company also collected data from standard diesel counterpart vehicles to establish baseline data and compared it against the electric vehicle data. carbonBLU's work included conducting monthly site visits to the port tenants to generate reports confirming proper data recording and the viability of the data for analysis.

The project included a powerful and innovative approach for supporting disadvantaged communities, with the specific objective of greater inclusion and representation. This project directly benefited the disadvantaged communities surrounding POSD, which included Barrio Logan, National City, and parts of Chula Vista. SDPTA partnered with two social justice organizations, The Greenlining Institute and GC Green, to head this aspect of the project. The Greenlining Institute led engagement with disadvantaged communities during the demonstration period and represented equity issues in workshops, conferences, and outreach. GC Green expanded opportunities for veteran- and disabled-veteran businesses to participate in the planning, design, and implementation of the demonstrations of the zero-emission vehicles.

2.1.2 Goals and Objectives

SDPTA designed the project to enhance market acceptance and deployment of a range of advanced vehicle technologies that will reduce GHG emissions, reduce petroleum use, and benefit disadvantaged communities in order to align with the emission reduction objectives of the State of California, POSD, and CAP.

Market Acceptance of Electric Vehicle Technology. Success in the demanding waterfront environment of San Diego's terminals could lead to widespread use of electric freight vehicles by other San Diego port tenants and, more broadly, ports worldwide. California's leadership in demonstrating zero-emission forklifts and MDHD vehicles could help stimulate the adoption of such vehicles across the US and globally.

Deploy a Range of Advanced Electric Vehicle Technologies. The project encompassed five distinct vehicle or heavy-duty equipment types, each with its own path to market. All were in the "emerging" stage of market development. The supply chain relationships that developed, and the lessons learned throughout this project, provided a strong foundation to scale up manufacturing of electric vehicles as user demand for electric MDHD vehicles continues to increase.

Reduce GHG Emissions. The adoption of zero-emission technologies would yield immediate and long-term reductions in GHG and criteria pollutant emissions. SDPTA estimated in their proposal that the project would result in the reduction of about 944 metric tons of carbon dioxide equivalents (MT CO_2e) and nearly 0.36 tons of NO_x.

Reduce Petroleum Use. Demonstrating electric freight vehicles would provide immediate and long-term reductions in petroleum consumption. Initial estimates suggested that this project would result in the reduction of more than 88,000 gallons of diesel over the entirety of the project.

Benefit Disadvantaged Communities. The project provided significant immediate and long-term air quality benefits to its neighboring communities, such as Barrio Logan, due to the reduction in criteria air pollutants emitted. Beyond that, neighboring disadvantaged communities also leveraged this opportunity to better understand community needs and increased their share in the state's booming green economy through participation in education and workforce development opportunities.

To meet the goals of the project, SDPTA pursued the following objectives throughout the project:

- **Build and demonstrate 10 advanced technology vehicles.** Port tenants and technology vendors worked together to design, build, and commission new or repowered MDHD zero-emission vehicles for deployment and field demonstration. These demonstrations provided valuable insight into improving manufacturing and the use of electric vehicles at freight facilities, and also showed that new job skills and even new occupations could be added as a direct result.

- **Plan, design, install, and commission the FSP system and components for integration into demonstration vehicles.** The FSP system established a traffic signal priority along the South Harbor Drive corridor for freight vehicles operating between the Tenth Avenue Marine Terminal and the National Distribution Center located in National City. The goal was to assess whether a signal priority would reduce travel times, stops, and emissions from freight movement.
- **Develop a disadvantaged community program and conduct outreach.** SDPTA created the disadvantaged community program to 1) evaluate the project's potential disadvantaged community impacts on project partnerships, project suppliers, supply chains, and workforce support; 2) conduct outreach within the community and solicit feedback on the deployment of project technologies; and 3) report on project findings.
- **Data collection and analysis of the demonstration.** The project team collected data on a minimum of 20 vehicles placed in MDHD and FSP service. carbonBLU led this process on the demonstrated vehicles, while STC Traffic collected real-time data on the vehicles participating in the FSP demonstration.

2.2 Project Team

The project team possessed the skillset necessary to ensure project completion and to lead the broader technology deployment. SDPTA and Momentum collectively have expertise in event planning, coordination, project management, fund development, and grant administration. The technology providers - BYD, Cummins, and TransPower - all have expertise in the development of their respective vehicles and equipment. The seven strategic partners helped support and develop the project goals and deliverables, addressing early any anticipated barriers to success and including all relevant stakeholders. All participating port tenants have expertise and experience in operating the conventional, and in some cases alternative-fueled, versions of types of vehicles and equipment proposed in this project. STC Traffic specializes in the design and implementation of high-tech ITS, traffic engineering, and control applications. Both GC Green and The Greenlining Institute are leaders in the fields of environmental consulting and environmental justice, respectively. Finally, carbonBLU has extensive experience in data collection and fleet analysis.

2.2.1 Project Management

SDPTA served as the prime contractor on the grant. SDPTA engaged Momentum to oversee day-to-day project management and provide strategic guidance.

San Diego Port Tenants Association: Formed in 1989, the SDPTA is a coalition of businesses and industries dedicated to enhancing trade, recreation, commerce, and tourism on San Diego Bay's tidelands, while protecting the area's environment. A 2019 analysis on the "Economic Impacts of the San Diego Unified Port District" for FY2017 reports the port's direct and indirect contribution to regional employment is 70,000 jobs, making it the second-largest employer in San Diego County. The businesses located within the port's boundaries generate $9.4 Billion annually in the regional economic impact.

Momentum: Based in Sacramento, California, Momentum has a global reach, delivering strategic planning, fund development, project management, communication, and commercialization services across the country and around the world. Since 2005, Momentum has raised approximately $1 billion in grants, loans, and other incentives for companies working on transformative advanced energy, water, transportation, and manufacturing projects.

For this project, Momentum provided strategic project management services to the SDPTA for the duration of the grant. Support services include, but not limited to, regular reporting to the CEC, day-to-day project management, and strategic coordination with all project stakeholders. Additionally, when carbonBLU was unable to provide the final analysis report of their data collection, Momentum stepped into complete that deliverable on behalf of the project.

2.2.2 Strategic Partners

To assist in ensuring the project's success, SDPTA partnered with several strategic partners. These strategic partners were kept apprised of the progress throughout the project and assisted in navigating some of the hurdles that posed any barriers to meeting the project's goals and deliverables. The strategic partners included:

Port of San Diego: Established in 1962 under the Port Act, the port implements the Tidelands Trust Doctrine. For over 50 years, the port's five member cities—Chula Vista, Coronado, Imperial Beach, National City, and San Diego—have worked together to develop and promote commerce, navigation, recreation, and fisheries on and around San Diego Bay. Self-funded, the port contributes billions annually to San Diego's economy, benefiting the community, local businesses, and employees. Businesses at the port provide thousands of well-paying jobs, supporting individuals and families throughout the region. Each year, millions of people enjoy a remarkable way of life offered by San Diego Bay and its waterfront communities.

San Diego Association of Governments (SANDAG): Eighteen cities and county governments comprise SANDAG, the San Diego Association of Governments. This public agency serves as the forum for regional decision-making. SANDAG builds consensus; makes strategic plans; obtains and allocates resources; plans, engineers, and builds public transportation; and provides information on a broad range of topics pertinent to the region's quality of life. A board of directors governs SANDAG and is composed of mayors, councilmembers, and county supervisors from each of the region's 19 local governments. Supplementing these voting members are advisory representatives from Imperial County, the US Department of Defense, Caltrans, POSD, Metropolitan Transit System, North County Transit District, San Diego County Water Authority, Southern California Tribal Chairmen's Association, Mexico, and the San Diego County Regional Airport Authority.

The City of San Diego: San Diego hosts cutting-edge businesses in telecommunications, biotechnology, software, electronics, and other major industries. Tackling climate change has created an opportunity for San Diego to benefit the environment while also boosting its economy. Its CAP strategies promote job creation through capital improvements and corresponding research, development, and innovation. These high-paying jobs are primarily in high-growth "green job" or "clean tech" industries. In 2018, job growth in the five CAP-related industry groups continued to rise. Nearly four out of five new jobs are in the Energy and Water Efficient Buildings industry.

The City of National City: National City is located five miles south of downtown San Diego, on the San Diego Bay, in southern San Diego County, and 10 miles north of Baja California, Mexico. National City shares city limit lines with San Diego to the north and east, by Chula Vista to the south, by unincorporated areas of San Diego County to the south and southeast, and by San Diego Bay to the west. National City is a disadvantaged community. According to the statewide pollution screening tool, CalEnviroScreen 3.0, National City currently ranks among the top 5 to 10 percent of communities in California impacted by pollution. Local elected officials are hoping to change that with new policies and plans addressing housing and transportation options in the city.

California Department of Transportation: Caltrans manages more than 50,000 miles of California's highway and freeway lanes, provides inter-city rail services, permits more than 400 public-use airports and special-use hospital heliports, and works with local agencies. Caltrans carries out its mission of providing a safe, sustainable, integrated, and efficient transportation system to enhance California's economy and livability, with six primary programs: aeronautics, highway transportation, mass transportation, transportation planning, administration, and the equipment service center.

San Diego Gas & Electric: SDG&E is a regulated public utility that provides energy service to 3.6 million people through 1.4 million electric meters and 873,000 natural gas meters in San Diego and southern Orange counties. To facilitate the transition to zero-emission transportation—a key strategy for meeting California's climate action goals—SDG&E has been working aggressively to expand EV charging infrastructure in the region. The infrastructure supports electric cars and medium- and heavy-duty vehicles and equipment, such as electric buses, trucks, shuttles, and forklifts.

Naval Base San Diego: As the United States Navy's premier Pacific Fleet surface force installation, Naval Base San Diego provides comprehensive fleet support for 54 home ported ships and over 150 tenant commands. Naval Base San Diego comprises the main naval base on the San Diego Bay, as well as the Broadway Complex, which serves as the headquarters for Navy Region Southwest, the Naval Medical Center San Diego complex, which serves as the home for the Bob Wilson Naval Hospital and Naval Medicine West, and the Admiral Baker Golf Course and Recreation Center, which serve the recreational needs of sailors, family members, and retirees throughout the region. The base also oversees 18 housing areas, including the large Murphy Canyon housing complex that provides more than 4,900 homes for Navy families.

2.2.3 Technology Demonstrators

Port tenants are companies that lease out space at the port to conduct business. In all, the participating technology demonstrators, or port tenants, understood that a transition to a cleaner economy and port were already well underway. In the upcoming years, all port tenants will need to take steps to decarbonize operations to meet the goals of the port's CAP. By participating in these kinds of demonstration projects, technology demonstrators receive the opportunity to work hands-on with technology providers to improve electric vehicle technology that meets operational and functional needs in a port setting. A list of the participating technology demonstrators follows:

Dole Food Company: Dole Food Company is the largest fruit and vegetable producer in the world and one of the largest employers at the port. Its worldwide team of growers, packers, processors, shippers, and employees is committed to consistently providing safe, high-quality fresh fruit, vegetables, and food products, while protecting the environment in which its products are grown and processed. Dole's dedication to quality is a commitment solidly backed by comprehensive programs for food safety, scientific crop protection programs, stringent quality control measures, state-of-the-art production and transportation technologies, continuous improvement through research and innovation, and dedication to safety and the environment. For this project, Dole demonstrated two Class 8 electric yard tractors manufactured by BYD starting in June 2018.

Marine Group Boat Works: MGBW is a family-owned, full-service boat and super yacht refit and repair facility occupying more than 15 acres of land and water. Located at the southern part of the San Diego Bay, MGBW specializes in refits, repairs, and new construction of boats and ships up to 220 feet long. Specific to the commercial and government sectors, MGBW also provides highly specialized services, including new construction, custom metal fabrications, and emergent work repairs for vessels ranging from range training support crafts, workboats, tugboats, and barges. For this project, MGBW demonstrated two 12,000-lb electric forklifts manufactured by Cummins starting in December 2018.

The Pasha Group: Pasha is a family-owned diversified global logistics and transportation services company. Pasha's mission is to be a leader in providing customized, cost-effective, and profitable value-added services to the automotive, maritime, and relocation industries through the integration of Pasha's network of global logistics entities and strategic partners. For this project, Pasha demonstrated one Class 8 electric yard tractor and two Class 8 electric drayage trucks, all manufactured by BYD. Demonstrations of these vehicles began in December 2018, January 2019, and June 2019, respectively.

Terminalift: Owned by General Dynamics NASSCO, Terminalift is a cargo-handling equipment company operating out of the port and other California locations. Founded in 2004 and originally dedicated to cargo handling at the port, Terminalift quickly expanded its capabilities in the safe handling of specialized cargos ranging from wind power equipment, electric trolley cars, air frames, diesel-powered turbines, transformers, imported steel for ship building, Department of Defense orders, Americas Cup sailboats, large-scale power generation equipment, and various bulk freight items. For this project, Terminalift demonstrated two Class 8 electric drayage trucks designed and manufactured by BYD beginning in February 2020. The company also demonstrated an electric 40,000-lb forklift engineered by TransPower.

STC Traffic: STC Traffic specializes in the design, implementation, and operation of high-tech ITS and traffic engineering and control applications to its Southern California clients. Its team of engineers brings a wide range of expertise and technical know-how to the traffic engineering field. SDPTA contracted STC Traffic to manage the FSP demonstration after the withdrawal of the original subcontractor, Peloton. STC Traffic managed the installation of the traffic control infrastructure and the on-board units and collected data for the FSP demonstration.

carbonBLU: carbonBLU is an environmental consulting firm specializing in outreach and education about clean technology and environmentally sound business practices. The company offers workshops, training, and tools free of cost to interested organizations. It also actively participates in the installation of infrastructure, engine optimization, data collection, development of funding mechanisms, and the purchasing and proliferation of green technology, alternative fuel, and advanced vehicles. carbonBLU performed the data collection for the 10 demonstrated electric vehicles and a comparable diesel counterpart for each as a baseline comparison where available.

2.2.4 Technology Providers

Electric vehicle technology continues to be a relatively immature technology on its way to mass commercialization. Many original equipment manufacturers (OEMs) in the MDHD vehicle and equipment market still lack the core competencies to design or manufacture complex electrical and mechanical systems for electric vehicles. This project gave technology providers the opportunity to better understand the needs of the port market, and to improve upon the design, manufacturing, and demonstration of MDHD electric vehicles. Through these kinds of demonstration projects, technology providers find great value in the data collected to develop innovations that can be integrated cost-effectively and then translated into dollar savings. Demonstrations are also used to refine prototype vehicle designs and advance pre-commercial technology on the path to market. The participating technology providers are as follows:

BYD Motors: BYD is a Chinese company with an assembly plant in California. It specializes in battery technologies and is one of the world's largest manufacturer of rechargeable batteries. Backed up by its core Iron-Phosphate battery technology, BYD focuses on electrified transportation, including automobiles, buses, trucks, and utility vehicles. BYD's electric clean air technology is silent, efficient, and usable anywhere there is standard AC power. BYD designed, manufactured, and deployed three Class 8 electric yard tractors and four Class 8 electric drayage trucks for this project, demonstrated by Dole Food Company, Pasha, and Terminalift.

Cummins Inc./Efficient Drive Trains: Cummins creates the world's leading clean engine technology. It is a corporation of complementary business units that design, engineer, manufacture, distribute, and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions, and electrical power generation systems. In 2017, Cummins acquired the original project partner, Efficient Drivetrains, Inc. (EDI), to build out and scale its renewable technology portfolio. The original intention was for EDI to provide and demonstrate two Class 8 drayage trucks with Terminalift and forklifts MGBW. After Cummins purchased EDI, however, it no longer wanted to provide the Class 8 trucks. The forklift demonstration remained intact, but BYD stepped in and provided the Class 8 truck demonstration vehicles. Cummins contributed two 12,000-lb electric forklifts to MGBW and concluded the demonstration before withdrawing from the project in January 2020.

Transportation Power: TransPower, a California-based company, was founded in 2010 for the express purpose of manufacturing components for zero-emission heavy-duty vehicles. TransPower has established itself as an industry leader in adapting zero emission technologies to port vehicles such as drayage trucks, yard tractors, and reach stackers. After an early focus on developing its "ElecTruck™" battery-electric drive system for drayage trucks, TransPower branched into the development of battery-electric yard tractors and an electric version of a port reach stacker vehicle. Meritor Electric Vehicles, LLC acquired TransPower in January 2020, but continued to operate as Transportation Power, LLC. Meritor is a leading supplier of drivetrain, mobility, braking, and aftermarket solutions focused on on-highway applications. As a result of this transition, the forklift division was slated for dissolution, leading to minimal staff support for the 40,000-lb forklift development. However, Transportation Power and

Meritor completed the engineering and delivery of one 40,000-lb. electric forklift to Terminalift in December 2020, and saw the demonstration through until the conclusion of the grant in April 2021

2.2.5 Disadvantaged Community/Equity Partners

As newer and lower emission technology continues to develop and commercialize, it is crucial to include affected communities and social equity efforts in efforts to innovate. This project deployed zero-emission technology that reduce emissions and harmful environmental impacts in the communities surrounding the port, many of which are disadvantaged communities. Furthermore, this project engaged social equity partners to conduct workshops, conferences, and outreach activities to educate community members about the project and the deployed technology and engage them in meaningful conversations around equity and the port. Social equity partners included:

The Greenlining Institute: The Greenlining Institute is a policy, research, organizing, and leadership institute working for racial and economic justice. Headquartered in California, The Greenlining Institute's approach focuses on bringing grassroots community leaders face to face with leading public and private-sector leaders. The organization designs and supports policies designed to open doors to opportunity and is a strong advocate for programs that encourage large companies to do business with minority small businesses. The California Public Utility Commission's supplier diversity program, governed by General Order 156, represents an outstanding model. The Greenlining Institute monitors the impact of this program, issuing an updated report every spring, and works to expand the use of this model in other fields to bring investments to communities of color.

GC Green: GC Green is a service-disabled veteran-owned general contracting and consulting firm specializing in identifying and installing best of class benchmarking, energy efficiency, water efficiency, renewable energy, and environmental consulting solutions for residential/multifamily, commercial, and governmental customers. This San Diego company is also woman- and Native American-owned.

CHAPTER 3: Summary and Analysis of Vehicle Demonstrations

The port's CAP calls for a 10 percent reduction in GHG emissions by 2020 and 25 percent by 2035 compared to 2006 levels. Transportation was, and continues to be, the most significant source of emissions at the port, encompassing maritime freight, trucks, cargo-handling equipment, and commercial vehicles, and also all the vehicles that visit tenants and their amenities. While the port does not bear full responsibility for all of those sources, it influenced efforts to address environmental impacts through different incentives and the promotion of zero-emission vehicles.

In alignment with the port's CAP, the project demonstrated some of the port's first zero-emission MDHD freight vehicles. Technology demonstrators included the four port tenants previously mentioned. Through these demonstrations, technology demonstrators had a voice in the design of MDHD electric vehicles coming to market and gained the confidence needed to commit to fleet electrification, and technology vendors received the customer feedback needed to improve their products and accelerate the transition to electrified transportation.

The demonstrations tested a variety of pre-commercial MDHD freight vehicles in a marine port environment. Port operations tend to be rigorous and demanding, so the demonstrations were a true test of electric vehicle performance compared to the proven diesel counterparts. Additionally, SDPTA was interested in understanding the impact of the San Diego coastal climate on long-term vehicle operability and performance. This project demonstrated Class 8 yard tractors, Class 8 drayage trucks, and heavy-duty forklifts, all of which are types of vehicles and equipment upon which a multitude of port tenants depend to carry out their daily operations.

Together, these stakeholders successfully demonstrated 10 zero-emission MDHD vehicles, leading the way to an electrified transportation sector at the port and globally.

3.1 Summary and Evaluation of Dole/BYD Demonstration

Dole's operations at the port are located at the Tenth Avenue Marine Terminal. On this project, Dole demonstrated two Class 8 electric yard tractors provided by BYD. Dole is a large corporation with the financial means to overcome burdensome costs other port tenants may encounter when electrifying fleets. Since the electric yard tractors are on-port freight vehicles, they have reduced insurance requirements compared to on-road vehicles, making this opportunity a relatively low-risk investment. With its emphasis on environmental protection, Dole was an enthusiastic technology demonstrator, fully utilizing the electric yard tractors' potential in its operations for the demonstration and continued to regularly use the vehicles beyond the term of the agreement.

As a global pioneer in new energy solutions, BYD was a dependable and collaborative technology vendor throughout this project. Having the opportunity to work with a large company like Dole enabled BYD to gain insight into maritime applications of electric freight vehicles and build a relationship with a potential customer as Dole looks to electrify its fleets.

Overall, the Dole/BYD demonstration ran smoothly. BYD made a few changes to the design to increase the range of the vehicles and upon request, made the necessary changes to ensure that the operators could safely and efficiently use these vehicles in operation. Dole was able to utilize the BYD electric yard tractors as intended, with some maintenance needed to the vehicles on occasion.

3.1.1 Yard Tractors BYT-D1 and BYT-D2

A yard tractor, also commonly known as a utility tractor rig (UTR), is a semi-tractor designed to move trailers within a cargo yard. It typically has a single-person cab offset to the side of the engine, a sliding rear door for easy access to trailer connections, a very short wheelbase—usually with a solidly mounted rear axle—and a 360-degree view to facilitate multiple moves per hour. Off-road versions do not have to drive on highways, so a typical top speed is just 25 miles per hour.

BYD designed, manufactured, and deployed the two electric yard tractors demonstrated by Dole, referred to in this report as BYT-D1 and BYT-D2 (Figure 4). BYD delivered both BYT-D1 and BYT-D2 to Dole's San Diego terminal on May 30, 2018. After tests and inspections, the trucks officially began demonstrations on June 1, 2018.

Figure 3: Dole's BYD Electric Yard Tractors BYT-D1 and BYT-D2

Credit: Dole

3.1.1.1 Vehicle Design and Deployment

BYT-D1 and BYT-D2 were second generation pre-commercial Class 8 electric yard tractors that evolved in response to feedback from users in areas such as cab comfort, ergonomics, height of cab, and foot area. The vehicles utilized the first battery that was purpose-built for vehicle electrification. Its proprietary lithium iron phosphate technology was the core of BYD's delivery truck, enabling more than 8 hours of operation between charges and gradual battery degradation. BYD provided Dole with two 100 kW chargers, and a half hour of charging increased the charge by 25 percent. A series of half-hour charges were sufficient to keep the vehicle running all day. The electric yard tractor included a proprietary battery management system (BMS) to assist with thermal balancing and charging safety.

The United States Department of Energy (DOE) technology readiness level (TRL) of these vehicles was about TRL 5 at the time the proposal for this project was written. By the time the trucks deployed, they were estimated to be TRL 7[2]. The cost of these vehicles at the time of deployment was around $300,000. Industry experts expect the prices to drop as the market matures. Comparable conventional vehicles had a unit cost of about $95,000 at the time of deployment.

SDPTA recorded the expected specifications for these electric yard tractors in the grant proposal for this project. Some of those specifications changed during the planning and building stages. As seen in Table 1, BYD used a larger battery than originally planned, extending the range of the vehicles. Note that SDPTA recorded the initial values for gross combined weight rating (GCWR) and top speed incorrectly in the proposal for this project and have been corrected in Table 2.

Table 1: Initial Specifications and Changes BYT-D1 and BYT-D2

Factor	Initial	Changes	Notes
Range (hours)	8	10	A larger battery was substituted, with a longer range.
Curb Weight (pounds)	19,000	--	
GCWR (pounds)	81,000	102,000	Original value was incorrect.
Top Speed (mph)	56	29	Original value was incorrect.
Max Power (hp)	241	--	
Torque (foot-pound)	738	--	
Capacity Degradation (% Charge after 10,000 cycles)	70%	--	
Battery Capacity (kilowatt-hour)	175	209	New battery has higher capacity.
Charging Capacity (kilowatt)	100	--	
Charging Time (hours)	1.75	2.0	New battery has a slightly longer charging time.

Source: Momentum

Upon delivery, the trucks passed all inspection tests needed for commissioning. During this process, BYD made some additional adjustments to BYT-D2, which included replacing chassis air lines, installing a cab fan, and installing a fire extinguisher. On June 1, 2018, both BYT-D1 and BYT-D2 began demonstration.

3.1.1.2 Performance Analysis

Once put into use by the operators, a few unexpected problems with the vehicle design arose. In August 2018, Dole reported multiple design issues for BYD to address:

2 The definition of TRL 7 is "Prototype near or at planned operational system – Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment."

1. The back window was smaller than preferred for visibility. The back window had a slide back design rather than a roll down design.
2. The position of the driver chair was slightly too high for visibility.
3. People and objects continuously bumped the passenger side mirror because it was too large.
4. The fifth wheel stopped lower than the height of the rails.

BYD addressed these issues by updating the back window design, installing a smaller driver chair, installing a smaller passenger mirror, and putting in place stoppers for the fifth wheel. BYD found this feedback to be of great value and chose to incorporate these design changes into its 2019 model as well.

After BYD fixed the initial design issues, Dole reported that the vehicles were performing well and that it would give the vehicles a one-hour break to charge, which would allow the vehicles to last through another 8-hour shift.

Table 3 summarizes the maintenance issues reported during the demonstration.

Table 2: Dole's Service and Maintenance Summary for BYT-D1 and BYT-D2

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
BYT-D2	Dysfunctional charging cable.	June 2019	BYD technician was onsite to install a longer cable and troubleshoot. Was determined to be a battery pack issue and immediately put back into service	June 2019
BYT-D2	Battery was dead and unable to be recharged. It was transferred to the BYD facility in Lancaster for maintenance and repair due to a bad battery cell.	April 2020	BYD's engineers performed repairs to the battery and replaced the battery pack cover to accommodate for some water accumulation	May 18, 2020
BYT-D1	Out of service for a high voltage issue preventing the battery from functioning	September 2020	Sent for repairs in Lancaster. The Battery was replaced	October 1, 2020
BYT-D1 and D2	Both trucks are experiencing charging issues.	November 2020	Unit 301 and Unit 302 non-operational and sent to Lancaster for repairs to the batteries.	December 2020

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
BYT-D1 and D2	Both trucks continue to experience battery issues when charging. The trucks' ability to charge varies on a day-to-day basis. When plugged in, the battery is draining instead of charging. Confirmed it is an issue with the vehicles not the infrastructure.	January 2021	BYD engineers on-site for repair when a vehicle is down.	Issues are ongoing. Somedays vehicles work, other days they do not.

Source: Momentum

Overall, Dole was pleased with how well the electric yard tractors performed. Once BYD fixed the design issues, the vehicles ran well and were valuable to their work. Dole operators enjoyed the reduced noise and pollution. However, the vehicles were not always reliable. Starting in April 2020, the electric yard tractors started to have battery issues and had to stop work many times for repair and maintenance, as detailed in Table 3. Additionally, the repair and maintenance service from BYD was not always satisfactory and it seemed like BYD did not always prioritize the repair and maintenance service for these vehicles or there was a lack of staff that knew how to repair electric vehicles. Dole believes that more work needs to be done to have an apple-to-apple comparison for the electric yard tractors to be directly compared to their diesel counterparts. Otherwise, a customer would be paying double for a less reliable asset. Dole would be interested in a next-generation model of the BYD electric yard tractor. Dole is now talking to other manufacturers about more electric vehicles.

During the course of the project, the Dole/BYD yard tractor demonstration resulted the following measurable objectives:

1. The two yard tractors combined drove nearly 9,900 miles.
2. Removed about 2,250 gallons of diesel fuel.
3. Reduced GHG emissions by about 23.0 MT CO2e.
4. Reduced criteria pollutant emissions by around 1.5 tons of NOx.
5. Reduced PM by nearly 100 lbs.

3.2 Summary and Evaluation of Pasha/BYD Demonstration

Pasha operations at the port are located at the National City Marine Terminal. For the project, Pasha demonstrated one Class 8 electric yard tractor (BYT-P) and two Class 8 electric drayage trucks (BDT-P and BDT-Ce) all manufactured by BYD. Pasha is a large company, so costs are less of a barrier to fleet electrification compared to other port tenants in the area. With Pasha's drive to invest in new technology as a commitment to continuously increase its productivity, quality, and profitability, Pasha was willing to demonstrate this technology for the project, taking on two electric drayage truck demonstrations on top of its originally committed electric yard tractor demonstration when two technology demonstrators withdrew from the project.

As a global pioneer in new energy solutions, BYD was a dependable and collaborative technology vendor throughout this project. Having the opportunity to work with a large company like Pasha enabled BYD to gain insight into maritime applications of electric freight vehicles and to build a relationship with a potential customer as Pasha looks to electrify its fleets.

The Pasha/BYD demonstrations did run into multiple challenges, including issues with vehicle design and performance, and also keeping the demonstration going during the COVID-19 global pandemic. Overall, Pasha was extremely grateful to have the opportunity to further enhance the design and performance of electric freight vehicles in a port setting and serve as a leader at the port for freight vehicle electrification.

3.2.1 Yard Tractor BYT-P

Pasha intended to use the BYD electric yard tractor for its break bulk or "over-high and wide" cargo destined for Hawaii. This truck is known as BYT-P. BYD delivered this truck to Pasha's terminal at the port, and it began demonstration on January 31, 2019.

Figure 4: Pasha's BYD Electric Yard Tractor BYT-P

Credit: Pasha

3.2.1.1 Vehicle Design and Deployment

BYT-P was another pre-commercial Class 8 electric yard tractor, model 8Y, a second-generation model, evolving in response to feedback from users in areas such as cab comfort, ergonomics, height of cab, and foot area. Similar to Dole's electric yard tractors, it includes a proprietary BMS to assist with thermal balancing and charging safety. A half hour of charging increases the charge by 25 percent. A series of half-hour charges is sufficient to keep the vehicle running all day.

At the time of the proposal, SDPTA estimated the TRL of this truck to be TRL 5, but estimated the TRL to be TRL 7 at the time of deployment. The approximate cost of this vehicle at deployment was about $300,000 but industry experts expect that price to drop to $250,000 over the next few years as the market matures. Comparable conventional vehicles had a unit cost of about $95,000 at the time of deployment.

The grant proposal recorded the expectations of BYT-P. Some of those specifications changed during the planning and building stages. Table 4 shows that BYD included a larger battery than originally planned to extend the truck's range.

Table 3: Initial Specifications and Changes for BYT-P

Factor	Initial	Changes	Notes
Range (hours)	8	10	A larger battery was substituted with a longer range.
Curb Weight (pounds)	19,800	--	
GCWR (pounds)	81,000	102,000	Original value was incorrect
Top Speed (mph)	56	29	Original value was incorrect
Max Power (horsepower)	241	--	
Torque (foot-pound)	1,106	--	
Capacity Degradation (% Charge after 4,000 cycles)	70%	--	
Battery Capacity (kilowatt-hour)	175	209	New battery has greater energy density
Charging Capacity (kilowatt)	100	--	
Charing Time (hours)	1.75	2	Larger battery requires slightly longer charging time

Source: Momentum

Upon delivery of the vehicle, BYT-P passed all inspection tests needed for commissioning. On January 31, 2019, BYT-P began its demonstration.

BYD provided Pasha with the charger necessary to demonstrate this electric yard tractor. The charger is a 100kW charger designed and manufactured by BYD.

3.2.1.2 Performance Analysis

In March 2019, after receiving and deploying the BYD electric yard tractor, operators noted an error message on the charger. BYD technicians assessed the use and determined that there had been a battery pack malfunction. BYD sent the vehicle to its Lancaster plant in May 2019 for the necessary repairs. It was returned to Pasha a few days later and put back into operation.

The vehicle operators did have a few critical issues with the vehicle design. These issues included:

1. The vehicle's driver seat and steering not being able to swivel. This is a necessary function for safe performance during their roll-on/roll-off ship loading activities. These roll-on/roll-off activities require the vehicle to drive in a back-and-forth motion, rather than turning around in a circular motion, to load and off-load ship cargo.
2. The fifth wheel could not be lifted or lowered while in the drive gear. The operator would have to stop the vehicle to move the fifth wheel. This is inefficient, and it can also be dangerous since these vehicles have to operate with cargo on a ramp.

As a result of these two issues, Pasha and BYD investigated the cost and time needed to make repairs and adjustments to the design but unfortunately found the upgrades to be too costly. Therefore, Pasha reassigned BYT-P to yard movements instead of the intended roll-on/roll-off activity since it could not operate safely in that application. In 2020 the COVID-19 global pandemic hit and slowed Pasha's operations. Pasha decided that this would be an ideal time to relocate its charging stations to be closer to electric vehicle operations and delayed the reassignment of BYT-P. The City of National City significantly delayed the relocation approval process. Since the charging stations could not be energized, the yard tractor demonstration was put temporarily on hold. The permits needed to energize the stations were not issued until February 23, 2021.

Table 5 provides a summary of service and maintenance issues during the yard tractor demonstration.

Table 4: Pasha's Service and Maintenance Summary for BYT-P

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
Yard Tractor BYT-P	Battery pack malfunction	March 2019	Sent to BYD Lancaster plant for repairs and was reassigned to yard movements	May 2019
Yard Tractor BYT-P	Charging meter displays an error code when the yard tractor is plugged in. The vehicle is still able to charge. On April 8, 2021, the error message continued but the charger will not charge the vehicle anymore.	March 2021/ April 8, 2021	A BYD technician visited the site when it was reported that the charger stopped working. The technician noticed that the 24 volt switch was turned off, which was causing the error message. Switch was turned on and the vehicle charges with no issues.	April 9, 2021

Source: Momentum

After the demonstration, SDPTA surveyed the vehicle operators on their experience using the yard tractor. Operators reported that before the pause due to relocation, they used truck on average of one day per week. One operator noted that the fifth wheel was not able to lift or lower while in motion and instead the vehicle had to be in park, that the truck did not have torque to travel up high or low grades, and that the driver seat did not swivel. SDPTA also asked the operators to rank the vehicle on a scale of one to five in comparison to its diesel counterparts for various design and performance aspects. A rating of one is poor or does not perform in comparison, a rank of three is adequate or comparable, and a rank of five is excellent or outperforms in comparison. Figure 6 shows the results of the operators' rankings.

Figure 5: Pasha's Operator Feedback on BYT-P

Credit: Momentum

Pasha's demonstration of the electric yard tractor had some unique challenges. Although BYD's design was compatible for Dole's operations, this was not the case for Pasha's roll-on/roll-off ship loading activities. In order to continue the demonstration, Pasha reassigned the yard tractor to yard movements, where the operators could safely drive it. Unfortunately, with the difficulties in relocating the charging stations, the demonstration was unable to resume until the last couple months of the grant period.

This demonstration was useful for BYD to learn about roll-on/roll-off operations. For Pasha it was useful to gain hands-on experience with the electric freight vehicles coming to market and understand the challenges and opportunities ahead. Pasha noted built-in charging as one of the largest foreseeable challenges to electrification. Currently, there is a lack of standardized charging and each vehicle needs its own particular charger. If the charger is down, the vehicle cannot be used. This can be extremely disruptive to a busy port operation that needs all vehicles in use. For this reason, Pasha was unable to operate the electric yard tractor for several months. Looking forward, Pasha would be interested in mobile charging, which would bypass the construction costs, permitting difficulties, and other administrative difficulties associated with built-in charging infrastructure. Mobile charging would also alleviate concerns with the range of electric vehicles in a geographically large operation.

During the course of the project, the Pasha/BYD yard tractor demonstration resulted the following measurable objectives:

1. The yard tractor drove about 150 miles.
2. Removed about 39 gallons of diesel fuel.
3. Reduced GHG emissions by 0.4 MT CO2e.
4. Reduced criteria pollutant emissions by nearly 1.0 lb. of NOx.
5. Reduced PM by nearly 30 lbs.

3.2.2 Drayage Truck BDT-P (BYD First-Generation)

Drayage is the transport of goods over a short distance, transferring shipments to and from other means of transportation, such as from a ship to a local warehouse. The term "drayage" is typically used to describe the trucking service from an ocean port to a rail ramp, warehouse, or other destination. Drayage trucks are designed to transport goods over a short distance, transferring shipments to and from other means of transportation.

Two electric drayage trucks provided by BYD took part in this demonstration. The intention of electric drayage trucks provided to Pasha was to transport, or dray, shipments from a shipyard to a local warehouse. The first electric drayage truck demonstrated by Pasha, referred to as BDT-P, was a first-generation truck designed, manufactured, and deployed by BYD. BYD delivered BDT-P to Pasha's terminal the port and began its demonstration on December 20, 2018.

Figure 6: Pasha's BYD First-Generation Electric Drayage Truck BDT-P

Credit: Pasha

3.2.2.1 Vehicle Design and Deployment

BDT-P was a Class 8 electric drayage truck, model 8TT, also a first-generation model. It included a proprietary BMS to assist with thermal balancing and charging safety while maintaining the battery's long lifespan. An hour of charging increased the expected range by 20 percent. A series of half-hour charges was sufficient to keep the vehicle running all day.

The estimated TRL of this truck was TRL 5 at time of proposal but was TRL 7 at the time of deployment. The approximate cost of one of these vehicles at the time of deployment was $330,000 but industry experts expect that amount to drop to $280,000 over the next few years as the market matures. Comparable conventional vehicles had a unit cost of about $155,000 at the time of deployment.

SDPTA recorded the expected specifications for BDT-P in the original grant proposal (Table 5). During the planning and building stages, SDPTA needed to make no further changes to the initial design.

Table 5: Initial Specifications and Changes for BDT-P

Factor	Initial	Changes
Range (miles)	80	--
Curb Weight (pounds)	23,149	--
GCWR (pounds)	105,000	--
Top Speed (mph)	56	--
Max Power (horsepower)	482	--
Torque (foot-pound)	2,212	--
Capacity Degradation (% Charge after 4,000 cycles)	70%	--
Battery Capacity (kilowatt-hour)	207	--
Charging Capacity (kilowatt)	80	--
Charing Time (hours)	3	--

Source: Momentum

Upon delivery of the vehicle, BDT-P passed all inspection tests needed for commissioning and on December 20, 2018, BDT-P began its demonstration.

BYD provided Pasha with the charger necessary to demonstrate this first-generation electric drayage truck. The charger was an 80kW charger designed and manufactured by BYD.

3.2.2.2 Performance Analysis

When performing test runs with the BDT-P, an issue with the performance capability with the vehicle immediately arose. Drivers found that the vehicle could only perform one round trip from the port operations to a nearby storage facility before being hooked up to the charger. Compared to its diesel counterpart which is able to do a full-day of drayage operations, four to five roundtrips non-stop, BDT-P significantly underperformed. Pasha found that trying to utilize BDT-P during operations was very inefficient. Every time the vehicle charged, the operator would have to detach the trailer from BDT-P and transfer it to a different vehicle to ensure that all trailers were continuously in use. Attaching and detaching the trailers takes significant time—and thus money. The drivers therefore limited the use of BDT-P on busy days.

To meet the data obligations of the grant, BDT-P did need to be in use on a somewhat regular basis. As a compromise, drivers agreed to use the vehicle one to two times per month for the duration of the demonstration. However, in 2020 the COVID-19 global pandemic hit and impacted Pasha's supply chain and volume levels. Due to the significant decrease in shipment, there was limited need for drayage. Pasha decided that this would be an ideal time to relocate its charging stations to be closer to their electric vehicle operations, which would put a temporary hold on the electric vehicle demonstrations, including BDT-P. The relocation process unfortunately was significantly delayed at the City of National City, and the permits needed to energize the stations were not issued until February 23, 2021. However, even with the charging stations energized, volumes remained too low to support drayage operations operations, so the drayage truck was unable to resume its demonstration before the closeout of the project.

Table 7 provides a summary of service and maintenance issues during the drayage truck demonstration.

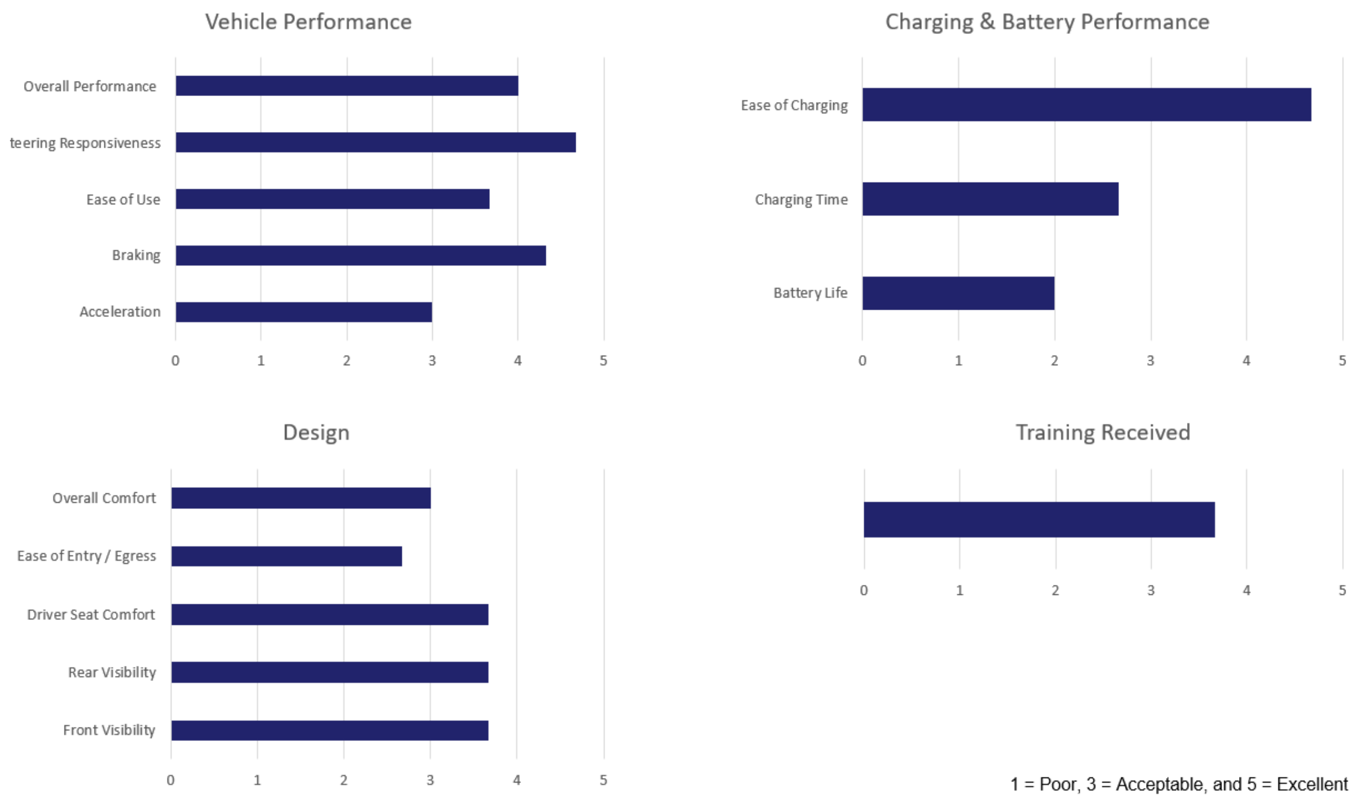
Table 6: Pasha's Service and Maintenance Summary BDT-P

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
Drayage Truck BDT-P	Malfunctioning power cables between the trailer and truck	September 2020	Repurpose truck to on-port operations and reduce use in order to complete data collection obligations for the grant period	September 2020

Source: Momentum

After the demonstration, SDPTA surveyed vehicle operators on their experience using the first-generation drayage truck. Operators reported that before the pause due to relocation, they used the truck on average of two to three days per week. One operator reiterated that the insufficient battery performance limited their ability to efficiently perform the yard and warehouse operations and overall, their ability to utilize the vehicle. SDPTA also asked the operators to rank the vehicle on a scale of one to five in comparison to its diesel counterpart for various design and performance aspects. Figure 8 shows the results of the operators' rankings.

Figure 7: Pasha's Operator Feedback on BDT-P



Credit: Momentum

Overall, the demonstration was a highly valuable case study for BYD. BYD was able to study the faults of the first-generation model and incorporate the feedback into the development of the second-generation model. Although Pasha's first-generation drayage truck was unable to meet performance standards, Pasha provided BYD with the feedback needed to significantly improve performance in the next generation model and overall help advance electric drayage truck technology.

During the course of the project, the Pasha/BYD first-generation drayage truck demonstration resulted the following measurable objectives:

1. The drayage truck drove about 1,580 miles.
2. Removed about 340 gallons of diesel fuel.
3. Reduced GHG emissions by 3.5 MT CO2e.
4. Reduced criteria pollutant emissions by about 1.0 lb. of NOx.
5. Reduced PM by nearly 1.0 lb.

3.2.3 Drayage Truck BDT-Ce (BYD Second-Generation)

After receiving feedback on the first-generation electric drayage truck, BYD was able to finalize a second-generation model, which Pasha demonstrated. BYD delivered the second-generation electric drayage truck, referred to as BDT-Ce, to Pasha's terminal the port on June 28, 2019. After acceptance tests and inspections, Pasha officially deployed it on July 5, 2019.

Figure 8: Pasha's BYD Second-Generation Electric Drayage Truck BDT-CE

Credit: Pasha

3.2.3.1 Vehicle Design and Deployment

BDT-Ce was a Class 8 electric drayage truck, second-generation of model 8TT, evolving in response to feedback from users. It included improvements to cab comfort, ergonomics, and the propulsion profile. It included a proprietary BMS to assist with thermal balancing and charging safety while maintaining the battery's long lifespan. An hour of charging increased the expected range by 20 percent. A series of half-hour charges was sufficient to keep the vehicle running all day.

The estimated TRL of this truck was TRL 5 at time of proposal but estimated to be TRL 7 at the time of deployment. The approximate cost of ones these vehicles at the time of deployment was $330,000, but industry experts expect that amount to drop to $280,000 over the next few years as the market matures. Comparable conventional vehicles had a unit cost of about $155,000 at the time of deployment.

SDPTA recorded the expected specifications for BDT-Ce in the original grant proposal. During the planning and building stages, the initial design needed no further changes. Compared to the first-generation model, the second-generation model was a significant improvement in terms of range and battery performance.

Table 7: Initial Specifications and Changes for BDT-CE

Factor	Initial	Changes
Range (miles)	125	--
Curb Weight (pounds)	23,235	--
GCWR (pounds)	105,000	--
Top Speed (mph)	65	--
Max Power (horsepower)	482	--
Torque (foot-pound)	1,770	--
Capacity Degradation (% Charge after 4,000 cycles)	70%	--
Battery Capacity (kilowatt-hour)	435	--
Charging Capacity (kilowatt)	40	--
Charing Time (hours)	11	--

Source: Momentum

BYD delivered BDT-Ce to Pasha on June 28, 2019. Pasha conducted the inspection tests needed for commissioning d on July 5, 2019, and Pasha commissioned it for service the same day.

BYD provided Pasha with the charger necessary to demonstrate this second-generation electric drayage truck. The charger is a 40 kW charger designed and manufactured by BYD.

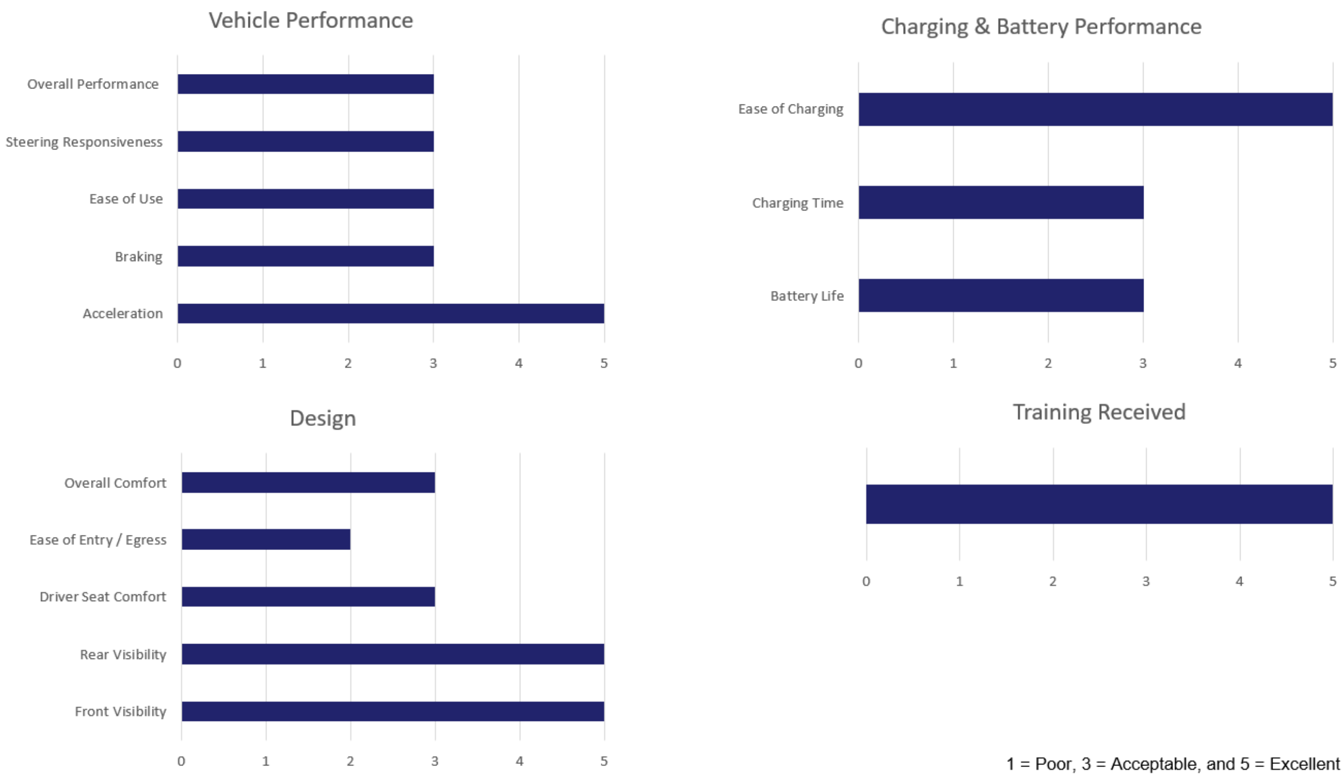
3.2.3.2 Performance Analysis

As hoped, the second-generation drayage truck was a significant improvement on the first-generation model in terms of performance. The second-generation model was able to perform just as well as its diesel counterpart for Pasha's drayage operations, lasting an entire day of work, roughly four to five non-stop rounds trips from the port operations to a nearby facility.

However, in 2020 the COVID-19 global pandemic hit and impacted Pasha's supply chain and volume levels. Due to the significant decrease in shipments, there was limited need for drayage operations. Pasha decided that this would be an ideal time to relocate its charging stations to be closer to their electric vehicle operations, which put a temporary hold on the electric vehicle demonstrations, including BDT-Ce. The relocation process unfortunately was significantly delayed at the City of National City, and the permits needed to energize the stations were not issued until February 23, 2021. However, even with the charging stations energized, volumes remained too low to support drayage operations, so the drayage truck was unable to resume its demonstration before the closeout of the project.

After the demonstration, SDPTA surveyed the vehicle operators on their experience using the second-generation drayage truck. Operators reported that before the pause due to relocation, they used the truck on average three days per week. SDPTA also asked the operators to rank the vehicle on a scale of one to five in comparison to its diesel counterparts (for various design and performance aspects. Figure 10 shows the results of the operators' rankings.

Figure 9: Pasha's Operator Feedback on BDT-CE



Credit: Momentum

As mentioned previously, BYD was able to study the faults of the first-generation model and incorporate Pasha's feedback into the development of the second-generation model. Pasha was impressed with the improvements made and the power of the second-generation truck. Before COVID-19 affected Pasha's drayage operations, Pasha used the second-generation truck often since it was able to keep up with its diesel counterparts.

During the course of the project, the Pasha/BYD second-generation drayage truck demonstration resulted the following measurable objectives:

1. The drayage truck drove about 5,220 miles.
2. Removed about 995 gallons of diesel fuel.
3. Reduced GHG emissions by more than 10 MT CO2e.
4. Reduced criteria pollutant emissions by about 4.0 lbs. of NOx.
5. Reduced PM by nearly 1.0 lb.

3.3 Summary and Evaluation of Terminalift/BYD Demonstration

Terminalift's operations at the port are located at the Tenth Avenue Marine Terminal. For the project, Terminalift demonstrated two Class 8 Electric Drayage Trucks (BDT-T1 and BDT-T2) manufactured by BYD. Terminalift is a small organization that benefits greatly from these kinds of demonstration projects. Terminalift is extremely eager to electrify it operations and has been a key leader and ally at the port in ensuring the success of this project.

As a global pioneer in new energy solutions, BYD was a dependable and collaborative technology vendor throughout this project, agreeing to also manufacture Terminalift's two electric drayage trucks after one of the technology vendors withdrew from the demonstration. Having the opportunity to work with Terminalift's specialty operations enabled BYD to gain insight into the various maritime applications of electric freight vehicles, expanding its product reach by ensuring that BYD products are able to cater to more specialized operations.

The Terminalift/BYD demonstration had a somewhat slow start due to a power supply issue at the terminal preventing on-road use, but once things were up and running, Terminalift acquired the necessary registrations and the BYD trucks hit the road.

3.3.1 Drayage Trucks BDT-T1 and BDT-T2

EDI was the original technology vendor to provide two Class 8 electric drayage trucks. However, Cummins acquired EDI in August 2018 and subsequently requested to be removed from the project in June 2019 due to a conflict with internal company objectives. By September 2019, Terminalift decided to move forward with BYD as its technology vendor instead. BYD provided two electric drayage to take part in this demonstration with Terminalift. Terminalift intended for these trucks to support Terminalift's on-road drayage operations. Both of these electric drayage trucks, referred to as BDT-T1 and BDT-T2, are BYD's second-generation drayage trucks delivered to Terminalift's terminal at the port and began demonstration on January 31, 2020, and January 30, 2020, respectively.

Figure 10: Terminalift's BYD Electric Drayage Trucks BDT-T1 and BDT-T2

Credit: Terminalift

3.3.1.1 Vehicle Design and Deployment

BDT-T1 and BDT-T2 are Class 8 electric drayage trucks, model 8TT second-generation, designed, manufactured, and deployed by BYD. The vehicles included a proprietary BMS to assist with thermal balancing and charging safety while maintaining the battery's long lifespan. Although these trucks were capable of receiving a one-hour charge that increased the expected range by 20 percent, Terminalift deployed them with lower-power chargers that were expected to provide sufficient charge for a full day of use based on typical drayage truck duty cycles.

SDPTA estimated the TRL of this truck to be TRL 5 at the time of the proposal but estimated it at TRL 8[3] at the time of deployment. The cost of one these vehicles was approximately twice the cost of a comparable diesel vehicle at the time of deployment but industry experts expecgt that amount to drop over the next few years as the market matures and the cost of batteries go down. Comparable conventional vehicles had a unit cost of approximately $155,000 at the time of deployment. The cost per unit for this demonstration was $300,000.

SDPTA recorded the expected specifications for Terminalift's BYD electric drayage in the grant proposal for this project. During the planning and building stages, BYD changed some of the specifications. Table 11 shows the changes to the Max Power and Battery Capacity for both trucks.

Table 8: Initial Specifications and Changes for BDT-T1 and BDT-T2

Factor	BYD Drayage Truck (BDT-T1)		BYD Drayage Truck (BDT-T2)	
	Initial	Changes	Initial	Changes
Range (miles)	125	--	125	--
Curb Weight (pounds)	26,235	--	26,235	--
GCWR (pounds)	105,000	--	105,000	--
Top Speed (mph)	65	--	65	--
Max Power (horsepower)	482	483	482	483
Torque (foot-pound)	1,770	--	1,770	--
Capacity Degradation (% Charge after 4,000 cycles)	70	5 years or 250,000 miles	70	5 years or 250,000 miles
Battery Capacity (kilowatt-hour)	435	409	435	409
Charging Capacity (kilowatt)	40	--	40	--
Charging Time (hours)	11	--	11	--

Source: Momentum

Upon delivery of the vehicles, both trucks passed all inspection tests needed for commissioning and on January 31, 2020, BDT-T1 and BDT-T2 began their demonstrations.

3 The definition of TRL 8 is "The technology has been provided to work in its final form and under expected conditions. In almost all cases, this TRL represent the end of true system development."

BYD provided Terminalift with two chargers necessary to demonstrate these electric drayage trucks. The chargers were 40kW chargers designed and manufactured by BYD.

3.3.1.2 Performance Analysis

In February 2020, Terminalift experienced a power supply issue at its terminal, delaying the intended on-road use of the BYD electric drayage trucks, but fortunately not delaying the project demonstration. Terminalift found that the BYD chargers were not outputting enough voltage to charge the trucks according to the performance specifications and therefore did not feel comfortable deploying the vehicles for on-road use without the infrastructure in place to support those operations. BYD worked with Terminalift to troubleshoot the issue and found that the port terminal housing Terminalift's operations was not providing sufficient power to meet the charging performance specifications and therefore helped install a new transformer at the terminal to meet the power demand.

BYD assisted with the installation of a new transformer at the terminal on August 20, 2020, to fix the power supply problem. After some troubleshooting and adjustments, the chargers worked according to the specifications. While BYD was fixing the issue, Terminalift had to acquire the on-road registration for both trucks, which took some time to budget out. During these setbacks, Terminalift used the trucks to offload shipments for their work in the port yard. Terminalift reported excellent performance, mentioning that the trucks could be used for multiple back-to-back shifts without needing to be charged.

Terminalift completed purchase of the on-road registration on January 12, 2021; however, shortly thereafter Terminalift reported an issue with the trailer plug-in on one of the trucks. When an on-road trailer was attached to the drayage truck, the turn signal fuses would unexpectedly blow, and the turn signals would stop working without the truck driver's knowledge. This posed a large danger to the truck operators and any surrounding cars on the road. Terminalift decided to limit the drayage trucks to on-port operations until BYD was able to resolve the issue and the trucks could be used safely in traffic. BYD resolved the issue in March 2021, as described in Table 10.

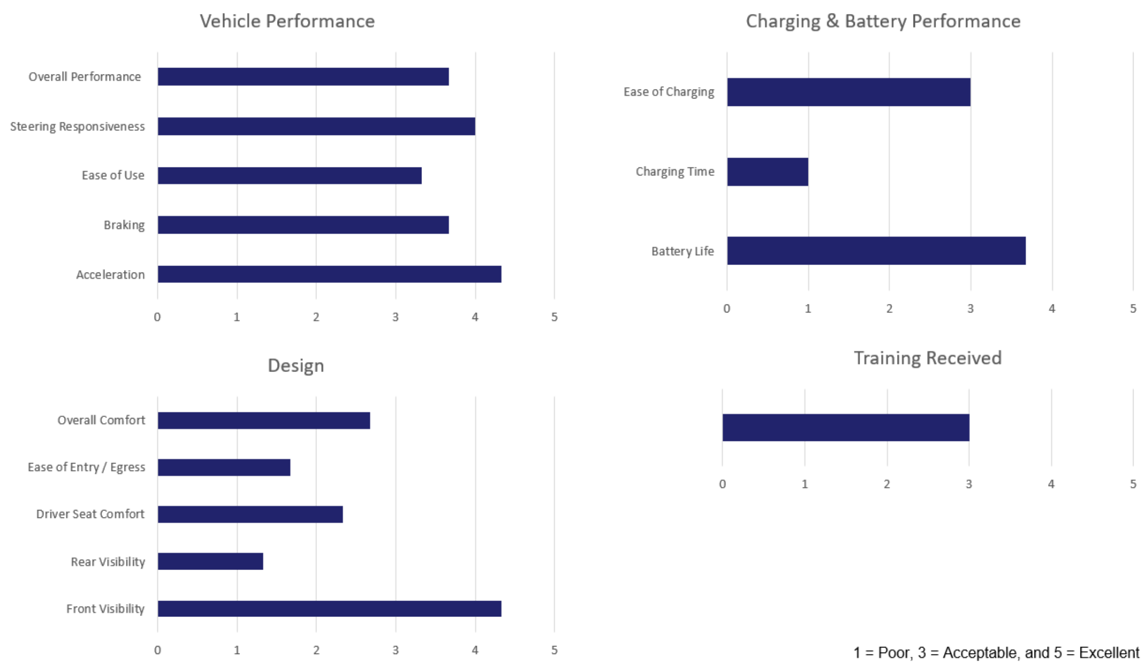
Table 9: Terminalift's Service and Maintenance Summary for BDT-T1 and BDT-T2

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
BDT-T1	Turn signal not working when on-road drayage trailer is attached. Turn signal fuse blows unpredictably and may occur without the driver's knowledge if while driving.	February 2021	An upgrade to LED lighting in the trailer did not resolve the issue. A technician noticed that two wires on the electrical system were wired backwards. The technician re-wired them and the issue was resolved.	March 2021
BDT-T2	N/A	N/A	N/A	N/A

Source: Momentum

After the demonstration, SDPTA surveyed the vehicle operators on their experience using the two electric drayage trucks. Operators reported that they used trucks on average of one to two days per week. SDPTA also asked the operators to rank the vehicle on a scale of one to five in comparison to its diesel counterparts for various design and performance aspects. Figure 12 shows the results of the operators' rankings.

Figure 11: Terminalift's Operator Feedback on BDT-T1 and BDT-T2



Credit: Momentum

Terminalift did have some trouble getting the trucks on-road as intended. However, the demonstration was successful overall. The electric drayage trucks were reliable and met all performance expectations. Terminalift noted that the repair and maintenance service could use some improvement to be faster. This project increased Terminalift's confidence in electric freight vehicles and in reaching its own climate goals. Terminalift is currently looking for electric trucks with a 300-mile range and would be interested in a third-generation model of the BYD drayage truck demonstrated.

During the course of the project, the Terminalift/BYD drayage truck demonstration resulted the following measurable objectives:

1. The two drayage trucks combined drove more than 860 miles.
2. Removed about 150 gallons of diesel fuel.
3. Reduced GHG emissions by 1.5 MT CO2e.
4. Reduced criteria pollutant emissions by about 1.0 lb. of NOx.
5. Reduced PM by nearly 1.0 lb.

3.4 Summary and Evaluation of Terminalift/TransPower Demonstration

For this project, Terminalift also took on the 40,00-lb electric forklift demonstration after the original tenant withdrew from the project. Terminalift is a small organization that benefits greatly from these kinds of publicly funded demonstration projects. Additionally, Terminalift runs a number of heavy-duty forklifts in its operations, utilizing them for a multitude of specialized cargo, so adding its first electric 40,000-lb forklift to the fleet was extremely valuable and exciting. Terminalift is extremely eager to electrify it operations and has been a key leader and ally at the port in ensuring the success of this project.

Kalmar manufactured the 40,000-lb forklift (TFL-T) and TransPower upgraded it with a BMS. TransPower ran into multiple challenges with making the new-tech upgrades with limited staff available and the transitioning management due to the acquisition by Meritor. After the acquisition, Meritor discontinued TransPower's forklift division, initially leaving only one engineer to complete and deliver the forklift. Therefore TFL-T is a one-of-a-kind vehicle that Terminalift was excited to demonstrate and put to use.

The project had originally contracted with Continental Maritime to demonstrate the forklift, but as the prototype forklift was being manufactured, concerns over the vehicle's ability to meet Continental Maritime's performance standards and its fit for the terminal and operations ultimately led to the transfer of the demonstration to a different tenant.

3.4.1 Forklift TFL-T

A forklift is a powered industrial truck used to lift and move materials short distances. Forklifts are unique in that they have rear-wheel steering, and they have a continually varying center of gravity when loaded. They are designed for maneuverability, as they often enter warehouses to lift and move items.

TransPower added an array of innovative components, but multiple unforeseen challenges in the design and delivery of the forklift unfortunately caused multiple delays to the demonstration throughout the project period. TransPower ultimately delivered the TFL-T to Terminalift on December 24, 2020, and immediately was put to use, beginning its demonstration.

Figure 12: Terminalift's TransPower Forklift (TFL-T)

Credit: TransPower

3.4.1.1 Vehicle Design and Deployment

The forklift is a Kalmar lead-acid variant electric forklift, model ECG90-180 9-18T. Terminalift purchased the vehicle new from Kalmar, without the two-stock lead-acid battery packs. TransPower engineered a new lithium battery pack for the forklift. The forklift is compliant with OSHA standards and has a lift capacity of 40,000-lb.

The technology readiness level, TRL, of the forklift was TRL 6 when the project team wrote the proposal. By the time the trucks were in use, the TRL was at TRL 7[4]. The unit baseline cost for this forklift was $250,293 with an additional cost of $308,789 for the battery upgrade, for a total cost of $559,082. Since this is a one-of-a-kind prototype, future market costs are not applicable for this vehicle.

The project team recorded the expected Kalmar specifications for Terminalift's electric forklift. TransPower's engineered lithium battery resulted in multiple changes many to the initial specifications, as recorded in Table 11 below.

Table 10: Initial Specifications and Changes for TFL-T

Factor	Terminalift Forklift TFL-T	
	Initial	Changes
Curb Weight (pounds)	35,500	54,840
GCWR (pounds)	50,500	94,840
Top Speed (mph)	12	16
Run Time (hours)	Not available	6

4 The definition of TRL 7 is "Prototype near or at planned operational system – Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment."

Factor	Terminalift Forklift TFL-T	
	Initial	Changes
Max Power (horsepower)	Drive Motor 2x49.6 hp; Pump Motors 2x67 hp (50kW) – S3 15%; Brake Pump Motor 1x1.68 hp (5.1 kW) – S3 15%	--
Torque (foot-pound)	Not available	--
Capacity Degradation (% Charge after 4,000 cycles)	Not available	95%
Battery Capacity (kilowatt-hour)	260	200
Charging Capacity (kilowatt)	25.8	19.2
Charging Time (hours)	2 hours at 120 amps	10 hours at 80 amps

Source: Momentum

Through the procurement and build of the forklift, TransPower encountered many challenges which delayed the delivery and deployment of the forklift multiple times. When TransPower and Continental Maritime, the original port tenant demonstrating the forklift, first initiated their contract agreement in 2017, the parties initially estimated delivery to take place in September 2018.

TransPower planned to purchase a diesel Kalmar forklift and convert it into an electric drive. In January 2018, Kalmar, the forklift vendor, offered TransPower and Continental Maritime the chance to purchase its new forklift model that already ran on electric power for a comparable price. TransPower and Continental Maritime agreed to move forward with this offer and brought on TransPower's Jim Burns to lead the engineering of the battery upgrades needed to meet the agreed upon technical requirements of the electric forklift. However, upon purchasing the forklift from Kalmar, Kalmar said that shipping of the vehicle to TransPower would be significantly delayed and that it would take up to 26 weeks for the vehicle to be delivered.

TransPower was able to work on the battery designs and start some of the build but could not make much progress until the forklift arrived. The Kalmar forklift arrived at the TransPower facility during the last week of December 2018. TransPower immediately began the build out of the vehicle's battery upgrades and the updated the planned delivery date to Continental Maritime to June 2019. Many of the battery components also experienced delayed shipping, including a missing battery pack connector that had to be ordered from Kalmar. By November 2019, the build out of the forklift was nearly complete, marking anticipated delivery for January 2020.

However, in December 2020, Jim Burns, the primary engineer developing the forklift, encountered significant health issues causing significant delays to the final adjustments and verification testing before TransPower could deliver the vehicle. Jim made arrangements to hire a few technicians to assume his responsibilities during this period.

Coinciding with this series of setbacks, on January 16, 2020, TransPower notified the project team that Meritor—a leading global supplier of drivetrain, mobility, braking, and aftermarket solutions focused on on-highway applications—had purchased the company. With the new acquisition, Meritor did not prioritize the forklift because it represented a project not connected to Meritor's specialty in on-highway vehicles. Head engineer, Jim Burns, retired from TransPower at this time although dedicated himself to seeing the project through as an independent contractor under TransPower/Meritor.

In early 2020, COVID-19 emerged as a global pandemic, impacting supply chains and work at facilities. Through these challenges and setbacks, TransPower delivered the 40,000-lb forklift to Continental Maritime on June 26, 2020.

Upon delivery of the forklift, the commissioning process experienced significant issues almost immediately. On July 8, 2020, the Occupational Safety and Health Administration (OSHA) performed a weight test on the forklift and certified it for 30,000-lb capacity, but that was 3,000 lbs. less than the 40,000-lb. lift capacity as intended. Furthermore, during the weight test the forklift broke down and became non-operational. The idle vehicle quickly became a safety concern since the small terminal had limited space for operations. At this time, Jim Burns was out-of-state due to a family emergency and TransPower/Meritor did not accept the forklift back at its facility. SDPTA managed to find a temporary location at Terminalift's terminal to house the forklift until it was repaired and ready to be returned to Continental Maritime.

This incident increased Continental Maritime's concerns about the forklift's ability to perform and its fit for the terminal that Continental Maritime operates on, which is small and has limited space. As a result, Continental Maritime requested that TransPower add additional parts or have the ability to move the forklift manually and easily in the case of another breakdown. After a number of months, TransPower's engineers concluded that this would not be feasible given the time constraint of the grant.

In the meantime, repairs slowed down due to Jim's family emergency, which caused him to travel out-of-state on a regular basis. Troubleshooting showed that the battery strings had become unbalanced, and that one string was pulling too much power from the battery, engaging a safety feature for the fuse to blow and the forklift to completely shut down. Once TransPower made the repairs, added weight, and ensured many of the commissioning items were satisfactory, another weight certification test was scheduled for September 30, 2020. On the morning of the test to certify the forklift at the 40,000-lb lift capacity, the testing team the found the forklift battery drained and the vehicle non-operational. TransPower then agreed to tow the forklift back to its facility for further repair and work.

Aware of Continental Maritime's growing concerns about the forklift, SDPTA and Momentum approached Terminalift on its interest to take on the forklift demonstration. Terminalift noted that it operated a number of heavy-duty diesel forklifts at its terminal and would be more than willing to add its first electric forklift the fleet. On October 12, 2020, all parties agreed to transfer the demonstration from Continental Maritime to Terminalift, and Terminalift installed the charger from Continental Maritime that month. During this time, TransPower/Meritor elevated the importance of the project's completion and sought to acquire more staff to take on Jim's knowledge of the forklift as his health limited the attention he could give to the project. Meritor expeditiously added additional staff support to assist Jim in the repair and commissioning of the forklift.

Troubleshooting revealed that one of the battery cells was below voltage, which disabled the entire battery. Once repaired and operational, the forklift completed the weight certification test for the 40,000-lb. lift capacity on November 3, 2020. However, further issues with the forklift battery rose early December 2020, causing continued breakdowns. Technicians concluded that what caused the shutdowns was weak wiring in some areas, which the technicians quickly resolved. A series of test runs allowed the team to identify small software issues that they also needed to address. Additionally, the team identified that Kalmar, the manufacturer of the forklift, had provided the vehicle with a shortage of fluid in the front differentials which was causing some damage to two small bearings. Additional parts were rush ordered and immediately installed, finishing TransPower's work on the vehicle design. On December 24, 2020, TransPower delivered the forklift to Terminalift.

Figure 13: Delivery of TFL-T to Terminalift

Credit: TransPower

TransPower provided Terminalift with the charger necessary to demonstrate this electric forklift. The charger was a 19.2kW charger designed and manufactured by Tesla.

3.4.1.2 Performance Analysis

Terminalift immediately put the forklift to work at its operations. There was a small learning curve since it was the first electric forklift in its fleet. Since this forklift is larger than the rest of their fleet, the forks were also slightly larger which impaired Terminalift's ability to use the forklift as their go-to forklift due to compatibility with the dunnage on many freight trucks. However, this did not affect Terminalift's ability to carry out the demonstration.

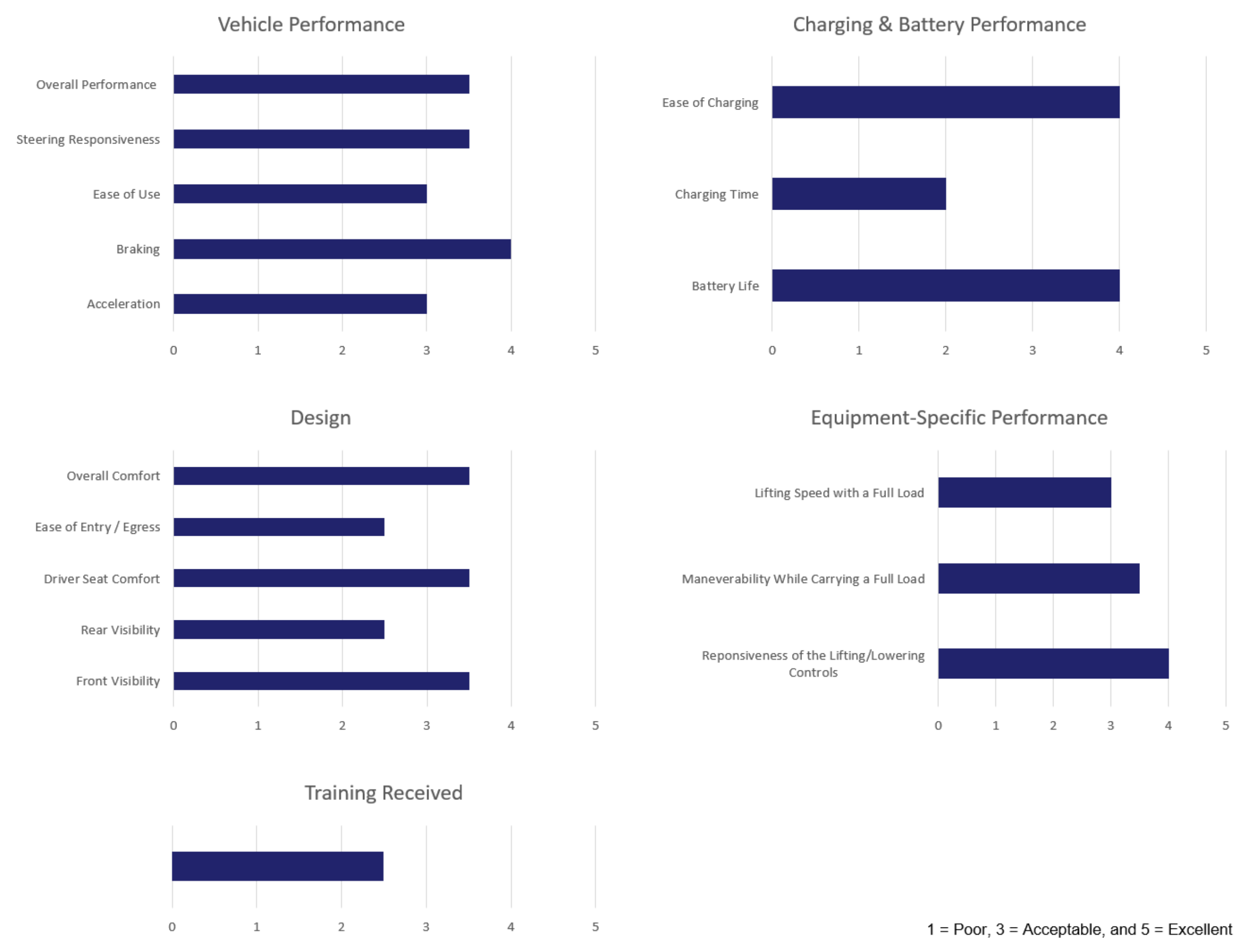
Table 11: Terminalift's Service and Maintenance Summary for TFL-T

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
TransPower Forklift	Fork size too big	March 25, 2021	Terminalift is looking into purchasing smaller size forks	NA
TransPower Forklift	Hydraulic hose fail	April 20, 2021	Terminalift paid for an emergency mechanic to replace the hose	April 21, 2021

Source: Momentum

After the demonstration, SDPTA surveyed the vehicle operators on their experience using the electric forklift. Operators reported that they used the forklift an average of one day per week and for moving cargo on to or off of a vessel or freight truck and for yard or warehouse movements. SDPTA also asked the operators to rank the vehicle on a scale of one to five in comparison to its diesel counterparts for various design and performance aspects. Figure 15 shows the results of the operators' rankings.

Figure 14: Terminalift's Operator Feedback on TFL-T



Credit: Momentum

Overall, Terminalift was delighted to have demonstrated the electric forklift. Terminalift's drive to decarbonize its entire operation and its confidence in electric vehicle technology made them the perfect candidate to carry out the demonstration. This TransPower electric forklift is Terminalift's first electric forklift, but is not intended to be the last.

During the course of the project, the Terminalift/TransPower forklift demonstration resulted the following measurable objectives:

1. The forklift drove nearly 45 miles.
2. Removed about 95 gallons of diesel fuel.
3. Reduced GHG emissions by about 1.0 MT CO2e.
4. Reduced criteria pollutant emissions by about 16 lbs. of NOx.
5. Reduced PM by nearly 1.0 lb.

3.5 Summary and Evaluation of Marine Group Boat Works/Cummins Demonstration

MGBW Chula Vista and National City locations at the port are where its two forklift demonstrations took place. On this project, MGBW demonstrated two lithium-ion electric forklifts (EFL-M1 and EFL-M2) manufactured by XL Lifts and repowered by Cummins. MGBW is a local business and environmental steward that benefits greatly from these kinds of demonstration projects.

The project had originally contracted with EDI to engineer these electric forklifts, but during the project, EDI agreed to the acquisition by Cummins to build out and scale the larger company's renewable technology portfolio. The transition was challenging to navigate, but ultimately Cummins fulfilled the two forklift demonstrations.

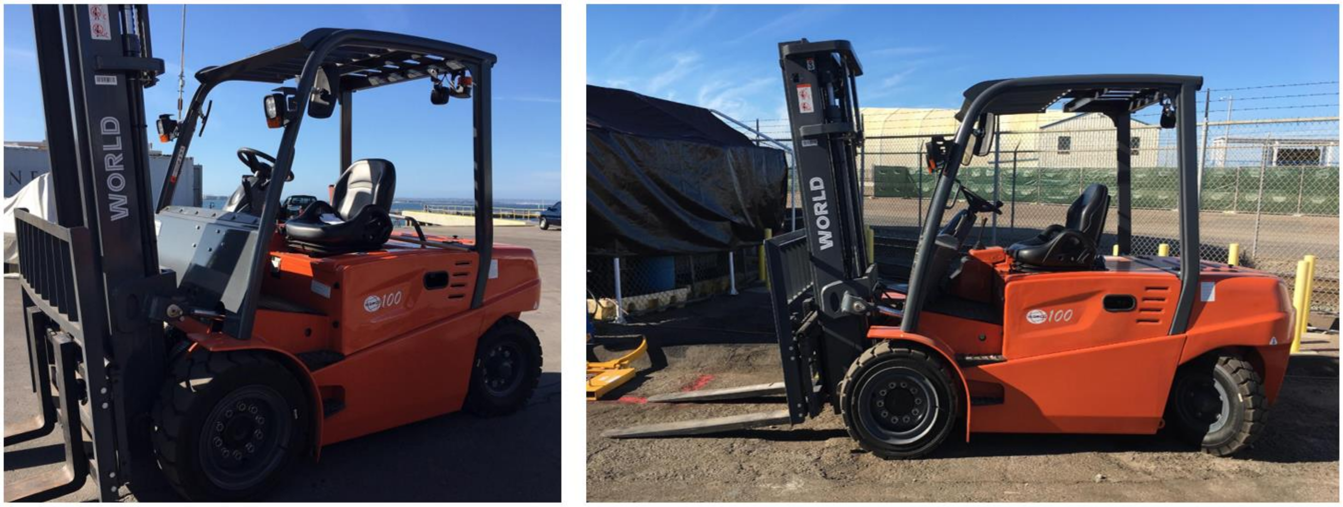
The goal of the MGBW/Cummins demonstration was to deliver a forklift that operated with the full-power performance of a traditional fossil-fuel based forklift, with the added benefit of higher energy density compared to lead-acid forklifts. Both parties believe the forklifts met this goal.

3.5.1 Forklifts EFL-M1 and EFL-M2

A forklift is a powered industrial truck used to lift and move materials short distances. Forklifts are unique in that they have rear-wheel steering, and they have a continually varying center of gravity when loaded. They are designed for maneuverability, as they often enter warehouses to lift and move items.

Two electric forklifts, referred to as EFL-M1 and EFL-M2, were provided by Cummins and manufactured by World-Lift to take part in this demonstration with MGBW. MGBW intended for these electric forklifts to support its port operations, primarily used for moving loads within the boat area. Cummins delivered EFL-M1 and EFL-M2 to MGBW's terminal in Chula Vista on December 13, 2018, and after tests and inspections, the forklifts officially began demonstration the same day.

Figure 15: MGBW's Cummins Forklifts EFL-M1 and EFL-M2



Credit: MGBW

3.5.1.1 Vehicle Design and Deployment

EFL-M1 and EFL-M2 were Class-1, lead-acid, electric forklifts, model WFE 100 manufactured by XL Lifts, Inc. Cummins purchased these vehicles from XL Lifts and upgraded the lead-acid batteries with lithium-ion batteries in an effort to improve performance and efficiency and maintain zero-emission operations for marine applications. Cummins was not aware at that time of any other demonstrations being done with this particular model. Thus, MGBW's demonstration was truly a pioneer project for electric freight vehicles everywhere.

The US DOE TRL of the WFE 100 forklift was at TRL 9[5] at the time of deployment. The unit baseline cost for these forklifts was $80,750, with an additional cost of $39,400 for the battery upgrade.

SDPTA reported the expected specifications for the electric forklifts in the grant proposal. During the planning and building stages of the vehicles, Cummins changed some of those specifications. Table 13 shows a summary of the specifications, and any changes made for the demonstration.

Table 12: Initial Specifications and Changes for EFL-M1 and EFL-M2

Factor	Initial	Changes	Notes
Range (hours)	N/A		
Curb Weight (pounds)	N/A	17,310 (with attachments)	
GCWR (pounds)	10,000 to 15,000	10,000	
Top Speed (mph)	N/A	8.7	

5 According to the DOE, TRL 9 indicates that the technology is in its final form and operational under the full range of operating conditions.

Factor	Initial	Changes	Notes
Max Power	N/A	9.1 x 2 kilowatt Drive Motor	
Torque (foot-pound)	N/A		
Capacity Degradation (% Charge after 10,000 cycles)	N/A		
Battery Capacity	35 kilowatt-hour, 80 V Nominal	540 Ah	A specially designed battery system was originally proposed, but a commercially available system was used instead.
Charging Power	6.6 kilowatt	200 A, 80 V	A specially designed battery system was originally proposed, but a commercially available system was used instead.

Source: Momentum

The integration of the lithium-ion battery packs into the forklifts was a straightforward process, as the industrial packaging was in line with the traditional lead-acid packs and required no incremental parts creation for mounting and securing within the forklift. Minor software interface work was required to ensure the vehicle accessories (i.e. signal lights, dash, etc.) operated to traditional standards. Cummins estimated that it could complete future installations of batteries and software calibration in under two weeks versus four to eight weeks, if built in an OEM factory production line rather than through an upfitter or systems integrator partner.

Upon delivery of the vehicles, both forklifts passed all inspection tests needed for commissioning and on December 13, 2018, EFL-M1 and EFL-M2 began demonstrations. MGBW deployed one of the forklifts at its Chula Vista location and the other at its neighboring National City location.

Cummins provided MGBW with two chargers necessary to demonstrate these electric forklifts. The chargers were 12.48 kW EcoTech chargers designed and manufactured by Micropower.

3.5.1.2 Performance Analysis

Regarding the design of the forklifts, MGBW indicated its preference for a higher-reaching fork and longer prongs. Although XL Lifts could not make these upgrades during the project, it did note the request for future forklift designs.

The lithium-ion battery technology tested on these forklifts proved to have significantly higher energy density than lead acid batteries, giving the vehicle the ability to store and discharge more energy, and powering the vehicle for longer periods of time. Up to 95 percent of the energy stored in a lithium-ion battery can be used, compared to 80 percent to 85 percent in lead-acid batteries. However, lithium-ion batteries today are still significantly more expensive and will take a number of years to be at par with lead-acid.

Overall, MGBW's user experience and performance with the forklifts was extremely positive. There were no indications that the forklifts were unable to keep up with the demand of its operations, making these forklifts a viable alternative to conventional forklifts.

Only one performance issue arose during the demonstration. In January 2020, MGBW reported that it was experiencing intermittent speed performance issues with the forklift located at its Chula Vista location. Jean-Baptiste Gallo, the Cummins Project Manager overseeing this demonstration, was on leave during this time. Upon his return in April 2020, he reached out to the forklift vendor to see if there was anything that could be done to resolve this performance issue. The vendor sent a repaired battery to MGBW to install, which resolved the issue.

Since the kick-off of this project, MGBW has added many other electric forklifts to its fleet in efforts to decarbonize its operations.

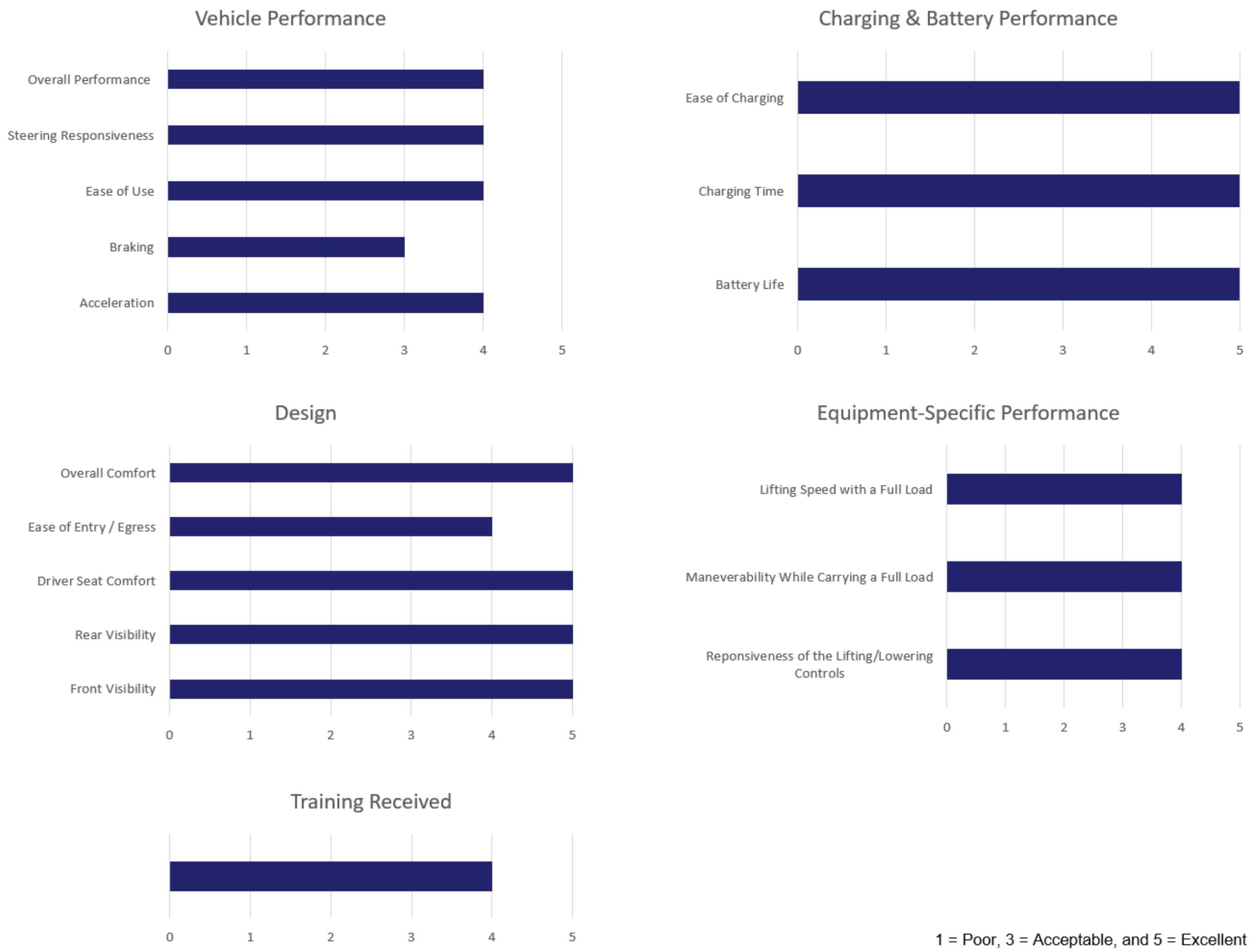
Table 13: MGBW's Service and Maintenance Summary for EFL-M1 and EFL-M2

Vehicle	Description of Issue	Date Reported	Resolution of Issue	Returned to Operation
EFL-M1	Chula Vista forklift has been experiencing recent speed performance issues, from time to time. It is slower than normal.	1/10/20	Repaired battery delivered.	April 2020
EFL-M2	N/A	N/A	N/A	N/A

Source: Momentum

After the demonstration, SDPTA surveyed the vehicle operators on their experience using electric forklifts. Operators reported that they used the forklifts an average of five days per week moving cargo. SDPTA also asked operators to rank the vehicle on a scale of one to five in comparison to its diesel counterparts for various design and performance aspects. Figure 17 shows the results of the operators' rankings.

Figure 16: MGBW's Operator Feedback on EFL-M1 and EFL-M2



Credit: Momentum

The forklifts were comparable to their diesel counterparts in performance, although the forklifts were also much quieter. MGBW did note that the batteries had issues with moisture from the marine climate. Since the technology is still new to the manufacturer, repair and maintenance service was more difficult and took longer to complete. MGBW has already electrified 85 percent of its forklift fleet and mentioned that this demonstration helped define workforce criteria to hire new staff to support its electric vehicle program.

During the course of the project, the MGBW/Cummins forklift demonstration resulted the following measurable objectives:

1. The two forklifts combined operated for nearly 2,310 hours.
2. Removed about 1,265 gallons of diesel fuel.
3. Reduced GHG emissions by almost 13 MT CO2e.
4. Reduced criteria pollutant emissions by about 40 lbs. of NOx.
5. Reduced PM by nearly 1.5 lbs.

3.6 Summary and Analysis of Stakeholder Feedback

SDPTA designed this project to inform innovation strategies that would ultimately increase vehicle drivability, performance, and reliability and thus—in combination with the project's outreach—lead to greater adoption for zero-emission MDHD vehicles. Throughout the project, SDPTA interviewed major stakeholders, including port tenants, manufacturers, SDPTA, the port, and the local utility to gain a better understanding of thoughts around these vehicle demonstrations and the overall impact of the project.

All the stakeholders had clear ideas about what they had hoped to learn from the demonstration. For the most part, the stakeholders were enthusiastic about the prospect of using electric vehicles, although they needed to see the technology working in the field to truly have confidence. These demonstrations were to be a useful exercise that would provide critical information needed for future decision-making. The main objectives for the adoption of zero-emission MDHD vehicles from all of the respondents were operations, infrastructure, costs, and performance.

- **Operations:** The most common area of stakeholder concern was how the electric vehicles would fit into existing operations at the port and if the vehicletheirould function as needed to fulfill operations with the same efficiency as its diesel counterparts. While some vehicles were very successful in this aspect, a few were not. In Pasha's electric yard tractor demonstration, the vehicle's fifth wheel could not operate unless the vehicle was in park. Not only was this inefficient, but it also posed a danger since the vehicle had to operate on a ramp. Additionally, the driver seat and steering column did not swivel to be able to safely perform the roll-on/roll-off operations. For these two reasons, Pasha had to reassign its electric yard tractor to yard movements since it could not operate efficiently and safely as intended. Pasha ranked operational fit as the most important factor to electrification. Pasha emphasized that electric vehicles need to be valuable to the operators. An electric vehicle's ability to work within operations takes priority over policy, goals, metrics, and all other reasons to go electric. Like many other port tenants, Pasha does not have turnkey operations. Technology partners must be able to adjust vehicles to tenants' needs instead of making a one-size-fits-all kind of a vehicle.
- **Infrastructure:** All port tenants saw infrastructure as a large barrier to electrification. Many noted that some grants do not include funds to cover infrastructure costs. This can make publicly funded projects unattractive. As learned from this project, building infrastructure is not only costly but also has a lot of red tape associated with it. For example, Pasha wanted to relocate its charging stations to be closer to where the electric vehicles would be operated. However, it experienced many issues and delays with getting permits approved by the City of National City. Pasha noted that mobile charging could be a possibility worth considering bypassing some of the costs and regulations with built-in infrastructure. This also would alleviate concerns with range.
  - The port currently does not have widespread infrastructure, which is a widely acknowledged issue with electric vehicles generally. SDG&E and the port are currently addressing this problem closely in order to align both short- and long-term objectives in an impactful and cost-effective way and to identify additional funding sources to support these objectives.

  - Port tenants raised specific concerns regarding maintenance of the charging infrastructure. SDG&E established a maintenance plan for the charging stations and committed to making crews available as needed for issues that arose during these demonstrations. Since the operation and maintenance needs of charging infrastructure are not well known, SDPTA required the end users to keep maintenance logs throughout the demonstration and share lessons learned from their experiences.
  - Some did raise concern over the lack of standardization of truck requirements for charging infrastructure. If each electric vehicle needs to have a specific charger, electrification will be complicated. One stakeholder noted that the standard charging cables provided by some vendors were too short to reach their trucks and had to be replaced by longer cables. This stakeholder recommended a longer standard length for CHE charging systems which would provide more flexibility for the end users.
- **Costs:** Another crucial objective was to demonstrate financial viability. If the technology worked and could be delivered at "a reasonable or a lower price," then it would be an easy to sell to management. The stakeholders had to consider the entire cost of ownership, including incremental first cost of the vehicles, and the cost of infrastructure installation, maintenance, repairs, battery replacement, electricity, parts (such as belts and fluids), and labor (for charging, maintenance, repairs, and driving) associated with their participation in the project and willingness to accept the vehicle. From a manufacturing standpoint, the technology vendors came to a variety of conclusions after completing the demonstrations. As its technology improved, BYD gained confidence in its expectations that the overall cost of its vehicles would continue to decrease over a short period of time. After the MGBW forklift demonstration, Cummins concluded that although the lithium-ion forklifts would perform better than lead-acid or fossil-fuel forklifts, the lithium-ion batteries were significantly more expensive than lead-acid batteries and would take a number of years the cost to be at par with lead-acid batteries.
- **Performance:** Several of the stakeholders recognized that the application of electric vehicles to port operations was a challenging one. Operations can be intense, with 16-hour shifts, often with only short breaks for charging. The vehicles must remain up and running almost continuously for multiple days in a row. While some of the tenant operations included periodic breaks (from 3am to 8am, for example), occasionally operators faced situations where they needed to move a shipment out quickly and breaks would not be possible under the time constraint. Many of the port tenants oversee large operations geographically, and vehicles must be able to travel far distances. Coastal weather can be hard on equipment, and reliability under these intense conditions was critically important. With the high cost of the vehicles, the tenants could not afford to have back-ups in case something goes wrong. Given these constraints, demonstrating that electric vehicles were up to the job was a high priority for these demonstrations. A great example of this performance concern came up with Pasha's electric drayage trucks. The first-generation truck that Pasha demonstrated did not have the battery capabilities to keep up with drayage operations and could only perform one round trip versus the four to five round trips needed in a typical day of drayage operations. However, BYD made significant improvements to tackle this

performance issue in the second-generation drayage truck, which was able to keep up with Pasha's diesel counterparts.

Each stakeholder had a different vision for the future of electric vehicles and, in particular, the role that different parties would play in moving the industry forward.

Initially, some tenants were not excited about moving forward with electric vehicles. They did, however, realize they would eventually have to act to meet the port and State's climate policies in place. This grant program provided the impetus to begin the transition. Some tenants recognized the potential of helping the environment, in terms of providing a marketing edge. These corporations were willing to move forward, as long as operations continued to be efficient.

Several of the tenants—such as the shipyards and hoteliers—were enthusiastic champions of electric vehicles and green energy. For example, MGBW and Terminalift were and continue to be interested in alternative fuels, such as cleaner fuels and electricity, and are making further investments. Some tenants have actually applied for electric vehicle grants individually. Pasha has a record of seeking out green energy alternatives where feasible and cost effective. Pasha already operates its entire terminal on 100 percent renewable energy through the EcoChoice Program run by SDG&E and is currently using four small, electric forklifts in its automotive parts warehouse. Pasha is also installing electric charging stations at its terminal for future fleet vehicles and for use by customers and visitors to the port.

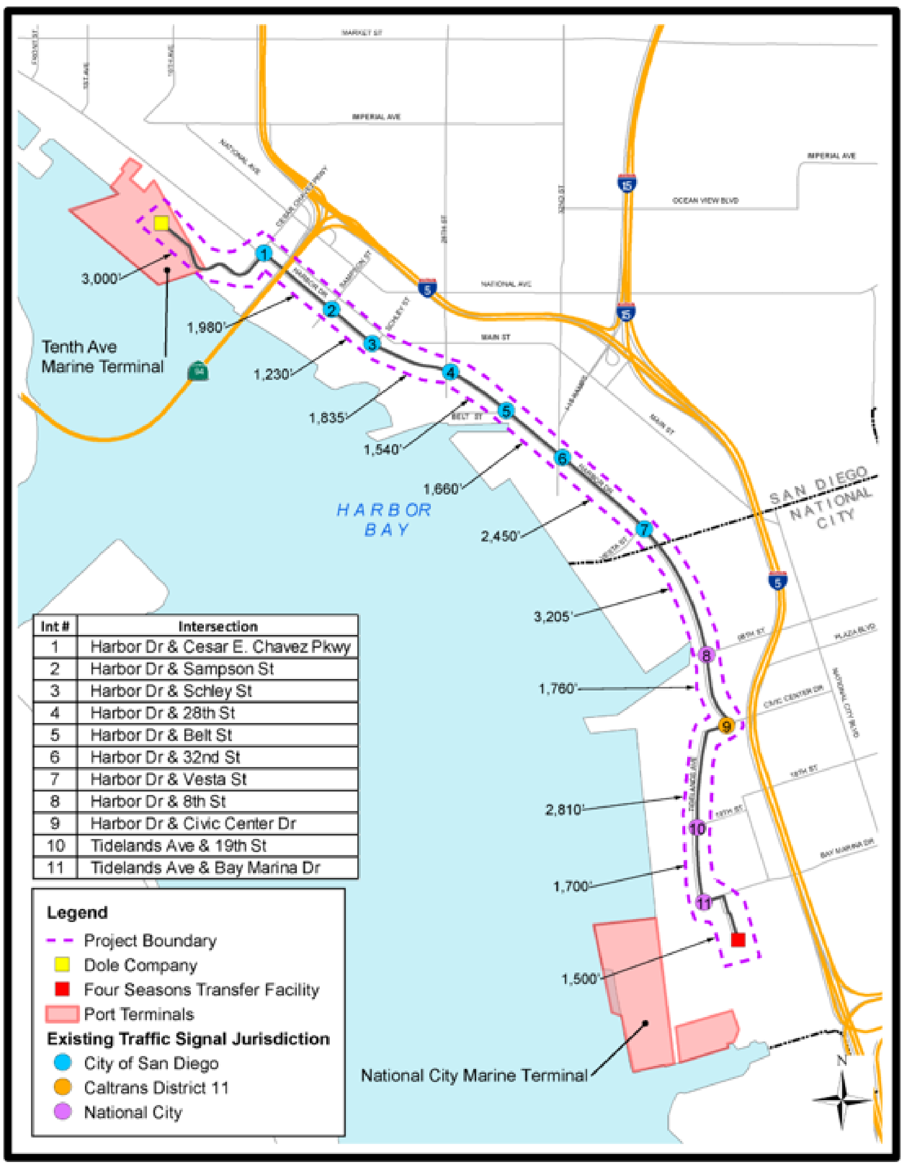
The electric vehicle manufacturers are clearly strong champions for the transition to electric vehicles. Manufacturers are backing an industry-wide push to move to 100 percent electrically fueled yard tractors by 2035, or even sooner. On the flip side, as observed from the two technology vendor acquisitions, the playing field is becoming more condensed, which has its pros and cons.

While all of the stakeholders are proactively working to promote electric vehicles, each of the interviewees mentioned the importance of public-private partnerships in overcoming the barriers to implementation. Although many parties have demonstrated a high level of financial sophistication, grants and incentives have proven to be critical in determining the viability of electrification for anyone—no matter the size of the company. Just as importantly, state funding is critical to help companies obtain the knowledge it needs to judge whether investing in electric vehicles is a viable option. Public-private partnerships, such as this one, are also helpful in assessing community-wide benefits, such as reducing emissions in industrial areas where people live. These partnerships also help enable a diverse community to come together to develop a common solution to a regional problem. Several interviewees mentioned that working to develop workable green energy alternatives is an important part of being a good neighbor. Specifically, one noted that the port together with its tenants, surrounding communities, and municipal utility have a sense of community. "We all live here—we're family". This spirit may be critical in achieving common goals.

CHAPTER 4: Summary and Evaluation of the Freight Signal Prioritization Demonstration

SDPTA intended the FSP portion of the project to establish traffic signal priority along the South Harbor Drive corridor for freight vehicles operating between the Tenth Avenue Marine Terminal and the National Distribution Center located in National City. The goal of the FSP was to assess whether signal priority would reduce travel times, stops, and therefore emissions from freight movement. SDPTA coordinated with STC Traffic for the implementation, testing, and reporting of the FSP project. STC Traffic consulted with Denso, which was responsible for the hardware pieces of the signal prioritization. Partner agencies included POSD, the Cities of San Diego and National City, the Caltrans, and SANDAG.

Figure 17: FSP Map



Credit: STC Traffic

STC Traffic was responsible for fulfilling the following services in order to complete the FSP demonstration:

- Create a method to integrate traffic signal and vehicle performance data into visualizations that will be used for reporting.
- Validate data with empirical observations.
- Provide a presentation to POSD regarding results of data collection and analysis.

4.1 Project Purpose and Goals

Harbor Drive extends between the Tenth Avenue Marine Terminal and National City. It is a designated freight corridor adjacent to the communities of Barrio Logan and National City. It typically is a congested corridor, serving as the primary access point for both the Tenth Avenue and National City Marine Terminals. While traffic volumes increase, there are limited opportunities to add more lanes to this urban arterial roadway. Intelligent transportation systems, such as the FSP system, are important to the port because it offers relatively low-cost solutions for emissions reductions and efficiency increases without adding more lanes or right-of-way on Harbor Drive. Providing priority signalization to designated vehicles based on real-time traffic data can reduce idling times, increase efficiency, and reduce emissions in the corridor.

Deploying ITS on a broad basis required significant regional collaboration. While the port does not control the signal lights along Harbor Drive, STC Traffic's regional collaboration with transportation agencies such as Caltrans, SANDAG, the City of San Diego, the City of National City, and the United States Navy was key in identifying the opportunities for ITS improvements along the corridor.

The goals of the FSP system were to:

1. Reduce GHG emissions for freight vehicles.
2. Increase fuel economy.
3. Enhance market acceptance of FSP.

The FSP project demonstrated the power of regional collaboration to reduce idle time, reduce emissions from freight trucks, and increase time savings for users. The results of the FSP project contributed to the region's body of knowledge about emission reductions that the San Diego Region can consider for improving transportation efficiency.

4.2 Design

The FSP system included a series of 12 intersections along Harbor Drive between Cesar E. Chavez Parkway and Bay Marina Drive. Seven intersections were under management by the City of San Diego, three by National City, and one by Caltrans. Four Seasons Fresh Transport (FSFT) managed one intersection along the route since the intersection is right next to its transfer facility. STC Traffic equipped this intersection with a radio, but none of the other FSP technologies.

STC Traffic divided the technology design for the FSP system into the following three subsystems:

- Vehicle-to-infrastructure
- Infrastructure-to-infrastructure

- Center-to-infrastructure:

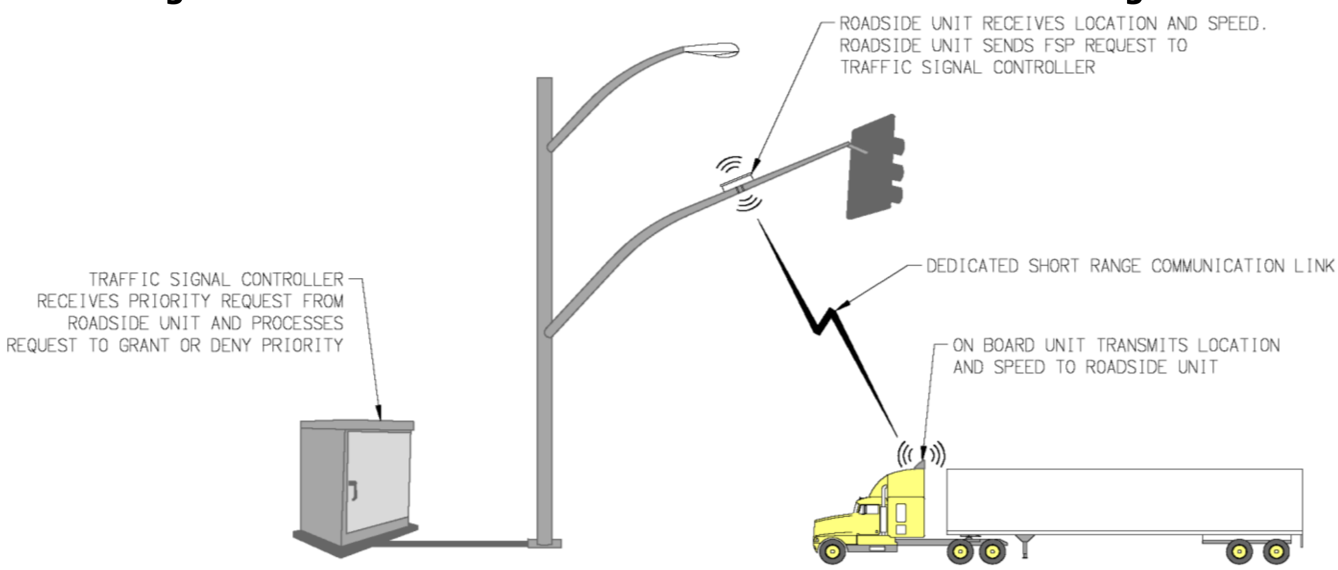
4.2.1 Vehicle-to-Infrastructure

Vehicle to Infrastructure (V2I) describes how the priority request signal travels from the freight vehicle to the traffic signal controller to either grant the vehicle traffic signal priority or not. The V2I subsystem consisted of three major components:

- Onboard Unit (OBU) – A component that is installed on each freight vehicle and is connected to the vehicle's power supply and ignition through a wiring harness located at the mounting location. It uses a Global Navigation Satellite System to calculate accurate time stamps between and arrival times of vehicles at the traffic intersection. The OBU is capable of storing data, broadcasting signal request messages, and specifically sending the arrival times to the Roadside Unit.
- Roadside Unit (RSU) – A component that is mounted to the traffic signal infrastructure and connected to the traffic signal controller. It is capable of communicating with the OBU to determine arrival time and in return broadcasts MAP data, data containing geographic characteristics of the intersection such as line locations, intersection lane geometry, etc., back to the OBU.
- Advance Traffic Signal Controller (ATC) – A component installed at each of the traffic signal cabinets. It is capable of creating and sharing Signal Phase and Timing data, receiving the priority request with ETA, and granting or denying the priority request.

First the OBU sends a priority request signal and vehicle information to the RSU. The RSU receives that priority request signal from the OBU and calculates the truck's estimated time of arrival (ETA). The RSU then sends the priority request signal and ETA to the ATC located inside a traffic signal controller via a wired connection. The ATC utilizes FSP logic to analyze the priority request signal and information to determine whether priority will be granted or denied.

Figure 18: FSP Vehicle-to-Infrastructure Communications Diagram



Credit: STC Traffic

4.2.2 Infrastructure-to-Infrastructure

Infrastructure-to-Infrastructure (I2I) describes how the communication equipment at signalized intersections transmits information between intersections and to a centralized location. The I2I subsystem consists of five major components:

- ATC
- RSU
- Wireless ethernet radios
- Ethernet network switches
- Conflict monitor unit

For the I2I subsystem, the ATCs and RSUs have additional functional requirements. The ATC generates high-resolution (HI-RES) data by utilizing existing induction loops, an electromagnetic detection system, and video vehicle detection on the infrastructure along the project corridor. HI-RES data contains Coordinated Universal Time (UTC) timestamps from the vehicles and pedestrian/bicycle push button call counts. HI-RES counts collected by the ATCs are used to validate counts collected by the RSU's. The HI-RES and Signal Phase and Timing data from the ATCs are sent to the ethernet network switches where the data is then transferred to the wireless radios mounted on the traffic signal poles. The wireless radios send the data along the corridor from wireless radio to wireless radio. STC Traffic collects the data at a designated signalized project intersection and stored on a local corridor server in the traffic signal cabinet.

4.2.3 Center-to-Infrastructure

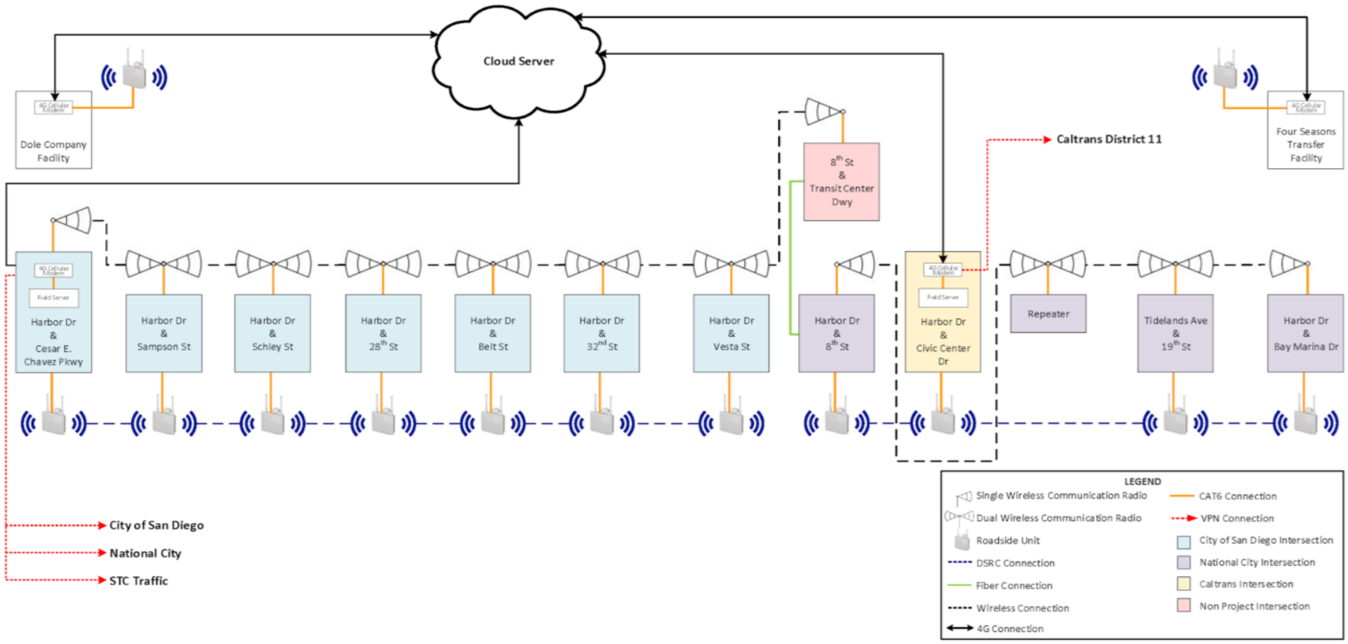
Center-to-Infrastructure (C2I) describes how the communication equipment on freight vehicles and at the centralized location and are used to transmit information between the vehicles, intersections, and centralized locations. Additionally, it describes how the software functions to collect and present traffic signal and vehicle data. The C2I subsystem consists of four major components:

- 4G cellular modems
- Local corridor server
- Caltrans Roadside Processor
- Remote cloud server

The FSP system communicates between a central location and the local corridor servers. The C2I subsystem allows remote monitoring and agency access to the signalized project intersections in the jurisdiction of the FSP. Additionally, the C2I subsystem communicates between the local corridor server and the cloud server for data aggregation and processing. The cities, Caltrans, and FSFT all have their own individual C2I operations.

Figure 20 describes how I2I and C2I work together.

Figure 19: FSP I2I and C2I Communications Diagram



Credit: STC Traffic

4.3 Installation and Implementation

4.3.1 Installation

STC Traffic installed the OBUs on the truck's outer and upper rear-end cabin on an existing mounting bracket to meet the following requirements:

- OBUs shall require no driver interface.
- OBUs shall not impact the truck in any significant way.
- OBU shall interface with the truck's battery for power supply.

STC Traffic installed RSUs at each signalized project intersection on Harbor Drive between Cesar E. Chavez Parkway and Bay Marina Drive. It mounted each RSU to the nearest/optimal traffic signal pole to the traffic signal cabinet at each intersection. STC Traffic connected the RSU to the ATC inside the traffic signal cabinet via a Category 6 (CAT 6) cable using existing conduit. Power-over-ethernet (PoE) powered the RSUs.

STC Traffic installed wireless ethernet radios on traffic signal poles at each signalized project intersection and connected each radio to a switch located in the traffic signal cabinet through an ethernet cable and powered by a PoE Injector.

STC Traffic installed ethernet network switches in the traffic signal cabinets and connect to the ATCs and wireless ethernet radios using a CAT 6 patch cord cable at each signalized location. They then installed conflict monitor units (CMU) at each signalized intersection to monitor the traffic signal inputs and outputs for faults in the system. New CMUs replaced existing CMUs at each signalized intersection, and STC Traffic returned all salvaged CMUs to each local agency.

STC Traffic installed 4G cellular modems at a designated location for the cities, Caltrans, and at FSFT's transfer facility. They then installed 4G cellular modems for the cities and Caltrans inside the traffic signal cabinet, as well as installing the 4G cellular modem at FSFT's transfer facility on the warehouse roof and securing it inside a weatherproof box on a roof mount pole.

4.3.2 Implementation

Ensuring that all the components to the design of the FSP system were in place, functional, and properly communicating took a number of months. Since the technology was a prototype system that had never been implemented before, a number of unforeseen issues and challenges were discovered during the testing of the system, thereby delaying the activation of the FSP system and demonstration multiple times; however, the troubleshooting, necessary repairs and adjustments, and testing performed to ensure the stability and reliability of the communication technologies were all crucial efforts that led to the success of the FSP demonstration. STC Traffic official activated and commissioned the FSP system on December 3, 2020, marking the beginning of the demonstration. The technical challenges faced in implementing the FSP system were:

- **Radio Interference:** In May 2020, STC Traffic had completed the installation of all of the communication equipment that made up the FSP system. When first evaluating the fully completed system, STC Traffic immediately noticed interference on the radios, especially during busy operation hours at the port. This signal interference prevented the different components of the FSP system from communicating information with one another and prevented data from being recorded on the cloud server. To resolve this issue, STC Traffic worked with the radio manufacturer to improve the capabilities of the radios installed along the corridor. Additionally, more radios and cellar modems were added to improve the connection to the server and increase the reliability of the data collection.
- **Firmware Updates:** In June 2020, STC noticed that the OBU radios were not able to communicate with the cloud server correctly, and in July 2020, noticed an issue with the RSU that prevented the ATC from receiving the vehicle ETA and location information. STC Traffic concluded that both issues had to do with the firmware, which they resolved through an update. In September 2020, DENSO assisted STC Traffic in performing the firmware updates and revisions to the firmware codes on each of the OBUs and RSUs in the system. A field verification test confirmed that the controllers were receiving the correct ETA and location data from the OBUs and RSUs.
- **Programming Configurations:** On October 22, 2020, STC Traffic scheduled a test with the Cities of San Diego and National City to commission the FSP system. Unfortunately, during the test, the RSUs were not properly recognizing the OBU communication and information, so STC Traffic delayed the FSP system commissioning. Further testing and troubleshooting identified that the programming configurations were not properly set up. DENSO quickly resolved the issue and STC Traffic was able to move forward with scheduling a second commissioning test was set up with the cities.
- **Data Accuracy:** In November 2020, STC Traffic discovered invalid data on the BlueArgus data reports. Further investigation and review showed that a technician improperly put an ID parameter in the database causing technicians to misread the data. STC Traffic reported the issue to TrafficCast, who resolved the issue.
- **OBU Mounting:** In October 2020, STC Traffic recruited a FSFT truck driver that offered to provide six trucks to participate in the FSP demonstration. However, when inspected for OBU installation, the vehicles would require different OBU mounting

equipment, procedures, and location on the vehicle than what STC Traffic had originally used on past vehicles. STC Traffic coordinated with DENSO to engineer a new mounting solution for these vehicles and successfully installed all six OBUs on February 12 and 13, 2021.

- **COVID-19 Restrictions:** In March 2020, the COVID-19 global pandemic caused business to impose various restrictions and safety measures, which caused some slowing of work on the FSP system. For example, Caltrans imposed a travel restriction on their employees, which prevented work on the Caltrans intersection at the port for a number of months. Additionally, STC Traffic and the port developed various safety protocols and procedures for employees and visitors to the port. These protocols included daily temperature screenings, mask wearing, social distancing, and increased sanitization, which at times slowed some of the hands-on work for the FSP system.

Aside from the technical challenges faced, STC Traffic also ran into many issues with recruiting truck drivers to participate in the FSP demonstration. The project's Scope of Work called for 10 vehicles to participate; however, STC Traffic encountered many challenges to achieve that number, including:

- **Information Security Concerns:** At the beginning of STC Traffic's work on the FSP system in 2019, FSFT truck drivers had intended to provide the 10 vehicles for the FSP demonstration. However, in December 2019, STC Traffic advised the drivers that the trucks would interact with the signal sensors to collect data. Although the FSP equipment would not track the truck's individual data, such as vehicle ID, truck drivers remained concerned about data privacy and were hesitant to participate in the FSP demonstration. Therefore, all but one of the participating FSFT truck drivers backed out of the demonstration, leaving STC Traffic with only four participating vehicles and the need to conduct further outreach and recruitment.
- **Potential Damage to the Vehicles:** In May 2020, SDPTA and Momentum approached Terminalift to inquire if it had vehicles running along the corridor and would be interested in participating in the ITS-FPS demonstration. Terminalift was a highly enthusiastic project demonstrator with continued interest in new technologies that would reduce emissions within its operations. Initially, Terminalift offered two of its diesel trucks and its two electric trucks for participation in the demonstration. STC Traffic visited Terminalift in August 2020 to perform its OBU pre-installation inspection. During the consultation, STC Traffic explained to Terminalift the OBU installation process, and Terminalift had concerns with potentially damaging the vehicles by the OBU interfering with the electronics and the holes that technicians would drill for the mounting of the OBUs. Additionally, Terminalift did not anticipate that the electric trucks would have the on-road registration that would allow them to travel the corridor in time for the activation of the FSP system. For these reasons, Terminalift decided not to go through with its participation in the FSP demonstration.

Independent Operators and Truck Owners: By September 2020, STC Traffic had four OBUs installed on vehicles that a FSFT truck driver provided. However, on September 10, 2020, STC Traffic could not locate the four vehicles on its map or in-person at the port. Additionally, the truck driver did not respond to all forms of communication STC Traffic used. Also, due to confidentiality reasons, FSFT also could not provide STC Traffic with any information without administrative approval. STC Traffic immediately informed SDPTA of the situation and sought to contact David Noriega, Director of Operations at FSFT, to try to locate the vehicles. In October 2020, David reported that there was reason to believe that the truck driver, who was the owner of the four vehicles and had been an independent contractor of FSFT, sold the trucks. In response to this unfortunate news, David agreed to assist the project team in efforts to promote the FSP opportunity amongst the FSFT drivers. STC Traffic was unable to make contact with the driver and never retrieved the four lost OBUs. Fortunately, DENSO was easily able to provide more OBUs for future installations. Near the end of the project, a similar incident happened again. In February 2021, STC Traffic installed six OBUs. In March 2021, STC Traffic discovered that all six of those trucks relocated. This demonstration showed that it is not uncommon for these independent owner/operator trucks to be reassigned to different routes, sometimes permanently.

4.4 Summary of the FSP Plan

STC Traffic conducted a series of tests and acceptance procedures before beginning the FSP demonstration. The test plan involved a pre-installation Check (PIC) and an installation acceptance test (IAT) that verified that the three subsystems (V2I, I2I, and C2I) functioned properly and consistently.

1. **Pre-Installation Check:** The PIC consisted of two phases to test the three subsystem components. Phase 1 is Bench Testing of the three subsystems and Phase 2 is on-site demonstration.
   - Phase 1 Bench Testing: Bench Testing tested all field equipment of the three subsystems. It ensured that the technology turned on, had a signal if applicable, and functioned and/or communicated as intended.
   - Phase 2 On-Site Demonstration: After technicians installed all field equipment, they installed all the data transmission equipment, mounted all required in-vehicle equipment on each freight truck, and then STC Traffic sent a notice to the City of San Diego, City of National City, and Caltrans that the test period could begin. Phase 2, the on-site demonstration, consisted of at least one test vehicle and one project intersection. Phase 2 verified that:
     - The OBU could transmit information to the RSU.
     - The RSU could send the proper signal to the ATC.
     - The ATC event log could document the request signal and deliver the Signal Phase and Timing data to the RSU.
     - The wireless ethernet radios could communicate with other radios along corridor using the wireless radio web.
     - STC Traffic achieved communication from the RSU to the cloud, and logged the proper data in the TrafficCast BlueARGUS cloud.
2. **Installation Acceptance Test:** After completing Phase 2, the IAT could begin. STC Traffic performed the IAT seven days after initial testing and again after a ninety day minimum period to verify the accuracy of the system. STC Traffic also performed the IAT at every project intersection and verified that:
   - The traffic controller, software, and FSP equipment were installed and connected according to the agency-approved project plans and specifications and was consistent with the manufacturer install procedures.

- The traffic controllers were configured with appropriate timing plans and signals were fully tested and operational per the agency's standards. Once confirmed, STC Traffic converted the existing timing plans to operate in the new controllers and provided the new timing sheets to the correct agency for approval. Once approved, STC Traffic input the new timing plans into the controllers. Prior to signal turn-on, STC Traffic installed the FSP equipment, ensure that it was operating correctly, and positioned it to optimize views of upstream freight vehicles in all lanes.
- The phasing and channel wiring were consistent at all signals.
- The equipment was functioning for each direction/phase for which RSUs were installed at each intersection. This could be determined from the transparity and call logs.
- The controller was receiving its timing information from the RSU clock source. STC Traffic tested this GPS clock on all OBU, RSU and ATC equipment per the manufacturer's recommended test procedures.

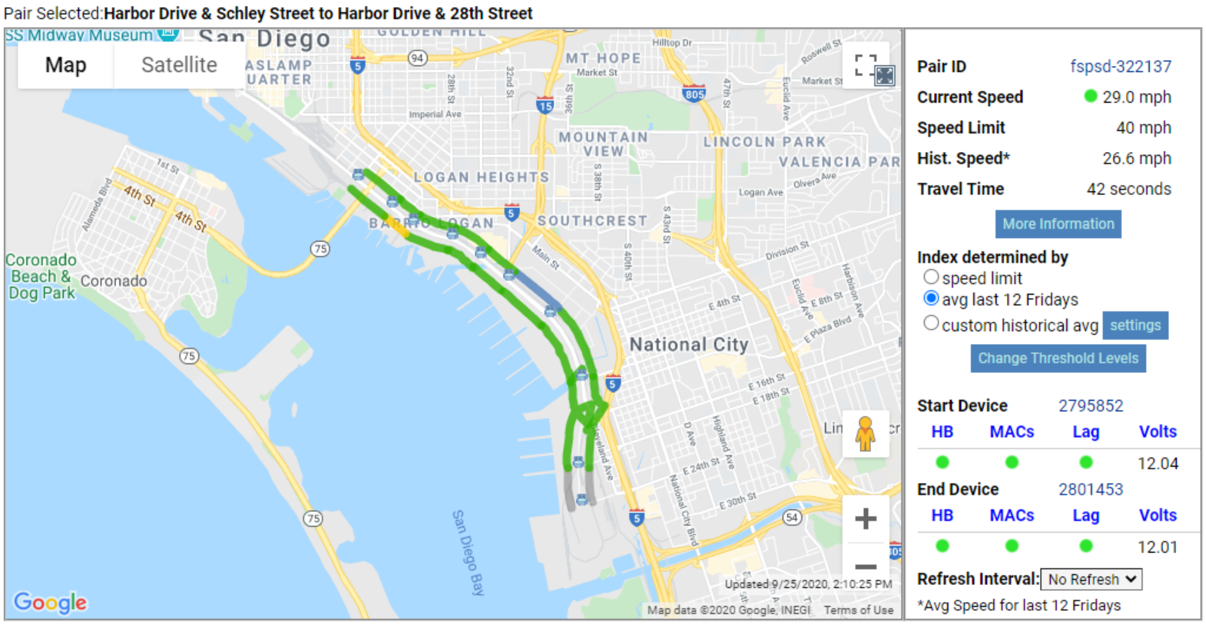
4.5 Data Processing

The data processing system is the final and most crucial component of the FSP system. The FSP data system consists of data collection, storage, database management, and analytics that provides the ability to measure overall system performance and assemble the final reporting. Primary FSP data system considerations include:

- Data collection
- Data processing
- System access

To manage these aspects, STC Traffic used the BlueARGUS TrafficCast software as the cloud server to collect real-time data along the corridor from the FSP subsystems. Not only does the software show the historical or real-time traffic flow along the corridor but would be able to show the FSP system in comparison by tracking the participating vehicles with the installed OBUs as they are traveling through the corridor.

Figure 20: BlueARGUS TrafficCast Freight Signal Prioritization Map



Credit: STC Traffic

4.6 Measurements and Reporting

The collected data was used to measure and report the system effectiveness measures, including travel time, fuel consumption, and freight and ambient vehicle emissions. Data analytics and industry standard calculations were used to obtain the following system performance measures:

- Travel Time Improvements
- Reduced Idle Times/Reduced Stops
- Vehicle Fuel Efficiency
- Emission Reduction (Emission Factor (EMFAC) Model[6])
  - Oxides of Nitrogen
  - Non-methane Hydrocarbons
  - Particulate Matter

STC Traffic established baseline conditions using historical data and existing conditions. They obtained historical data from Detroit Diesel Electronic Control system reports obtained from FSFT. They were then able to obtain existing conditions once the system was fully implemented. They could then collect data without actual FSP operations, including data for ambient traffic and the freight vehicles OBUs.

4.6.1 Travel Time

Travel time is the amount of time for the truck to travel the corridor end-to-end in one direction. Table 15 and Figure 22 show a summary of the travel times by weekday "before"

[6] California Air Resources Board Emission Factor website (https://arb.ca.gov/emfac/)

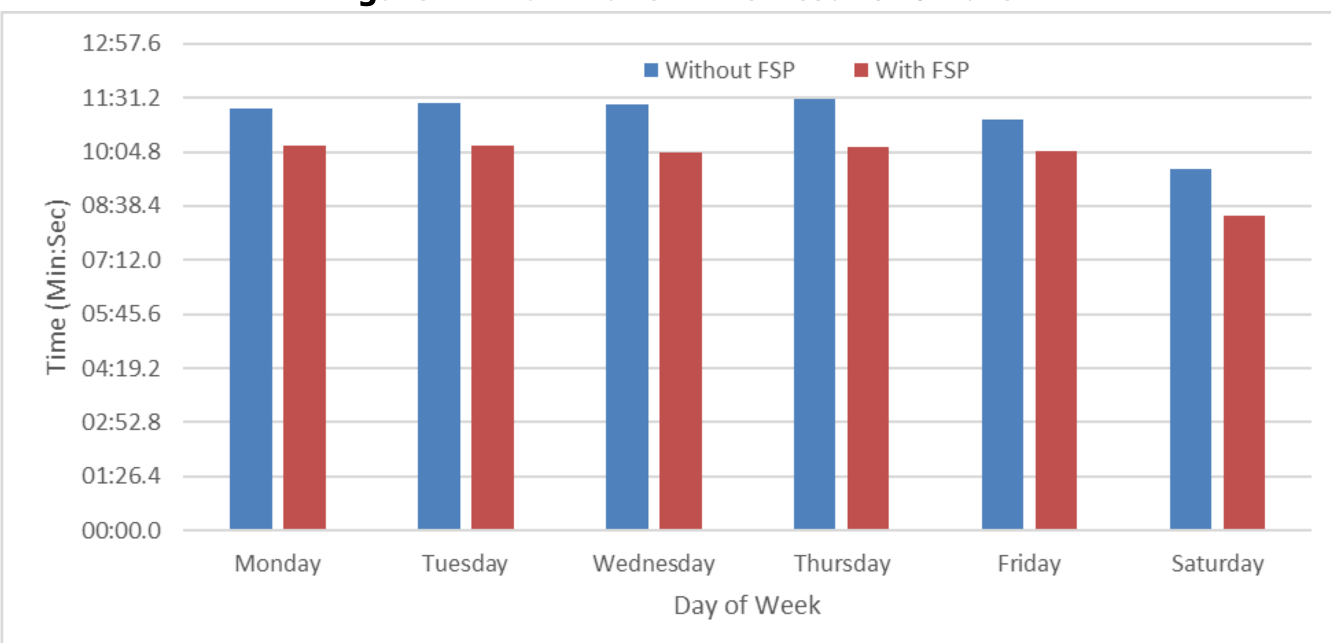
and "after" FSP activation. The average (per run) travel time saved with FSP is 1 minute and 4 seconds.

Table 14: FSP Travel Time Results to Date

Day of Week	Average Travel Time without FSP (Min:Sec)	Average Travel Time with FSP (Min:Sec)	Time Saved (Min:Sec)
Monday	11:15.1	10:15.5	00:59.6
Tuesday	11:23.9	10:16.0	01:07.9
Wednesday	11:21.5	10:03.2	01:18.3
Thursday	11:28.6	10:13.2	01:15.4
Friday	10:55.8	10:06.6	00:49.2
Saturday	09:36.6	08:23.4	01:13.2
Average	11:15.5	10:11.5	01:03.9
		% Change	9.5%

Source: STC Traffic

Figure 21: FSP Travel Time Results to Date



Credit: STC Traffic

4.6.2 Idle Time and Number of Stops

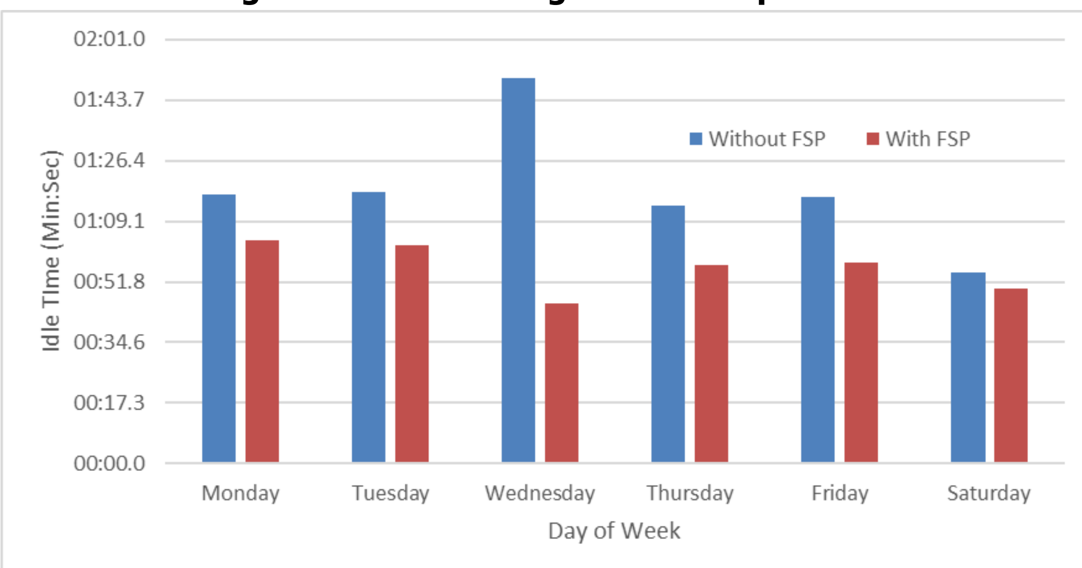
The truck idle time and number of stops demonstrate the ability of the FSP system to reduce the amount GHGs the trucks emit when stopped at intersections along the route. The daily averages of idle time per run, stops per run, and idle time per stop before and after FSP activation are shown on Table 16, Figure 23, Table 17, Figure 24, Table 18, and Figure 25, respectively. The results show the average (per run) idle time reduction with FSP is 23 seconds, the average stops (per run) decreased by 0.65, and the average idle time (per stop) decreased by 1.9 seconds.

Table 15: FSP Average Idle Time per Run

Day of Week	Without FSP (Min:Sec)	With FSP (Min:Sec)	Time Saved (Min:Sec)
Monday	01:16.8	01:03.7	00:13.1
Tuesday	01:17.6	01:02.3	00:15.3
Wednesday	01:50.1	00:45.8	01:04.3
Thursday	01:13.5	00:56.5	00:17.0
Friday	01:16.1	00:57.3	00:18.7
Saturday	00:54.4	00:49.8	00:04.6
Average	01:22.0	00:58.4	00:23.6
		% Change	28.8%

Source: STC Traffic

Figure 22: FSP Average Idle Time per Run



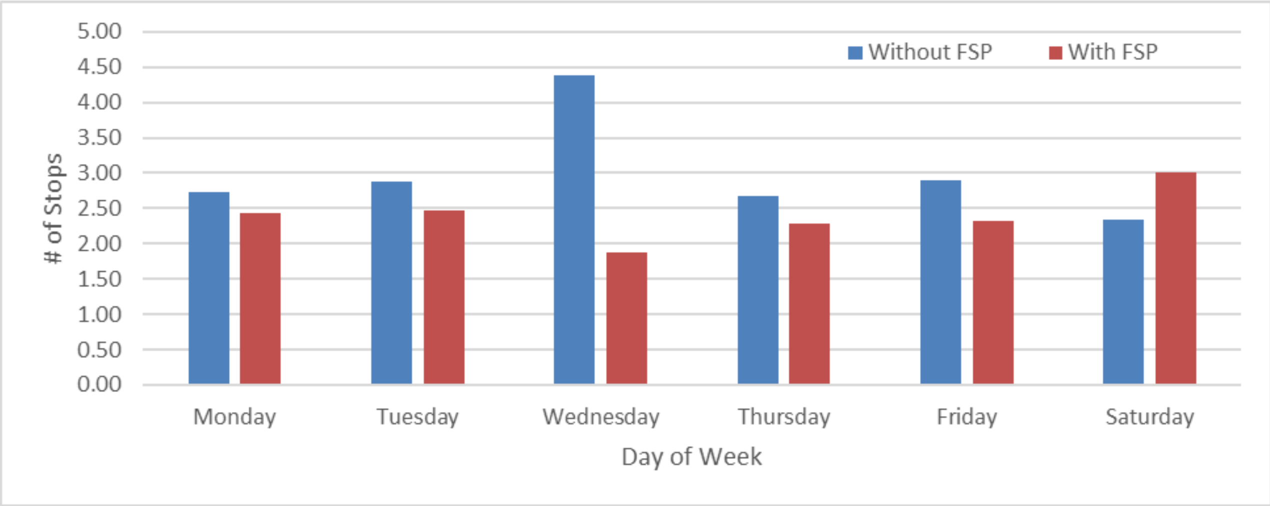
Credit: STC Traffic

Table 16: FSP Average Stops per Run

Day of Week	Without FSP (Min:Sec)	With FSP (Min:Sec)	Stops Removed
Monday	2.73	2.33	0.40
Tuesday	2.87	2.32	0.55
Wednesday	4.39	1.88	2.51
Thursday	2.68	2.21	0.47
Friday	2.89	2.27	0.62
Saturday	2.33	3.00	-0.67
Average	2.98	2.33	.65
		% Change	21.7%

Source: STC Traffic

Figure 23: FSP Average Stops per Run



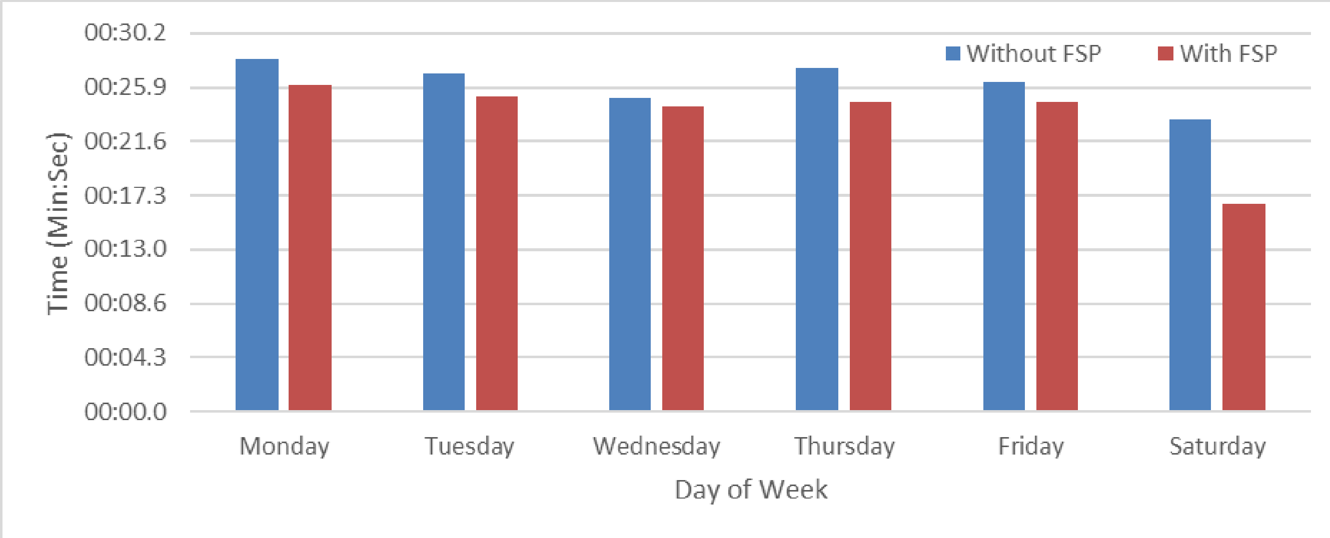
Credit: STC Traffic

Table 17: FSP Average Idle Time per Stop

Day of Week	Without FSP (Min:Sec)	With FSP (Min:Sec)	Time Saved (Min:Sec)
Monday	00:28.1	00:27.4	00:00.8
Tuesday	00:27.0	00:26.8	00:00.2
Wednesday	00:25.1	00:24.4	00:00.7
Thursday	00:27.4	00:25.6	00:01.8
Friday	00:26.3	00:25.2	00:01.1
Saturday	00:23.3	00:16.6	00:06.7
Average	00:26.2	00:24.3	00:01.9
		% Change	7.17%

Source: STC Traffic

Figure 24: FSP Average Idle Time per Stop



Credit: STC Traffic

4.6.3 Average Speed

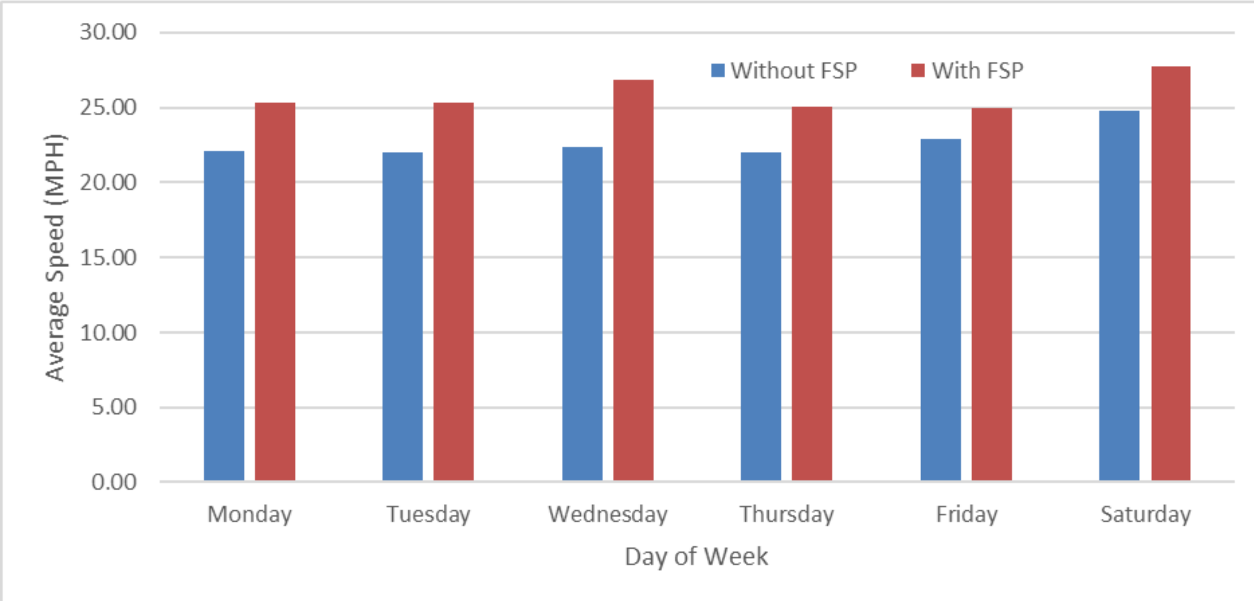
An increase in the average speed reflects the trucks' ability to travel the corridor without having to slow as often for traffic signals. Table 19 and Figure 26 show weekday averages before and after FSP activation. Average (per run) speed with FSP increased by 3.11 mph.

Table 18: FSP Average Weekday Speed

Day of Week	Without FSP	With FSP	Increase
Monday	22.13	25.33	3.20
Tuesday	22.01	25.36	3.35
Wednesday	22.37	26.85	4.48
Thursday	22.03	25.05	3.02
Friday	22.87	24.94	2.07
Saturday	24.76	27.72	2.96
Average	22.31	25.42	3.11
		% Change	13.9%

Source: STC Traffic

Figure 25: FSP Average Weekday Speed



Credit: STC Traffic

4.6.4 Emissions

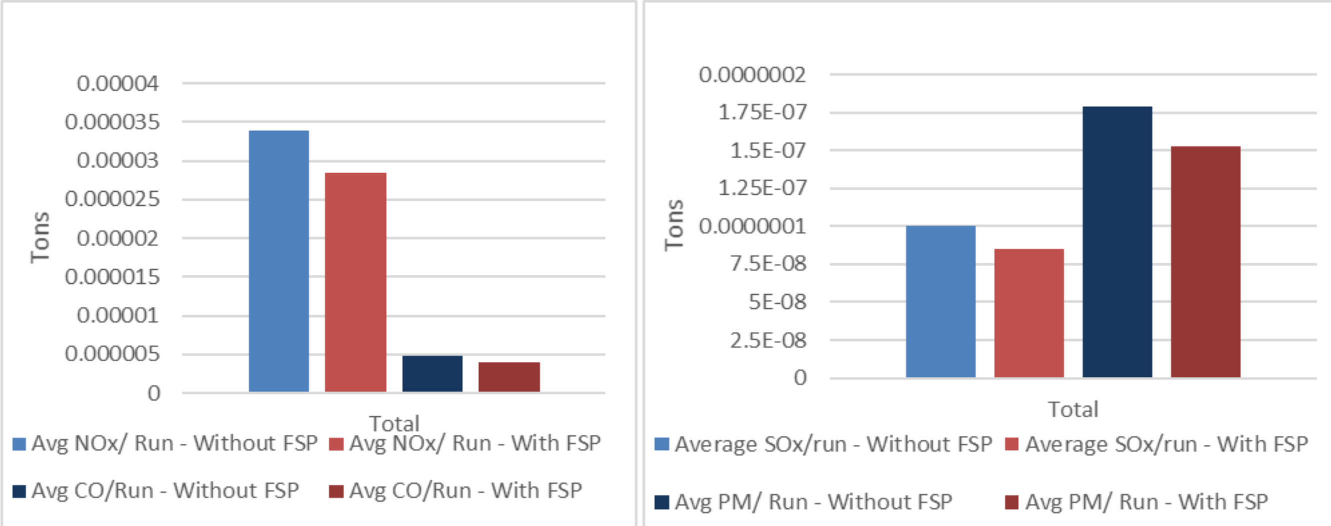
The EMFAC's main reporting is based on emission output per vehicle speed in 5 mph increments. STC Traffic recorded speeds and used them to derive emissions outputs for each line of data, and then summed for each run. Table 20 shows the average emissions for each run before and after FSP activation, and Figure 27 shows nitrous oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx), and particulate matter smaller than 10 microns (PM 10) emissions. Every emissions category saw a reduction of at least 15 percent with FSP active.

Table 19: FSP Average Traveling Emissions

	Avg Speed (m/h)	NOx/ Run	CO / Run	Avg SOx/run	Avg PM10/ Run
Without FSP	22.31	3.3925E-05	4.84063E-06	1.0071E-07	1.78667E-07
With FSP	25.42	2.84806E-05	3.98163E-06	8.52401E-08	1.52734E-07
Difference	3.11	5.4444E-06	8.59004E-07	1.54701E-08	2.59332E-08
% Change	13.9%	16.0%	17.7%	15.4%	14.5%

Source: STC Traffic

Figure 26: FSP Average Traveling Emissions



Credit: STC Traffic

Emission factors for speeds 5 mph to 15 mph are greater than the emission factors for speeds between 20 mph to 35 mph. As the effectiveness of the FSP system increases, stops are decreased, and the time at speeds below 15 mph is reduced. The increased amount of time at cruising speed creates emissions reduction.

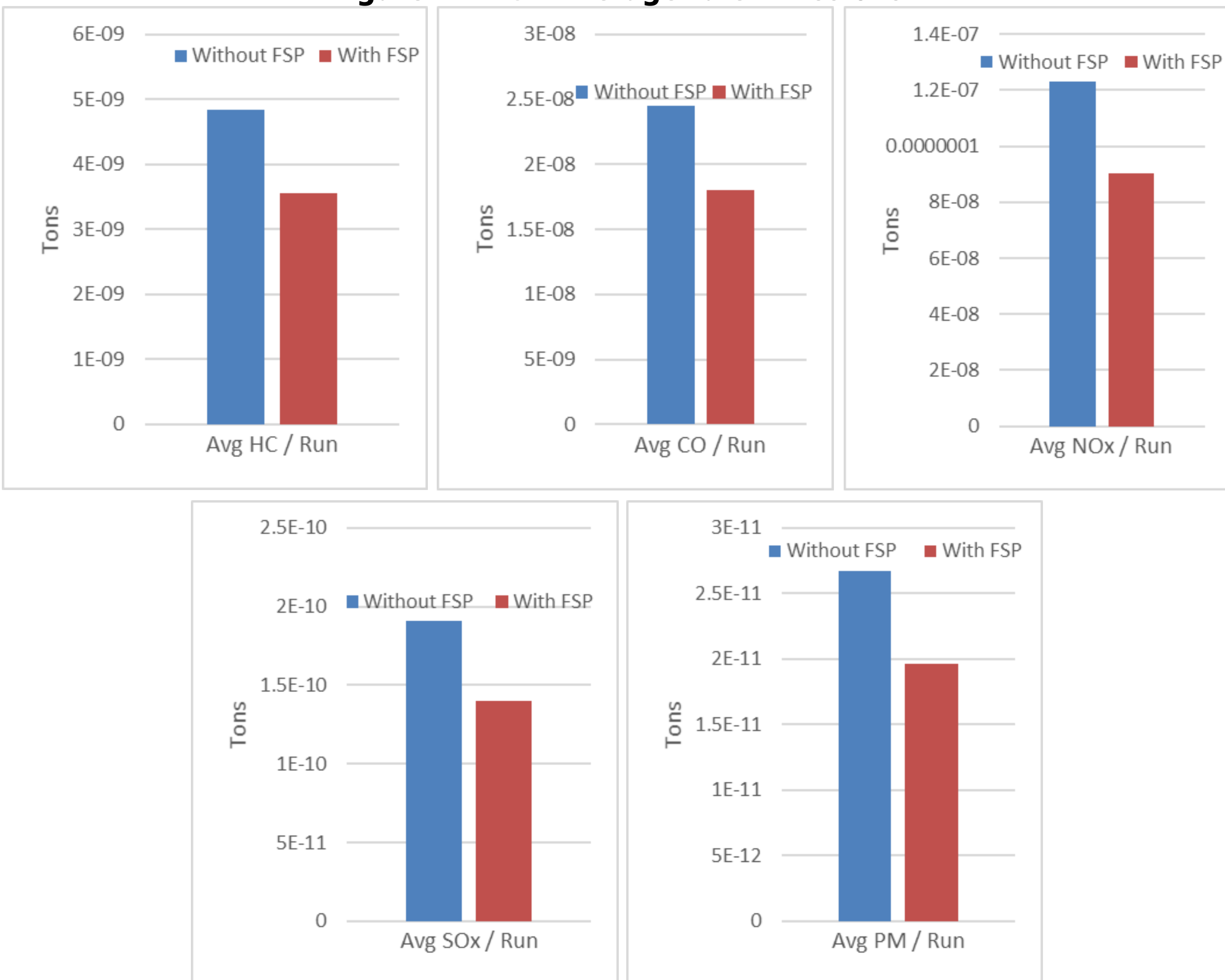
Table 21 and Figure 28 show the comparison of the average idle emissions with and without FSP activated. The measured GHG used for idle emissions include hydrocarbons (HC), CO, NOx, SOx, and PM 10. The trucks reduced their average (per run) idle emissions by 27 percent in every category with FSP. The trucks also reduced the total time spent idling per run since the trucks stopped fewer times.

Table 20: FSP Average Idle Emissions

	Avg Idle HC / Run	Avg Idle CO / Run	Avg Idle NOx / Run	Avg Idle SOx / Run	Avg Idle PM / Run
Without FSP	4.84001E-09	2.45188E-08	1.2299E-07	1.9056E-10	2.67232E-11
With FSP	3.55315E-09	1.79998E-08	9.02897E-08	1.39895E-10	1.96181E-11
Difference	1.28685E-09	6.51902E-09	3.27004E-08	5.06659E-11	7.10512E-12
% Change	27%	27%	27%	27%	27%

Source: STC Traffic

Figure 27: FSP Average Idle Emissions



Credit: STC Traffic

CHAPTER 5: Disadvantaged Community Program

Fossil fuel emissions disproportionally harm low-income communities and communities of color. It is crucial to embed equity in climate-related policies and grant programs so that the most-polluted and under-resourced disadvantaged communities can achieve a clean energy future. Having an equity plan in place directly addresses the environmental and economic injustices these communities face and ensures that local communities have an active role in, and can fully benefit from, a green economy.

Communities next to ports, freight operations, and freight hubs are generally low-income communities. Ports can provide multiple benefits to these regions by creating local jobs and business opportunities. New technologies stimulate demand for new jobs and new skills. However, ports also create many challenges for these communities. Port operations disproportionately impact these communities, which exposes them to harmful pollutants from diesel-powered vehicles and equipment, noise, and traffic congestion.

The project sought to reduce freight traffic impacts felt by the disadvantaged communities surrounding the port by decreasing GHG emissions, improving air quality, and providing health benefits. The Greenlining Institute and GC Green spearheaded the project's equity plan. Additionally, multiple project stakeholders were involved in the implementation of outreach activities to bring together the port and local communities.

5.1 Equity Plan

According to The Greenlining Institute, "social equity" means increasing access to power, redistributing and providing resources, and eliminating barriers to opportunity in order to empower marginalized groups such as low-income communities of color to thrive and reach its full potential. Incorporating equity into a policy, plan, program, or project at its inception makes it more likely that such policies will be prioritized in procedural and implementation efforts. The *San Diego Port Sustainable Freight Demonstration and Equity Plan* (Equity Plan) developed by The Greenlining Institute for this project ensured that project prioritized equity in all aspects of the project, from goals and process through implementation, measurement, and analysis.

Goals: Having clear equity goals and clear identification of priority communities at the outset of a policy, plan, program, or project helps improve transparency and accountability. In the Equity Plan, The Greenlining Institute recommended the following goals for this project:

1. Be explicit about equity goals and communities the project will benefit.
2. Include equity goals that generate direct, meaningful, measurable, and assured benefits.

Process: Community buy-in is critical for ports projects. Often, agencies only inform vulnerable communities that a project is happening, rather than being fully engaged and empowered in all stages. Community engagement in projects should not be an add-on benefit or just a checkbox to fill—it should help drive the project's direction. Robust engagement can drive better decisions through increased input from different perspectives, which will lead to increased buy-in and acceptance of decisions and support for their implementation. In addition, relationships with impacted port communities should be built over time to develop trust and true partnership and not be ad hoc. This process included the following steps:

1. Promote meaningful community engagement.
2. Promote community power and governance.
3. Design port project applications and review process with equity built in.

Implementation: The benefits of a policy, plan, program, or project are only as good as its implementation, so equity must be at the center of these efforts. Ports should promote and incentivize the number of well-paying jobs and require that economic benefits reach surrounding port communities. Policies and practices should target individuals with high barriers to employment and should provide high-quality jobs. The port's efforts to become zero-emission should include a robust and diverse procurement goal that requires contracts with companies owned by racial minorities, women, disabled veterans, and lesbian/gay/transgender/bisexual/queer groups. It should also provide support to workforce development programs aimed at training and hiring low-income people of color and other individuals that have barriers to employment. To do so, The Greenlining Institute recommended the following actions take place:

1. Ensure the project addresses the needs identified by port communities.
2. Ensure the project provides direct, meaningful, measurable, and environmental and health benefits to port communities.
3. Ensure project provides direct, meaningful, measurable, and assured economic benefits to low-income people of color and other individuals with barriers to employment.
4. Ensure the project provides direct, meaningful, measurable, and assured economic benefits to diverse-owned small businesses, particularly minority-owned business.

Measurement and Analysis: In general, climate and clean energy-related efforts do not adequately measure and evaluate equity outcomes. The Greenlining Institute strongly believes that sustainable port policies, plans, programs, and projects should measure and analyze equity goals and outcomes. The evaluation should analyze the port's efforts, indicate strengths and areas for improvement in meeting equity goals, and be used to inform the direction of the port effort moving forward. The Greenlining Institute recommended that the port's efforts to become zero-emission be implemented with a strong commitment to "adaptive management", which could be defined as an intentional approach to making decisions and adjustments in response to new information and changes in context". This is also sometimes described as "learning by doing." Put differently, thoughtfully incorporating an adaptive management approach to program implementation allows the implementer to test approaches and assumptions, learn what works and what does not, and adapt by making adjustments in order to ensure the program achieves its desired outcomes. This project used the following objectives to measure its success in meeting the equity goals.

1. Ensure the project collects and reports data on intended equity outcomes.
2. Ensure the project analyses, learns, adjusts, and communicates equity outcomes.

5.2 Outreach Activities

Additionally, to communicate the interim project results to affected stakeholders, SDPTA and the project team, conducted a number of outreach activities in the local communities and beyond. Table 21 below, summarizes the number of outreach activities that took place throughout the project.

Table 21: Summary of Outreach Activities

Event	Date	Summary
Media Availability Event at Marine Group Boat Works	July 18, 2018	Kick off of grant award. Presentation at Marine Group Boat Works which highlighted the grant deliverables and goals
CEC Alternative And Renewable Fuel And Vehicle Technology Program Showcase Event	March 7, 2018	Participants in CEC event and showcased their project through a booth.
Port of San Diego Board Meeting: SDPTA Presentation	March 13, 2018	A special meeting to report on the showcase at CEC
SDPTA Press Conference at Tenth Avenue Marine Terminal	July 26, 2018	Showcased the first piece of equipment to be delivered and the types of equipment to be demonstrated at the port. There was a strong attendance at this conference including various commissioners through the region.
Preliminary Findings of Economic Opportunities Presentation	Aug 17, 2018	Associated with the draft Equity Plan, the Project team presented findings to port Staff, San Diego staff and end-users
Veterans Energy Seminar	Aug 18, 2018	Phil Gibbons with POSD presented on behalf of the Project team to discuss the benefits of the Project. The theme of the seminar was to provide veterans with information and real-life practice of careers in the energy space. Key stakeholders in the audience included veterans, academics, and local experts working in careers focused on the transition to renewable energy resources and electrification of vehicles and equipment. Phil provided information about the SDPTA CEC grant and spoke about electrification in the medium- and heavy-duty market and the demonstration of these vehicles along the Working Waterfront. Phil also participated in a panel discussion with Brendan Reed from the Airport, Mick Wasco with Marine Corps Air Station Mirimar, and David Weil from UCSD.

Event	Date	Summary
SANDAG Freight Stakeholders Working Group Meeting	Oct 11, 2018	General update
CEC Ports Meeting: Greenlining Institute and GC Green Presentation	February 27, 2020	On February 27, 2020, a CEC Ports Meeting took place at the San Diego Port Administration Building. At this meeting, The Greenlining Institute gave a presentation on the Equity Plan, reminding all of the project stakeholders how initiatives such as this project, can act as a tool to elevate the disadvantaged communities living next door. These kinds of projects force us to address existing barriers such as redlining of communities of color, economic equity, and prioritizing communities. This meeting reminded stakeholders to be explicit about the port communities that will benefit from a zero-emission project and generate multiple direct meaningful assured benefits as well. After the Greenlining Institute's presentation, GC Green led a roundtable discussion about Equity Plan recommendations to improve the equity, environmental, and social health of the surrounding disadvantaged communities. This roundtable generated a lively and interesting discussion and was helpful in bringing attention to some of the "holes" in the Equity Plan and project that need more attention. Since there are limited guidelines from funding organizations on how best to include equity initiatives throughout these kinds of projects, the *project* is truly acting as a pilot project. The lessons learned from these equity initiatives will be a valuable resource for similar projects in the future. Integrating equity in this project has been a slow learning curve for stakeholders, but it is promising that there is a common desire to figure out best practices. As one member of The Greenlining Institute mentioned, "…if you are going to affect the communities, you need to include the communities."
Port of San Diego Board Meeting: Terminalift Presentation	July 14, 2020	General update

Event	Date	Summary
Mini Documentary Film	2020 through 2021 Documentary released 12/11/20	During 2020 and 2021, project stakeholders had to navigate the COVID-19 global pandemic. Due to this pandemic, many in-person events were either canceled or moved to a virtual format. With these considerations in mind, SDPTA received approval to create a mini documentary film to support and enhance its outreach activities conducted via webinars and online meetings. A documentary is not a typical disadvantaged community outreach activity, but in the moment was a creative and safe solution to extend the reach into various disadvantaged community communities. For the development of the documentary, SDPTA contracted with MIG|MJE, a San Diego-based multidisciplinary firm for its expertise in environmental storytelling. The video was named "Clearing the Air: San Diego Port Tenants Association Zero-Emission Freight Project" and included both footage of the demonstrations and interviews with some of the stakeholders. The video is available for public viewing at this web address: https://www.youtube.com/watch?v=RC0HGs86YHs

Event	Date	Summary
AB 617 Portside Steering Committee Meeting	January 19, 2021	On January 19, 2021, SDPTA and the project team were invited to give a brief presentation at the AB 617 Portside Steering Committee virtual meeting on the project and its efforts to reduce emissions and harmful environmental impacts to the local communities and highlight the Equity Plan created. SDPTA and Momentum provided attendees with the mini documentary film to view beforehand and during the meeting gave an overview of the project's deliverables and the zero-emission technologies being deployed. SDPTA and Momentum covered common concerns amongst freight operators at the port regarding zero-emission freight technology, such as sufficient battery capacity, power and performance, durability, design, and lack of existing infrastructure. Additionally, two case studies were presented. The first case study was on the BYD drayage trucks demonstrated at Pasha, and how BYD incorporated feedback from the first-generation truck to make significant improvements to its second-generation truck. The second case study was comparing the yard tractors demonstrated at Dole and Pasha, showing that although the trucks are the same type of vehicle, operational needs of the vehicle may vary according to the port end user. GC Green presented on the Equity Plan and its findings, highlighting that the Equity Plan is truly a first-of-its-kind resource on how projects focused on lowering emissions through technology can identify and incorporate measurable equity outcomes, as well as initiate structured dialog with local impacted communities from the beginning of the project and throughout. GC Green concluded with a reminder that there is still room for improvement and that the Equity Plan is just the beginning of many good things to come. The audience feedback on the presentation and project was extremely positive. Notably, one audience member emphasized how grants can make a huge impact in reducing harmful environmental impacts. Another stressed the importance of the lessons learned from these kinds of projects and how it can be incorporated into further state-wide sustainable freight action plans and policy.

Event	Date	Summary
Port of San Diego Board Meeting	February 11, 2021	On February 11, 2021, the Maritime Clean Air Strategy invited SDPTA and the project team to give a brief statement about the project during presentation at POSD Board Meeting. SDPTA and Momentum shared lessons that they learned from the project. They also shared the value that pilot projects like this one can bring to communities and how vital regional partners and communities are in the success of grants. GC Green shared the suggestions from the Equity Plan. They also made clear how communities play a critical role in making decisions and that there is always room to improve.
Barrio Logan Planning Group Meeting	February 17, 2021	On February 17, 2021, SDPTA and the project team presented at the Barrio Logan Planning Group. SDPTA and Momentum gave an overview of the project and its key lessons and results. GC Green shared the Equity Plan and noted how crucial it is to work with the community early on and often in grant-funded projects as well as other initiatives at the port. GC Green also noted that there is room to improve and that there is still work to be done to have operational equity. Afterward, one of the group members states again how vital it is to keep the community informed of what is actually going on at the port. They also liked the idea of including community members in key decisions that are made at the port.

Event	Date	Summary
Workforce and Supply Chain Inclusion Workshop	April 8, 2021	In partnership with GC Green and in support of the SDPTA, Momentum hosted the Workforce and Supply Chain Inclusion Workshop. The virtual workshop focused on the medium and heavy-duty advanced vehicle technology demonstration at POSD and how it created a model for benefits for the surrounding communities through both environmental and health improvements and increased economic development especially in opportunities for workforce and supply chain inclusion. 82 people registered for this event. 18 of those registered were able to attend and participate in the workshop, along with 14 staff and panelists. The workshop opened with a viewing of the "Clearing the Air: San Diego Port Tenants Association Zero-Emission Freight Project" video and an overview of the Equity Plan and its findings and recommendations, presented by Elizabeth Perez, CEO and Founder of GC Green. This set the stage for a panel discussion by project team members on the technology development, installation, and maintenance process, and the associated workforce and supply chain needs and opportunities. Panelists included Dana Friez, Workforce Development Training Manager at Long Beach Community College, Phil Gibbons, Program Manager for Energy and Sustainability at POSD, Joerg Ferchau, General Manager at Cummins Electrified Systems (formerly EDI), Jason Stack, Owner of STC Traffic, Jerry Krug, General Manager of TransPower, and Sophie Silvestri, Manager of Business Development and Government Affairs at Pasha Automotive Services. After the panel discussion, panelists and audience members were broken up into three breakout sessions for more focused conversations. Topics included 1.) Growing the workforce roadmap and training opportunities, 2.) Extended conversations on the technology, and 3.) How others can use this project as a model to set up a project like this in their community.

Source: San Diego Port Tenants Association / Momentum

CHAPTER 6: Conclusions and Recommendations

6.1. Summary and Analysis of Data Collection and Results

The following sections summarize the data collection results of the 10 zero-emission vehicle (ZEV) technology demonstrations and the FSP system.

6.1.1 Vehicle Demonstrations

The project successfully demonstrated the viability of these new technologies to operate in their intended port and drayage applications, yet the data collection components of the project revealed unforeseen challenges and opportunities with these advanced technologies. Over the phased deployment schedule, carbonBLU intended to install HEM Data's "DAWN Mini Logger™" on each of the demonstrated zero-emission vehicles and cargo handling equipment, yet carbonBLU was not able to fully resolve multiple issues during the demonstration period and that prevented their reliable use and generated inconsistent data. For instance, discrepancies in the vehicle-to-logger communication formats over the controller area network and the lack of a standardized on-board diagnostics system for MDHD ZEVs resulted in the logging of select data while not capturing the cumulative operational data, critical to accurate estimation of project benefits. Ultimately, data relied upon for determining the project environmental benefits came from manual odometer reads and reporting provided by the demonstration partners while using the limited viable data collected from the data loggers to extrapolate potential project emissions reductions (Table 23 and Table 24).

Table 22: Project Operational Data Collected Manually

Operator	Unit	Hours Operated	Miles Driven
Dole	BYT-D1	1,544.3	4,687
Dole	BYT-D2	1,834.6	5,207
Pasha	BYT-P	N/A	152
Pasha	BDT-P	206.8	1,581
Pasha	BDT-Ce	377.2	5,220
Terminalift	BDT-T1	245.4	363
Terminalift	BDT-T2	260.8	499
Terminalift	TFL-T	38	43
MGBW	EFLM-1	1,028.9	N/A
MGBW	EFLM-2	1,278.7	N/A
	Project Totals	**5,270.40**	**13,065**

Source: Momentum

Table 23: Calculated Project Emissions Reductions

Operator	Unit	NO_X (tons)	ROG (tons)	PM (tons)	MT CO_2e	Diesel Avoided (gal)
Dole	BYT-D1	0.68493095	0.04964654	0.01965844	10.522	1,029.5
Dole	BYT-D2	o.83436000	0.06655988	0.02493892	12.500	1,223.1
Pasha	BYT-P	0.48556548	0.04149554	0.01496354	3.495	342.0
Pasha	BDT-P	0.00007646	0.00028937	0.00000891	0.403	39.4
Pasha	BDT-Ce	0.00195232	0.00029054	0.00000902	10.162	994.3
Terminalift	BDT-T1	0.00012259	0.00028955	0.00000892	0.645	63.1
Terminalift	BDT-T2	0.00016857	0.00028959	0.00000892	0.887	86.8
Terminalift	TFL-T	0.00785845	0.00030560	0.00025020	0.971	95.0
MGBW	EFLM-1	0.01182185	0.01182185	0.00045973	0.00037638	6.493
MGBW	EFLM-2	0.01182185	0.01182185	0.00045973	0.00037638	6.413
Project Totals		**2.03868**	**0.16009**	**0.06060**	**52.49**	**5,136.0**

Source: Momentum

To estimate the above project emissions reductions, Momentum made a comparison between the emissions and fuel consumption of baseline equipment operated by the demonstration partners and the advanced, zero-emission technologies deployed under this project. These calculations relied upon the Carl Moyer Memorial Air Standards Attainment Program emissions quantification guidelines as well as fuel and equipment energy conversion factors from the Low Carbon Fuel Standard.

As discussed above, the project team relied upon data obtained by manual reads of the vehicle and equipment odometers and hour meters to provide primary emissions reduction estimates. Yet, some partial data was retrievable from carbonBLU's data loggers for providing limited temporal snapshots of project operations. SDPTA utilized this limited data, including that collected on select pieces of baseline equipment, to forecast potential emissions reductions by extrapolating it to represent annualized operations. These annualized emissions reductions rely upon the assumption that operations during the timeframes in which data was collected are generally representative of operations (Table 25).

Table 24: Annualized Emissions Reductions

Operator	Unit	NO_X (tons)	ROG (tons)	PM (tons)	MT CO_2e	Diesel Avoided (gal)
Dole	BYT-D1	0.00144766	0.00029071	0.00000904	7.52	736.00
Dole	BYT-D2	0.00225104	0.00029147	0.00000912	11.61	1,136.00
Pasha	BYT-P	0.00733961	0.00018555	0.00000611	56.95	5,572.46

Operator	Unit	NO_X (tons)	ROG (tons)	PM (tons)	MT CO_2e	Diesel Avoided (gal)
Pasha	BDT-P	0.00007646	0.00028937	0.00000891	0.403	39.4
Pasha	BDT-Ce	0.00195232	0.00029054	0.00000902	10.162	994.3
Terminalift	BDT-T1	0.00287536	0.00029173	0.00000914	14.79	1,447.30
Terminalift	BDT-T2	0.00102921	0.00029020	0.00000899	5.37	525.91
Terminalift	TFL-T	0.02785581	0.00143462	0.00101420	4.71	461.00
MGBW	EFLM-1	0.01182185	0.00045973	0.00037638	6.493	635.3
MGBW	EFLM-2	0.01182185	0.00045973	0.00037638	6.413	627.5
Annualized Totals		**0.06847**	**0.00428**	**0.00183**	**124.421**	**12,175.17**

Source: Momentum

6.1.2 Freight Signal Prioritization Demonstration

FSP has shown effectiveness in each performance measure category. The summarized improvements for an average run with FSP:

- The average travel time saved is one minute, a 9.5 percent decrease.
- Average idle time reduction of 23 seconds, a 29 percent decrease.
- Average stops decreased by 0.65, a 22 percent decrease.
- Average idle time per stop decreased by 2.0 seconds.
- Average speed increased 3.0 mph, a 14 percent increase.
- Average moving emissions reduced by at least 15 percent per run in each category.
- Average idle emissions reduced by 27 percent per run in each category.

Table 26 shows the performance measures for the average run for each month. The "without FSP" (February to December 2020) and "with FSP" (January to April 2021) report actual truck performance data.

STC Traffic extrapolated the "with FSP" data for May to December 2021 based on the January to April 2021 results. STC Traffic also added the 2020 monthly "without FSP" provided the baseline and the average improvement in each of the categories for January to April 2021 to the 2020 baseline to extrapolate the "with FSP" condition for each month from May to December 2021.

Table 25: Average Run by Month – Speed, Stop, and Travel Time

Month	Without FSP Avg Speed (m/h)	With FSP Avg Speed (m/h)	Without FSP Avg # of Stops	With FSP Avg # of Stops	Without FSP Avg of Travel Time	With FSP Avg of Travel Time	Without FSP Avg Stop Duration	With FSP Avg Stop Duration
Jan	-	23.26	-	2.04	-	10:13.0	-	00:53.0
Feb	21.10	25.29	3.20	2.49	11:28.1	10:05.8	01:33.7	00:57.6
Mar	22.62	25.62	2.81	2.35	10:32.9	10:16.7	01:13.5	01:05.1
Apr	22.67	23.94	2.15	2.91	10:24.9	10:26.8	01:01.4	01:20.4
May	22.16	*25.26	2.89	*2.24	10:38.0	*09:34.0	01:12.8	*00:49.1
Jun	20.98	*24.08	2.91	*2.26	11:21.2	*10:17.3	01:25.6	*01:02.0
Jul	20.97	*24.08	2.81	*2.16	11:19.1	*10:15.2	01:16.1	*00:52.5
Aug	21.14	*24.25	2.86	*2.22	11:23.0	*10:19.0	01:20.0	*00:56.4
Sep	21.05	*24.15	2.97	*2.33	11:26.5	*10:22.5	01:20.9	*00:57.3
Oct	21.09	*24.20	3.01	*2.37	11:25.3	*10:21.4	01:19.8	*00:56.1
Nov	26.17	*29.27	2.66	*2.01	11:40.7	*10:36.8	01:08.9	*00:45.2
Dec	26.30	*29.40	2.50	*1.85	12:00.5	*10:56.6	00:56.1	*00:32.5

*Extrapolated

Source: STC Traffic

Table 27 shows the estimated run savings per truck. The trucks averaged 70 runs per month on the corridor. STC Traffic calculated this data using the average benefit per run for each measure and the average of 70 runs per month, the average benefit for one month, then six months, and then 12 months.

Table 26: Estimated Run Savings per Truck for 12 Months

Savings With FSP Activated	Per Run	1 Month	6 Months	12 Months
Miles Traveled	4	280	1680	3360
Average Time Saved (Hr:Min:Sec)	0:01:04	1:14:36	7:27:35	14:55:10
Average Number of Stops Removed	0.65	45.32	271.92	543.84
NOx Reduced	16.0%			
CO Reduced	17.7%			
SOx Reduced	15.4%			
PM 10 Reduced	14.5%			
Idle HC Reduced	26.6%			
Idle CO Reduced	26.6%			

Idle NOx Reduced	26.6%
Idle SOx Reduced	26.6%
Idle PM Reduced	26.6%

Source: STC Traffic

6.2 Lessons Learned

SDPTA and its subcontractors experienced numerous unexpected challenges including restrictions at the state-level prohibiting the demonstration of platooning, acquisitions of technology vendors by large OEMs that deprioritized specific equipment pieces, relocation of terminal operators requiring new site hosts, union labor strikes, a global pandemic, and administrative processes with CEC contracting. Despite these challenges, SDPTA and its partners deployed some of California's first zero-emission port equipment. At the conclusion of this project, the team had many lessons learned to pass on to future groups looking to demonstrate zero-emission MDHD vehicles. This project team intended this project to serve as a valuable resource to stimulate the adoption of such vehicles across the U.S. and globally.

Throughout the project, multiple challenges arose that the project team resolved through flexibility and collaboration amongst stakeholders. The project team is hopeful that the CEC and broader audience will see value in both the desired and unexpected outcomes and can use the lessons learned in future projects. Below are some of the biggest challenges faced during this project. how the project team overcame them, and what lessons were learned in the process.

- **Grant Structure:** This was the first time that most of the port tenants had participated in a grant. All came to realize the large value grants have in helping port tenants electrify their operations and helping to advance early-stage technologies on the path to market. However, many came to realize very quickly that grants can be complicated.

  After completing the grant, technology demonstrators noted the reasons why the port tenants would see a grant as daunting and may deter them. Reimbursement models can be hard on both small and large companies. Electric vehicles and other new technologies have a huge upfront cost that port tenants would still have to pay. Although the CEC eventually reimburses the port tenants, they experience the cost barrier firsthand. Building out the infrastructure needed to support the electric vehicles is another large expense. Many grants do not include funds to cover infrastructure, causing more financial hardships. Additionally, when labor is not eligible for match funds, it is difficult to meet the match requirement. However, there is still tremendous value gained from participating in a grant. Funding agencies should make incentives very clear to get more demonstrators onboard and dedicated to carrying out the grant.
- **Subcontract Structure**: Although it may seem simple, it is crucial that all stakeholders fully understand the contract structure, scope of work, and flow of money for grant-funded projects, which can be complex. In other words, setting the project team up for success early on is the key to a successful project.

  When the project first began, fleet tenants ran into issues with how the subcontracts were set up. Originally, SDPTA required the fleet tenants to have separate subcontracts with specific technology providers, in addition to their subcontract with SDPTA. By contracting with technology providers, fleet tenants would take on different legal obligations, accounting costs, and administrative oversight. Not only were the fleet tenants assuming that SDPTA would take on a larger administrative role as the awardee, but additionally, some of the fleet tenants are small businesses and cannot take on the extra legal liability, work, and costs itself. Having small businesses participate in technology demonstrations is crucial to advancing new technologies because transitioning to zero- or near-zero-emission machinery is significantly more difficult for a small business due to a combination of upfront costs and uncertainty. To resolve this issue, SDPTA submitted an amendment to modify the subcontracts to a third-party agreement, which removed some of the obligation from the end-users.

- **Administrative Processes:** It is vital that all stakeholders work with the CEC to fully understand the way grant project works. The contract structure, scope of work, and flow of money can be hard to grasp, especially for someone who has never participated in a grant before. Changes to the original project agreement are inevitable. Unfortunately, during this project, the time it took for administrative review and approval of amendments varied greatly and, in some cases, caused further delays in the project schedule. Overall, the project stakeholders have been very thankful to have the direct assistance from the CEC and acknowledge that this a learning process on all sides and that the CEC is tracking its own lessons learned to improve this process on future projects.

  As mentioned before, this was the first time many of the members of the project team were involved with a grant. Without clear guidance, the project team had some trouble navigating administrative processes and did not have the experience to recognize when things were off or what not to do. For example, when the CEC first awarded the grant, the project team was excited and eager to get started. The CEC and SDPTA held the kick-off meeting in July 2016 and SDPTA incurred some expenses to make the event a celebratory beginning. SDPTA invited project stakeholders and the CEC to the event. However, it was not until after SDPTA incurred expenses that the CEC informed them that the expenses would not be billable because the CEC and SDPTA had not yet executed the grant agreement. Additionally, executing the contract took a long time to and there was sparse communication on where it was in approval process.

  During this project, SDPTA submitted four official amendments to the CEC:

  - ***Amendment #1***: On August 7, 2017, SDPTA requested a change to the subcontract structure. Originally, the subcontracts were set up so that the flow of money ran from the CEC, to SDPTA, to demonstration partners, and to technology providers. The demonstration partners voiced concerns about this structure and did not want to have funds flow through them. Therefore, SDPTA submitted its first amendment to drop the demonstration partners from the flow of money. Instead SDPTA would directly pay the technology providers as subcontractors and the port tenants would have lease agreements with the technology providers during the project. At the end of the project, the technology providers would sell the vehicles/equipment for a small fee to the fleet tenants, who would continue to use them as part of their fleets. The CEC approved this amendment on March 16, 2018. While this solved one problem, it created new problems relating to how technology vendors typically invoice for their equipment.
  - ***Amendment #2:*** On November 7, 2018, the project team requested that the removal of Peloton Platooning Technology from the project since Peloton discovered

that platooning was illegal in the state of California. The amendment requested the reallocation of funds to ramp up the traffic system part of the project. It would also move some of the funds from DENSO's subcontract budget to STC Traffic's. The CEC issued a stop work order after submitting this amendment for all work on the traffic system (Task 3) and did not lift the order until April 12, 2019. The CEC approved this amendment on May 29, 2019.

  - ***Amendment #3:*** In the wake of the Cummins acquisition of EDI, Cummins voiced its desire in June 2019 to drop the Terminalift drayage truck demonstration that EDI had previously agreed to. Upon learning the news, on June 21, 2019, the CEC issued a stop work order on Terminalift drayage truck demonstration aspects of tasks two and five.

    On November 5, 2019, SDPTA submitted the third amendment due to Cummins' desire to no longer provide two drayage trucks to Terminalift. The majority of the funds for the trucks would be reallocated to Terminalift's equipment budget so that it could purchase the vehicles through BYD instead. On November 12, 2019, the CEC lifted the stop work order on the Terminalift drayage truck demonstration. The CEC approved Amendment #3 on January 23, 2020.

  - ***Amendment #4****: On* August 31, 2020, SDPTA submitted the fourth amendment to request the project end date to be extended from December 31, 2020, to April 30, 2021, which was the last date on which expenses would be accepted for reimbursement, with the liquidation date being June 30, 2021. At the time of the amendment development and submission, some of the project demonstrations were still unfolding and one had yet to even to begin. Since SDPTA is a small non-profit, continuing the demonstration beyond April 30, 2021, was not financially possible. Additionally, the amendment requested formal revisions to the data collection requirements under the agreement to allow for the collection of sufficient data to support meaningful project findings and key lessons learned that a broad stakeholder audience can discuss and share. The CEC approved this amendment on October 8, 2020.

  In summary, some amendment approvals took longer than others. Additionally, some required a stop work order to be issued as the amendment went through administrative review. Ultimately, these amendments caused additional delays to the project's ability to continuously progress. During this time, the CEC did not have a more transparent tracking mechanism in place, so updates on amendment review processes came from the Commission Agreement Manager, who did not always know where the amendment was in the review process. The CEC is aware of this issue in many of its grant-funded projects and is currently making adjustments to increase transparency for project stakeholders.

- **Policies and Restrictions at a State and Local Level:** As new technologies develop, it is crucial that demonstration projects are aware of and understand the state and local policies in place that may impede their ability to demonstrate a new technology.

  When SDPTA originally proposed this project, Task 3, the ITS portion, looked vastly different than what was actually demonstrated. The original contractor, Peloton Technology, was to lead the development and deployment of a never before demonstrated hybrid truck platooning system and freight signal priority system. Platooning is a line of vehicles traveling very close together at a safe and consistent speed using intelligent communication technology. In operation, the Platoon Signal Priority would enable drivers to form fuel-efficient platoons—both at highway speeds and at slower speeds—generating significant reductions in fuel consumption and reduced freight traffic impacts on the streets and at intersections in and around the port. In April 2018, Peloton reported that although it had believed that the state of California was on a path to allow commercial deployment of freight platooning at the time of the proposal in 2016, by 2018 the legislature limited authorized testing, but it still did not allow commercial deployments. As a result, SDPTA had to drop the platooning aspect from the project, but the FSP system would still be viable. This required a significant amendment to the scope of work, causing a stop work order until the amendment approval in April 2019, and the identification of a different prime contractor for the FSP system, which in June 2019 officially became STC Traffic.

- **Pre-Commercial Technology:** Testing new technology is sure to come with many challenges, but it is crucial to make the switch to a zero-emission future.

  Many of the vehicles in this project had design or function issues. The Dole Food Company and Pasha yard tractors had small design issues, such as the small back window being too small and the driver seat and steering unable to swivel. Even though these issues may seem small, it does make a big difference in a driver's ability to do their job well and safely and later choose to (or not to) buy a vehicle.

  Using BYD's first-generation drayage truck, Pasha had the chance to give direct feedback to BYD, resulting in a big improvement to the second-generation truck. As Pasha noted, the second-generation truck was able to perform just as well as its diesel drayage trucks. Even though the first-generation truck may not have met Pasha's needs, its direct feedback helped BYD to make a new truck that did. The direct collaboration between partners in projects like this creates a win-win relationship where vendors get the feedback they need to perfect technologies, and demonstrators can gain the confidence and solutions they need to electrify their fleets.

  Of course, projects like this one can be uncertain. In May 2017, Harborside decided to leave the project when its operations relocated off of the port. Pasha accepted and took over Harborside's planned demonstration of a Class 8 drayage truck. After many delays and issues with the battery system, in October 2020, Continental Maritime transferred its 40,000-lb forklift to Terminalift.

  Many of the MDHD vehicles demonstrated in this project posed design and/or performance issues. The UTRs demonstrated at Dole Food Company and Pasha had small design issues, such as the small back window being smaller than preferred and the driver seat and steering not being able to swivel. Although these issues may seem small, it does make a big difference in an operator's ability to efficiently and safely do his or her job and ultimately decide to purchase a vehicle for operations.

  As a demonstrator of BYD's first-generation electric drayage truck, Pasha had the opportunity to provide direct feedback to BYD amongst other customers, resulting in a significant improvement to the performance of the second-generation truck. As Pasha noted, the second-generation electric drayage truck was able to perform just as well as its diesel drayage trucks. Although the first-generation vehicle may not have met

Pasha's performance needs, its direct feedback enabled BYD to provide a new truck that did. The direct collaboration between technology vendors and technology demonstrators that demonstration projects create fosters a win-win relationship where technology vendors receive the feedback needed to perfect its technologies for commercialization, and technology demonstrators gain the confidence and solutions needed to electrify its fleets and operations.

Of course, the development and demonstration of pre-commercial technology can naturally raise feelings of uncertainty. In May 2017, Harborside made the decision to withdraw from the project. Pasha willingly assumed its Class 8 drayage truck demonstration. After experiencing multiple delays in manufacturing and issues with the battery system in production, in October 2020, Continental Maritime transferred its 40,000-lb forklift demonstration to Terminalift. Although demonstrating pre-commercial technology can be a risk, throughout this project hesitation has consistently met an overwhelming amount of support and excitement for zero-emission technology.

Demonstration projects allow businesses to gain a deep understanding of the new technology being developed. All new technology has high cost and high risk. All port tenants mentioned operational fit as was one of the most important factors when buying new vehicles. To justify the costs, electric vehicles must prove that they can work well, survive, and make money on an ongoing basis. All port tenants appreciated the opportunity to demonstrate these new technologies. One port tenant said that this project reaffirmed that the technology is moving in the right direction. All would be interested in participating in another project like this. Some are even pursuing or have already purchased other electric vehicles and equipment.

- **Infrastructure:** All port tenants say infrastructure as a large barrier to electrification. Many of the port tenants mentioned that a lot of grants do not include funding to cover infrastructure costs, which can make publicly funded demonstration projects like this one unattractive. Infrastructure is extremely expensive to purchase and build out and is difficult to put in place due to regulations and permitting. Electrification of vehicles is a two-part initiative. It would be helpful for operations to receive financial assistance on both parts from the same grant.

  Additionally, there is no industry standard for chargers. Currently, each electric vehicle may require its own specific charger. If one vehicle can only use one charger, the larger infrastructure investment of time and money is not worth the risk. If a vehicle needs a specific kind of charger, this may limit the operational range of the vehicle. Port operations need vehicles to be flexible. Some of the port tenants in San Diego have operations at different ports throughout the country or world and they could relocate the vehicles to another operation at a different port. Additionally, drayage operations can cover large areas and serve multiple locations. To be compatible with how ports operate, chargers need to either become standardized and widely available or mobile.

- **OEMs:** Another common issue amongst the technology demonstrators was the repair and maintenance service provided by the OEMs. Since electric vehicle technology is still new and the vehicles demonstrated were prototypes, repair and maintenance was often complicated. One of the key lessons learned from one of the port tenants, was that the relationship between the technology provider and technology demonstrator is crucial. The port tenants want to be able to depend on OEMs.

When a vehicle is out of service, it is disruptive to the operation. During busy operations, a port tenant will want to have all vehicles in use. If time means money, it is crucial that repair and maintenance services move as fast as possible. Another concern that came up in this project is how to move a vehicle out of the way if it were to break down in an inconvenient location.

Technology demonstrators need to know going into demonstrations how the OEM will provide the services needed. Technology demonstrators also need to know if the OEM is local or not. Vehicle operators always prefer to have maintenance and repair services nearby.

- **Acquisitions:** When working with technology vendors who are developing cutting-edge technology, it is common for technology acquisitions to occur, especially in today's emerging and evolving cleantech market. Although these business decisions are often beneficial to the technology vendors, the change in management and company goals may be in conflict with the contracts and intentions to carry out these kinds of grant-funded pilot demonstrations.

  In 2017, Cummins purchased EDI in order to build out and scale Cummins' renewable technology portfolio. As a result of the acquisition, production priority was not given to the drayage trucks that EDI intended to repower, so on March 16, 2020, the contract was amended so that Cummins would only be responsible for carrying out the forklift demonstration with MGBW. BYD was willing to take on the dropped responsibilities to ensure Terminalift's drayage truck demonstration.

  In January 2020, TransPower announced its official acquisition by Meritor. As a result of the acquisition, TransPower faced multiple management and staff changes along with changes to their company's product selection. For example, Meritor dissolved the forklift division, making this project one of the last demonstrations of TransPower's engineered forklifts. Meritor management also expressed desire to withdraw from the project, but since the forklift was close to being finished, it agreed to finish deploying the forklift but not take on the warranty responsibilities of the contract. SDPTA and Continental Maritime agreed to this because the main engineer of the forklift had retired from TransPower in 2020 and could be hired as an individual contractor for the warranty period. However, the dissolution of the forklift division left few staff to support the engineering of the forklift, causing multiple delays to the delivery since there was only one engineer working on the machine. Both the challenges in getting the forklift deployed and Meritor's withdrawal from the warranty made the original technology demonstrator, Continental Maritime, lose confidence in the technology's ability to perform and raised concern over it being a liability instead of an asset. As a result, Continental Maritime transferred the demonstration to Terminalift, a much more enthusiastic technology demonstrator of the TransPower forklift.

- **Workforce Education:** It is important that all stakeholders, including the workforce that will be interacting with these newer technologies but are not necessarily in the grant conversations, understand the specifics of the project and how these technologies work.

  The truck drivers and operators who will ultimately operate the vehicles and use these technologies on a daily basis are often not involved in project administration discussions. Because these deployed technologies may be new, the operators and drivers may initially react with hesitation and/or caution due to a lack of education about these technologies. For example, FSFT, a participating company in the FSP demonstration backed out because its truck drivers were unaware of how the FSP system worked. Once STC Traffic told the drivers that the trucks would interact with the signal sensors to collect data, they were concerned about data privacy. Even though individual truck data, such as vehicle ID, would not be tracked, the employees remained hesitant and the company backed out of the demonstration. STC Traffic then had a difficult time recruiting truck drivers in the area to participate in the FSP demonstration to meet the grant obligations of having 10 vehicles participate. STC Traffic believed that once the FSP system was up and running, it would gain the interest of drivers in the area, but to have 10 vehicles signed on by the activation date, STC Traffic had to advertise an incentive to meet the obligations.

SDPTA also learned that including all stakeholders from the very start of the project is key. SDPTA is an advocate for community inclusion at the port. The Equity Plan recommends including community members early on and frequently throughout the project. Since the port employs much of the surrounding communities, their voices and opinions are really crucial. Community members should be at the discussion table when the port evaluates future funding opportunities and initiatives.

- **Data Collection:** Data collection and analysis is one of the most crucial aspects of any grant and/or project. The data collected from these demonstration projects determine the progress of technology innovation and the need for further funding. For these kinds of projects, it is crucial that the data collection contractor fully understands the requirements of the project and is dedicated to fulfilling assigned duties with transparency.

  Unfortunately, this project ran into multiple challenges with the project partner for data collection from the 10 MDHD electric freight vehicles. The data collection subcontractor allocated one employee for the data logging and analysis of the demonstrated vehicles for this project. In addition to the existing challenges to log new technologies that are present in any pilot project, issues arose with this particular contractor. Communication with the contractor was difficult, and time and prioritization for this project seemed limited.

  When Cummins delivered the forklifts to MGBW in December 2018, carbonBLU was unable to obtain a data logger that was compatible with the technology and therefore moved forward with obtaining charging data from the battery supply manufacturer.

  In February 2020, carbonBLU discovered that there had been a problem with how it installed the data loggers on all of the BYD vehicles at Dole and Pasha, and therefore all of the data collected was unusable. carbonBLU installed new data and the contractor agreed to regularly check that the data loggers were collecting usable data. Going forward, the contractor would conduct monthly site visits to check on all of the demonstrated and baseline vehicles, provide the notes from each site visit, create monthly and quarterly reports, and regularly upload the data to a shared Google Drive with SDPTA and Momentum. Although carbonBLU completed these new tasks, they were often done later than promised and required constant reminders from SDPTA and Momentum.

- **COVID-19 Impacts:** In late 2019, a new and highly contagious virus, called Coronavirus, emerged overseas causing the COVID-19 global pandemic. By early 2020, the virus had spread around the world, impacting supply chains, commerce, day-to-day operations, and personal livelihoods. Although these types of events are unpredictable and cause hardships and delays to projects such as this one, they also provide a reminder of the project purpose, to accelerate innovation and create economic opportunity on a global scale.

  The COVID-19 global pandemic affected every aspect of this project. This impacted many of the port tenants' supply chains, resulting in reduced need and/or staff to operate the demonstrated vehicles on a regular basis. Pasha decided to move its charging stations to a closer location during this slowdown, but this resulted in Pasha not using the electric vehicles for many months. Safety measures for social distancing and less staff on-hand caused operations and work to be less efficient in many places. SDPTA and the CEC added some additional time to TransPower and STC Traffic's work, although both parties navigated through persistently to ensure progress on their respective demonstrations. Many organizations had their travel. However, the carbonBLU contractor for this project was an independent contractor of multiple other organizations and had other clients and projects in the San Diego region. This being the case, the contractor made the decision to continue to perform the monthly site visits for this project while the travel restriction is in place as long his other projects continue to bring him to the region. Despite the circumstances, all stakeholders brought a sense of flexibility and optimism that allowed this project to progress and successfully conclude during the COVID-19 global pandemic.
- **Spillover Effects:** Demonstration projects like this are an inspiration for other businesses and people in the area. The port has put in place a CAP to reduce emissions from the port operations. Port tenants must make changes to their operations to meet the goals listed in the CAP. Since transportation is a large portion of the port's emissions, port tenants will have to electrify their vehicles and equipment in a short period of time. This project was one of the first initiatives deployed at the port to electrify freight vehicles and many port tenants and community members used it as a case study. SDPTA has consistently shared the progress and lessons learned from this project through outreach activities with all stakeholders, including port tenants, the workforce, and the surrounding community. Since the beginning of this project, the port has made a lot of progress in terms of electrification, and the community is as engaged as ever.

6.3 Recommendations for Future Projects and Improvements

ARV-15-068, the project is in a sense a pilot project, testing new electric forklifts, vehicles, and a traffic system. The project is doing this to make vehicles more drivable and reliable, work better, and more likely to fully commercialize soon. This project is meant to be used as a good reference for port or freight vehicle electrification projects around the world. For similar projects in the future, the project team advises to:

1. **Ensure a reliable team and communicate with transparency.** Set the project team up for success! At the beginning of the project, make sure that all stakeholders fully understand the contract structure, scope of work, and flow of money. Partner with those who are excited to test new pre-commercial technology. These partners will often

be the ones who are there and willing to pick up further responsibilities to ensure the success of the project. Communicate often and with full transparency with all project stakeholders, including the funding agency, since everyone has a part to play and can only improve from lessons learned.

2. **Proactive engagement and flexibility are keys for success in projects with nascent technologies that are not yet commercially available.** It is important to have realistic expectations and to navigate challenges and delays with flexibility. The unexpected is inevitable when demonstrating new technologies. All parties need to maintain clear communication and expectations when working through these challenges to prevent additional unnecessary delays to the project.
3. **Early engagement with community and workforce groups during solicitation design and development and project design and development creates greater benefits and stronger projects.** New technology and a zero-emission future can be both exciting and uncertain, depending on the perspective. Everyone views new technologies in different ways. Some welcome new technology with open arms. New zero-emission technology brings multiple benefits such as reduced emissions and traffic impacts for nearby disadvantaged communities. For others, new technology can be a serious concern. Port tenants and operators want to ensure that an electric vehicle performs and operates just as well as its diesel counterparts. In either case, it is important that all affected individuals, community members and/or the workforce are aware of the zero-emission initiatives in place and understand why these types of projects are important and how they can affect them. Lastly, it is important to include all project stakeholders in a platform to provide feedback in the transition to a zero-emission future.
4. **Public funds are imperative to advance and adopt new technology and achieve public policy goals.** The high cost of new technologies and the significant investment to develop charging infrastructure are major barriers that prohibit many businesses from becoming early adopters of ZEV freight equipment. Public funding plays a crucial role by filling in that financial gap. Opportunities for real-world demonstrations in the port environment provide the necessary information to keep ZEV freight technology development moving forward, closer to the tipping point of being affordable, reliable, and rugged enough to handle the demands required of them. Funding opportunities that limit applicable cost share and do not allow for labor as match can be prohibitive, as can the exclusion of infrastructure as an eligible expense.

GLOSSARY

ADVANCE TRAFFIC SIGNAL CONTROLLER (ATC) - A component of the Freight Signal Prioritization system that is installed at each of the traffic signal cabinets. It is capable of creating and sharing Signal Phase and Timing data, receiving the priority request with ETA, and granting or denying the priority request.

CALIFORNIA DEPARTMENT OF TRANSPORTATION (Caltrans) - A California Department responsible for the design, construction, maintenance, and operation of the California State Highway System, as well as that portion of the Interstate Highway System within the state's boundaries.

CALIFORNIA ENERGY COMMISSION (CEC) - The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies

Funding for the Commission's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account and other sources.

CENTER-TO-INFRASTRUCTURE (C2I) - Center is defined as the point of process activity for the Freight Signal Prioritization system. C2I is the technology and communications that connect the two.

SAN DIEGO CLIMATE ACTION PLAN (CAP) - A community-wide goal of net zero emissions by 2035, committing San Diego to an accelerated trajectory for greenhouse gas reductions.[7]

CONFLICT MONITOR UNIT (CMU) – A component of the Freight Signal Prioritization system that is installed at each signalized intersection to monitor the traffic signal inputs and outputs for faults in the system.

COORDINATED UNIVERSAL TIME (UTC) - The primary time standard by which the world regulates clocks and time.

DISADVANTAGED COMMUNITY - Disadvantaged communities are communities that are most affected by many sources of pollution, and where people are often especially vulnerable to pollution's effects.

[7] The City of San Diego Climate Action Plan (https://www.sandiego.gov/sustainability/climate-action-plan)

EMISSION FACTOR (EMFAC) - An emissions inventories of on-road and off-road mobile sources and tools to perform project-level assessment with custom meteorological conditions and scenario analysis with custom vehicle activity.[8]

ESTIMATED TIME OF ARRIVAL (ETA) - A predicted measure time that an object will arrive at a specified location.

FREIGHT SIGNAL PRIORITY (FSP) - An intelligent transportation system technology that gives signal priority to freight vehicles approaching a signalized intersection. Priority decisions are based on real-time traffic and emissions data to produce the fewest emissions at signalized intersections.[9]

GLOBAL POSITIONING SYSTEM (GPS) - An accurate worldwide navigational and surveying facility based on the reception of signals from an array of orbiting satellites.

GROSS COMBINATION WEIGHT RATING (GCWR) - The value specified by the commercial motor vehicle manufacturer. (US Department of Transportation)

HIGH-RESOLUTION (HI-RES) - Data containing UTC timestamps from the Freight Signal Prioritization vehicles and pedestrian/bicycle push button call counts.

INFRASTRUCTURE-TO-INFRASTRUCTURE (I2I) - The technology and communications that connect the various components of the Freight Signal Prioritization infrastructure.

INSTALLATION ACCEPTANCE TEST (IAT) - The second Freight Signal Prioritization test in the Test Plan.

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) - A system of technologies that improves transportation safety and mobility and enhances productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles.[10]

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

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

MARINE GROUP BOAT WORKS (MGBW) - One of the technology demonstrators for this project. It is a family-owned, full-service boat and super yacht refit and repair facility at the Port of San Diego.

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[8] California Air Resources Board Emissions Factor website (https://arb.ca.gov/emfac/)

[9] United States Department of Transportation ITS Joint Program Office website (https://www.its.dot.gov/infographs/Eco_freight_signal.htm)

[10] United States Department of Transportation ITS Glossary website (https://www.standards.its.dot.gov/LearnAboutStandards/Glossary)

MEDIUM-DUTY AND HEAVY-DUTY (MDHD) Medium Duty vehicles are Vehicle Class 3-6 and Heavy Duty vehicles are Vehicle Class 7-8. (Federal Highway Administration)

MILES PER HOUR (MPH) - A unit for measuring speed that calculates the number of miles traveled within one hour.

ONBOARD UNIT (OBU) - A component of the Freight Signal Prioritization system that is installed on each freight vehicle and is connected to the vehicle's power supply and ignition through a wiring harness located at the mounting location. It uses a Global Navigation Satellite System to calculates accurate time stamps between and arrival times of vehicles to the traffic intersection. The OBU is capable of storing data, broadcasting signal request messages, and specifically sending the arrival times to the RSU.

PORT OF SAN DIEGO (POSD, or port) - The location of the project. The Port of San Diego is also the organization that manages the working waterfront and facilitates and is a project stakeholder.

POWER-OVER-ETHERNET (PoE) - A technique for delivering direct current power to devices over copper Ethernet cabling, eliminating the need for separate power supplies and outlets. (Cisco)

PRE-INSTALLATION CHECK (PIC) - The first Freight Signal Prioritization test in the Test Plan.

ROADSIDE UNIT (RSU) - A component of the Freight Signal Prioritization system that is mounted to the traffic signal infrastructure and connected to the traffic signal controller. It is capable of communicating with the OBU to determine arrival time and in return broadcasts MAP data, data containing geographic characteristics of the intersection such as line locations, intersection lane geometry, etc., back to the OBU.

SAN DIEGO ASSOCIATION OF GOVERNMENTS (SANDAG): On of the strategic partners for this project. SANDAG builds consensus; makes strategic plans; obtains and allocates resources; plans, engineers, and builds public transportation; and provides information on a broad range of topics pertinent to the region's quality of life.

SAN DIEGO GAS & ELECTRIC (SDG&E): On of the strategic partners for this project. SDG&E is a regulated public utility that provides energy service to 3.6 million people through 1.4 million electric meters and 873,000 natural gas meters in San Diego and southern Orange counties.

SAN DIEGO PORT TENANTS ASSOCIATION (SDPTA) - The prime applicant for this project. There are a coalition of businesses and industries dedicated to enhancing trade, recreation, commerce, and tourism on San Diego Bay's tidelines, while protecting the area's environment.

TECHNOLOGY READINESS LEVEL (TRL) - A type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest.[11]

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[11] National Aeronautics and Space Administration website (https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level)

US DEPARTMENT OF ENERGY (DOE) - The federal department established by the Department of Energy Organization Act to consolidate the major federal energy functions into one cabinet-level department that would formulate a comprehensive, balanced national energy policy. DOE's main headquarters are in Washington, D.C.

VEHICLE-TO-INFRASTRUCTURE (V2I) - V2I technologies capture vehicle- and infrastructure-generated traffic data, wirelessly providing information such as advisories from the infrastructure to the vehicle that inform the driver of safety, mobility, or environment-related conditions.[12]

ZERO-EMISSION VEHICLE (ZEV) - Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

[12] United States Department of Transportation ITS Joint Program Office website (https://www.its.dot.gov/v2i/)