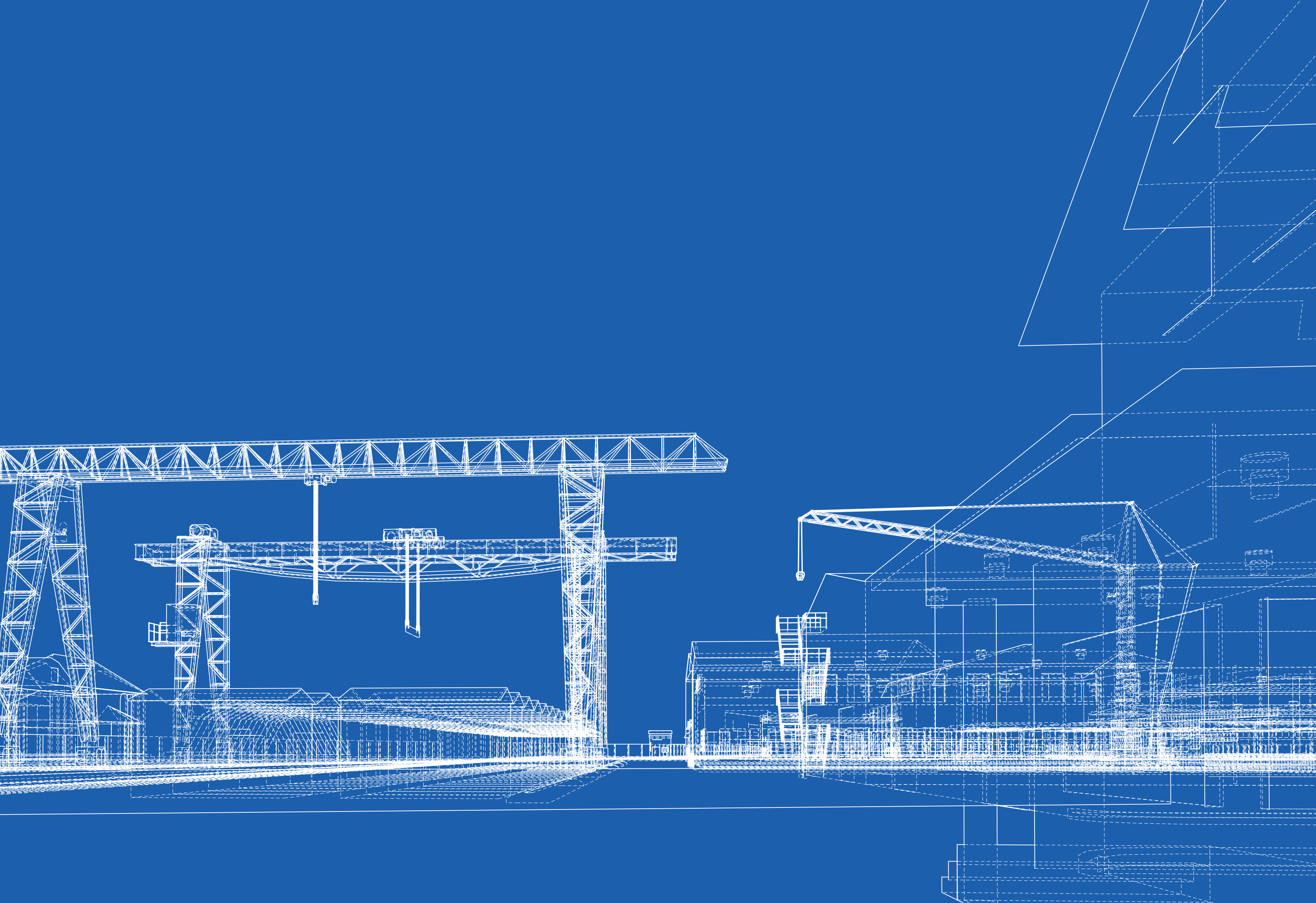
Charging Ahead: The Port Community Electric Vehicle Blueprint

May 2019



Port of
LONG BEACH
The Green Port

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The Port Community Electric Vehicle Blueprint

May 2019

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List of Abbreviations

ARFVTP	Alternative and Renewable Fueled Vehicle Technology Program
BATS	Broadly-Applicable Truck Specifications
BE	Battery Electric
Blueprint	Port Community Electric Vehicle Blueprint
BUILD	Better Utilizing Investments to Leverage Development
BYD	Build Your Dreams (company name)
CAAP	Clean Air Action Plan
CapEx	Capital Expense
CARB	California Air Resources Board
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CEVT	Certified Electric Vehicle Technician Training Program
CIS	Community Impact Study
CITT	Center for International Trade and Transportation
CNG	Compressed Natural Gas
CPCFA	California Pollution Control Finance Authority
CPUC	California Public Utilities Commission
dBA	A-weighted decibels (sounds in air as perceived by the human ear)
DEFT	Dynamic Energy Forecasting Tool
DERA	Clean Diesel Funding Program (pursuant to the Diesel Emission Reduction Act)
DERs	Distributed Energy Resources
DWP	Los Angeles Department of Public Works
e.g.	exempli gratia ("for example")
EDI	Electric Drivetrains Inc (company name)
EER	Engine Economy Ratio
EPA	United State Environmental Protection Agency
ESAM-TAC	Energy Storage and Microgrid Training and Certification
EV	Electric Vehicle
EVITP	Electric Vehicle Infrastructure Training Program
GHG	Greenhouse Gas
H_2	Hydrogen
i.e.	id est ("in other words")
IAM	International Associations of Machinists
IBEW	International Brotherhood of Electrical Workers
ICE	Internal Combustion Engine
ILWU	International Longshore and Warehouse Union
ITS	International Transportation Services (company name)
JCCC	Joint Command and Control Center
kg	kilogram
kWh	Kilowatt-Hour
LBCC	Long Beach City College
LBCT	Long Beach Container Terminal (company name)
LCFS	Low Carbon Fuel Standard

L_{dn}	Day-Night Sound Level
MVA	Mega Volt-Amp
MWh	Megawatt-Hour
NG	Natural Gas
NOx	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NZE	Near-Zero Emission
OEMs	Original Equipment Manufacturers
OpEx	Operational Expense
PAYS	Pay as You Save
PEACE	Planning, Environmental, Administration, Commercial, and Engineering
PM	Particulate Matter
PMA	Pacific Maritime Association
PMSA	Pacific Merchant Shipping Association
RIN	Renewable Identification Number
ROM	Rough Order of Magnitude
RTG	Rubber-Tired Gantry Cranes
SAE	Society for Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SMF	Steam Methane Reforming
TAP	Technology Advancement Program
TCO	Total Cost of Ownership
TTI	Total Terminals International (company name)
US	United States
V	Volt
VMT	Vehicle Miles Traveled
WRAP	Water Resources Action Plan
ZE	Zero Emission

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Executive Summary

A blueprint is a plan to build. It results in something real and tangible. It might be an architect's design for a house or a plan to change the direction of an organization, or – in the case of the Port of Long Beach (Port) – a plan to achieve a zero-emissions future.

The Port has adopted some of the world's most aggressive clean-air strategies, including goals of zero-emissions terminal equipment and trucks within the next 15 years. We have led the way in helping to develop and demonstrate emerging seaport technologies, in designing and constructing heavy-duty charging infrastructure, and in developing tools to inform our next steps. The Port Community Electric Vehicle Blueprint (Blueprint) is designed to accelerate the deployment of electrified transportation at local and regional levels with a holistic and forward-thinking view of regional transportation planning.

The Blueprint development was supported by a Guidance Committee including representatives from the Port's Environmental Planning, Finance, Engineering, Real Estate, and Commercial Operations, Southern California Edison (SCE), the National Renewable Energy Laboratory (NREL), Center for International Trade and Transportation (CITT), Pacific Merchant Shipping Association (PMSA), and the City of Long Beach, Office of Sustainability. Additionally, the Port established a broader stakeholder advisory group of environmental justice and community-based organizations, labor and workforce development groups, technology developers, original equipment manufacturers (OEMs), utilities, terminal operators, trucking companies, charging station and hydrogen fueling providers, regulatory agencies, and finance partners.

Process

The Blueprint was developed through a four-step process: 1) Pre-Plan Development; 2) Plan Development; 3) Final Plan; and 4) Knowledge Transfer. The Blueprint development process was structured to incorporate information from across a spectrum of relevant topic areas including: Uncertainty, Equipment/Vehicles, Infrastructure, Financing, Workforce Development, and Community.

Findings

The Blueprint resulted in the identification of near-term next steps – summarized and presented in the following tables – to advance the Blueprint's goals and objectives. Actions in **bold** require leadership from a stakeholder other than the Port itself, reaffirming the importance of the entire Port Community.

Zero-Emissions Equipment/Vehicles	
Inventory	Conduct annual equipment inventories to assess zero-emissions transition progress.
Baseline	Further develop specific duty and drive cycle information to better understand when one-to-one zero-emissions replacement of traditional technology can be achieved.
Demonstrate	Validate new technologies as they emerge in real-world testing.
Assess	Continue technology feasibility assessments on a regular basis as part of the CAAP.
Synthesize	**Develop and maintain, in partnership with other agencies, a library of port-specific data and synthesized analyses associated with zero-emissions port technologies.**
Accelerate	Work with major manufacturers to accelerate commercialization with standard warranties, parts replacement, and customer service.
Experience	Facilitate short-term demonstrations, ride-and-drive events, and tours for operators.
Scale	Explore bulk purchasing programs to scale production and reduce unit costs.
Engage	**Collaborate with other seaport communities in order to spur greater market acceptance.**
Drive	Implement the CAAP and monitor regulatory efforts to drive market acceptance.

Charging/Refueling Infrastructure	
Catalog	Maintain a detailed inventory of existing charging and fueling infrastructure.
Forecast	Update high-level assessments of new energy needs based on equipment performance and energy consumption learned through technology demonstrations.
Evaluate	Organize infrastructure providers to help stakeholder evaluate cost-effective solutions and demonstrate innovative charging options.
Standardize	**Work with associations and state agencies to drive the adoption of heavy-duty charging standards through funding eligibility requirements or other mechanisms.**
Adopt	As standards are developed, adopt these standards into the Port's design process.
Collaborate	**Collaborate on regional infrastructure plans for zero-emissions drayage trucks.**
Integrate	Continue to execute the Energy Initiative Roadmap and integrate zero emissions into the Port's Business Continuity Plan and Coastal Resiliency Planning efforts.
Secure	Engage security and law enforcement agencies to address cybersecurity concerns.
Design	Develop design plans with terminal operators for the zero-emissions transformation.
Execute	Execute design plans as lease opportunities arise and identify funding mechanisms or incentives to bring terminal operators to the table prior to a lease expiration.

Financial and Business Model Considerations	
Refine	Refine cost estimates as equipment matures and terminal design efforts are conducted.
Relate	**Support the development of more refined Total Cost of Ownership (TCO) calculations to better compare zero-emissions technologies to diesel technologies.**
Incentivize	Encourage the use of public funding programs, including LCFS, where necessary to promote early adoption of high-risk, initial-stage technologies.
Guide	Work with funding agencies to minimize barriers associated with grant funding programs.
Iterate	**Conduct outreach to the private and public finance stakeholders to ensure awareness of the opportunities and challenges associated with port projects.**
Innovate	**Identify innovative financing options and tools to help stakeholders calculate the benefits.**
Fund	Develop funding plans for each project in collaboration with operators.

Workforce Development	
Certify	Evaluate national certification programs for applicability to port-related projects and work with community colleges to offer certification trainings.
Train	Review and potentially expand programs that train the existing longshore workforce for electric-automotive mechanic positions.
Align	Align curriculum and training programs for the zero-emissions transition.
Champion	**Champion more funding for workforce education, training, and curriculum development.**
Support	Identify and address potential barriers to entry for the incumbent workforce, which may include financial assistance.

Community Benefits	
Document	Continue to monitor emissions benefits and support ways to better aggregate health outcome data to identify on-the-ground community health improvements.
Cultivate	Continue to support programs that hire Long Beach residents and disadvantaged workers to cultivate the local workforce.
Educate	Expand awareness of educational and career pathways to make sure local residents take advantage of workforce training and community hire programs.
Partner	Work with the City and community groups to identify opportunities to demonstrate second-life battery applications for community resiliency.
Advocate	Continue to partner with community groups to jointly advocate for zero-emissions policies and funding, where it makes sense.

1 About the Port Community Electric Vehicle Blueprint

A blueprint is a plan to build. It results in something real and tangible. It might be an architect's design for a house or a plan to change the direction of an organization, or – in the case of the Port of Long Beach – a plan to achieve a zero-emissions future.

The Port of Long Beach has adopted some of the world's most aggressive clean-air strategies, including goals of zero-emissions terminal equipment and trucks within the next 15 years. We have led the way in helping to develop and demonstrate emerging seaport technologies, in designing and constructing heavy-duty charging infrastructure, and in developing tools to inform our next steps.

We have laid the foundation. Now we need to build. The Port Community Electric Vehicle Blueprint (Blueprint) is a critical step toward making our zero-emissions future real and tangible.

This Blueprint reflects the unique character of our seaport community; incorporates lessons learned from our substantial progress to date; and defines concrete actions to help us achieve our ambitious zero-emissions goals. This Blueprint is meant to be:

- **Inclusive:** Just as a house cannot be built without carpenters, electricians, and painters, the Port's zero-emissions future cannot be built without a diverse ecosystem of independent stakeholders, from terminal operators and labor unions to environmental justice groups and finance agencies. The Port needs collaboration among all of these players to reach our goals, and this Blueprint reflects their input.

- **Replicable:** The Port would benefit from having other seaports join the move toward zero emissions to improve economies of scale and to broaden the market for the cleanest equipment. As such, we have developed this Blueprint to be replicated by other seaport communities, creating a "user's manual" for others to follow. The Blueprint includes helpful checklists, tips, tools, and case studies to assist other port communities in making the transition.

- **Dynamic and Iterative:** Each element of the Blueprint is informed by another element. Equipment has an impact on infrastructure. Infrastructure has an impact on workforce. Funding availability and costs have an impact on the scale of community benefits. Thus, the Blueprint is more aptly seen as a dynamic and iterative *process* rather than a static plan of action. As the Port learns more from early technology demonstrations and deployments, it must continue to work with its stakeholders to refine the Blueprint.

This plan represents the first-ever electric vehicle Blueprint for a seaport community. With no template to follow, we have charted our own path. Our hope is that this work can support other seaport communities as they move down the ambitious and exciting road to zero emissions.

2 Project Background

2.1 Introduction

California's interconnected system of ports, railroads, highways, and roads are responsible for one-third of the State's economic activity, with freight-dependent industries accounting for over $740 billion in gross domestic product and over five million jobs.[1] Maintaining the competitiveness of this economic engine is vital. Yet, freight transportation in California also generates a high portion of air emissions in parts of the state with poor air quality. Reducing these pollutants is an important local, regional, and State priority, as well as a matter of compliance with the federal Clean Air Act.

To that end, the Port of Long Beach has adopted the world's most aggressive strategies to reduce port-related air emissions, chiefly by accelerating the transition to zero emissions. The 2017 Clean Air Action Plan Update (CAAP), which was jointly adopted by the Boards of Harbor Commissioners for the Port of Long Beach and Port of Los Angeles, formalized the path to zero emissions with two key goals:

- Transition up to 100% of the terminal equipment to zero emissions by 2030
- Transition up to 100% of the drayage trucks to zero emissions by 2035

The path to achieving these goals will not be easy. Seaports are faced with unique constraints when deploying zero-emissions vehicles and equipment due to, among other factors, high energy demand, restrictive duty cycle requirements, and diverse tenant and operational interests. Even more, at most California seaports, including the Port of Long Beach, the port authorities do not typically own or operate the equipment targeted for zero-emissions transformation and thus must work with private operators to turn over equipment and vehicles and to install infrastructure suitable for a company's individual operations. Further complicating matters in this dynamic, 24/7 port environment, everything is interdependent, with an astonishingly broad array of light-, medium-, and heavy-duty equipment and vehicles in operation.

IN THE TOOLBOX

Setting concrete and measurable goals is a key step on the road to zero emissions. The **2017 Clean Air Action Plan Update**, which was developed with the Port of Los Angeles, describes the process, including stakeholder engagement, used to establish these goals and the resulting clean-air strategies. It can be a useful guide for other ports looking to do the same. Find it at *www.cleanairactionplan.org.*

No other seaport complex in the world has set such ambitious zero-emissions goals, and without significant and deliberate planning, the Port cannot achieve them.

To address this challenge, the Port of Long Beach has developed the Blueprint to establish a comprehensive strategy to assist in the identification of the most cost-effective technologies, financial incentives, and infrastructure upgrades for creating the model sustainable, zero-emissions port ecosystem of the 21st century. The Blueprint is designed to accelerate the deployment of electrified transportation at local and regional levels with a holistic and forward-thinking view of regional transportation planning.

[1] "California Sustainable Freight Action Plan," Brown Jr., Governor Edmund G., p. 1. http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/theplan.html

2.2 Project Goals

The goals of the Blueprint are:

1. **Establish a comprehensive, yet nimble, strategy to assist in the identification of the most cost-effective technology suites, financial incentives, infrastructure upgrades, and equipment mixes for creating the model sustainable, zero-emissions port ecosystem of the 21st century.**
    - Establish communication pathways between technology developers and terminal operators to share information about duty and drive cycles, performance demands specific to the Port Community, and facilitate awareness of best-in-class-technologies.
    - Establish communication pathways between zero-emissions fueling providers, terminal operators, utilities (including SCE and hydrogen distributers), and Port engineering staff to develop technology standards and best-practices to serve off-road heavy-duty equipment within the Port Community.
    - Evaluate private financing opportunities that have been developed in the light- and medium-duty sectors for potential opportunity within the Port Community for both equipment fleets and/or infrastructure (e.g. using Low Carbon Fuel Standard (LCFS) credits, power purchase agreements, etc.).
    - Strategically identify public funding that can support early-stage demonstration and information gathering for priority projects that will de-risk the transition to zero-emissions technologies.
2. **Accelerate the deployment of zero-emissions transportation at local and regional levels with a holistic and forward-thinking view of regional transportation planning.**
    - Build the zero-emissions transition into the Port's internal work structure to establish milestones and actionable steps towards the zero-emissions transition.
    - Establish the Port as a local and regional champion of zero-emissions technologies and infrastructure in the Port's visitor serving areas (e.g. Queen Mary). As a local and regional champion, support efforts to prepare the workforce and local businesses for the zero-emissions transformation.
    - Develop energy management strategies to prepare for the influx of new energy (increased electricity consumption and new hydrogen utilization).
    - Work with regional stakeholders to develop the infrastructure and network needed to support the Port's zero-emissions on-road truck goals.
3. **Propagate, organize, and simplify the process of transitioning one of the world's busiest seaports to zero-emissions operations.**
    - Establish strategic pilot/demonstration goals with terminal operators to learn about and evaluate new technologies, solidifying the Port's statewide position as an early adopter and zero-emissions technology advocate.

- Structure master planning efforts to prepare for the zero-emissions transition and terminal operator lease negotiations.
- Establish workforce development partnerships to prepare relevant stakeholders for the introduction and operation of new zero-emissions technologies.

2.3 Project Scope: The Port Community

The Port of Long Beach is the second busiest port in the United States. The Port provides economic benefits at the local, regional, state, and national levels by supporting more than 50,000 jobs in Long Beach, nearly 580,000 jobs throughout Southern California, and 2.6 million jobs throughout the United States.[2] The Port's robust economic activity, however, has an impact on the communities surrounding these operations. While the Port (Figure 1) has a positive effect on neighboring communities by providing high-paying jobs and generating significant local tax revenues, it also has environmental and public health impacts on the surrounding communities through increased air, noise, light, and water pollution, as well as the disruption of local transportation systems.[3]

Figure 1: Geographic Boundaries of the Blueprint – Harbor District of the Port of Long Beach

[2] EDR Group, "Port of Long Beach Economic Impact Study," January 31, 2019. Available at http://www.polb.com/civica/filebank/blobdload.asp?BlobID=14938

[3] ICF International. 2016. Port of Long Beach Community Impact Study. April. (ICF 683.15.) San Diego, CA. Prepared for Port of Long Beach, Long Beach, CA. p. 1-1. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=13319

The Port has made important strides to mitigate these negative environmental impacts through its Green Port Policy, as well as through project-specific mitigation measures implemented as requirements of the California Environmental Quality Act (CEQA). Over the last decade, the Port has been a leader in addressing its environmental and public health impacts through such groundbreaking efforts as the CAAP and the Water Resources Action Plan (WRAP), which contain numerous aggressive and innovative pollution-reduction strategies.

The Port's success is evident. Since 2005, Port-related air pollution is down 87%, and the San Pedro Bay is home to a thriving array of plant and animal life. The Port recognizes, however, that its environmental impacts have had years to accumulate, and even the Port's cutting-edge and aggressive mitigation efforts do not fully address the cumulative effects of Port operations on neighboring communities.[4]

To identify both the direct impacts of Port-related operations on the local community and community-based mitigation measures to relieve these impacts, the Port conducted a Community Impact Study (CIS) in 2016. The CIS identified Port-related community impacts through a CEQA-like analysis that used quantitative and qualitative, industry-accepted technical methodologies to demonstrate a connection between Port operations, the impact on the community, and possible ways to reduce these impacts. The CIS examined community impacts outside the Harbor District. Some key findings include[5]:

- Port-related operations have a direct impact on criteria pollutant and greenhouse gas (GHG) emissions in the community;
- Population-weighted cancer risk associated with operations at the Port of Long Beach averages 66 in a million, rising to an average of 143 in a million for residents living within approximately 1.25 miles of the port and major goods movement routes;
- The area experiencing the most significant Port traffic impact encompasses areas within about 10 miles of the Port. These areas experience approximately 371,939 daily vehicle miles traveled (VMT), equating to 102,283,225 VMT over the course of a year;
- Noise from Port-related trucks exceeds 65 dBA L_{dn} (a common threshold for excessive noise) at land uses directly adjacent to many of the roadways in the affected region; and
- Locations where Port trucks make a perceptible or noticeable increase to the overall traffic noise levels are generally located within about 5 miles of the Port.

Because Port impacts extend beyond its perimeter, the Port determined that its Blueprint had to include the Harbor District (Figure 1), which includes hotels and the Long Beach Carnival Cruise Ship Terminal, but must also consider the possible impacts on and benefits to adjacent residential, commercial, and industrial areas – including many census tracts categorized as disadvantaged area communities – and the immediate vicinity of driving routes into the Port.

2.4 Project Team

Given the complexity of advancing zero emissions in a heavy-duty port environment comprised of loosely connected stakeholders, the Port could not be successful in developing a Blueprint without the support

[4] ICF International. 2016. Port of Long Beach Community Impact Study. April. (ICF 683.15.) San Diego, CA. Prepared for Port of Long Beach, Long Beach, CA. p. 1-1. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=13319

[5] ICF International. 2016. Port of Long Beach Community Impact Study. April. (ICF 683.15.) San Diego, CA. Prepared for Port of Long Beach, Long Beach, CA. p. 1-1. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=13319

of others. To that end, the Port assembled a Guidance Committee consisting of highly-qualified and diverse industry experts.

- **Port of Long Beach** representatives from Environmental Planning, Finance, and Engineering provided project oversight, insight into Port operations, and strategy;
- **SCE** provided insight on how the Blueprint might impact grid and utility rates, accounting for behavior and increasing loads from vehicle electrification while achieving community energy savings and zero net energy community status;
- **NREL** evaluated power demand and impact analysis, identified relevant analytical tools and models;
- **CITT** identified workforce development needs and opportunities;
- **PMSA** represented the needs of terminal operators and shipping companies in relation to transportation electrification; and
- **City of Long Beach, Office of Sustainability** provided insight on the tourist-serving areas of Long Beach, including the hotels and Queen Mary.

The Port enlisted The Grant Farm to manage the Blueprint planning, outreach, and development. Additionally, the Port established a broader stakeholder advisory group of environmental justice and community-based organizations, labor and workforce development groups, technology developers, major manufacturers (OEMs), utilities, terminal operators, trucking companies, charging station manufacturers, hydrogen fuel providers, regulatory agencies, and finance organizations (Table 1).

Table 1: Current Active and Engaged Stakeholder List

Stakeholder Group	Stakeholders		
Technology Developers	Build Your Dreams (BYD)	Cavotec	Conductix Wampfler
	Cummins, formerly Electric Drivetrains Inc. (EDI)	DANNAR	General Electric Transportation
	Lightning Systems	Nikola	Plug Power
	Siemens	Thermo King	Thor
	TransPower	Unique Electric Solutions	US Hybrid
Major Manufacturers	Capacity	Hyster	Kalmar
	Kenworth	Nordco	Peterbilt
	Taylor Machine Works	Tesla	Toyota
	Volvo	Wiggins	ZPMC (Shanghai Zhenhua Heavy Industries Co.)
Utilities	SCE		
Terminal Operators	International Transportation Services (ITS)	Long Beach Container Terminal (LBCT)	PMSA
	SSA Marine	Toyota	Total Terminals International (TTI)
Trucking	Harbor Trucking Association	Shippers Transport Express	

Stakeholder Group	**Stakeholders**		
Charging Station Manufacturers	ABB	BTCPower	ChargePoint
	CharIN	Clipper Creek	EVgo
	Efacec	eMotorWerks	FreeWire
	Greenlots	Innogy	Schneider Electric
	Siemens	Tritium	Wave IPT
Hydrogen Fueling	Air Liquide	Air Products	California Fuel Cell Partnership
	Linde	NEL Hydrogen	ITM Power
	Shell	Stratos Fuel	
Labor & Workforce	International Brotherhood of Electrical Workers (IBEW)	International Longshore and Warehouse Union (ILWU)	Pacific Maritime Association (PMA)
	CITT		
Community-Based Organizations & Environmental Justice	East Yard Communities	Earthjustice	Natural Resources Defense Council
	Coalition for Clean Air		
Regulatory Agencies	South Coast Air Quality Management District (SCAQMD)	California Air Resources Board (CARB)	California Energy Commission (CEC)
	California Public Utilities Commission (CPUC)	United State Environmental Protection Agency (EPA)	
Financing Organizations	Amply	Andeavor	Bluesource
	California Pollution Control Finance Authority (CPCFA)	CALSTART	Crossroads Financial
	Diode Ventures	Dynamic Energy Networks	Exelon Ventures
	GE Power	GEF Capital Partners	Generate Capital
	Hydrogen Partners	Iron Oak Finance	Marquarie Capital
	Milken Institute	National Grid Ventures	PRAG Advisors
	Schneider Electric	State Treasurer's Office	Wells Fargo
	Westoff, Cohn & Holmstedt		

2.5 Blueprint Process

The Blueprint was developed through a four-step process: 1) Pre-Plan Development; 2) Plan Development; 3) Final Plan; and 4) Knowledge Transfer (Figure 2). Pre-Plan Development included a baseline data collection phase to accumulate the existing resources, activities, and knowledge available to the Port stakeholders; the Research Report can be found in Appendix A. Preliminary data collection included outreach to key stakeholders to create a metric by which to evaluate the successes of Blueprint activities.

Figure 2: Blueprint Development Process

The Blueprint development process was structured to incorporate information from across a spectrum of relevant topic areas:

- **Technology**: Technologies represent the equipment and components that will be deployed to successfully achieve the CAAP goals. A defined approach to technology, including equipment analysis, demonstration projects, and feasibility assessments, are an important aspect of the Blueprint.

- **Infrastructure**: The transition to zero-emissions technologies requires the adoption of new energy sourcing, requiring significant infrastructure improvements. The Port needs to create a pathway to balancing the long-lead-time nature of major capital improvement projects with a rapidly changing technology ecosystem. Infrastructure, as it relates to the Blueprint, includes standardization of fueling/charging infrastructure, site specific analyses, cybersecurity concerns, energy resiliency, and integration into the Port's well-established capital improvement process.

- **Financing**: The zero-emissions transition is projected to cost billions of dollars in capital costs to adopt new technologies and to install new infrastructure. While the Port has access to significant capital, additional financing models will be important to limit risk associated with technology deployments and to accelerate the timeline for technology and infrastructure adoption.

- **Workforce**: The Port supports a robust economic hub in the South Coast region, supporting hundreds of thousands of workers. The transition to zero emissions will require the workforce to adopt new protocols and procedures to operate, maintain, and service new equipment. Education is the key component to successful inclusion of the workforce. With thousands of impacted workers, the Port must proactively develop strategies to prepare the workforce well before large-scale technology deployments occur.

- **Community**: The Port has identified a broad and expansive list of stakeholders across the Port Community. The success of the zero-emissions transition is predicated on the community working together to achieve a goal that is primarily based on environmental stewardship but also key economic and equity metrics.

3 Framing the Blueprint

Transitioning to zero emissions in a port community is fraught with uncertainty. With few exceptions, much of the port-suitable zero-emissions equipment remains in the prototype phase and, even when commercialized, faces a tough working environment with ambiguous long-term operations and maintenance costs. To complicate matters, heavy-duty infrastructure standards are still under development and detailed understanding of workforce implications are only now beginning to emerge.

The Port's ability to achieve its 2030 and 2035 zero-emissions goals is dependent on identifying the risks and uncertainty ahead and more importantly mitigating them. To do that, the Port must engage in a thoughtful process to uncover the main barriers and identify opportunities.

The Blueprint Engagement Report (Appendix B) started this process by identifying the Port Community's understanding of and expectations for zero emissions across a wide range of issue areas. Stakeholders expressed a high degree of uncertainty around zero-emissions equipment costs, the availability of necessary infrastructure, and the long-term benefits of transitioning to a zero-emissions future. The discrepancies in stakeholder expectations and understanding of the issues underscored the need for robust analysis and planning before forging ahead.

To further refine these uncertainties, the Port built upon this initial survey by conducting a more targeted risk assessment analysis, as summarized here and described in more detail in Appendix C.

3.1 Methodology for Assessing Uncertainty

To understand the challenges and opportunities ahead, the Port conducted a qualitative and quantitative assessment modeled after traditional risk assessment. Risk assessment is the systematic process of planning for, identifying, analyzing, responding to, mitigating, and monitoring project risks. Risk assessments are most effective when performed early in the life of the project and throughout the project's life cycle.

The Port uses a holistic approach to assess risk for major construction and development projects in order to identify potential positive and negative impacts on budget, schedule, scope, and stakeholder acceptance as described in the Port's Risk Assessment Manual (2014).[6] The Port's risk assessment approach, which is well integrated into the design and construction process, will be used for specific zero-emission-related infrastructure projects when the time comes. But this process can also be useful for identifying the high-level programmatic challenges and opportunities associated with zero emissions. To that end, the Port adapted and adopted the engineering risk assessment framework to evaluate the challenges and opportunities inherent in the zero-emissions transition, allowing the Port to predict and manage uncertainty.

The uncertainty is categorized upon a scale of likelihood (Table 2) and impact (Table 3). Likelihood measures the chance of event occurrence. Impact measures the gravity of the impact across six categories: Safety and Health, Environment, Financial, Schedule, Reputation, and Operational/Business Impact.

[6] Available for download at: http://www.polb.com/civica/filebank/blobdload.asp?BlobID=14377

Table 2: Uncertainty Assessment Likelihood

Likelihood Category				
A	**B**	**C**	**D**	**E**
The event is very likely to occur (95% chance of occurring)	The event is likely to occur (80% chance of occurring)	The event has occurred on a similar project (50% chance of occurring)	Given current practices and procedures, this even is unlikely to occur (20% chance of occurring)	Highly unlikely to occur (5% chance of occurring)

Table 3: Uncertainty Assessment Category

Impact				
1 – Insignificant	**2 – Minor**	**3 – Moderate**	**4 – Major**	**5 – Highly Significant**
No impact or minimal impact	Localized, short term, impact duration in the scale of months	Localized, long-term impacts, lasting a year	Localized, long-term impacts, lastly multiple years or long-term regional impact lasting a year	Long term regional impact, lastly multiple years

The complete sequence of risk management protocols includes a four-step process, which is described in the Port Risk Assessment Manual and modified for the Blueprint in order to gauge uncertainty and to assess challenges and opportunities ahead.

3.2 Uncertainty Assessment

The Blueprint Uncertainty Questionnaire was developed to attempt to understand many factors impacting the transition to zero-emissions operations. The prompts are outlined in detail in the Uncertainty Assessment (Appendix C). The questionnaire was distributed to the stakeholders identified in Table 1. The information collected from the questionnaire was used to identify where there was agreement and disagreement among stakeholders and to identify the greatest uncertainties. Key findings are summarized in this section.

3.2.1 Importance

Importance was measured as a combination of high likelihood of occurrence and high impact. The factors that were considered to have the greatest importance were:

- Adoption of zero-emissions technology improves air quality and public health;
- Warranties for zero-emissions equipment adequately protect the purchaser/lessor;
- 100% zero-emissions terminal equipment is deployed successfully by 2030;
- The upfront cost of purchasing/leasing zero-emissions equipment is significantly more than traditional equipment; and
- There are enough qualified personnel for the operation and maintenance of zero-emissions equipment.

3.2.2 Consistency of Responses

Similar to the analysis in the Engagement Report, responses from the uncertainty questionnaire were analyzed to see how consistently respondents selected likelihood and impact rankings. The consistency level of the responses was used as a measure of agreement among stakeholders. The factors with the highest level of response consistency were:

- Adoption of zero-emissions technology improves air quality and public health;
- Warranties for zero-emissions equipment adequately protect the purchaser;
- Upfront cost of purchasing/leasing zero-emissions equipment is significantly more than traditional equipment;
- 100% zero-emissions terminal equipment is deployed successfully by 2030;
- The lack of noise will not lead to an increase likelihood of collisions/accidents; and
- Adoption of zero-emissions technology creates increased job opportunities in the local area to service the new technology.

The factors with the lowest level of response consistency were:

- Non-traditional financing of zero-emissions equipment assigns rights to financing parties other than the owner/operator;
- Purchasers find that their revenue increases after adoption of zero-emissions equipment;
- Terminal operators must engage in/adapt to significant operational changes to achieve zero-emissions terminal equipment goals (e.g. yard reconfiguration, moving piers);
- The adoption of zero-emissions equipment results in increased insurance costs due to the higher cost of electric equipment, limited qualified maintenance facilities, and general unfamiliarity by insurance providers;
- Purchasers find that their costs increase after adoption of zero-emissions equipment;
- Adoption of zero-emissions terminal equipment reduces the flexibility of your operation to make changes; and
- Zero-emissions equipment is unlikely to cause operational disruption.

These inconsistencies represent areas that may require more investigation, stakeholder engagement, or concerted action to drive the Port Community toward a common understanding of the risks and opportunities associated with transitioning to zero emissions and, more importantly, to the solutions.

3.3 Uncertainty as a Driver for the Blueprint

The Blueprint is separated into five segments: Vehicles/Equipment, Infrastructure, Finance, Workforce, and Community Benefits. For each of these segments, the Blueprint discusses a logical and stepwise process that can be followed to responsibly make choices that will overcome uncertainties and advance the zero-emissions goals. Short-term action steps are identified in addition to a discussion of the broad overall trajectory of zero emissions.

4 Zero-Emissions Equipment and Vehicles

The Port is leading an effort that will require equipment and vehicles that have never before been demonstrated or, in many cases, even built. Zero-emissions technologies, particularly for the heavy-duty sector, have only recently appeared on the market after significant advancements in battery and fuel cell technologies. Evaluating and incorporating new technologies adds a unique layer of complication as the Port Community monitors new innovations, evaluates technical and operational feasibility, and considers, in real-time, the technologies needed to make lasting changes to their core business models.

As part of the CAAP, the Port has already initiated actions to support technology development and technology acceptance consistent with the CAAP goals. This section captures and outlines a strategic process that any port can use to support the development of zero-emissions technologies suitable for the port environment, and – equally as important – to garner acceptance of these technologies through the Port Community, particularly from operators:

1. Establish a Baseline
2. Identify Priorities
3. Evaluate Technologies
4. Create Market Acceptance

This strategic process applies to both heavy-duty and light-duty technologies, although the Port acknowledges that its sphere of influence is significantly greater with heavy-duty technologies.

4.1 Establish a Baseline

The Port maintains a database of equipment operating in and around the Port. As part of its annual emissions inventory,[7] the Port also quantifies the air emissions impacts of the equipment. Establishing the equipment and environmental baseline provides clear metrics to measure success and improvement and is critical to developing a strategy that can target areas of concern.

There are more than 1,400 pieces of terminal equipment operating at the Port, everything from yard trucks and forklifts, to excavators and cranes. A summary of terminal equipment data is presented in Table 4. "Other" electric equipment includes ship-to-shore cranes, automated guided vehicles (AGVs), and automatic stacking cranes.

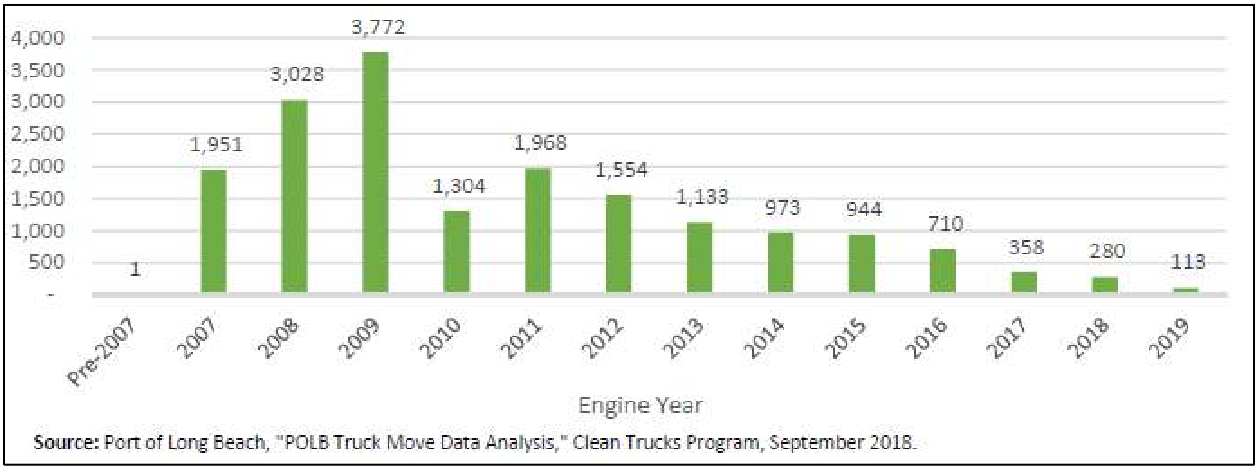
Table 4: Port Equipment Counts by Fuel Type

Equipment	Electric	Propane	Gasoline	Diesel	Total
Forklift	9	109	24	104	**246**
RTG Crane	0	0	0	67	**67**
Side Handler	0	0	0	13	**13**
Top Handler	0	0	0	195	**195**
Yard Tractor	0	7	80	564	**651**
Sweeper	1	6	0	6	**13**
Other	168	6	2	47	**223**
Total	**178**	**128**	**106**	**996**	**1,408**
Percent of Total	**13%**	**9%**	**8%**	**71%**	

[7] 2017 Emissions Inventory, www.polb.com/emissions

Figure 3 presents data for the drayage truck fleet. There are roughly 17,000 trucks that serve the port complex. About 3% of the active drayage fleet (roughly 360 trucks) is fueled by liquefied natural gas.[8]

Figure 3: Summary of Trucks with Access to Port of Los Angeles and Port of Long Beach by Engine Year



Overwhelmingly, equipment and vehicles operating at the Port are fueled by diesel, which has significant air quality and public health impacts. The Port can use the baseline data to develop informed priorities for reducing these impacts and to monitor progress toward the zero-emissions goals.

4.2 Identify Priorities

The Blueprint is focused on the implementation of CAAP clean-air goals. As such, the data collected in the 2017 emissions inventory provide information that can be used to establish Port of Long Beach-specific priorities for the Blueprint.

4.2.1.1 Terminal Equipment

To determine priority equipment, the Port aggregated emissions data by equipment type. Figure 4 and Figure 5 present the emissions profile by gross emissions by equipment type (orange dot), cumulative emissions (grey line), and population count (blue bar) for nitrogen oxides (NOx) (Figure 4) and GHGs (Figure 5).

[8] Port of Long Beach, "POLB Truck Move Data Analysis." Clean Trucks Program. March 2019. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6591

Figure 4. Emission Profile of Terminal Equipment: NOx Emissions

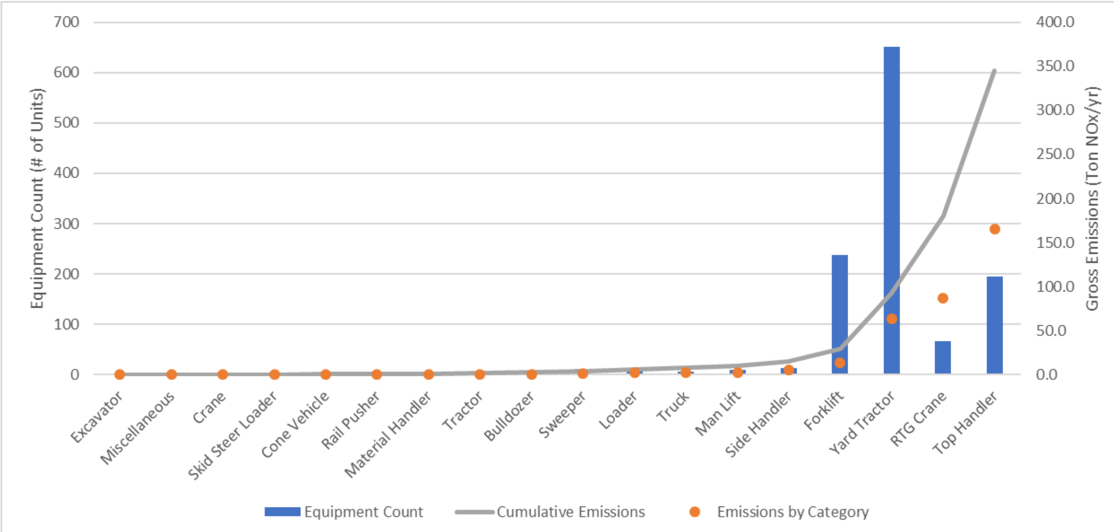
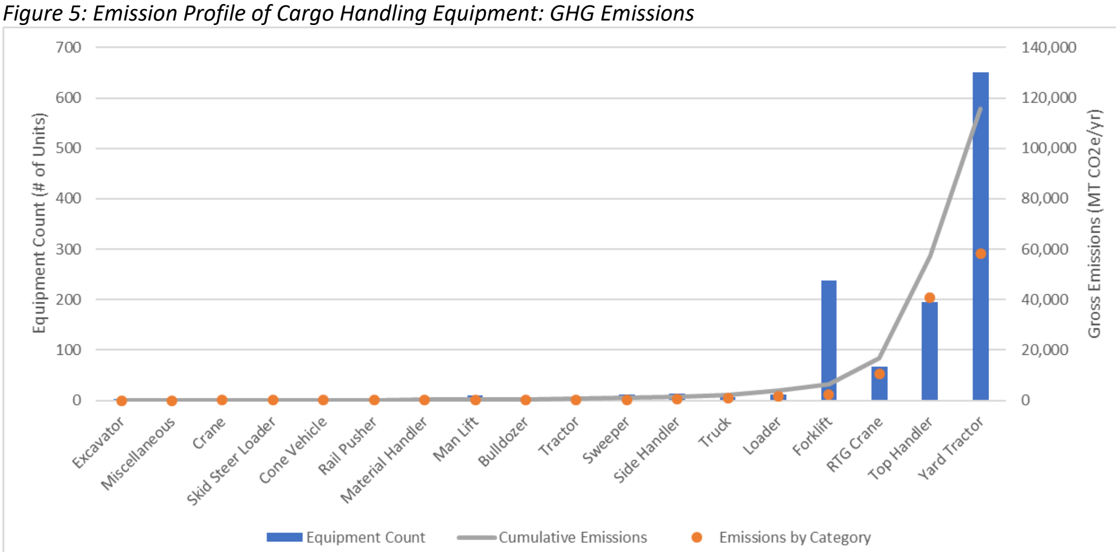


Figure 5: Emission Profile of Cargo Handling Equipment: GHG Emissions



The data show three equipment types – yard tractors, top handlers, and rubber-tired gantry (RTG) cranes – generate more than 91% of NOx emissions and nearly 95% of terminal equipment emissions while only representing 74% of the total fleet count. RTG cranes and top handlers, in particular, represent a disproportionate amount of emissions per unit in operation (Table 5). As such, RTG cranes and top handlers have been identified as priority equipment for the Blueprint. Additionally, yard tractors have been identified as a priority because of their large contribution to GHG emissions.

Table 5: Proportion of Emissions by Major Equipment Types

	NOx Emissions	GHG Emissions	Fleet Population
Yard Tractors	19%	50%	53%
RTG Crane	25%	9%	5%
Top Handler	48%	35%	16%

Using this prioritization framework, the Blueprint recommends a focused approach on three terminal equipment types, which are primarily found at container terminals:

- Yard Tractors;
- RTG Cranes; and
- Top Handlers.

To a lesser extent, forklifts also will be considered.

4.2.1.2 Drayage Trucks

As of late 2018, there were about 17,500 registered Class-8 trucks in the San Pedro Bay Ports' drayage fleet. Traditionally, the active fleet ranges from about 11,000 to 13,000 drayage trucks, due to seasonal demand changes among other factors.

Figure 3 (above) presents the distribution of engine model year within this fleet, with roughly half of these active trucks powered by engines that are model year 2010 or newer.

Today, the San Pedro Ports drayage fleet is dominated by conventional Class 8 trucks powered by heavy-duty diesel-fueled internal combustion engines. About 3% of the active drayage fleet (about 360 trucks) is fueled by liquefied natural gas.[9] The San Pedro Bay Ports Clean Truck Program has successfully modernized the fleet to 2007 and newer; however, as shown in Figure 3 (above), nearly 50% of the trucks are engine year 2007 through 2009. This decade-old fleet is preparing for replacement and the near-term guidance given by the CAAP will impact purchase decisions. The 2017 emissions inventory identifies the breakdown of VMT by cargo type; a summary is presented in Table 6.

Table 6: Vehicle Miles Traveled by Cargo Type

Terminal Type	Total Miles Traveled	% of Total	Total Hours Idling	% of Total
Auto	5,656	0.2%	9,721	0.4%
Break Bulk	8,472	0.3%	4,032	0.2%
Container	2,559,515	98%	2,372,606	99%
Dry Bulk	13,065	0.5%	1,126	0.0%
Liquid Bulk	9,875	0.4%	4,695	0.2%
Other	5,270	0.2%	8,701	0.4%
TOTAL	**2,601,853**		**2,400,881**	

[9] Port of Long Beach, "POLB Truck Move Data Analysis." Clean Trucks Program. March 2019. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6591

CASE STUDY

The Role of Hybrid-Electric Technology

The path to zero emissions could benefit from near-term investments in hybrid-electric systems, which – although not emissions-free – lay a foundation for full battery-electric equipment by integrating electric drivetrains, introducing the workforce to electric systems, and generating near-term emission reductions for the community. RTG cranes offer a good example of this technology evolution.

At Pier J, SSA Marine – with support from the CEC – is retrofitting its RTG cranes from diesel-powered to grid-tied electric. RTG cranes are one of the only diesel-powered pieces of terminal equipment that are traditionally designed with an electric drivetrain. In this configuration, the diesel engine generates electricity that powers the motor as opposed to the mechanically-driven configurations used in most other diesel-powered equipment.

Because the electric drivetrain is already in place, the RTG cranes can be more easily converted to zero-emissions by replacing the diesel generator with another zero-emissions source, in this case, a grid-tied cable management system. Alternative zero-emissions solutions could include fuel cells or batteries.

Hybrid-electric equipment is an interim step toward full electric but can be deployed quickly, without additional infrastructure, and at relatively little cost. Indeed, although SSA Marine is fully electrifying RTG cranes at Pier J, it is investing in hybrid RTG cranes at Pier A, where inadequate electrical infrastructure makes full-electric cost prohibitive at this time. As battery and fuel-cell technology improves, SSA will be well poised to convert these hybrids to full-electric.

In these early years, the Port Community should continue to evaluate the benefits of hybrid-electric RTG cranes, and possibly other large lifting equipment such as top handlers, to ease the transition to full electrification.

More than 98% of the VMT are associated with container terminal operations. Thus, the Blueprint recommends a focused approach on drayage trucks serving container terminals, which is consistent with the CAAP and Clean Trucks Program.

4.3 Evaluate Technology Development

Port equipment operates in a harsh and demanding environment, and duty and drive cycles within the Port Community are some of the most challenging in the transportation industry. The operational profile differs substantially from the light-duty sector, where zero-emissions technologies are most advanced, thus posing unique challenges for port-related technology development.

This section offers a framework for evaluating port-related zero-emissions equipment and trucks using assessments and demonstrations; summarizes the current state of zero-emissions technology based on this framework; and identifies potential gaps.

4.3.1 Technology Assessments

To assess the state of zero-emissions technologies, the San Pedro Bay Ports – as part of the CAAP – committed to evaluating the state of zero-emissions terminal equipment and drayage trucks on a regular basis. To that end, the Ports developed the "Framework for Developing Feasibility Assessments" in November 2017.[10] This framework outlines how the Port considers the following:

- Technical viability;
- Operational feasibility;
- Availability of supporting infrastructure and fuels;
- Key economic considerations (e.g. total cost of ownership (TCO), cost effectiveness); and
- Commercial availability.

These feasibility assessments are developed by an outside technical expert with third-party review from two other experts and the major air-quality regulatory agencies. Additionally, the assessments are released in draft form for public comment. This framework, as developed for the CAAP, is appropriate for this Blueprint and is broadly applicable across all California ports.

In 2019, the San Pedro Bay Ports completed the first feasibility assessments for terminal equipment and drayage trucks.[11] The assessments take a two-step approach for evaluating zero-emissions technologies. First, technologies are screened for technical viability and commercial availability. To be considered "commercial," a product must be offered by a major manufacturer or the equivalent. Second, technologies that pass the screening phase are evaluated against the remaining parameters.

Importantly, the assessments represent a snapshot in time, specifically the three-year increments beginning in 2018. The Blueprint is a long-term effort. Findings from the 2019 assessments are not intended to eliminate certain technologies from the discussion; instead they should be used to guide the actions necessary to achieve the zero-emissions goals of 2030 and 2035 for all viable technology platforms.

These findings will be updated every three years, if not more regularly. The reports are publicly available on the CAAP website. A summary of the findings is provided in Sections 4.3.1.1 and 4.3.1.2.

4.3.1.1 Terminal Equipment

The terminal equipment feasibility assessment screened four types of equipment for commercial availability and technical viability – yard tractors, top handlers, RTG cranes, and heavy-duty forklifts. Additionally, the assessment conducted a high-level, qualitative assessment of small forklifts.

Only two zero-emissions platforms passed the screening test for commercial availability and technical viability: battery-electric yard tractors and electric RTG cranes. These types of equipment were further analyzed for operational feasibility, infrastructure availability, and economic workability. The draft results for operational feasibility can be found in Table 7. Results for infrastructure availability and economic workability can be found in Sections 5 and 6 respectively.

[10] "Framework for Developing Feasibility Assessments," http://www.cleanairactionplan.org/documents/feasibility-assessment-framework.pdf/
[11] San Pedro Bay Ports Clean Air Action Plan, 2018 Feasibility Assessment for Drayage Trucks. April 2019. http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/

Table 7: Summary of Draft 2018 Findings for Terminal Equipment Operational Feasibility

"Operational Feasibility" Criteria	Base Considerations for Assessing "Operational Feasibility"	Yard Tractors		RTG Cranes	
		ZE BE	NZE NG ICE	ZE Grid-Electric	NZE Hybrid-Electric
Basic Performance	Demonstrated capability to meet MTO needs for basic performance parameters including power, torque, speed, operation of accessories, etc.	◑	●	●	●
Fuel Economy and Endurance	Demonstrated capability to achieve per-shift and daily operating time requirements found at San Pedro Bay terminals.	◔	●	●	●
Speed and Frequency of Refueling / Recharging	Demonstrated capability to meet MTO needs for speed and frequency to refuel / recharge such that revenue operation is not significantly reduced relative to diesel baseline.	◔	◕	◕	●
Operator Comfort, Safety, and Fueling Logistics	Proven ability to satisfy typical MTO needs for comfort, safety and refueling procedures.	◑	◕	●	●
Availability of Replacement Parts and Support for Maintenance / Training	Verifiable existence of and timely access (equivalent to baseline diesel) to all replacement parts needed to conduct scheduled and unscheduled maintenance procedures.	◑	◕	●	●

Legend: Operational Feasibility (2018)

○ ◔ ◑ ◕ ●

Little/No Achievement — Fully Achieved

Source: Estimated ratings are based on MTO interviews and site visits, footnoted studies, OEM product information, various government sources, and consultant's industry knowledge.

4.3.1.2 Drayage Trucks

The findings for drayage trucks are summarized in three key graphics: commercial availability (Table 8), technical viability (Table 9), operational feasibility (Table 10). Results for infrastructure availability and economic workability can be found in Sections 5 and 6 respectively. Notably, the assessment found that fuel cell trucks did not meet commercially-available thresholds and the technology was not reviewed for operational feasibility, infrastructure availability, and economic workability.

Table 8: Summary of Findings for 2018 Commercial Availability of Drayage Trucks

Commercialization Criteria	Base Considerations	Assessment of Criteria Achievement in 2018 by Leading ZE and NZE Fuel-Technology Drayage Truck Platforms				
		ZE Battery-Electric	ZE Fuel Cell	NZE Hybrid Electric	NZE NG ICE	NZE Diesel ICE
Production and Sales with Major OEM Involvement	Production and full certification by either a major Class 8 truck OEM, or by a proven technology provider that has partnered with the major OEM.	◑	◕	○	●	○
Proven Network / Capabilities for Sales, Support and Warranty	Demonstrated existing (or near-term planned) network of sufficient dealerships to sell, service, warranty and provide parts for all commercially deployed drayage trucks.	◑	◑	◑	●	●
Sufficient Means and Timeline for Production	Demonstrated capability to manufacture sufficient numbers of Class 8 trucks (suitable for drayage) within timeline to meet existing or expected demand.	◑	◔	◑	●	◑
Existence of Current and/or Near-Term Equipment Orders	Demonstrated backlog of orders, or credible expression of interest from prospective customers to submit near-term orders.	◑	◑	◔	●	○

Legend: Commercial Availability (2018)

○ Little/No Achievement — ◔ — ◑ — ◕ — ● Fully Achieved

Source of Ratings: based on OEM survey responses, OEM product information, various government sources, and consultant's industry knowledge.

Table 9: Summary of Findings for 2018 Technical Viability of Drayage Trucks

TRL	Relative Stage of Development	Late-2018 TRLs for Leading Fuel-Technology Platforms (Drayage)	~2021: Educated Prognoses (by or before)	Comments / Basis for 2021 Educated Prognosis
TRL 9	**Systems Operations**		NZE NG ICE (TRL 9)	**NZE NG ICE:** to reach TRL 9 in Class 8 port drayage, new NZE 12-liter engine <u>needs operational time</u>
TRL 8	**Systems Conditioning**	NZE NG ICE (TRL 8)	ZE Battery (TRL 8)	**ZE Battery Electric:** strong progress in transit bus / MDV sectors is likely to advance Class 8 drayage use; ongoing range challenge may <u>limit</u> to short-haul applications
TRL 7		ZE Battery (TRL 6 to 7)	ZE Fuel Cell or NZE Plug-in Hybrid (TRL 7??)	**ZE Fuel Cell:** biggest remaining hurdles relate to total cost of ownership, including access to / on-board storage of hydrogen fuel; **NZE Plug-in Hybrid:** prognosis is a wild card; OEM interest is hard to gauge, but plug-in architecture enables valued "zero-emission mile" capability
TRL 6	**Technology Demonstration**	ZE Fuel Cell or NZE Plug-in Hybrid (TRL 5 to 6)	NZE Diesel ICE (TRL 5, or higher?)	
TRL 5	**Technology Development**	NZE Diesel ICE (TRL 5)		**NZE Diesel ICE:** <u>could</u> **"leapfrog"** to TRL 8 or 9, but <u>only if</u> suitable diesel engine(s) get certified to 0.02 g/bhp-hr NOx (or other CARB OLNS)
TRL 4				

Source: TRL methodology adapted from U.S. DOE, "Technology Readiness Assessment Guide, Table 1: Technology Readiness Levels, September 2011 (see footnote). TRL ratings estimated based on input from 1) OEM surveys, 2) various technical reports, 3) demonstration activities, and 4) meetings with agency technical personnel (CARB, CEC, SCAQMD).

Table 10: Summary of Findings for 2018 Operational Feasibility of Drayage Trucks

Operational Feasibility Criteria / Parameter	Base Considerations for Drayage Platforms to Achieve Operational Feasibility	Achievement of Criteria in 2018 for Commercially Available Drayage Truck Platforms	
		ZE Battery-Electric	NZE NG ICE
Basic Performance	Demonstrated capability to meet drayage company needs for basic performance parameters including power, torque, gradeability, operation of accessories, etc.	◕	◕
Range	Demonstrated capability to achieve per-shift and daily range requirements found in San Pedro Bay drayage.	◑	●
Speed and Frequency of Refueling / Recharging	Demonstrated capability to meet drayage company needs for speed and frequency to refuel / recharge such that revenue operation is not significantly reduced relative to diesel baseline.	◔	●
Driver Comfort, Safety, and Refueling Logistics	Proven ability to satisfy typical drayage trucking company's needs for comfort, safety and refueling procedures.	◕	●
Availability of Replacement Parts and Support for Maintenance / Training	Verifiable existence of and timely access (equivalent to baseline diesel) to all replacement parts needed to conduct scheduled and unscheduled maintenance procedures.	◑	●
	Verifiable existence of maintenance procedure guidelines and manuals, including OEM-provided training courses upon purchase and deployment of new trucks.	◕	●

Legend: Operational Feasibility (2018)

○ ◔ ◑ ◕ ●

Little/No Achievement — Fully Achieved

Source: Based on Drayage Truck Operator Survey responses, footnoted studies, OEM product information, and consultant's industry knowledge.

4.3.2 Technology Demonstrations

As evidenced by the feasibility assessments, there is still much work to be done to achieve commercially available zero-emissions port equipment. Technology demonstrations, which include the development, deployment, and testing of zero-emissions equipment in a real-world port environment, have played a critical role in advancing the state of port-related technology, and they can be useful for other ports and operators to better understand the implications of these emerging technologies.

The Port of Long Beach is engaged in a number of active demonstration projects, everything from electric yard tractors and grid-tied RTG cranes to fuel-cell yard tractors and electric drayage trucks. These demonstrations are resource intensive.

<u>CHECKLIST:</u>

Key Considerations for a Demonstration

- ❒ Is this an equipment type, technology platform, or duty cycle that has not yet been tested?
- ❒ Is the technology ready for real-world testing (i.e., past the research and development phase)?
- ❒ Is there funding?
- ❒ Does it require infrastructure? If so, what are the time and budget implications?
- ❒ Is there a willing operator to test the equipment?
- ❒ Are the demonstration objectives well defined?
- ❒ Are there staff resources to manage the project?
- ❒ Can the information be obtained another way?

They require large amounts of capital to purchase zero-emissions equipment, infrastructure investments to facilitate fueling, significant data collection, and staff resources to manage multiple partners, including operators and technology developers.

Public funds – particularly from state grants and the Port's own Technology Advancement Program (TAP), a joint effort with the Port of Los Angeles – have helped to defray the capital costs associated with demonstrations. Still, the Port must be judicious in participating in demonstration projects given the resource strain. To that end, the Port vets every potential demonstration project with input from multiple port divisions, including Environmental Planning, Finance, Tenant Services, and Engineering (see inset box, "Checklist: Key Considerations for a Demonstration").

4.3.2.1 Test Protocols and Data Collection

The Port has worked with the Port of Los Angeles and other partners to develop testing protocols and procedures that can be used by all agencies engaged in similar demonstrations in order to support consistent data collection (see "In the Toolbox").

To a lesser extent, the Port has developed duty-cycle characterizations that can be beneficial for technology developers. As described in the Engagement Report (Appendix B), however, more work is needed to overcome the significant knowledge gaps in port duty and drive cycles among port stakeholders. Operators themselves have only limited knowledge of their own duty cycles, according to the survey results. This piece is critical: understanding the performance and operational requirements of new equipment will help ensure that 1) innovation is designed to the appropriate specifications, 2) equipment purchases can be made with confidence about the impact (or lack thereof) on operations, 3) the cost of capital (internal or external) can reasonably be reduced by lessening the investment risk profile.

> IN THE TOOLBOX
>
> The San Pedro Bay Ports have developed testing protocols for **drayage trucks** and **yard tractors**. These protocols can be found at *www.cleanairactionplan.org/tap.*

Gaps in knowledge – whether real or perceived – point to the need for more studies about port operations and more widespread sharing of this information across the Port Community. The Blueprint has revealed that such analyses should not be conducted in a vacuum. The Port has piloted a stakeholder-informed duty-cycle analysis in partnership with the NREL. This exercise is a useful case study for demonstrating how even technical work can benefit from stakeholder input (see case study: "Engaging Stakeholders in Technical Work").

4.3.2.2 Communicating Demonstration Results

Technology demonstrations help to advance the state of technology and scientific knowledge and to provide data to reduce early-stage technology risk. Individually, these projects collect valuable data, but the applicability of the data is limited by small sample sizes and unique deployment scenarios. Collectively, however, data from publicly-funded projects represent a wealth of information that if aggregated and synthesized could be used to educate numerous stakeholders beyond those immediately engaged in the demonstration projects.

The process of communicating demonstration results more broadly is only now beginning. CARB has started to host technology showcases for projects funded under the Low Carbon Transportation funds in order to share lessons learned. SCAQMD reports annually on the status of its demonstration projects as part of the Clean Fuels Advisory Group, and the Ports post final demonstration reports for all TAP-funded projects on the TAP website; however, the formal sharing of lessons learned is not consistent.

> CASE STUDY
> **Engaging Stakeholders in Technical Work**
>
> A recent effort with the NREL to assess yard tractor activity at a container terminal highlights the benefits of conducting technical work and doing so in conjunction with broader members of the Port Community.
>
> SSA Terminals plans to demonstrate 33 electric yard tractors and 1 electric top handler at the Pier C container terminal, which will be the largest deployment to date of conventionally operated zero-emissions equipment at a single terminal. The Port engaged NREL to analyze the terminal's existing operational profile and to propose strategies to curtail energy demand once the fleet goes electric.
>
> NREL installed data loggers on SSA's yard equipment and produced an initial report that aggregated the findings geospatially and temporally. The Port and NREL then engaged other Blueprint stakeholders to provide input. During a working session, NREL presented the initial findings to SSA Terminals, TransPower, SCE, and the Port's electrical and civil engineers. These stakeholders helped ground-truth the findings, validate the assumptions, and offered suggestions for further refinement of the data. More importantly, they kickstarted conversations about charging infrastructure siting, equipment specifications, and energy costs that are reflected in the final analysis and this Blueprint.
>
> The involvement of various stakeholders demonstrates the value of engaging different perspectives even in a seemingly straightforward duty-cycle analysis.

The Port Community would benefit from more regular and formal sharing of demonstration results, for example, through an accessible library of information related to port-related technology development. The CEC is starting to develop a database of port-related demonstration projects, and the World Ports Climate Initiative plans to launch an online clearinghouse for global port technology projects (see "In the Toolbox"). These efforts are an important first step. As these resources come to fruition, the Port Community must review and synthesize the findings to identify gaps.

As part of the Blueprint effort, the Port conducted a cursory review of port-related demonstration projects. Key findings include:

- The technology developers TransPower and BYD have established a leadership role in the space with numerous units set for deployment within the next few years;
- Zero-emissions forklifts, yard tractors, and drayage trucks have been the focus of demonstration and deployment projects; and
- There are few demonstrations of zero-emissions top handlers and non-grid-tied RTG cranes.

The Port should continue to monitor port-related demonstration projects, to synthesize the results of its own multiple demonstrations, to share these lessons learned more broadly across the Port Community, and more importantly, to use this information to develop new demonstration projects that will continue to diversify the portfolio of equipment types, technology vendors, and manufacturers.

> IN THE TOOLBOX
>
> Technology developers, operators, and seaports can benefit from sharing results from port-related technology demonstrations underway or completed. The following organizations are developing or have developed these resources:
>
> - *San Pedro Bay Ports Technology Advancement Program*: Final reports posted online at www.cleanairactionplan.org/tap.
> - *California Energy Commission Ports Collaborative Project Database*: Under development, expected 2019, updates at www.polb.com/zeroemissions.
> - *World Ports Climate Action Program: Zero-Emissions Cargo-Handling Equipment Clearinghouse*: Under development, updates at http://wpci.iaphworldports.org/.

4.4 Create Market Acceptance

The combination of technology development and economic feasibility results in commercialization and ultimately market acceptance. The Port's position as an early-adopter of new technologies comes with inherent risk and uncertainty. This uncertainty is one of the greatest barriers to the adoption of zero-emissions technologies. The Port has identified several strategies for reducing risk and uncertainty associated with technologies in the hope of achieving greater market acceptance, as described below:

- Integration with major manufacturers;
- Informal, short-term demonstrations to give users first-hand experience;
- Cost reduction strategies, including financial incentives and bulk purchasing programs;
- Community advocacy for market expansion; and
- Other strategies, such as regulatory action and CAAP.

4.4.1 Integration with OEMs

New technologies traditionally reach the commercial marketplace through partnerships with established manufacturers to accelerate production scale. The involvement of major manufacturers is key because the port equipment market is heavily concentrated in the hands of a few companies:

- Capacity and Kalmar each control about 50% of the San Pedro Bay market for yard tractors;
- Taylor Machine Works manufactures 90% of the top handlers in San Pedro Bay; and
- Daimler Trucks, maker of the Freightliner brand, holds nearly 40% of the North American drayage truck market. Paccar, whose brands include Peterbilt and Kenworth, holds 28% of the market share. Volvo comprises about 10% of the market.

These manufacturers have begun to invest in zero-emissions terminal equipment and trucks, which has turned the tide on technology advancement; however, these manufacturers are in the beginning stages of development and still have much to learn before zero-emissions vehicles can be considered commercialized. To achieve its zero-emissions goals, the Port needs to work with OEMs, who offer operators the long-term warranties, quick parts replacement, and customer service that is routine for diesel equipment and must become the norm for emerging technologies.

To that end, the Port commits to support only equipment or vehicle demonstration projects with an OEM partner. This practice will apply to Port-led projects seeking funding from other agencies and may apply to TAP-funded projects.

4.4.2 Short-Term Demonstrations

As technologies mature and reach the market, terminal operators and trucking companies must see new equipment and vehicles in action, and if possible, get the chance to test the equipment in short-term, informal demonstrations in their own duty cycle. “Ride and drive” events, tours, and short-term demonstrations can help operators gain familiarity with new technologies, and thus reduce uncertainties around performance, without operators having to make major commitments to multi-year demonstrations.

Specific activities could include:

- **Ride and Drive Events**: Ride and drive events offer operators an opportunity to get behind the wheel of a truck or piece of equipment to get first-hand experience with new technologies. These events are designed to build familiarity with the technology, typically demonstrating that the operations of the equipment are not particularly different from traditional equipment. PMSA and Harbor Trucking Association have hosted these types of events in the past, and the Port should work with these associations as well as local dealerships to do more such events as a greater number of zero-emissions options becomes available.

- **Tours**: Seeing a piece of equipment or truck in its typical working environment can give operators a better sense of what real deployment looks like. On a tour, operators can observe equipment movement, charging and refueling logistics, and container handling as it occurs in the real world, and can see zero-emissions equipment that is not able to move off-site, such as RTG cranes. Operators may be reluctant to let competitors see their operations; however, in the interest of greater market acceptance, the Port should work with its demonstration partners to offer tours to others.

- **Short Demonstrations**: From time to time, a manufacturer has been willing to “loan” a piece of zero-emissions equipment to an operator for a short test period, usually less than two weeks. The manufacturer benefits from getting additional performance data in an untested duty cycle, and the operator benefits by seeing a unit in action to validate technical performance over a sustained period of time without having to commit to a multi-year demonstration project. The Port should work with dealerships and manufacturers to identify opportunities for these short-term demonstrations and “loan” programs.

4.4.3 Cost Reduction Strategies

As confirmed by the Blueprint stakeholder outreach and CAAP feasibility assessments, the high cost of a zero-emissions piece of equipment relative to diesel is a significant barrier to commercialization and widespread market acceptance. Financial incentives can spur initial adoption, and there are numerous public-funding programs to do just that, as described in Section 6; however, rebates and cost subsidies come with their own inherent uncertainty about long-term availability and do little to bring down the commercialized price of each unit.

Continued technology development, particularly advancements in battery and fuel cell technology, is sure to bring down unit costs over time. Production scale can also help bring down per-unit costs, which may be achieved through bulk purchasing agreements. Most of our terminal operators and trucking companies have operations in multiple locations across the state and West Coast; the Port should work with its agency partners to explore the development of interstate funding programs, allowing operators to apply for equipment at multiple locations, and the Port should identify opportunities to help operators pool equipment purchases with other operators. The EPA is leading discussions about zero-emissions bulk purchasing, and the Port should continue to engage in these discussions.

4.4.4 Community Advocacy for Market Expansion

Close engagement with other seaports, community organizations, and environmental justice groups can help advance the market for zero-emissions equipment. Many community-based groups engage with other port communities around the country. To the extent that community organizations and environmental-justice groups can help leverage the Blueprint findings in other seaport communities, it could increase the deployment of zero-emissions equipment nationwide, thus minimizing real or perceived adverse impacts on Long Beach operators. Additionally, a larger zero-emissions equipment market should lead to better prices and a more sustainable business model.

4.4.5 Other Strategies

Historically, regulation has helped to drive widespread adoption of cleaner equipment and trucks. CARB is working on amendments to the terminal equipment and truck regulations, and these changes may move the market on zero emissions. Additionally, CAAP strategies, such as the new Clean Trucks Program, which incentivizes zero-emissions trucks, and our green leases, which require adoption of new equipment over time, should help to advance commercialization.

4.5 Actions

The Port has already begun working through the four-step process to evaluating and deploying zero-emissions technologies.

- **Step 1 – Establish a Baseline**: Through the annual emission inventories, the Port has created a mechanism for gathering detailed information about existing equipment and vehicles used at the port. This process provides sufficient information for the Port to make informed prioritization decisions. Other ports could adopt a similar framework to quantify equipment populations and associated emissions in order to make informed decisions around their own zero-emissions transition.

- **Step 2 – Identify Priorities**: The Blueprint has identified yard tractors, RTG cranes, top handlers, and drayage trucks as the top priority pieces of equipment based on the potential benefits to air quality. To better understand the duty and drive cycles of these technologies, the Port can serve as a data aggregator across terminal operators to provide technology developers with information about equipment utilization that is critical to product design. Focusing on these priorities can help direct limited resources towards the equipment that could achieve the highest benefits.

- **Step 3 – Evaluate Technology Development**: The Port uses two approaches for evaluating technologies: technology assessments and technology demonstrations. By adopting the *Framework for Developing Feasibility Assessments* as part of the CAAP, the Port has established a common approach for evaluating new zero-emissions technologies. The framework can be widely used for all California ports. Additionally, the Port is engaged in demonstration projects to test emerging technologies in a real-world port environment. The Port should aggregate, synthesize, and share the results of these demonstrations throughout the Port Community and support efforts by other agencies to do the same.

- **Step 4 – Create Market Acceptance**: Even the best technologies will not succeed without a large market. The Port must consider, develop, and adopt a strategic approach to creating a stable and predictable marketplace for zero-emissions technologies using education, incentives, and broad community engagement to create clear signals to manufacturers and operators. Strategies include:
    - Support projects with OEM partners;
    - Support ride-and-drive events, short-term demonstrations, and tours;
    - Identify bulk purchasing opportunities, working with funding agencies on interstate programs and operators on pooled purchases;
    - Collaborate with community-based groups to expand zero-emissions efforts nationally; and
    - Continue to monitor regulatory efforts and to implement CAAP strategies.

5 Charging and Refueling Infrastructure

Zero-emissions equipment requires a major investment in charging and fueling infrastructure. When surveyed, most Port Community stakeholders ranked the lack of charging infrastructure as a primary concern, outweighing even the availability of electric equipment.[12] The infrastructure challenge is complicated by the lack of heavy-duty charging standards, the significant cost and long timeframes needed to install infrastructure, poor awareness of charging options, and the operational and physical constraints in the Port, which limit charging windows and space for charging equipment.

Importantly, infrastructure includes not only the charging delivery systems – of which there are many options, from manual direct-connect to wireless induction – but also the significant investment in new substations, switchgear, transformers, and conduit. This electrical infrastructure is likely to take up substantial space on already crowded terminals and must be installed without impact to the Port's 24/7 operations, which requires careful phasing and advanced planning.

This section describes a six-step strategic process that any port can use to assess, develop, and support the necessary zero-emissions infrastructure:

1. Establish a Baseline
2. Forecast Future Need
3. Evaluate Fueling and Charging Options
4. Adopt Standards
5. Develop Infrastructure Design Plans
6. Execute Design Plans

5.1 Establish a Baseline

Refueling infrastructure varies by terminal equipment, on-road trucks, and cars. Terminal equipment, which is prohibited from driving on public roads, must refuel on each terminal. Currently, terminals use a mix of onsite fueling stations and mobile fuel carts. Thus, each terminal would require hydrogen fueling stations and/or electric charging onsite to support a zero-emissions fleet. On-road trucks, in contrast, generally access publicly-available fueling stations or, for large trucking companies, dedicated private stations at their facility. Hydrogen or electric-charging infrastructure would be required at trucking company facilities and at publicly-accessible stations. Cars would recharge at the tourist areas of the Harbor District or refuel at publicly-accessible hydrogen stations.

5.1.1 Hydrogen Infrastructure

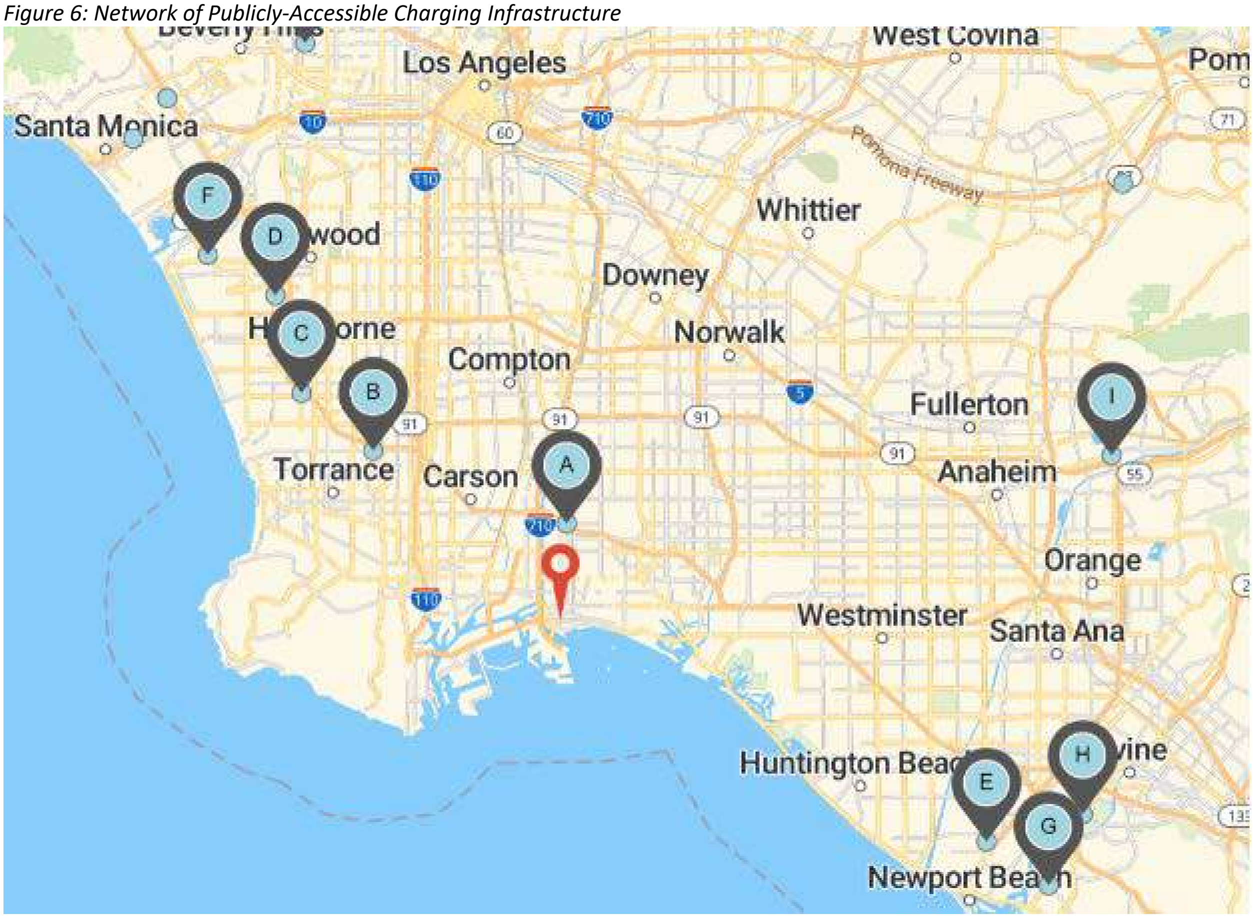
Currently there are no permanent heavy-duty hydrogen fueling stations on port terminals or in close proximity to the Port. At least one port trucking company – Total Transportation Services, Inc. – has a temporary hydrogen refueling station at its facility; however, permanent solutions do not exist.

The availability for cars is more positive with a growing network of publicly accessible stations as shown in Figure 6 with the closest station located about 3.5 miles from the Port of Long Beach.[13]

[12] PCEVB Engagement Report. See Appendix B of this document

[13] US Department of Energy: Alternative Fuels Data Center, Hydrogen Fueling Station Locations (https://afdc.energy.gov/fuels/hydrogen_locations.html#/find/nearest?fuel=HY). Accessed 1/17/2019.

Figure 6: Network of Publicly-Accessible Charging Infrastructure



Over the next few years, there are near-term plans for increased production and fueling capacity, particularly for heavy-duty trucks.

Within the Port, the Toyota Logistics Services is proposing to develop a 13,600-square-foot fuel cell power plant, called the Tri-Gen facility, designed to convert methane gas to electricity, hydrogen, and water. An existing underground pipeline, with some improvements to the network, would deliver biomethane generated from agricultural waste from Central Valley farms. The Tri-Gen facility is designed to produce about 2.3 megawatts of electricity per day, enough to run all terminal operations and provide a surplus of more than 15 million kilowatts that would be sold back to the grid.

In November 2017, Toyota announced plans to partner with FuelCell Energy, a global clean energy solutions company, to install and operate the facility. The plant would have the capacity to produce nearly 1.4 tons of compressed hydrogen per day to support three fueling stations for vehicles that run on hydrogen.

Second, the Port of Los Angeles, in partnership with Shell, is supporting the development of two new large capacity heavy-duty hydrogen fueling stations in Wilmington and Ontario, California. The new stations will join three additional stations located at Toyota facilities around Los Angeles to form an integrated, five-station heavy-duty hydrogen fueling network. Together, they will provide multiple sources of hydrogen throughout the region, including over one ton of 100% renewable hydrogen per day at the heavy-duty station to be operated by Shell, enabling zero-emissions freight transport. Stations supplied by Air Liquide at Toyota Logistics Services in Long Beach and Toyota Technical Center in Gardena will serve as important research and development locations. The Wilmington station is expected to come online in May 2020 and will provide a critical source of publicly accessible hydrogen for the drayage truck fleet.

5.1.2 Electric Charging Infrastructure

The Port has started to build on-terminal electric charging infrastructure to support demonstration projects but is in the very early stages. Figure 7 shows the locations of existing and planned near-term electrical charging infrastructure in and around the Port for terminal equipment, trucks, and cars. Table 11 provides more details on the deployments.

Figure 7: Existing and Planned Near-Term Electrical Charging Infrastructure

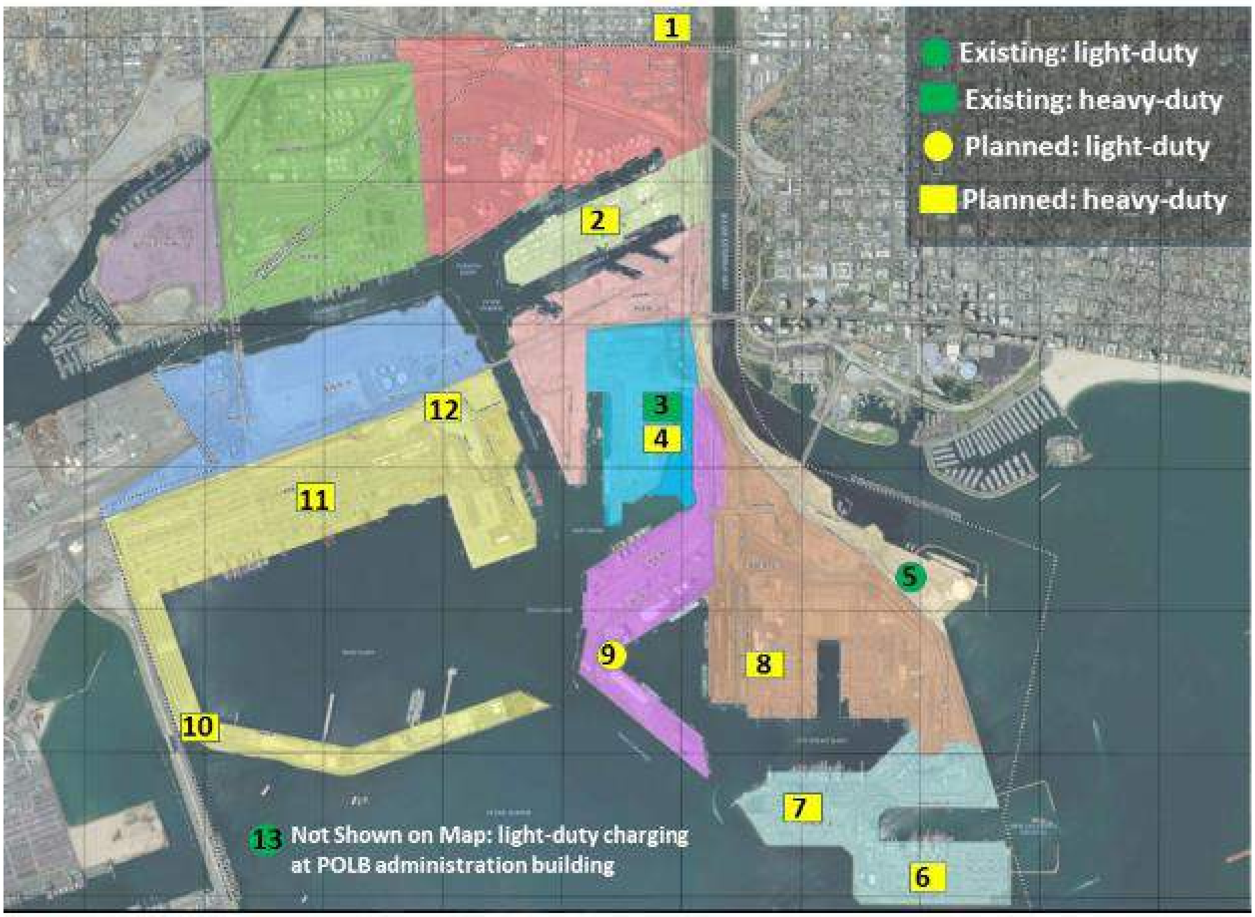


Table 11: Description of Existing and Planned Near-Term Electrical Charging Infrastructure

#	Description	Availability
1	5 charging units for heavy-duty trucks at a trucking facility, including 2 publicly accessible charging units at the Clean Trucks Program Center	2020
2	33 charging units for yard tractors and 1 charging unit for a top handler at a container terminal	2020
3	Battery exchange building for automated guided vehicles to enable battery swapping; full electrification of yard cranes at a container terminal; second battery exchange building is planned	Existing
4	6 charging units for non-automated yard tractors at a container terminal	Q2 2019
5	2 charging units for passenger cars at the Queen Mary	Existing
6	2 charging units for top handlers at a container terminal	2019
7	Electrical tie-ins for 9 grid-based electric RTG cranes at a container terminal	2019
8	20 charging units for yard tractors at a container terminal	2019
9	Charging units for passenger cars at the Port's security center; quantity undefined	TBD
10	27 charging units for yard tractors at a container terminal	2021
11	10 charging units for heavy-duty forklifts at a container terminal	2021
12	2 charging units for yard tractors at a container terminal	2021
13	2 charging units (4 plugs) for passenger cars at the Port's administration building	Existing

For terminal equipment, by the end of 2021, the Port is expected to have charging for 110 pieces of electric terminal equipment, including yard tractors, RTG cranes, forklifts, and top handlers.

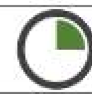
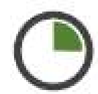
For on-road trucks, the availability of electric charging infrastructure is less clear. Most of the necessary electric charging infrastructure needs to be located at trucking company facilities, where roughly 70%-80% of the trucks park overnight.[14] It is unclear how many trucking facilities have installed charging infrastructure as those facilities are largely outside of the Harbor District. Trucks that do not park overnight at trucking facilities would require publicly accessible charging facilities. Currently, there are no publicly-accessible charging facilities for heavy-duty trucks in or around the Port. Two public charging outlets are expected to come online in late 2020 at the Clean Trucks Center in Long Beach.

Table 12 and Table 13 depict the infrastructure availability assessments for heavy-duty trucks and select terminal equipment from the CAAP feasibility assessments[15]. Of note, hydrogen fueling was not evaluated in these assessments due to the immaturity of the market.

[14] San Pedro Bay Ports Clean Air Action Plan, 2018 Feasibility Assessment for Drayage Trucks. April 2019. http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/

[15] CAAP feasibility assessments for trucks and terminal equipment, www.cleanairactionplan.org.

Table 12: Summary of Findings for Infrastructure Availability, Drayage Trucks

Infrastructure Criteria / Parameter	Base Considerations for Assessing Infrastructure Availability	Achievement of Criteria for Remaining Drayage Truck Platforms	
		ZE Battery-Electric	NZE NG ICE
Dwell Time at Station	Refueling/recharging can be accommodated within typical work breaks, lunches, other downtime compatible with trucking company schedules and operational needs.		
Station Location and Footprint	Fleets have existing onsite access to fueling infrastructure, or can be fueled/charged conveniently and affordably off site, at public or private stations. New infrastructure can be installed without extensive redesign, reconfiguration or operational disruptions and there is sufficient electrical or natural gas capacity at the site.		
Infrastructure Buildout	Infrastructure can be constructed at a pace consistent with fleet adoption and able to meet fleet fueling/charging requirements by the end of the assessment period.		
Existence of / Compatibility with Standards	A sufficient body of codes and standards exist from appropriate organizations that enables safe and effective refueling/recharging. The refueling/recharging station technology has already been installed at other trucking companies in the U.S., with sufficient time to assess performance and safety.		

Legend: **Infrastructure Availability (2018)**

Little/No Achievement — Fully Achieved

Source: based on preliminary OEM survey responses, OEM product information, various government sources, and Tetra Tech team's industry knowledge.

Table 13: Draft Summary of Findings for Infrastructure Availability, Yard Tractors and RTG Cranes

"Infrastructure Availability" Criteria	Base Considerations for Assessing "Infrastructure Availability"	Yard Tractors		RTG Cranes	
		ZE Battery-Electric	NZE NG ICE	ZE Grid-Electric	NZE Hybrid-Electric
Time Required for Fueling/Charging	Fueling/charging can be accommodated within typical work breaks, lunches, other downtime compatible with MTO schedules and operational needs.	◔	◕	●	●
Infrastructure Location and Footprint	MTOs have existing onsite access to fueling infrastructure. New infrastructure can be installed without extensive redesign, reconfiguration or operational disruptions and there is sufficient utility capacity at the site.	◔	◕	◕	●
Infrastructure Buildout	Infrastructure can be constructed at a pace consistent with fleet adoption and able to meet fleet fueling/charging requirements by the end of the assessment period.	◔	◕	◑	●
Existence of / Compatibility with Standards	A sufficient body of codes and standards exist from appropriate organizations that enables safe and effective fueling/charging. The fueling/charging technology has already been installed at other marine terminals in the U.S., with sufficient time to assess performance and safety.	◔	◕	●	●

Legend: Infrastructure Availability **(2018)**

○ ◔ ◑ ◕ ●

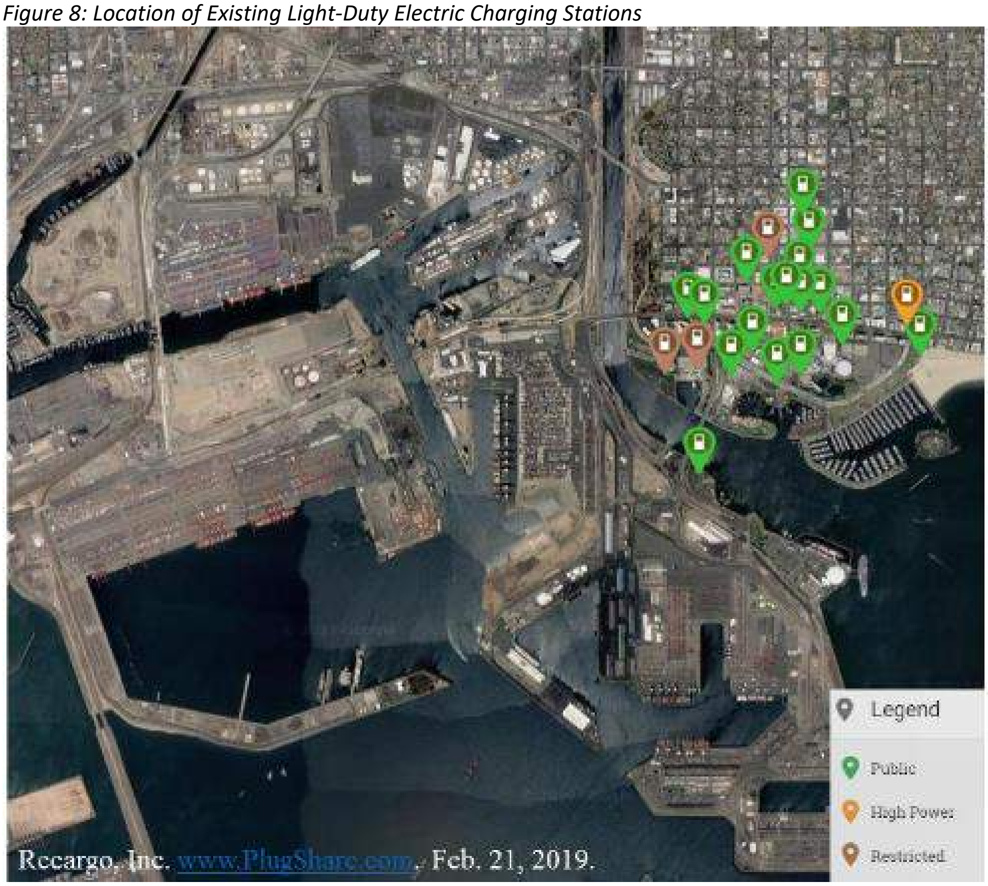
Little/No Achievement … Fully Achieved

Source: Estimated ratings are based on MTO interviews and site visits, footnoted studies, OEM product information, various government sources, and consultant's industry knowledge

For passenger cars, such as those operated by port employees and tourists visiting the Queen Mary, the immediate Port Community has limited light-duty charging infrastructure. There are five stations located nearby: two at the Queen Mary and three at the Hotel Maya (Figure 8).[16] Both charging locations within the immediate Port Community are located within paid parking areas and offer free charging. No other light-duty charging infrastructure exists within the Port.

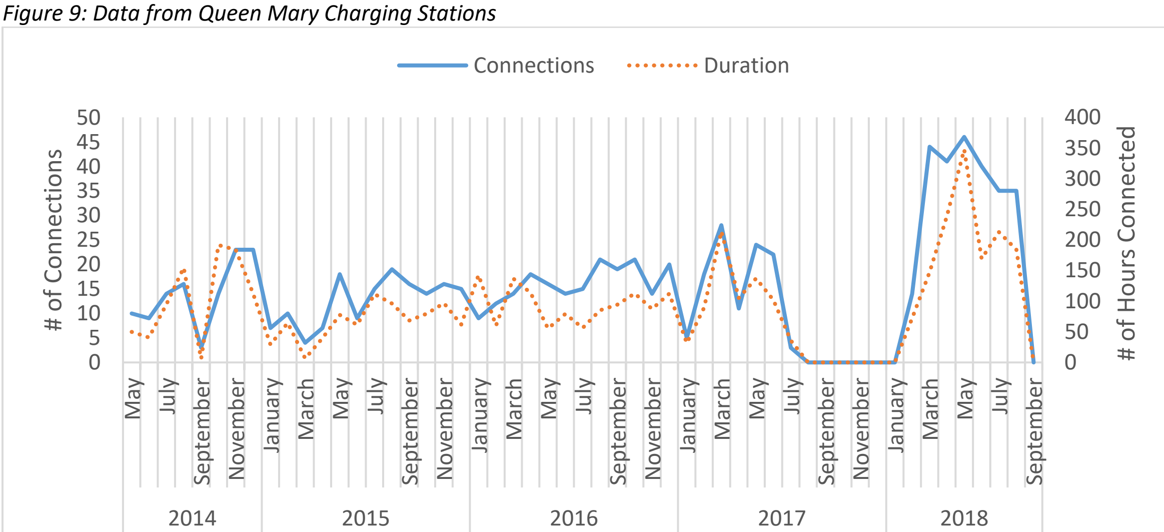
[16] www.plugshare.com accessed 1/17/2019

Figure 8: Location of Existing Light-Duty Electric Charging Stations



Data from the Queen Mary charging stations were provided by the City of Long Beach and are presented in Figure 9. The City has long-term plans to redevelop the Queen Mary tourist area and immediate plans to expand passenger services at the adjacent Carnival cruise terminal. The Carnival improvements are expected to result in an additional 50,000 visitors each year served by an expanded parking lot. Although underutilized today, the existing charging stations may see higher usage once these expansions take place.

Figure 9: Data from Queen Mary Charging Stations



5.2 Forecast Future Need

This section projects rough estimates of the hydrogen and electric infrastructure necessary to support terminal equipment, drayage trucks, and cars in the Port Community.

5.2.1 Terminal Equipment

There are more than 1,000 yard tractors, top handlers, RTG cranes, and forklifts at the Port of Long Beach – the prime candidates for zero-emissions transition. Notably, the Port is developing a tool to help operators make quick back-of-the-envelope calculations about projected energy requirements and associated infrastructure costs given specified deployments of zero-emissions equipment. This tool – the Dynamic Energy Forecasting Tool (DEFT) – will be made available to ports and other operators. This section provides an estimate of the projected hydrogen and electric charging necessary to support the fleet.

IN THE TOOLBOX

The Port's *Dynamic Energy Forecasting Tool (DEFT)* lets terminal operators and ports make quick calculations about energy and infrastructure costs as they transition to zero emissions. With a few simple inputs, operators can estimate:

- Projected total energy needs
- Projected energy needs by equipment type
- Rough infrastructure costs
- Rough energy consumption costs

For more information, go to www.polb.com/zeroemissions.

5.2.1.1 Hydrogen Infrastructure

To project future hydrogen demand, the Port used terminal-equipment energy consumption from its 2017 emissions inventory and the engine economy ratio (EER) for hydrogen used by the LCFS program.

Equipment at the Port uses about 148 million kWh of energy annually (referencing the energy content of the original fuel) to power its existing equipment based on the 2017 inventory. Although EERs vary by fuel type, the Port used a conservative EER of 1.9 to estimate the hydrogen demand of existing equipment.[17] A breakdown of that annual energy consumption by equipment fuel type is presented in Table 14.

Table 14: Equipment Energy Consumption for Existing Fleet

Equipment Type	Fossil Fuel Consumption (kWh)	Hydrogen Fuel Requirements (kWh)	Hydrogen Fuel Requirements (kg)
Diesel-Fueled	140,766,718	74,087,746	2,227,457
Gasoline-Fueled	6,847,873	3,604,144	108,359
Propane-Fueled	1,073,503	565,002	16,987
Total	**148,688,094**	**78,256,892**	**2,352,803**

Hydrogen is traditionally discussed as pounds or kilograms (instead of kWh). The amount of hydrogen needed to serve the entire Port fleet is about 2,352,803 kg.[18] The average consumption for the entire fleet would be about 6,450 kg/day.

[17] The EER measures the efficiency of an alternative fueled engine compared to a diesel baseline. The EER for diesel and gasoline engines are 1.0, the EER for hydrogen fuel-cell vehicles is 1.9, and the EER for hydrogen forklifts is 2.1. To be conservative, the EER of 1.9 will be used to estimate the hydrogen demand of existing equipment.

[18] 51,585 Btu/lb of Hydrogen; 3,412 Btu/kWh; and 2.2 lb/kg

5.2.1.2 Electric Charging Infrastructure

The Port has developed a preliminary "Engineering Study for Electrification of Terminal Equipment" for its terminals, which can be found in Appendix D. This document provides a high-level assessment and rough order of magnitude (ROM) costs for supporting the transition to zero-emissions yard tractors, top handlers, forklifts, and RTG cranes. It is assumed there will be one charger for each piece of equipment. Additional details about the methodology can be found in the document.

Table 15 describes the existing electrical capacity and projected electrical loads at each terminal based on this preliminary engineering assessment as well as data collection that has taken place since. Importantly, these loads are 1.5 to 2 times higher than the loads associated with shore power, which has been the most significant port electrification effort to date. Of note, Pier E (Middle Harbor) has already transitioned almost all of its fleet to zero-emissions electric, and as such, is not included here. It has ample spare capacity for any future deployments of electric.

Table 15: Existing Capacity and Projected Loads

	Existing			Future All Electric
Terminal	Total Capacity	Power Demand	Spare Capacity	Potential Additional Power Need
Pier A	14,000	9,073	4,927	61,000
Pier C	12,959	4,959	8,000	21,000
Pier G	84,000	9,026	74,974	78,000
Pier J	28,000	3,996	24,004	86,000
Pier T	105,000	10,890	94,110	128,000

** All units kVA*

The engineering analysis provides more details about each terminal, but at a high-level, no terminal is expected to have enough spare capacity to handle a full transition to zero emissions without additional infrastructure; however, there may be opportunities for small deployments today, or larger – but not complete – deployments given adequate infrastructure improvements, as described below:

- **Pier A**: Preliminary assessments of the existing infrastructure show limited opportunities for additional charging infrastructure; significant improvements are necessary to support even modest deployments of electric equipment.

- **Pier C:** Pier C is one of the smallest container terminals at the Port and will be the site for the deployment of 33 battery-electric yard tractors and one battery-electric top handler. The information collected during this demonstration project will provide valuable insights into the impacts of a large fleet of battery-electric units and is expected to help form the strategy for continued zero-emissions transitions within the pier. While this active project is underway, there are no recommendations for near-term additional infrastructure additions.

- **Pier G**: Pier G has significant available electrical capacity. As such, it is expected that Pier G will have opportunities for the near-term deployment of zero-emissions technologies with relatively low-cost electrical infrastructure. Pier G has historically been a challenging pier for demonstrations and deployments as the yard is split (with an east and west side) by a channel, limiting operational flexibility. Currently, SCE is installing 20 charging outlets for yard tractors.

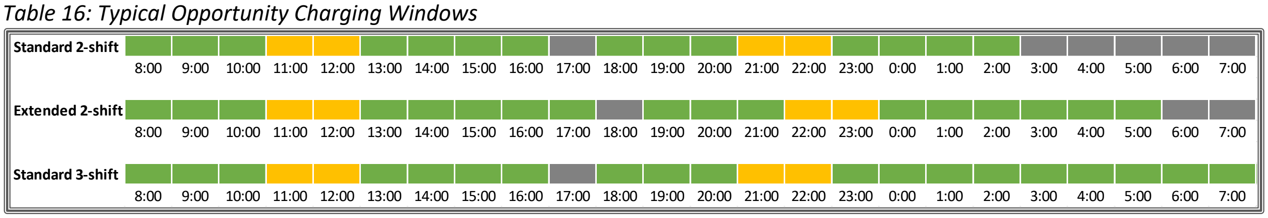
- **Pier J:** Pier J has modest electrical capacity (12 MVA representing about 16% of the total potential need), offering opportunities for hydrogen fuel cell and battery-electric equipment.

- **Pier T**: Pier T is one of the largest Port terminals. The Port is building out the infrastructure for the deployment of 27 battery-electric yard tractors and 10 heavy-duty battery-electric forklifts. With significant spare electrical capacity, Pier T would be an appropriate location for continued deployment of fuel cell electric or battery electric technologies.

5.2.1.3 Opportunity Charging

Unlike hydrogen refueling, which is expected to follow a model similar to the existing diesel refueling with mobile units or a central distribution facility, electric charging is not as mobile. Terminals work in shifts that limit the available charging windows. Although there may be slight variation from terminal to terminal, the three shift schedules are presented in Table 16. Green blocks indicate full operation, while yellow blocks indicate meal periods where typically half of workers are on meal breaks. Gray blocks indicate periods where cargo operations are not active. Gray and yellow blocks could be charging windows.

Table 16: Typical Opportunity Charging Windows



Source: 2018 Draft Feasibility Assessment for Cargo-Handling Equipment

This charging pattern differs significantly from other industries and the light-duty sector. When surveyed as part of the PCEVB Engagement Report, 60% of operators said they needed equipment capable of charging in less than four hours; 42% of other stakeholders – including many infrastructure providers – said at least 6-8 hours of charging would be tolerable for port operators, and 11% of stakeholders said more than 8 hours. This disparity underscores the need to communicate the port duty cycles to infrastructure providers, many of which do not serve the port market, to begin developing fast-charging solutions suitable for the port environment.

Additionally, the narrow charging windows highlight the need to develop charging and fueling solutions that maximize scant idling or parking time. The "Port of Long Beach Pier C – Phase 1 Yard Tractor Electrification Study" conducted by NREL (Appendix E) revealed that equipment often idles or parks briefly in locations not suitable for longer connections; however, these sites may be right for in-ground, in-motion charging systems. More analysis is needed.

5.2.2 Trucks

The *Feasibility Assessment for Drayage Trucks* did not estimate the hydrogen fueling requirements necessary to support the Port's fleet of drayage trucks given the immaturity of fuel-cell technology for heavy-duty trucks. The report, however, did project electric charging infrastructure needs. As stated earlier, most trucks would charge overnight at trucking facilities; these facilities are assumed to have enough physical space to accommodate charging for nearly 60% of their fleets.[19] For the remaining trucks, which would require public charging, the report estimates the need for 180 to 300 acres of land to support charging infrastructure to power 1,200 to 2,000 trucks simultaneously.

5.2.3 Cars – Visitors and Employees

There are nearly 10,000 dockworkers and employees who work at the port complex. Additionally, new development at the Queen Mary and tourist serving areas could include more than 1,000 new parking spaces depending on the ultimate use of the space. The City of Long Beach's building code requires EV charging infrastructure for new construction. For the Queen Mary project, the number of required EV-capable spaces – meaning that the conduit is in place and ready for charging station installation – is 25% of the total parking spaces. Also, 5% of the total spaces must be outfitted with Level 2 (208/240V) EV chargers. These chargers typically require 40-amp breakers, requiring nearly 2.4MW of capacity for simply the tourist-serving entities.

Installation of workplace charging at longshore parking locations and terminal administrative offices may be possible, and terminal operators should monitor demand over time. Installation of one or two Level 2 charging stations in workplace parking locations is not expected to strain existing infrastructure.

5.3 Evaluate Fueling and Charging Options

Because of the unique operational and space constraints at the Port, careful consideration must be given to the configuration of fueling and charging infrastructure. These considerations are described in this section.

5.3.1 Hydrogen Refueling Configurations

Hydrogen fueling stations function like traditional gasoline/diesel stations with short dwell times at the fueling station to achieve full range capacity. Terminal equipment would require hydrogen fueling facilities onsite, and large trucking companies may elect to do the same. Passenger cars and a small percentage of the drayage truck fleet are expected to fuel at publicly accessible stations.

Hydrogen fueling stations can be configured in a variety of ways with the five most common types listed below: [20]

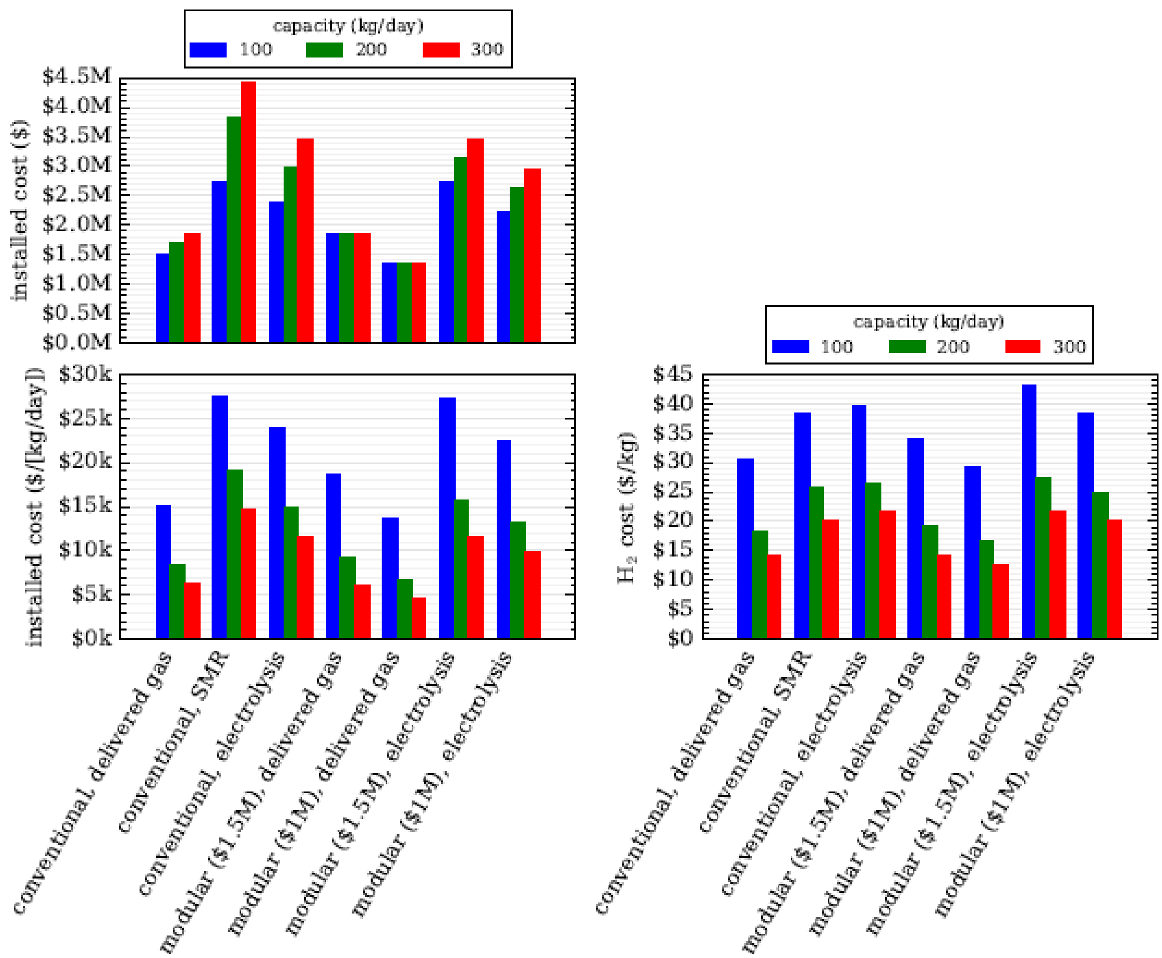
1. Conventional stations (assembled onsite) with hydrogen delivered as compressed gas from a centralized, already operational production facility
2. Conventional stations (assembled onsite) with hydrogen produced onsite through steam methane reforming (SMR)
3. Conventional stations (assembled onsite) with hydrogen produced onsite through electrolysis
4. Modular fueling stations with hydrogen delivered as compressed gas from a centralized production facility
5. Modular fueling stations with hydrogen produced through onsite electrolysis

[19] San Pedro Bay Ports Clean Air Action Plan, 2018 Feasibility Assessment for Drayage Trucks. April 2019. http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/

20 Hecht, Ethan, and Joseph William Pratt. Comparison of conventional vs. modular hydrogen refueling stations, and on-site production vs. delivery. No. SAND2017-2832. Sandia National Lab. (SNL-NM), Albuquerque, NM (United States); National Renewable Energy Laboratory, Golden, CO, 2017.

Stations served by centrally-produced, delivered gaseous hydrogen are more economical compared to those which generate onsite hydrogen via SMR or electrolysis, according to a 2017 NREL study. The cost of hydrogen is closely, and inversely, related to a station's production capacity (capacity is represented by the different colors in Figure 10). Notably, the revenues in the study's models did not include RIN and LCFS credit values. For conventionally delivered hydrogen, the prices are shown to range from $14/kg to $30/kg.

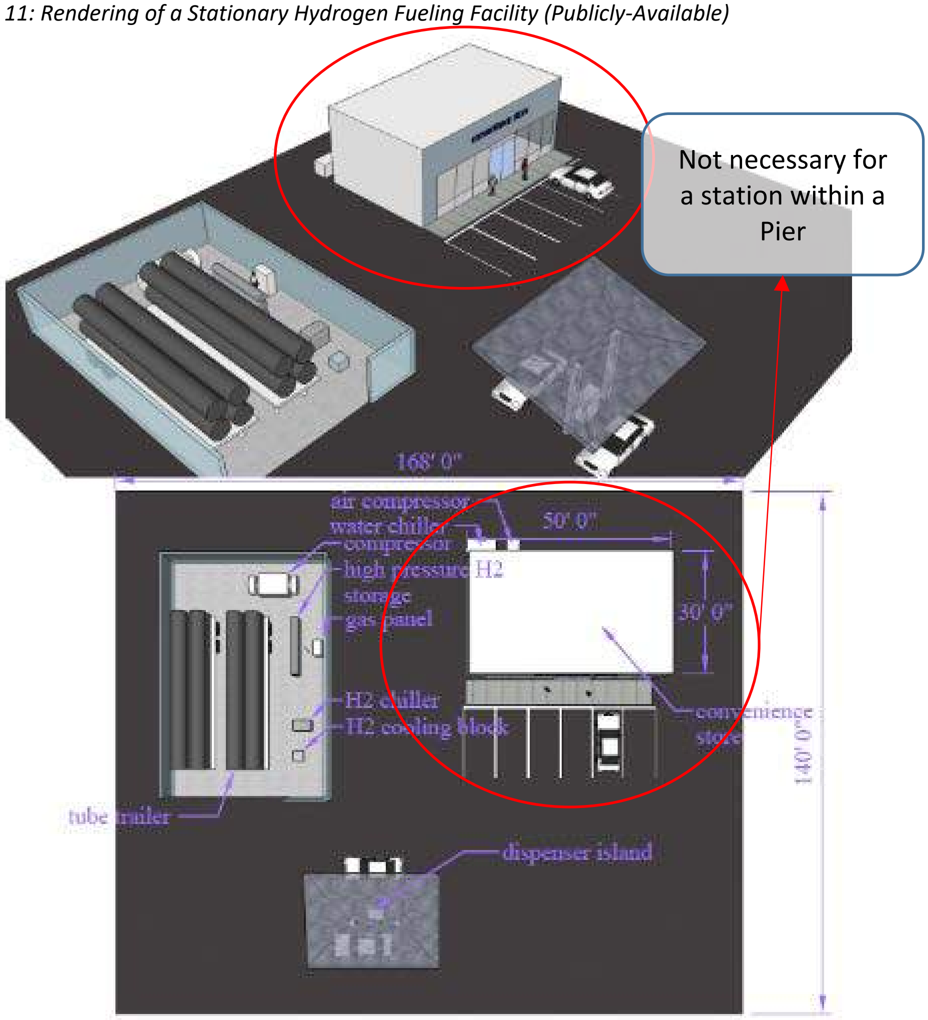
Figure 10: Summary of an economic analysis of hydrogen fueling station types (NREL and Sandia)



5.3.1.1 *Stationary Hydrogen Fueling Infrastructure*

Stationary hydrogen fueling infrastructure resembles traditional stationary gasoline/diesel fueling stations. The major features of a stationary fueling station that received hydrogen with deliveries from an external hydrogen manufacturing station include compressors, chillers, tube trailers, and a dispensing island. A rendering is presented in Figure 11 that includes a convenience store similar to those available at traditional gasoline/diesel stations. Without the convenience store, the approximate dimensions of the station would be 140 feet by 75 feet for this particular rendering (not accounting for the space necessary for tube trailer delivery). Onsite generation is expected to require roughly the same footprint as the tube trailer storage. As shown in Figure 10, the price of the station is estimated to be $1.5 million with very marginal cost increases for additional capacity fueling capacity.

Figure 11: Rendering of a Stationary Hydrogen Fueling Facility (Publicly-Available)



Source: NREL[21]

Additionally, the NREL study described modular stations built off-site with lower installation costs. As shown in Figure 10, the costs of modular or conventionally-built stations are similar. These figures give a sense of the scale needed to accommodate on-terminal hydrogen fueling and publicly accessible heavy-duty stations for trucks.

5.3.1.2 Mobile Hydrogen Fueling Infrastructure

As an alternative or complement to stationary hydrogen fueling, operators may elect to deploy mobile hydrogen fueling, allowing the hydrogen to move to the vehicle/equipment. The methodology is

21 Hecht, Ethan, and Joseph William Pratt. Comparison of conventional vs. modular hydrogen refueling stations, and on-site production vs. delivery. No. SAND2017-2832. Sandia National Lab. (SNL-NM), Albuquerque, NM (United States); National Renewable Energy Laboratory, Golden, CO, 2017.

consistent with current business operations across the port, with gasoline and diesel trucks often moving to different equipment pieces across the terminal.

5.3.2 Electric-Charging Configurations

Electric-charging technologies draw power from the grid and deliver these electrons to a vehicle or piece of equipment; there are many options, however, for *how* this electricity is delivered. The Port has identified the following charging delivery systems based on its technology demonstrations and a charging standards white paper developed by the NREL (Appendix F):

- **Manual connection**: An operator must physically take a cable from the charging outlet and connect it into the charging port on board the truck or piece of equipment. This approach is widely used in light-duty and has been the most common approach for nascent truck and terminal equipment demonstrations.

- **Automated conductive**: An arm automatically extends from a charging outlet to connect to the on-board charging port without hands-on contact. The Port is testing this approach as part of one of its technology demonstrations in partnership with Cavotec.

- **Pantograph**: An overhead connection automatically detects the connection and delivers electricity from the outlet to the equipment. The SCAQMD, in partnership with the Port and other agencies, tested a Siemens overhead pantograph system for trucks in motion in 2017.

- **Wireless induction**: In-ground and vehicle on-board inductive coils deliver electric power to the vehicle or equipment by creating a magnetic field, similar to the technology used to charge cell phones. Such systems have been deployed in Long Beach for buses and are being tested for terminal equipment at Port of Los Angeles with the company WAVE.

- **Battery swap**: The spent battery is removed from the vehicle or equipment and replaced with a fully charged battery. The Port's Middle Harbor terminal uses this system to change out lead-acid batteries on its automated guided vehicles.

Many of the charging technologies described above are only now being tested in a heavy-duty port environment with results not expected until 2021 at the earliest.

5.3.3 Charging and Refueling Considerations

Through the Port's technology demonstrations and as part of Blueprint stakeholder outreach and research, the Port has identified several key considerations for infrastructure selection:

- **Physical space and obstructions:** Terminals are tight spaces, and this land is among the most expensive in the country. Charging or refueling infrastructure that consumes a significant amount of real estate takes away from revenue-generating cargo areas. Additionally, any above-ground structure poses a collision hazard on terminals and at trucking facilities. Structures require safety bollards, which consume even more space. Operators are likely to prefer charging technologies that require minimal space and do not obstruct cargo movement.

- **Limited awareness of the charging/refueling options:** When surveyed, operators reported little awareness of the various providers for electric charging infrastructure and hydrogen fueling infrastructure, compared to all other stakeholders, who reported high familiarity.[22] This disparity could reflect a simple lack of awareness, necessitating more education, or it could point to the real lack of options for charging/refueling infrastructure in the heavy-duty space as opposed to the light-duty space, in which multiple providers have emerged.

- **High-voltage cable handling and storage:** The cables used to connect large pieces of terminal equipment – particularly top handlers, which can have 1 MWh batteries on board – can often weigh 40 pounds or more given the sheer cross-sectional diameter of cable needed to deliver that much power. Operators must consider the safe handling of these cables during connections, if using manual connections, as well as storage of these cables when not in use.

- **High-pressure gaseous or liquid fuel handling and storage**: Hydrogen is a low-density gas that requires high-pressures to transport and store energy without excessive fuel tank volumes. While standards and protocols have already been developed around hydrogen storage, facility design must account for additional safety precautions.

- **Fast connections**: Terminals operate on rigid work shifts with few breaks. Opportunity charging may be limited to two 1-hour breaks in a 16-hour cycle with a longer stretch of three to four hours in the early morning hours. Operators may have nearly 200 pieces of equipment requiring connection in those times. Given these tight timeframes for recharging and refueling, operators may prefer technologies that enable fast connections or refueling in a short period of time, such as fast chargers or those that automatically connect upon contact. This issue seems to be less pressing for trucking companies.

- **Ratio of charging outlets to equipment:** On a port terminal, the shift schedule demands that every piece of equipment is in use at the same time during working periods, and then – during breaks – parked and connected to the charging outlets. Thus, terminals are very likely to need one charger for each piece of equipment. Operators confirmed this assumption in the Blueprint survey.[23] This issue is less pressing for truck operators, who may have more flexibility.

5.4 Adopt Standards

A significant challenge to designing and constructing the appropriate infrastructure is the lack of charging and fueling standards for heavy-duty equipment. Additionally, the Port – which maintains strict design criteria and standards for terminals and electrical infrastructure – has not yet formalized criteria for charging or hydrogen fueling infrastructure.

[22] PCEVB Engagement Report. See Appendix B of this document.
[23] PCEVB Engagement Report. See Appendix B of this document.

5.4.1 *Charging and Fueling Standards*

5.4.1.1 Charging Standards

In 2017, the Port of Long Beach and Port of Los Angeles adopted an electric outlet standard to communicate to technology developers the type of infrastructure that would be provided at port terminals for the purposes of testing zero-emissions equipment: 250 AMP, 480 volts, 3-phase, with maximum 13000 AIC withstand rating.[24] As the Port learns more about electric equipment through its demonstrations, this standard is likely to change to a higher withstand rating and voltage. The Port also requires electric charging equipment to be UL-listed or have third-party certification. Most of the charging equipment deployed to date does not come with UL certification and will require on-site third-party testing, which is laborious and expensive. In order to have widespread deployment, charging equipment manufacturers must plan for UL certification, and the Port and other agencies must engage with them to accelerate this process.

The Port standard does not address the connector on board the equipment. The lack of clarity on the coupling system makes it difficult to design infrastructure to match. As described in the NREL charging standards white paper, the industry has not yet coalesced around a single connector, although the field of options is narrowing.

The Port alone cannot drive standardization; however, funding agencies and utilities could play a major role in advancing standardization by prescribing the connector systems and charging outlets eligible for funding.

5.4.1.2 Hydrogen Fueling Standards

The Society for Automotive Engineers (SAE) has been working on hydrogen fuel cell standardization for heavy-duty equipment through the adaption of light-duty SAE J2601 and SAE J2799. While the Port is not a party to this standard-setting process, it will monitor the progress and expects to review and adopt standards as developed.

5.4.2 *Infrastructure Design Standards*

The Port Engineering Bureau maintains two design-related documents that are likely to be impacted by the transition to electrification:

- **Design Criteria Manual**, last updated January 2014, which establishes the basic guidelines and minimum design criteria for Port infrastructure projects to assure consistent standardization; and

- **Electrical Design Criteria Manual**, last updated December 2017, which establishes a set of standards and rules that will be adopted by design professionals in preparing electrical designs and contract documents for Port projects.

These plans do not explicitly reference charging infrastructure or hydrogen fueling. In the near term, the Port should evaluate these manuals and plan to update these documents to reflect new design standards and criteria related to electric charging and hydrogen fueling infrastructure. The Port should continue to

[24] "Charging Outlet Standards for Cargo-Handling Equipment at the Port of Long Beach and Port of Los Angeles," February 27, 2017. http://www.cleanairactionplan.org/documents/charging-outlet-standards-cargo-handling-equipment.pdf/

monitor and refine these criteria as new information emerges. Lessons learned from the early zero-emissions demonstration projects should be incorporated into these criteria.

5.5 Develop Infrastructure Design Plans

The transition to zero-emissions equipment is likely to require considerable reorganization to account for new charging/fueling infrastructure, safety requirements, and operational management. The siting of refueling and recharging infrastructure requires careful consideration, particularly for heavy-duty equipment and vehicles with their large turning radii, reduced visibility and tall heights. Each terminal and facility will require a detailed design to appropriately site the infrastructure. Understanding the full impacts of infrastructure will require large-scale design master plans for each terminal, taking into account specific operational needs and physical layout.

That said, the Port has identified high-level evaluation criteria by which to assess potential fueling/charging locations for terminal equipment, trucks, and Port Community cars. These evaluation criteria are not intended to replace exhaustive engineering analyses but to provide a starting point by which to narrow the options.

5.5.1 Infrastructure Design and Planning Process

Infrastructure design master plans that integrate zero emissions will be critical to defining the costs associated with the transition and will be important aspects of lease negotiations in the upcoming decade.

Infrastructure design planning is a well-defined activity between the Port and the terminal operators. Designs can take place in the context of two approaches: retrofit or redevelopment. The Port in collaboration with the operator will decide on a case-by-case basis whether a retrofit or redevelopment makes the most sense for a given project.

Terminal Retrofit: The Port and operator work within the constraints of the existing terminal layout to add charging or fueling infrastructure. The terminal does not necessarily gain additional operational efficiency. Moreover, infrastructure may be considered “temporary” – useful for less than 10 years – if the terminal is ultimately redeveloped. Retrofits are less cost-effective on a per-installation basis but can be done more quickly than redevelopments. Pier J is an example of a terminal retrofit where nine RTG cranes are being electrified. This $8 million electrification will generate immediate air quality benefits once complete; however, long-range plans for Pier J may include filling the open water slips and reconfiguring the layout, which would render the current electrification obsolete.

Terminal Redevelopment: The Port and operator reimagine the space from the ground up. Yards are reconfigured. Utilities are moved and upgraded. New land may be added. The Port works closely with the operator to design a new terminal layout that maximizes operational efficiency and environmental benefits. Terminal redevelopments are rare given the Port’s long lease timelines. Middle Harbor is an example of a redevelopment in which the Port combined two outdated terminals into one state-of-the-art electrified terminal. In the process, the Port added 60 acres of new land and electrical infrastructure to accommodate 800 pieces of electric terminal equipment with a total electrical capacity of nearly 64 MW. This $2 billion project took 10 years to design and construct.

A redevelopment is the most efficient and cost-effective way to build out the necessary zero-emissions infrastructure and allows for sufficient time for utilities planning; however, as stated earlier, these opportunities are rare and require long timelines.

In either case, the process for terminal design planning is consistent. The key steps include:

- **Initiate Terminal Design Planning**: The individual terminal design plans focus on the operations specific to a terminal operator and its business model. Discussions about infrastructure improvements and operational changes – particularly if a large redevelopment is planned – often take place during lease negotiations. Thus, most zero-emissions design plans are likely to begin at this time. Most Port of Long Beach container terminal leases are expiring in mid-2020 (varies by terminal operator and location), which means prior to that time terminal design planning will be voluntary actions by the terminal operators. Achieving formal buy-in from the terminal operators for terminal design plans will be necessary to accelerate the transformation.

  Design plans address the following elements:

  - **Equipment Specifications**: Define equipment specifications, which include plan and section views with dimensions, power and communication needs, and any other special requirements such as maintenance, stowage, operations, etc.;
  - **Operational Modeling**: Identify space and clearance needs, develop safety requirements, identify permitting and code compliance requirements;
  - **Terminal Layouts**: Develop terminal layouts for the property when converted to zero-emissions operations, including infrastructure improvements (e.g. power, communications, fencing, striping, etc.); and
  - **Utilities Planning**: Engage SCE to project new load demands and to integrate terminal design plans into the utility's long-range planning forecast.

- **Develop ROM Estimates**: Based on the previous work, develop a ROM cost estimate for the entire transition and specific sub-tasks.

- **Establish a Project Schedule**: Create a Gantt chart for construction activities, identifying and differentiating between high-priority versus low-priority projects and retrofit versus redesign projects. Timelines must be developed to minimize the impacts to ongoing terminal operations.

- **Conduct Additional Studies (as needed)**: Additional studies to support design planning may include geotechnical investigations, coastal and navigational studies, environmental permitting, environmental risk analysis, constructability analysis, and construction material availability analysis.

Completing comprehensive terminal design plans will allow for appropriate time to develop and assess new permit needs; to signal to SCE the timing and scale of new electrical infrastructure demands, which is critical for the utility's long-range planning; and to secure funding to support the transition to zero emissions.

Importantly, a terminal master design plan does not necessarily lead to full construction. After completion of these plans, the Port and operator may elect to phase actual construction, prioritizing the most technologically advanced equipment first, or moving ahead with infrastructure installations that have the least amount of impact on terminal operations. The comprehensive plan, however, provides a full view before moving ahead.

To assist with planning, the Port has identified a number of considerations that should be assessed when designing and constructing terminal infrastructure.

5.5.2 Site Considerations for Terminal Equipment

As part of the master planning process, terminal operators must evaluate equipment parking locations and configurations, location and capacity of existing electric infrastructure, physical space and where additional space may be required, and operational parameters. Specific considerations that the Port has learned through its demonstration projects include:

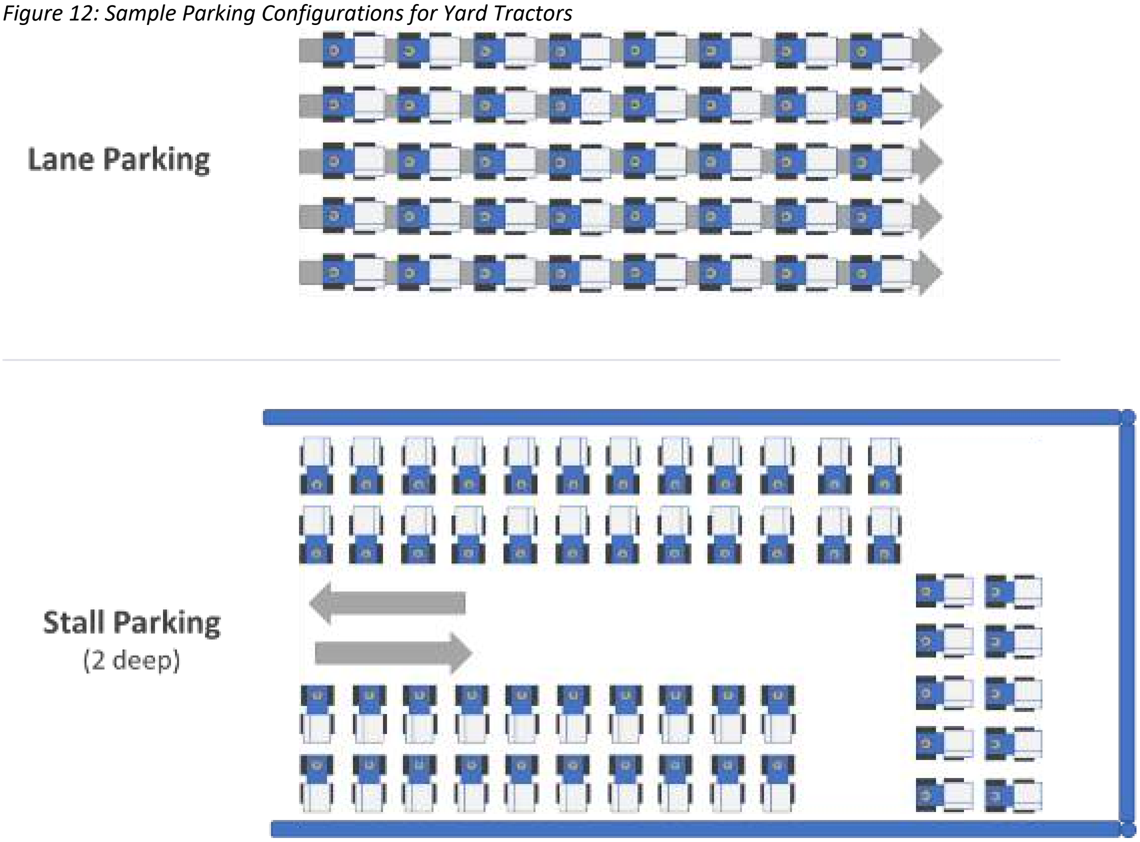
- **Proximity of charging outlets to in-place electrical or fueling infrastructure.** It is cheaper and more efficient to site charging outlets near substations and electrical infrastructure in order to maximize use of existing power, to minimize the length of conduit runs, and to reduce construction impacts on terminal operations. Similarly, taking advantage of existing fueling areas for hydrogen can minimize costs and improve efficiencies.

- **Proximity to equipment parking**. Operators park their equipment in designated areas, generally by equipment type. The parking locations are based on the terminal's specific operations. Relocating zero-emissions equipment to other areas of the terminal for the sake of charging could have significant impact on operations. Charging outlets should be sited at existing or future equipment parking locations when possible.

> CHECKLIST
> Terminal Equipment Site Considerations
>
> *Have you taken into account…*
> - ❒ Proximity to existing electrical or fueling infrastructure?
> - ❒ Proximity to equipment parking?
> - ❒ Parking configurations?
> - ❒ Physical space limitations, including safety barriers and walkways?
> - ❒ Cable management?
> - ❒ The need to maximize capacity of upstream electrical infrastructure?
> - ❒ Opportunity charging?

- **Parking configurations.** Parking configurations vary by terminal. Some operators park equipment head-to-head. Some use a more traditional head-in or back-in approach. Still others use a "chute" system resembling parallel parking. These configurations have an impact on the placement of charging equipment. Figure 12 depicts these parking configurations.

Figure 12: Sample Parking Configurations for Yard Tractors



Source: 2018 Draft Feasibility Assessment for Cargo-Handling Equipment

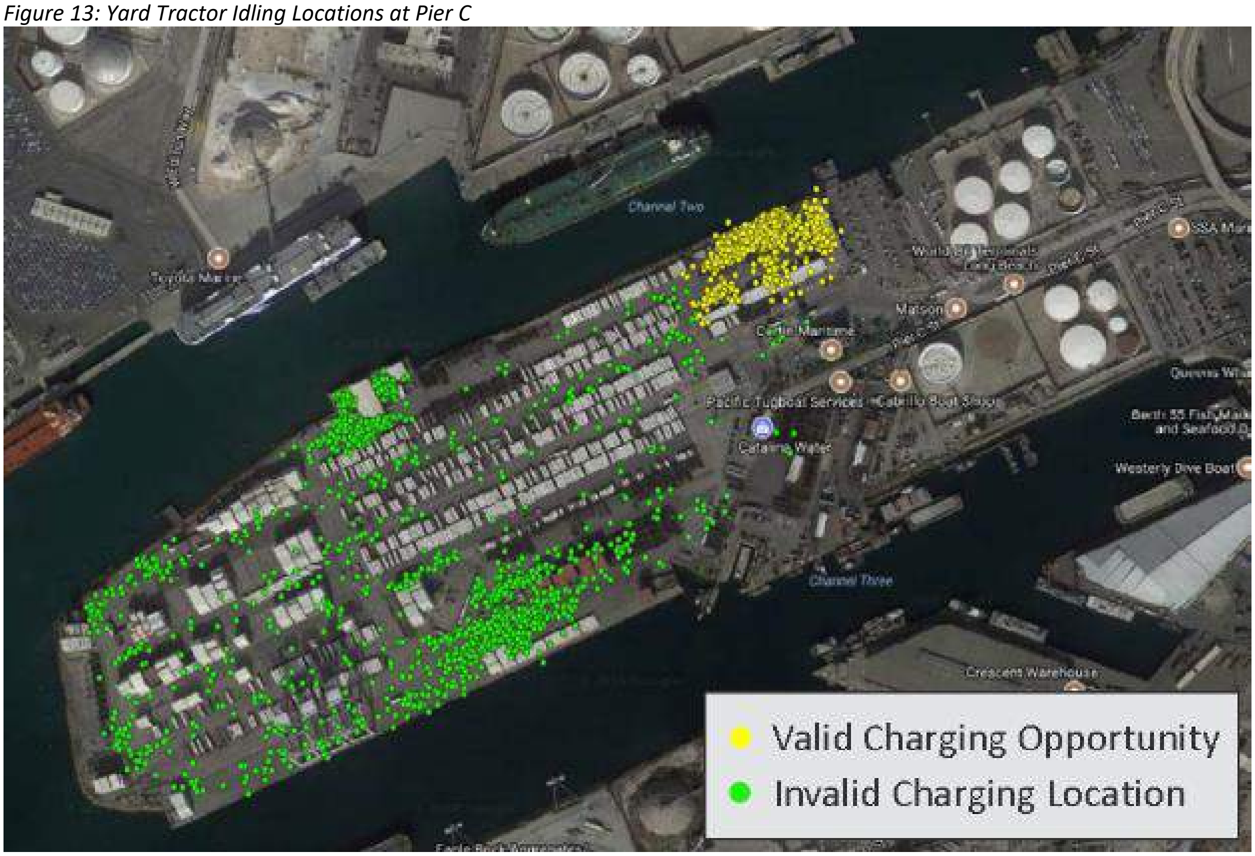
- **Physical space**. As stated earlier, terminal space is tight. The Port's technology demonstrations have found that even a relatively small charging device takes up a sizeable amount of space–upwards of 75 square feet–particularly once safety bollards and pedestrian safety walkways are taken into account. Substantial additional real estate is required for upstream substations and transformation. In almost all Port demonstrations to date, the charging equipment has consumed an area well beyond the parking stalls, forcing the operator to lose equipment parking spots.

- **Cable management systems.** Port equipment requires significant power, which increases the diameter of the charging-outlet connection cables. These high-voltage cables may pose a safety hazard if not properly contained when not in use.

- **Maximization of charging deployment.** Even a few new charging outlets may require a significant upgrade in upstream electrical equipment, such as substations and transformers. This electric equipment has a fixed capacity and may be capable of supporting more charging outlets than are deployed. For example, a transformer may be able to support up to 20 electric yard trucks; it is underutilized if only four yard trucks are deployed. For maximum efficiency and cost effectiveness, electrical equipment should be sized appropriately for the deployment, and charging outlets should be maximized to take advantage of the full infrastructure capacity.

- **Opportunity charging locations.** The NREL container terminal duty-cycle study found that equipment often idles or parks for brief moments (less than 10 minutes) in locations outside the designated parking areas, generally near restrooms and breakrooms, as indicated by the green dots in Figure 13. These stops were deemed too brief to warrant a charging connection; however, these locations may be considered for opportunity charging, particularly if the charging infrastructure does not impede operational flow or require time-consuming manual connection.

Figure 13: Yard Tractor Idling Locations at Pier C



Taken together, these considerations strongly suggest the need for a comprehensive and holistic approach to siting, designing, and constructing terminal infrastructure. They also suggest that a one-size-fits-all approach for all terminals is not likely to work.

Conceptual sites for charging at each terminal, based on current equipment parking, are provided in Figure 14 through Figure 19.

Figure 14: Pier A Conceptual Charging and Refueling Locations

Figure 15: Pier C Conceptual Charging and Refueling Locations

Figure 16: Pier G Conceptual Charging and Refueling Locations

Figure 17: Pier J Conceptual Charging and Refueling Locations

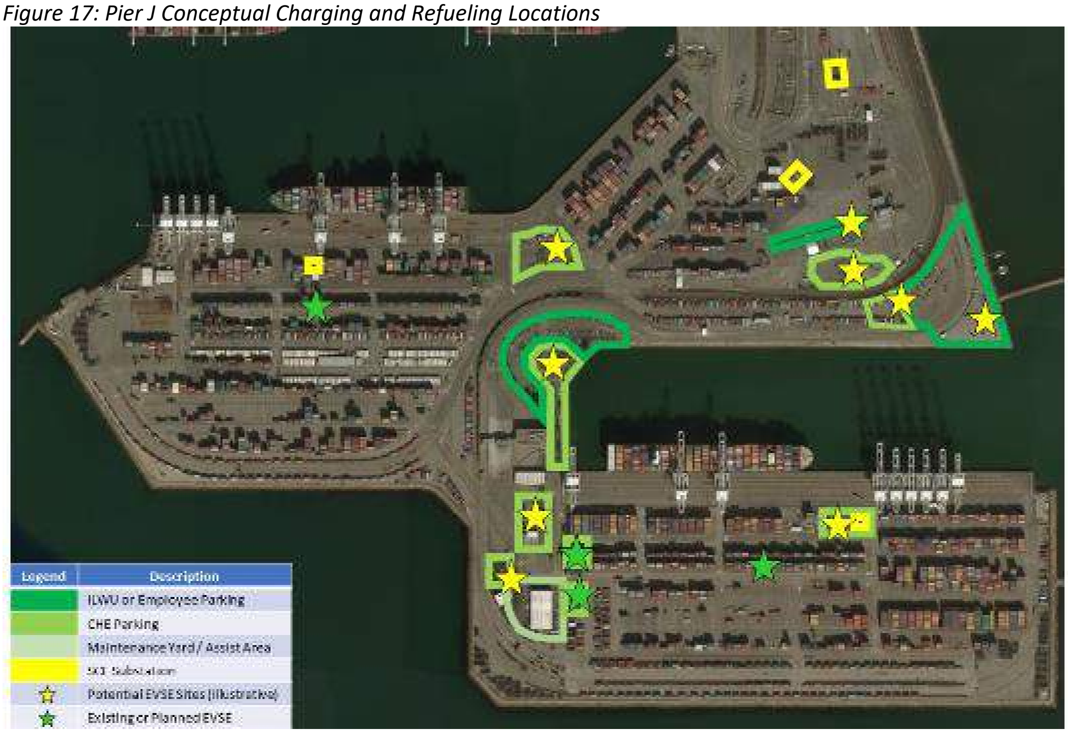


Figure 18: Pier T North Side Conceptual Charging and Refueling Locations

Figure 19: Pier T South Side Conceptual Charging and Refueling Locations

5.5.3 Site Considerations for Drayage Trucks

Most trucks are expected to refuel or recharge at trucking facilities, which are largely outside of the Harbor District and outside of the Port's jurisdiction. Planning for this infrastructure on private facilities must begin today, and the Port urges the development of a regional truck-charging plan in close coordination with the trucking industry and other partners. That said, the Port recognizes the potential need for opportunity charging sites within the Harbor District.

The following considerations should be assessed when designing and constructing publicly accessible truck-charging infrastructure within the Harbor District:

> CHECKLIST
> Drayage Truck Site Considerations
>
> *Have you taken into account…*
> - ❒ Impediments to truck flow?
> - ❒ Value of port land?
> - ❒ Areas where trucks already congregate?
> - ❒ Opportunities at existing heavy-duty fueling stations?

- **No impediments to truck flow.** The Port is a busy place, and to operate at top efficiency, it must move cargo off the terminals and out of the port complex as quickly as possible. Trucks that sit for long periods of time impede traffic flow and increase congestion. Thus, any publicly accessible charging sites in the Harbor District must not interfere with cargo flow, worsen congestion, or encourage prolonged truck loitering.

- **Port land value.** Port land is expensive, particularly along the water's edge. Even more, the Port has a fiduciary and regulatory responsibility under the state public trust doctrine to manage port lands for the benefit of water-related commerce and navigation. Thus, if the Port elects to use vacant port-owned land for truck charging, this land must be deemed to have little other commercial value.

- **Areas where trucks already congregate.** Priority consideration should be given to sites where trucks already safely congregate, such as truck stops or existing heavy-duty fueling stations that can be expanded to include hydrogen or electric charging. Throughout the Port, there are also unofficial truck stops where truckers stop, out of the flow of traffic, to buy food from food trucks or take phone calls. These sites should be evaluated on a case-by-case basis.

In all cases, as stated earlier, the Port must ensure that truck charging facilities do not impede the flow of goods, worsen congestion, or encourage trucks to stay in the Harbor District for prolonged periods of time for the sole purposes of refueling or charging. To discourage loitering, the Port should explore charging mechanisms that limit charge times or that assess escalating rates for electricity beyond a certain pre-determined time limit.

Figure 20 displays conceptual locations for publicly accessible truck charging within the Harbor District. These sites are port-owned vacant lots where trucks already safely congregate, including an existing natural gas fuel station, or in the case of Pier A West, could safely congregate if appropriately developed.

Of note, other potential sites for truck charging are the queue lines into terminals; these sites should be considered only with an in-ground charging solution that provides electricity while trucks are in motion so as not to worsen queuing. These sites are not indicated in Figure 20 as they would require substantial additional analysis.

Figure 20: Conceptual Sites for Publicly Accessible Truck Charging in the Harbor District

5.5.4 Site Considerations for Light-Duty Vehicles

Charging and refueling infrastructure for light-duty vehicles is necessary to serve the Port's own fleet of employee-driven pool vehicles, the port-related workforce – including longshoremen and terminal employees – and visitors to the public tourist-serving areas.

To support fuel-cell equipment, it is critical to develop a hydrogen fueling station close to the Port. With the current station about 3.5 miles from the Port, the added inconvenience could deter adoption of fuel cell technologies.

To support electric vehicles, the Port should explore installing charging stations at terminal administrative offices and longshore parking lots. Building codes now require new parking locations to have some EV charging infrastructure with capacity for further build out. These building codes, however, only apply to projects seeking new building permits. The Port and City could proactively commit to updating its infrastructure to meet or exceed current code requirements in support of increased EV adoption. Additionally, the need for more charging outlets should be evaluated in the Queen Mary/Carnival Cruise area, particularly as plans to redevelop the site move forward.

The Port also maintains a fleet of nearly 40 passenger cars for employee work travel and as part of its employee carpool program, almost all of which are hybrid-electric. The Port is gradually introducing electric vehicles to this fleet. As such, it will need to provide ample charging outlets at its headquarters and public fleet yard. Figure 21 and Figure 22 display conceptual sites for charging and hydrogen fuel for cars in the tourist-serving areas.

Figure 21: Conceptual Sites for Charging and Refueling at the Queen Mary/Carnival Cruise Terminal

Figure 22: Conceptual Sites for Charging and Refueling in the Hotel District

5.5.5 Considerations for Energy Resources and Resiliency

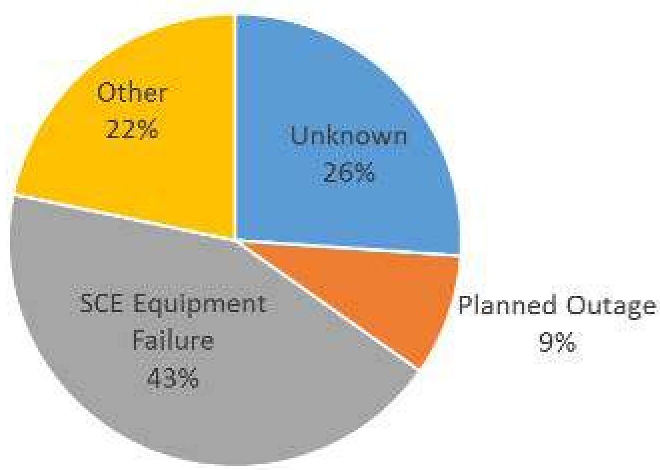
Moving toward zero emissions is expected to increase the Port's reliance on electrical power from an aging utility grid, making users more vulnerable to planned and unexpected grid outages. At the same time, utilities are able to readjust tariffs annually, making the prediction of this important operating cost difficult. At the Port, on-terminal electricity usage is predicted to quadruple by 2030 compared to 2005 levels.[25]

Not only must the Port plan for the significant projected rise in electricity usage, but the Port must also consider the impacts of multiple cost factors to the electricity users (e.g., operators) and impacts to the utilities and their rate payers as a result of the added loads. For example, at a container terminal operating two regular shifts, it is possible that most or all of the battery-electric terminal equipment will be charged during a 4- to 6-hour window, off-shift, in early morning. The impact to the utility grid, which could be either negative or positive, is unknown. If negative, utilities are likely to assign increased costs to users via capacity charges.

Distributed energy resources (DERs), such as stationary energy storage, could mitigate some of these impacts by smoothing demand, but the amount of power needed by a marine terminal and the space available for DERs pose additional challenges. Likewise, onsite renewable energy generation capabilities are often constrained by available space. In the future, the Port will be evaluating other DERs, such as local cogeneration plants, which may be sited outside the marine terminal footprint but could provide additional distributed power. The existing relationship of these DERs to the utility grid, and the tariffs that govern these relationships will also need to be evaluated.

Increased reliance on grid power will make fully electrified marine terminals increasingly vulnerable to grid outages. In 2017 and 2018, the Port reported 23 grid outages on terminals. These outages ranged from 30 minutes to 25 hours in duration. Figure 23 displays the causes for these outages:

Figure 23: Causes of Power Outages, 2017-2018



Although many of these outages were planned or caused by uncontrollable factors (e.g., traffic accidents, bird strikes), any outage has the potential to significantly impact port operations. Diesel equipment

[25] Port of Long Beach Energy Initiative Roadmap, 2017. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=15009

continues to function without utility power; electrified equipment does not. When terminals stopped operating during a 2002 labor dispute, the economy lost $1 billion a day, according to some reports.[26] A closure caused by an inability to power electric equipment could have similar devastating economic impacts.

The Port has several initiatives to address resiliency and business continuity in the event of an unforeseen or uncertain impact, although, as yet, none of these initiatives explicitly evaluate the new risks associated with zero emissions:

- **Business Continuity Plan**: The Port has developed and regularly updates a Business Continuity Plan that identifies critical processes and the ways in which the Port can maintain these processes in the event of a disruption. The Port's emergency mission is to facilitate cargo movement, maintain a safe and secure port environment, and meet its legal, regulatory, and financial requirements. Currently, the plan is focused on port authority operations and does not consider operational continuity of the terminals. In future iterations of the plan, the Port may expand its scope to do just that, and if so, should consider the impacts of electric outages or fueling interruptions on zero-emissions terminals.

- **Climate Adaptation and Coastal Resiliency Plan**: This plan[27] evaluated the potential impact of climate change on Port infrastructure, including sea-level rise and heat impacts. The plan identified the Port's most vulnerable assets and developed adaptation strategies to protect the Port. Electrical infrastructure was highlighted as one of the Port's most vulnerable systems, and specific mitigation strategies were identified to protect specific electrical substations from water inundation. As a result of this plan, the Port now requires sea-level rise analysis in Harbor Development Permits and is updating design documents to consider these effects. The City of Long Beach is also developing a Coastal Resiliency Plan, which would address the Queen Mary/Carnival Cruise tourist-serving areas.

- **Energy Initiative Roadmap**:[28] This roadmap aims to improve port-wide energy management and infrastructure. It describes steps the Port will take to provide system resiliency, create long-term cost stability, provide value for its customers, and create new business opportunities, while achieving the Port's environmental and regulatory mandates. The Roadmap contains near-, mid- and long-term actions, many around the issues of resiliency to support zero-emissions goals.

> IN THE TOOLBOX
>
> The Port's 2017 ***Energy Initiative Roadmap*** describes near-term, mid-term, and long-term actions to improve port-wide energy management and infrastructure. It is a useful tool for other ports looking to develop energy programs. Find it at www.polb.com/energy.

[26] Bonney, J. "Putting a Price on a Port Strike." Joc.com. 2013. https://www.joc.com/port-news/longshoreman-labor/international-longshoremen%E2%80%99s-association/putting-price-port-strike_20130215.html
[27] Port of Long Beach Climate Adaptation and Coastal Resiliency Plan, available at http://polb.com/civica/filebank/blobdload.asp?BlobID=13799.
[28] Port of Long Beach Energy Initiative Roadmap, 2017. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=15009

A key near-term action is the demonstration of a microgrid system. Microgrids – systems of DERs and controls that are capable of isolating from the grid – could protect marine terminals against grid failures, avoiding millions of dollars in damages to the local, state and national economy. The Port is now developing a microgrid system at its Joint Command and Control Center (JCCC), which will allow the Port to learn about design, installation, and operation of microgrid systems and share this knowledge with other industrial users in California. The project involves installation of a 300-kilowatt solar carport over the JCCC parking lot, installing an Energy Control Center that includes microgrid controls and a 330-kilowatt stationary battery energy storage system, and integrating a 250-kilowatt microgrid-extending mobile battery energy storage system. If successful, the mobile energy storage system could demonstrate the Port's ability to provide moveable power to electrified equipment in the event of an outage.

Additionally, the Roadmap recommended that the types of equipment incorporated into the energy planning process include supporting electric and alternative energy (such as hydrogen) equipment, and other emerging technologies.

Port Electricity Resiliency Assessment

To fully assess the risks of zero emissions and to ensure business continuity, the Port should conduct an electrical assessment with specific actions for energy resiliency. Among the questions to be answered:

- What does resiliency mean for the port? What does it look like?
- What level of resiliency do we need to achieve? What are the options to be able to achieve this level?
- What kind of outage are we planning for? Duration?
- What are the current resources to provide resiliency at port facilities?
- What is the best way to plan for resiliency?
- What do we need to plan and design for in future developments?
- What role does energy storage or energy generation play?
- How do we prioritize and focus the Port's efforts and resources for the greatest benefit?

These robust planning efforts have laid the foundation for zero-emissions resiliency; however, the significant transformation from diesel to electric or hydrogen – and the potential risks if an interruption occurs – requires even more analysis and action. As an important first step, the Port has begun to develop a "Port Electricity Resiliency Assessment" to define its expectations for resiliency, assess the resiliency of the current system for zero emissions, and develop specific actions. This assessment and subsequent actions must incorporate the previous continuity planning efforts and explicitly analyze a zero-emissions transformation.

5.5.6 Considerations for Cybersecurity

Electric charging systems often employ energy management software to distribute demand more efficiently and evenly across a fleet. The NREL charging standards white paper describes how electric-charging systems often employ smart sensors and other software-based systems. While desirable from an energy demand management perspective, these systems may expose terminal fleets to the threat of cyber-attacks via communication with a third-party cloud-based network or even the utility grid. Little is known about these risks; however, it is an area worthy of further study.

The Port has already begun this work with the microgrid project, which will incorporate advanced cybersecurity software to detect and react to external cyber threats to the Port security systems and SCE network. Additionally, the Port should engage security and law enforcement agencies, including the Cybersecurity Subcommittee under the United States Coast Guard's Area Maritime Security Committee for the Los Angeles/Long Beach sector. This group is comprised of law enforcement and safety experts and meets quarterly to discuss cybersecurity issues. The forum provides an ideal opportunity to communicate these possible risks and develop collaborative solutions to mitigate them. Additionally, future demonstrations of zero-emissions technologies should assess cybersecurity risks as robustly as equipment performance and other testing parameters.

5.6 Execute Design Plans

Following the design planning phase, which will provide a better understanding of the costs and scope of zero-emissions infrastructure for each terminal, the Port must decide how to execute the projects. As noted earlier, the Port can construct infrastructure as part of a terminal redevelopment or terminal retrofit.

CHECKLIST
Considerations for Terminal Redevelopment or Retrofit

The approach to designing and constructing zero-emissions infrastructure – whether as part of a massive facility redevelopment or as a retrofit – can impact cost, longevity of the improvements, and the immediacy of emission reductions. The chosen direction may vary by facility and depend heavily on pre-determined timelines and opportunities. There is no right way; each terminal should be evaluated on a case-by-case basis. The following questions can help guide the evaluation:

- ❑ Is there an imminent lease expiration that would bring both parties to the table for a discussion about long-term operations and land-use?
- ❑ What is the long-term vision for the terminal in the Port Master Plan?
- ❑ Is more or better financing available for one option over another?
- ❑ Are there timing drivers, such as regulation or environmental goals?
- ❑ Does the operator have a preference?
- ❑ Are there efficiency or productivity gains to be realized with one option over another?

Each terminal should be evaluated on a case-by-case basis considering the timing of a terminal's lease expiration, the facility design plans, budgets, environmental goals, and long-term land-use plans as informed by the Port Master Plan, a state-mandated plan that characterizes land use and future development in the Harbor District.

5.6.1 Timing

The Port and its operators typically discuss land improvements during lease negotiations. Generally, negotiations take place one year before a lease expires or at five-year "reopener" intervals, which focus on rates and financial terms. Also, the Port or operators can open leases outside this cycle, particularly if there is a specific need.

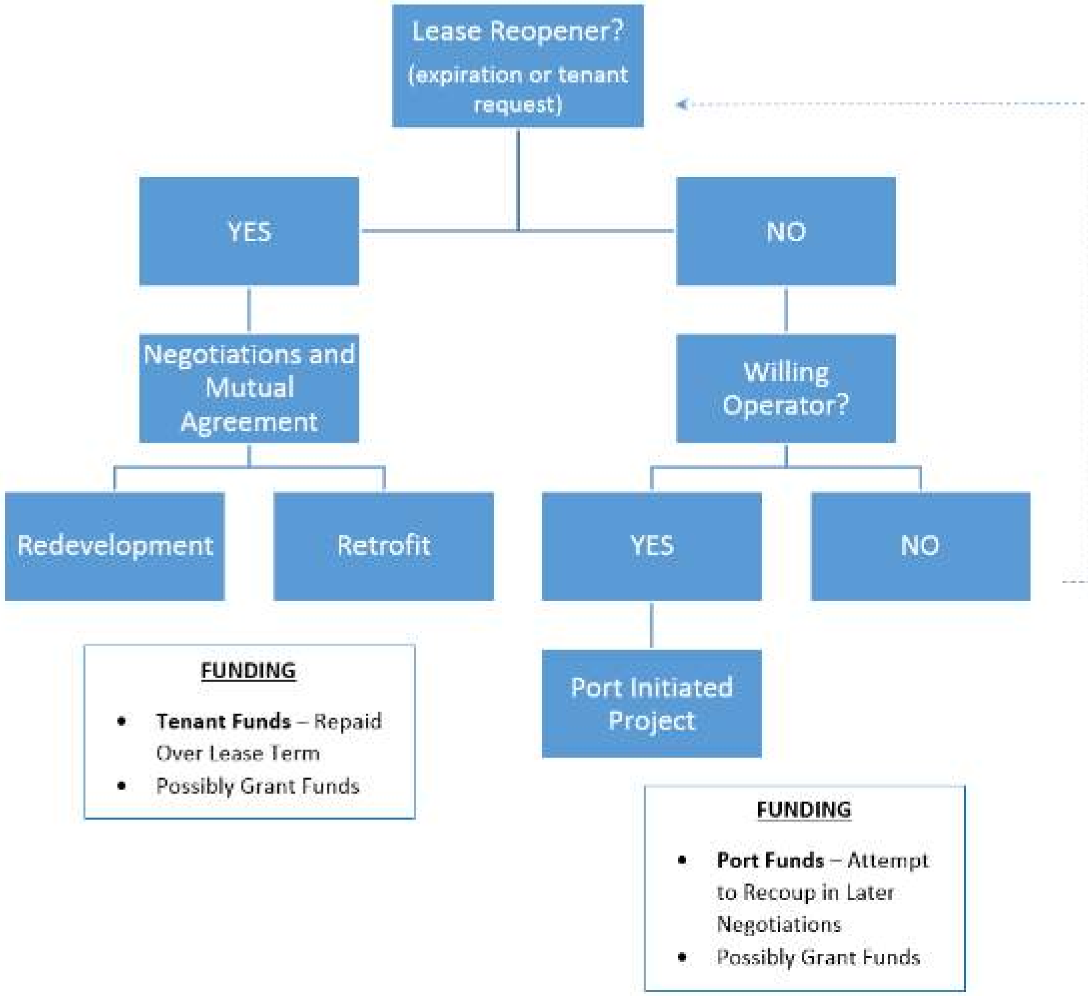
Absent a state regulation that necessitates immediate construction for compliance, discussions about zero-emissions infrastructure are expected to take place during lease negotiations. A lease expiration or an operator-driven reopener is the ideal time to have this discussion as this opportunity affords a broader conversation about long-term finances, operational efficiencies, environmental goals, and optimal land use. The Port also is in a better position to recoup upfront infrastructure investments from the operator, particularly if these investments result in a more valuable terminal. Most container terminal leases, however, are not due to expire until the mid- to late-2020s.

The Port can initiate zero-emissions infrastructure discussions outside of lease expirations; however, if the operator does not agree to fund improvements, the Port is likely to shoulder the full cost of the infrastructure, which makes public and private financing even more critical.

Figure 24 illustrates the decision-making process and associated financial considerations. In order to advance zero-emissions infrastructure by 2030, the Port must identify funding mechanisms and other incentives that encourage operators to come to the table prior to a lease expiration.

As noted earlier, redevelopments require a longer timeframe than retrofits, largely due to greater requirements for environmental documentation and more complexity in design and construction. A large redevelopment may take five to eight years. In contrast, retrofits could be done more quickly, as the permitting requirements are simpler and the design and construction may be less extensive. Retrofits may take three to five years, depending on the scale.

Figure 24: Decision Process for Executing Design Plans



5.7 Actions

The Port has already begun working through the six-step process to evaluating and deploying zero-emissions infrastructure.

- **Step 1 – Establish a Baseline**: The Port should continue to maintain a detailed inventory of the existing infrastructure and capacity of electrical infrastructure and hydrogen fueling within the Port property.

- **Step 2 – Forecast Future Need**: The Port has conducted high-level assessments of the potential need for electricity and hydrogen associated with the adoption of zero-emissions technologies. As the Port obtains more information about zero-emissions equipment performance and energy consumption through its technology demonstrations, these assessments will need to be updated.

- **Step 3 – Evaluate Infrastructure Options**: Technology development for charging and fueling solutions typically lag behind technology development for equipment. This highly dynamic market is constantly evolving as innovations are adopted from other on-road sectors and industrial applications. The Port should actively seek out cost-effective, innovative charging and fueling solutions for demonstration in a real-world port environment.

- **Step 4 – Adopt Standards**: The Port Community must push the heavy-duty industry to coalesce around a limited number of charging standards, potentially by linking public funds to specified eligible connector types. Additionally, the Port must evaluate and update its own infrastructure design standards to reflect zero emissions.

- **Step 5 – Develop Infrastructure Design Plans**: Working with terminal operators to ***develop design plans around the zero-emissions transformation is one of the most critical pieces of the Blueprint***. Design plans require a detailed and thorough evaluation of all possible terminal operations to establish if terminal redevelopments or retrofits are appropriate for the adoption of zero-emissions technologies and installation of charging/refueling infrastructure. Working on these plans now will be critically important to advancing the state of the zero-emissions transition.

  In addition to technology standards, the Port must ensure that zero-emissions technology is incorporated into the implementation of the Business Continuity Plan, Coastal Resiliency Plan, and Energy Initiative Roadmap and should begin developing a Port Electricity Resiliency Assessment. Also, the Port must continue to engage security and law enforcement agencies, including the Cybersecurity Subcommittee under the United States Coast Guard's Area Maritime Security Committee for the Los Angeles/Long Beach sector and to evaluate cybersecurity risks in future demonstrations.

- **Step 6 – Execute Design Plans:** The Port must identify opportunities to execute the design plans and construct the necessary infrastructure as part of terminal leases. The Port must identify funding mechanisms and other incentives that encourage operators to come to the table prior to a lease expiration.

6 Financial and Business Model Considerations

The discussion around zero-emissions technologies and infrastructure is focused on technical and operational feasibility: can it work? Demonstration projects hosted at the Port – and at others across California and the world – are accelerating the technological advancement, building a deep understanding of the full breadth of design and infrastructure considerations, and guiding innovation towards solutions that can be broadly deployed in a commercial setting. The transition from demonstration to commercialization represents the intersection of innovation and business sustainability. Terminal operators exist in a low-margin, high-volume, globally-competitive environment where operational reliability is paramount and changes to one part of the operations can have cascading impacts. Establishing reliable business models will accelerate the transition to zero-emissions technologies.

To fund the zero-emissions transition, the Port has developed a four-step approach:

1. Develop Cost Estimates
2. Identify Funding and Financing Options
3. Address Key Funding Barriers
4. Develop Project Funding Plans

6.1 Develop Cost Estimates

In order to identify sustainable funding strategies for the zero-emissions transition, the Port must understand the magnitude of costs. Today's costs are expected to drop over time as battery and fuel cell technology matures and larger-scale deployments enable manufacturing efficiencies, and these trends will improve the financial equation; however, as described in this section, the Port Community is still facing unprecedented costs to achieve zero emissions.

6.1.1 Capital Costs

As part of the CAAP framework, the San Pedro Bay Ports developed a preliminary cost estimate for key CAAP strategies. The full methodology is described in the document. The Ports assumed zero-emissions technologies are capable of replacing fossil-fueled equipment on a 1:1 basis. The costs identified in the *Preliminary Cost Estimates for Select Clean Air Action Plan Strategies*[29] are summarized in Table 17, Table 18, and Table 19.

[29] EnSafe, *Preliminary Cost Estimates for Select Clean Air Action Plan Strategies,* 2017. http://www.cleanairactionplan.org/documents/preliminary-cost-estimates-select-caap-strategies.pdf/

Table 17: Unit Terminal Equipment Cost Estimates

Table 4
Unit Cargo-Handling Equipment Cost Estimates

Equipment	Tier 4 Diesel Equipment Cost		Near-Zero Equipment Cost		Retrofit — Electric Equipment Cost		Electric Equipment Cost		Fuel Cell Equipment Cost	
	Low End	High End	Low End	High End	Low End	High End	Low End	High End	Low End	High End
Yard Truck	$125,000[1]	$125,000[1]	$155,000[1]	$170,000[1]	--	–	$250,000[7]	$300,000[7]	$350,000[3]	$420,000[3]
Top Handler	$520,000[1]	$600,000[1]	$728,000[4]	$840,000[4]	--	–	$1,600,000[5]	$1,800,000[5]	$2,520,000[3]	$2,520,000[3]
Forklift	$40,000[1]	$40,000[1]	$80,000[1]	$80,000[1]	--	–	$45,000[6]	$45,000[6]	$70,000[7]	$70,000[7]
RTG Crane	$1,300,000[1]	$1,300,000[1]	$1,820,000[4]	$1,820,000[4]	$425,000[13]	$425,000[16]	$2,500,000[1]	$2,500,000[1]	$3,500,000[7]	$3,500,000[3]
Side Pick	$315,000[1]	$600,000[1]	$441,000[4]	$840,000[4]	--	–	$1,600,000[9]	$1,800,000[9]	$2,520,000[7]	$2,520,000[7]
Straddle Carrier	$1,100,000[1]	$1,100,000[1]	$1,540,000[4]	$1,540,000[4]	--	–	$2,500,000[2]	$2,500,000[2]	$3,500,000[3]	$3,500,000[3]
Truck	$130,000[10]	$165,000	$190,000[12]	$225,000[14]	--	–	$300,000[11]	$400,000[11]	$420,000[3]	$560,000[3]

All footnotes are available in the reference document

Table 18: Estimate of Cost of Terminal Replacements/Retrofit for the Port of Long Beach

Electric Fleet Cost		Electric Incremental Fleet Cost		Fuel Cell Fleet Cost		Fuel Cell Incremental Fleet Cost	
Low End	High End	Low End	High End	Low End	High End	Low End	High End
$625,500,000	$694,900,000	$360,400,000	$411,900,000	$1,000,200,000	$1,111,400,000	$735,100,000	$828,400,000

Table 19: Estimate of Cost of Heavy-Duty Truck Replacements for that Serve the San Pedro Bay Ports

Electric Fleet Cost		Electric Incremental Fleet Cost		Fuel Cell Fleet Cost		Fuel Cell Incremental Fleet Cost	
Low End	High End	Low End	High End	Low End	High End	Low End	High End
$5,250,600,000	$7,000,800,000	$2,926,800,000	$4,088,700,000	$8,401,100,000	$11,201,300,000	$6,077,300,000	$8,289,200,000

In addition to equipment costs, the report includes high-level estimates of $40,000,000 of electrical infrastructure upgrades for each of the major container terminals and $1,000,000 of electrical infrastructure upgrades for each bulk terminal.

At the time of the report, the costs of hydrogen fueling for fuel cell equipment were deemed too speculative; however, using data presented in Section 6, the Port's terminal equipment would require an average of 6,500 kg of hydrogen per day across six primary piers (not including Middle Harbor, which has already electrified a significant portion of its fleet). With hydrogen fueling infrastructure (without onsite generation) estimated to be between $1,500,000 and $2,000,000 per installation (see Figure 10 in Section 5.2.1), hydrogen refueling infrastructure may yield significant cost savings compared to electrical infrastructure. For both electrical and hydrogen fueling infrastructure, additional detailed design planning will be critical to truly understand the potential cost impacts of both the infrastructure and additional yard reconfiguration.

6.1.2 Total Cost of Ownership

In addition to the capital investment, the TCO of zero-emissions equipment must be understood to understand how potential fuel and maintenance savings contribute to the overall economic considerations. As part of the Terminal Equipment and Drayage Truck Feasibility Assessment Reports, a TCO calculation was conducted for commercial and near-commercial ready technologies.

The findings for yard tractors and electric RTG cranes, which were the only terminal equipment types evaluated for TCO, are presented in Figure 25 and Figure 26.

Figure 25: Total Cost of Ownership, Yard Tractors

Figure 26: Total Cost of Ownership, RTG Cranes

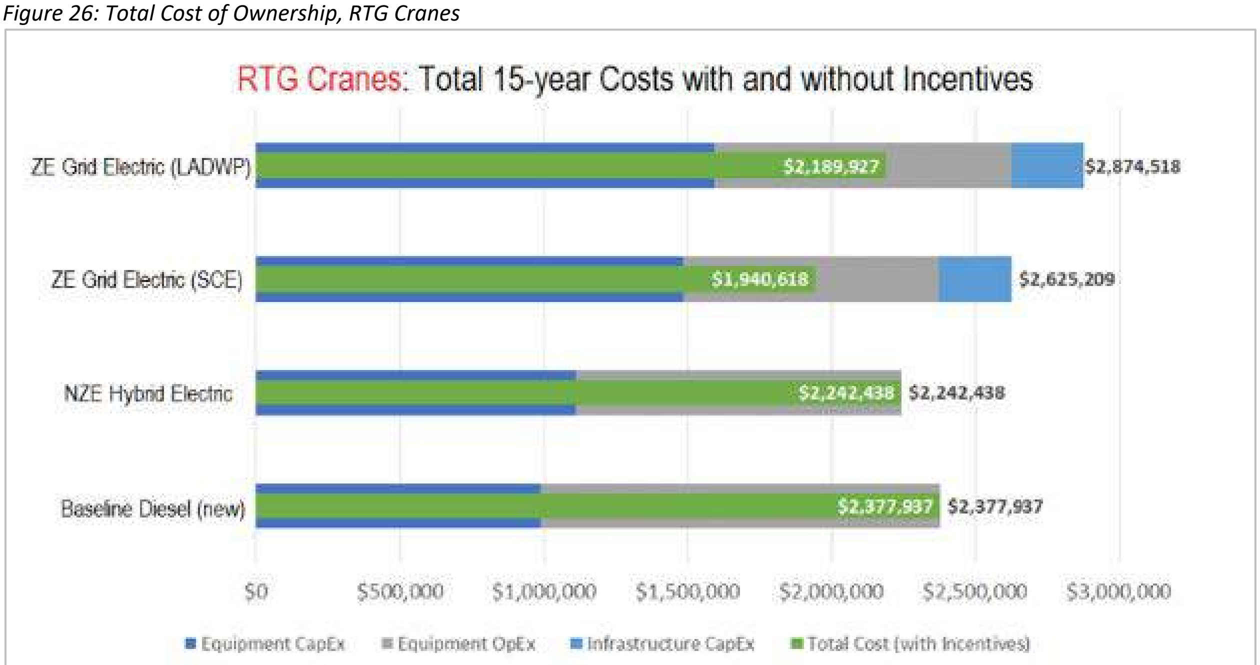


Figure 17. Total 15-year costs of ownership for the "Average RTG crane" scenario (NPV at 7% discount rate)

Additionally, the feasibility assessment provided an overall snapshot of "economic workability" for terminal equipment depicted in Figure 27.

Figure 27: Summary of Draft 2018 Findings for Terminal Equipment Economic Workability

"Economic Workability" Criteria	Base Considerations for Assessing "Economic Workability"	Yard Tractors		RTG Cranes	
		ZE BE	NZE NG ICE	ZE Grid-Electric	NZE Hybrid-Electric
Incremental Equipment Cost	The upfront capital cost for the new technology is affordable to end users, compared to the diesel baseline.				
Fuel and Other Operational Costs	The cost of fuel / energy for the new technology is affordable, on an energy-equivalent basis (taking into account vehicle efficiency). Demand charges / TOU charges (if any) are understood and affordable. Net operational costs help provide an overall attractive cost of ownership.				
Infrastructure Capital and Operational Costs	Infrastructure-related capital and operational costs (if any) are affordable for end users.				
Potential Economic or Workforce Impacts to Make Transition	There are no known major negative economic and/or workforce impacts that could potentially result from transitioning to the new equipment.				
Existence and Sustainability of Financing to Improve Cost of Ownership	Financing mechanisms, including incentives, are in place to help end users with incremental equipment costs and/or new infrastructure-related costs, and are likely remain available over the next several years.				

Legend: **Economic Workability (2018)**

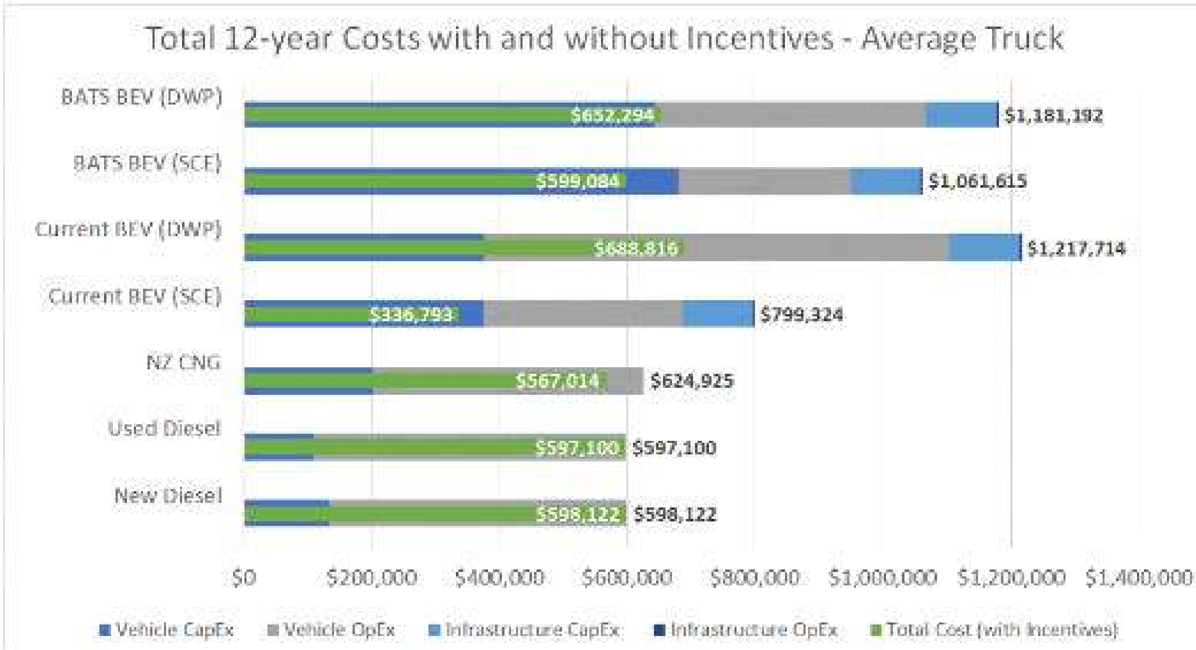
Little/No Achievement — Fully Achieved

Source: Estimated ratings based on MTO interviews and site visits, footnoted studies, OEM product information, various government sources, and consultant's industry knowledge.

For drayage trucks, the report does not evaluate the TCO for hydrogen fuel cell trucks; however, several stakeholders, including NREL and Ricardo Engineering are developing TCO models for hydrogen trucks that can be incorporated into the Blueprint when complete.

For battery-electric trucks, the TCO for currently-available models is shown to be lower than diesel-fueled trucks; however, these battery-electric models may have less operational capacity than the traditional diesel-fueled trucks. When accounting for vehicle operation that can satisfy broadly-applicable truck specifications (BATS), the TCO using SCE electricity rates is comparable to their diesel counterparts.

Figure 28: Total Cost of Ownership, Drayage Trucks



Additionally, the assessment provided an overall snapshot of “economic workability” for trucks, which is depicted in Figure 29.

Figure 29: Summary of 2018 Findings for Economic Workability, Drayage Trucks

Economic-Related Criteria / Issue	Base Considerations for Assessing General Economic Workability	Achievement of Criteria in 2018 (Commercially Available Truck Platforms)	
		ZE Battery-Electric	NZE NG ICE
Incremental Vehicle Cost	The upfront capital cost for the new technology is affordable to end users, compared to the diesel baseline.	◔	◕
Fuel and Other Operational Costs	The cost of fuel / energy for the new technology is affordable, on an energy-equivalent basis (taking into account vehicle efficiency). Demand charges / TOU charges (if any) are understood and affordable. Net operational costs help provide an overall attractive cost of ownership.	◑	●
Infrastructure Capital and Operational Costs	Infrastructure-related capital and operational costs (if any) are affordable for end users.	◔	●
Potential Economic or Workforce Impacts to Make Transition	There are no known major negative economic and/or workforce impacts that could potentially result from transitioning to the new equipment.	●	●
Existence and Sustainability of Financing to Improve Cost of Ownership	Financing mechanisms, including incentives, are in place to help end users with incremental vehicle costs and/or new infrastructure-related costs, and are likely remain available over the next several years.	◕	◕

Legend: Economic Workability (2018)

○ ◔ ◑ ◕ ●

Little/No Achievement — Fully Achieved

Source: based on preliminary OEM survey responses, OEM product information, various government sources, and Tetra Tech team's industry knowledge.

Understanding the true cost of ownership can help reduce uncertainty around the transition to zero emissions; however, the Port Community may not even agree on what should be measured or how.

To further refine the TCO models, the Port Community should work together to develop "TCO Assessment Protocols," similar to what was done for technology demonstrations (e.g., testing protocols for yard tractors and trucks), to ensure that all agencies are assessing TCO and collecting the requisite data in a consistent manner.

6.2 Identify Funding and Financing Options

The Port Community in California has access to one of the most vibrant and robust funding landscapes with diverse public funding and some of the world's most innovative private finance groups. This diversity is critical because the costs for zero emissions will be borne by many different actors, public and private. The Port will bear the significant cost of utility upgrades and upstream electrical work to facilitate on-terminal charging and fueling. Operators will bear the cost of new equipment and charging delivery systems. Understanding the landscape helps identify the most viable funding pathways for zero emissions for all parties.

As part of the Blueprint, The Grant Farm conducted a study of public funding and private investment options and innovative business models for zero-emissions equipment and infrastructure to determine which models, if any, could support the zero-emissions transition. These studies, "2019 California Public Funding" and "2019 Innovations in Private Finance," can be found in Appendix G and Appendix H respectively and contain more details about the public and private options described in this section.

In general, the funding landscape can be viewed on a continuum of technology readiness. Traditionally, public funding is available with the express and explicit goals of supporting the commercialization of new and innovative technologies. Private funding is better geared towards large-scale transitions of commercially-available technologies and has less focus on demonstration projects.

6.2.1 Public Funding

Many state and federal agencies, including CARB, CEC, and EPA, provide grants and subsidies to support the development and deployment of zero-emissions equipment and infrastructure. These agencies have also created programs that support workforce development, education, and the ongoing operational costs associated with zero-emissions equipment. Public funding is typically competitive, either through grants or first-come-first served vouchers.

Generally, public funding supports six types of zero-emissions program areas:

- **Research, Demonstration, and Deployment**: This type of funding focuses on limited-scope demonstrations with the goal of gathering three to 12 months of data. Research, demonstration, and deployment funding typically covers infrastructure and equipment purchase with limited funding for operations. Examples include the CEC's Alternative and Renewable Fueled Vehicle Technology Program (ARFVTP) and the CARB's Clean Transportation Incentives Program.

- **Infrastructure Expansion**: This type focuses largely on one-time costs to develop charging and fueling infrastructure. There has been significant investment in on-road public charging and hydrogen fueling infrastructure in the past few years to help with the chicken-versus-egg problem in which equipment purchases are not feasible without the supporting infrastructure. The US Department of Transportation's Better Utilizing Investments to Leverage Development (BUILD) program supports large-scale infrastructure projects. Other programs, including ARFVTP, fund smaller projects.

- **Commercial Equipment Price Buy-Downs**: This funding type focuses on reducing the costs associated with new commercial equipment. Various structures have been developed to validate commercial viability, principally scrap-and-replace or repower following a registration process with the funding agency. The federal Clean Diesel Funding Program (DERA), Carl Moyer Program, and the Volkswagen Settlement Fund are examples of scrap-and-replace programs.

- **Tax Credits and Revolving Loans**: For large deployments, the state has created programs to help private companies access low-interest debt that is traditionally only available to public entities.

- **Operational Support**: The LCFS program is designed to support the ongoing use of low carbon transportation fuels, including electricity and hydrogen. Operators can earn and sell credits for using equipment not powered by fossil fuels. Larger deployments earn more revenue. Programs such as this provide ongoing and regular funds to support operations. The Port has developed a quick calculator to help operators estimate their potential LCFS benefits (see "In the Toolbox").

- **Workforce Development**: The state provides funding in limited amounts for workforce development related to zero emissions through the CEC. Additionally, workforce training may be an eligible project under the Supplemental Environmental Projects program, which uses penalty fees paid from air-quality violations to support efforts that do not have other avenues of funding.

> IN THE TOOLBOX
>
> The Port has developed the ***LCFS Calculator*** to help operators estimate the potential value of LCFS credits. Operators input their expected energy usage or equipment deployment into a spreadsheet and the tool provides credit and revenue estimates. The tool can be downloaded at: *www.polb.com/zeroemissions.*

The public funding landscape, particularly for the research, demonstration, and deployment and infrastructure expansion funding, is highly fluid with most agencies developing annual funding plans and actively soliciting input for the next year's plan.

This process makes long-range planning difficult; however, it also gives the Port Community a chance to signal needs and barriers to the agencies and to engage proactively on funding solutions to support zero emissions. Joint advocacy efforts may be effective in steering funds to areas that can create the greatest positive impacts. On an annual basis, the Port must review the investment plans of major public grant programs and provide comments that reflect our real-life experiences deploying zero-emissions and our needs going forward.

6.2.2 Private Funding and Innovative Business Models

Private financing, which includes traditional models such as bonds and loans as well as emerging innovative business models tailored to zero-emissions deployment, offers unique opportunities for rapid, large-scale investment in new infrastructure and technologies.

Many private-sector investment firms interested in zero-emissions technologies have experience in renewable energy procurement (electricity and renewable natural gas). Through their expertise with these business models, numerous innovative financial strategies, instruments, and structures have been developed to support zero-emissions technology deployment. There is no "one size fits all" type of structure, and the particular approach will be highly dependent on the specifics of any given project or deal, in particular the risk profile and the resulting required returns from investors. Traditionally, the Port Community has accessed low-risk investment-grade funds; however, the nascence of zero-emissions may lead to higher-risk, higher-return investments.

CASE STUDY

Macquarie Principal Finance and Port of Los Angeles

The Harbor Performance Enhancement Center (HPEC) at the Port of Los Angeles is a $130 million public-private partnership dedicated to facilitating sustainable freight movement and supply chain efficiencies throughout the United States.

When completed, the 110-acre facility on Terminal Island is expected to take about 3,500 truckloads a day from nearby container terminals to the HPEC staging area. The 5.5-million-square-foot facility will use a hub-and-spoke distribution model to improve efficiency. Additionally, the facility is expected to use the cleanest available equipment and trucks, and alternative fuels will be available onsite.

Macquarie Principal Finance provided capital for the development of the container staging hub, demonstrating the private financing world's interest in port-related projects.

Private funding engages a number of new financial models for zero- and near-zero-emissions transportation markets that have largely been developed in the light-duty sector. A selection of relevant models is described below with more details in Appendix H:

- **Municipal Bonds, including "Green Bonds":** As a municipal agency, the Port has access to low-interest bonds to help finance major infrastructure projects. The Port has issued several series of bonds since 2010 to finance the Middle Harbor Terminal and Gerald Desmond Bridge replacement. A subset of municipal bonds is "green bonds," a relatively new mechanism that allows public issuers to access low cost capital for public infrastructure projects with environmental benefits.

- **SB 350 Transportation Electrification Funds:** Under SB 350, investor-owned utilities, including SCE, are required to invest in transportation electrification. To that end, SCE is expanding upon its existing make-ready charging infrastructure program for light-duty with a charging infrastructure program for heavy-duty equipment called Charge Ready Transport. For a given project, SCE installs the necessary electrical infrastructure beyond the meter up to a stub-out on which the charging device can be installed. Operators receive favorable charging rates and reduced demand charges. A certain percentage of funds for Charge Ready Transport must be spent in seaports/goods movement, disadvantaged communities, and on forklifts, including port equipment.

- **Tariffed On-Bill Investment Programs**: Also known as "Pay as You Save" (PAYS) or inclusive financing, these programs integrate equipment financing directly into the underlying pricing of the tariff. Voluntary participants in a tariffed repayment program typically carry no debt or lien on the improvement. The capital can be sourced either by the utility or from a third party. The utility recovers the costs on utility bills for improvements at the customer location at a rate that is less than the estimated savings the electrification produces.

- **Battery Financing**: The FAST ACT established the opportunity for capital leasing of zero-emission vehicle components and "removeable power sources," including batteries and fuel cells. This provision allows the battery or fuel cell to be leased separately from the remainder of the vehicle. In the electric bus sector, Proterra and BYD have both created battery financing models that allow the vehicle operator to own the vehicle and separately lease the battery. This model allows the battery-lease partner to accept the cost and risk associated with new technologies. These organizations typically expect the lease cost to be paid as fuel and maintenance savings are realized over the lifetime of the vehicle. Additionally, these organizations take the used battery and are better positioned to redeploy the battery in second-life applications, such as stationary storage.

- **"Charging as a Service" and "Mobility as a Service" Payment Models:** These models typically bundle financing for the vehicle, the alternative energy distribution infrastructure, the charging/refueling equipment, and the energy in a 10+ year financing structure with a firm "pay by the unit" or "pay by the mile" fee. In practice, the model requires minimal or no up-front financing, and acts similarly to a Power Purchase Agreement for E-Fueling or E-Mobility. It enables access to capital needed to handle the battery/fuel cell costs and infrastructure upgrades required to make the initial transition to zero-emissions transportation, within an operational expense framework that is familiar to operators.

- **Collaborative Approaches to Purchasing Zero-Emissions Equipment and Infrastructure:** Collaborative procurement programs have long been utilized by government agencies to access discount bulk pricing, gather required capital threshold for improved financing rates, and to create administrative efficiency through reduced procurement barriers and knowledge transfer. The Port has not traditionally been involved in equipment purchases for port operators; however, the new zero-emissions goals have prompted new conversations around bulk purchasing to drive down equipment costs.

- **Vehicle Grid Integration Opportunities:** When not in use, battery-electric equipment could discharge unused energy back into the grid. Operators who can sell this energy to the utility reap the revenue benefits. Given the round-the-clock operations of the Port, it is not clear whether there will be such opportunities in the future as electric equipment begins to be deployed in large numbers. That said, the larger capacity of batteries in many Port applications will provide a unique test bed opportunity to determine revenue potential.

6.2.3 Port Community Financing Approaches

The Port Community uses a mix of public and private financing options to support infrastructure and equipment and is expected to require this mix moving forward.

The Port's revenues are comprised largely of lease payments from terminals and cash available through debt. Large infrastructure projects are typically funded by municipal bonds, and more recently, the Port has accessed green bonds to support rail development at Middle Harbor. Due to its current capital projects program, the Port has nearly $1 billion in debt and spends roughly 10% of that amount annually on interest and principal repayment. The Port also has secured hundreds of millions of dollars in grants and low-interest federal loans to offset infrastructure projects. Grants and loans are the preferred methods of funding large infrastructure projects; debt and the Port's own funds are least desirable.

CASE STUDY

Financing Zero Emissions Two Ways at Port of Long Beach

The Port is using a variety of ways to pay for the early deployment of zero-emissions terminal equipment. Some approaches are more traditional – as in the case of the Middle Harbor terminal – and others are more innovative, heavily reliant on public funding and emerging infrastructure programs, as is the case at Pier J.

For Middle Harbor, which combined two outdated container terminals in a nearly $2 billion zero-emissions redevelopment, the Port took its traditional approach of financing the upfront property improvements and then recouping those costs through an unprecedented $4.6 billion, 40-year lease with the operator, Orient Overseas Container Line. Because the Middle Harbor improvements enhanced the layout and productivity of the terminal, the land itself became more valuable, enabling the Port to recoup its investment. To fund the construction, the Port sold municipal bonds, including "green" bonds, at favorable rates. The Port also helped the operator secure nearly $3 million in federal grants for zero-emissions equipment.

At Pier J, the operator SSA Marine is repowering nine RTG cranes to full electric. The $8.8 million project on its own does not enhance terminal productivity or the value of the land and as such, it is uncertain whether the Port could recoup infrastructure investments through a future lease negotiation. Thus, to make the project attractive, the Port helped the operator secure more than $5.3 million in state and federal grants. Additionally, SCE, as part of the SB 350 Transportation Electrification program, contributed $3.4 million for infrastructure. These grants and innovative financing mechanisms made this zero-emissions project economically feasible.

Moving forward, the Port and operators must evaluate the return on investment for zero-emissions projects in order to develop appropriate funding plans.

The Port attempts to recoup terminal infrastructure investments through its lease agreements. Leases are always subject to negotiation with the operator; the Port is more successful at recovering costs when an improvement raises the value of a terminal, as in the case of Middle Harbor.

Operators are responsible for funding their equipment and rely on a mix of private third-party financing and their own funds. The Port has helped secure grant funds on behalf of operators for zero-emissions equipment.

6.3 Address Key Funding Barriers

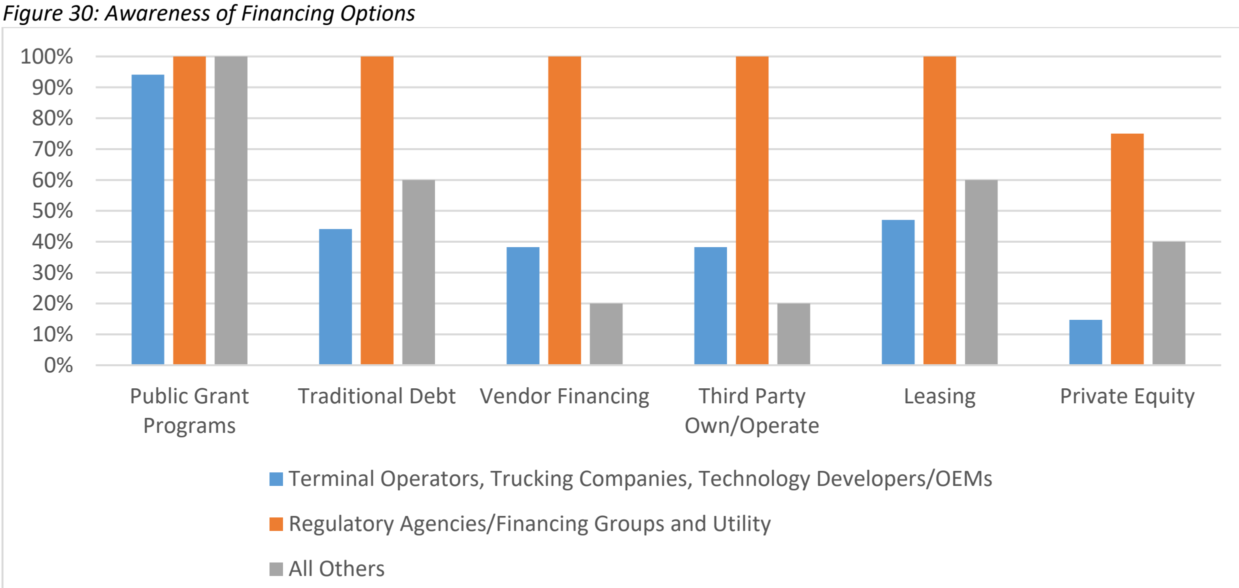
Given the significant costs associated with the zero-emissions transition, the Port Community must identify financing mechanisms that support not only the initial deployments – whose high costs still reflect the risk inherent in prototype and pre-commercial technology – but also the full integration of zero-emissions vehicles and equipment into long-term procurement planning. As part of the Blueprint, the Port reached out to operators and other port stakeholders, public funding agencies, and private funding agencies to identify key barriers for securing the funds necessary for zero emissions.

6.3.1 Lack of Awareness

One of the most noticeable barriers is unfamiliarity with the level and types of funding available. When surveyed, only 17% of stakeholders – all operators, utilities, regulatory agencies/finance groups, and technology developers/OEMs – believed that external funding was readily available for new zero-emissions equipment and infrastructure.

Even more, they seemed unaware of the diversity of funding options. Figure 30 demonstrates wide disparities among stakeholders in the awareness of public and private financing options. Operators are very familiar with public grant programs for zero emissions; however, while beneficial in the near term to defray the risk of technology advancement and pre-commercial deployments, grants are not a sustainable funding source for commercialized equipment.

Figure 30: Awareness of Financing Options



Source: PCEVB Engagement Report (Appendix B)

As part of the Blueprint, the Port convened a workshop for operators and public and private funding organizations. The workshop introduced port operators to the various financing options and generated conversations about how best to stimulate the emerging port zero-emissions market. The Port can help increase awareness by hosting more educational events.

6.3.2 Competitive Concerns

The Port operates in a low-margin, high-volume, globally-competitive business. Capital investments typically need to result in additional revenue or reduced costs. Zero-emissions technologies and infrastructure, although beneficial for public health, have not been demonstrated to increase productivity and raise the value of Port land. When surveyed as part of the Blueprint, most operators did not know if – or flatly rejected the idea that – zero emissions would lead to a competitive business advantage. Likewise, the Port is not expected to gain market share against other ports by offering zero-emissions terminals and facilities.

This lack of competitive advantage – whether real or perceived – impacts financial considerations and funding approaches. Traditionally the Port has funded large-scale infrastructure projects through low-interest bonds, including green bonds, loans, and to a lesser extent, grants. These funding models work well when the Port can recoup costs from private operators over time through leases, particularly when infrastructure improvements result in a more desirable and productive terminal, as was the case with Middle Harbor. But terminal operators may not be willing to pay for the infrastructure necessary to support zero emissions if these improvements do not improve their bottom line, and the Port may not be able to extract repayment of its hefty upfront investments.

These competitive concerns require the identification of sustainable funding models that can enable zero emissions without putting Port operators at a competitive disadvantage and thus inhibiting local economic and workforce growth.

6.3.3 Barriers to Specific Funding Options

In addition to the high-level barriers, the Port's stakeholder outreach revealed specific barriers to public and private funding. These challenges are described in this section.

6.3.3.1 Key Barriers for Public Funding

Public funding, particularly grants, is attractive for operators wanting to support the zero-emissions transition but unwilling to shoulder the high risk and high cost of early deployments. The restrictions and guidelines for some public funding programs, however, make these programs less desirable. Additionally, the competitive nature of these grants and vouchers limits the availability for all willing operators. Specific barriers are described below:

- **Scrapping Requirements:** At this early stage of zero emissions, many operators are unwilling to scrap a piece of functioning diesel equipment for a zero-emissions version with uncertain performance and reliability. Programs such as DERA and Carl Moyer require scrapping, often within 90 days of receiving the new equipment. Uptake of these programs for zero emissions is likely to be limited until the technology is closer to commercialization.

- **Complicated Applications:** Public funding application processes are often cumbersome and complicated, requiring cost-effective analyses, emission calculations, and other technical components. Many operators need outside expertise to complete these applications, which is an expense without a guarantee of success. The Port has assisted many operators with applications, shouldering the administrative and technical burden, and should continue to do so.

- **High Administrative Burden:** Public funding demands strict accountability for taxpayer funds and thus imposes stringent reporting, accounting, and auditing requirements on recipients. Many operators do not have the resources to manage ongoing reporting and grant administration requirements. These often-onerous requirements are a deterrent to many otherwise willing operators. Again, the Port can assist by assuming this administrative burden, if it has the resources to do so.

- **Short Execution Timeframes:** By legislation, funding agencies often have prescribed windows of time by which to encumber and liquidate the grant funds. Many of CARB's grant funds, for example, must be encumbered within two years and liquidated within two years. This structure often gives grant recipients only two years to design, develop, deploy, and demonstrate unproven zero-emissions technologies and to build out the required infrastructure. Given the legal mandates for competitive bidding and procurement for public agencies, these timelines are often unworkable. Longer liquidation deadlines would greatly enhance the diversity and scale of zero-emissions demonstration projects.

To address these barriers, the Port can rely on its technical expertise and resources to help the operators access public funding programs if it has the resources to do so. Additionally, the Port must continue to communicate these challenges to public agencies, who often recognize the challenges but are bound by legislative guidelines. Joint regulatory and legislative advocacy with other members of the Port Community can raise these issues and generate pathways to resolution.

6.3.3.2 Key Barriers for Third-Party Private Finance

Port operators rely on private financing for their equipment purchases, and they are very familiar with this model for conventional, diesel-fueled equipment and trucks. The switch to zero emissions, however, introduces new complexities in terms of the uncertainty of equipment performance and availability, charging and fueling infrastructure, and the sheer expense of this new equipment. As noted previously, the price of zero-emissions equipment is two to three times higher than today's equipment. These complexities require new approaches to private financing. Several key barriers complicate the landscape for funding the zero-emissions transition.

- **Multi-Tenant Split Incentives**: Multi-tenant property management arrangements can result in split incentives between tenants and owners. In some scenarios, the costs of electrical upgrades may be borne by the owner, while the benefits are enjoyed mainly by the tenants. Conversely, if tenants bear the zero-emissions infrastructure upgrade costs, their tenancy may be too short to reap the full benefits over the lifetime of the equipment. This split incentive is apparent at the Port in the relationship between terminal operators, who lease their space, and the Port as the property owner. Zero-emissions solutions must consider the needs, limitations, and benefits of project implementation for both terminal operators and the Port as the property owner.

- **Prohibitive Capital Costs**: The zero-emissions transition requires significant capital costs not required for traditional diesel equipment. Moreover, little is known about the long-term operating costs and full TCO implications. Full cost accounting models are better able to capture all aggregate costs – including capital costs of equipment, discount rate, infrastructure retrofit, and variable operations and maintenance costs – to better inform decision making. More information will become available as the early zero-emissions equipment accumulates a higher number of operational hours.

- **Increased Complexity**: Adoption of electrified assets presents new complexities to fleet operators and asset owners. Initial procurements will present challenges relative to operational capabilities, installation, interconnection, and the need to navigate new financing structures. Port staff and other informed stakeholders may need to provide more technical assistance to ensure that terminal operators have the information they need to efficiently adopt and integrate zero-emissions vehicles and related infrastructure.

- **Inexperience**: Uncertainty-driven risk and a lack of deal uniformity for zero-emissions fleet projects is a near-term barrier for widespread adoption and for larger (over $100 million) zero-emissions equipment and infrastructure deals. Initial projects may be small (less than $15 million) and ad hoc until successful business models, structures, and opportunities can be validated. Infrastructure and utility upgrade timelines and hydrogen availability will be critical risk factors, and a significant barrier, to the Port's successful zero-emissions transition.

Traditionally, the Port has not been involved in operator financing of equipment. With the transition to zero emissions, however, the Port may want to help alleviate barriers to private finance by broadly distributing information on zero-emissions equipment and infrastructure, convening regular workgroups of operators and finance agencies, and by ensuring that lease terms and other guiding documents do not preclude investment by outside firms if desired by the operators.

6.4 Develop Project Funding Plans

Financing the transition to zero emissions requires a tailored approach for each operator and project. There is a wide diversity of public and private options and no one-size-fits-all approach. Understanding and accessing these different funding options requires expertise, time, and resources; the Port can apply its own expertise and resources to help operators identify the best funding strategy.

Working closely with operators, the Port should develop a funding plan for every zero-emissions project. A project could be small, such as demonstrating a few pieces of electric equipment, or it could be large, such as deploying a 50-piece fleet or redeveloping an entire terminal for zero emissions and other efficiencies. In either case, the Port and operator should identify and evaluate potential funding mechanisms, evaluate whether these mechanisms align with the timeline and objectives of the project, and develop a funding plan for each project.

Funding plans should include the following elements:

- Project cost estimates and schedules;
- Identification of all viable funding mechanisms, public and private;
- Expected timeline for funding availability;
- Expected dollar amount, if known;
- Other grant or voucher requirements; and
- Roles and responsibilities.

The Port has developed informal funding plans on a case-by-case basis to support technology demonstrations, but to advance commercialization, the Port should formalize this process.

6.5 Actions

Based on the findings from the Blueprint effort, direct communication and engagement between finance entities and terminal operators and trucking companies will create a better understanding of the opportunities and challenges of investing in the Port's zero-emissions transition efforts. To support the development of viable financial pathways and business models, the Port may consider further engagement across the four primary steps.

- **Step 1 – Develop Cost Estimates**: The technology demonstrations identified in Section 4 and terminal design and planning process identified in Section 5 will result in an important refinement of costs for each individual facility. Additionally, the Port Community should develop consistent protocols for assessing TCO and collecting the necessary data.

- **Step 2 – Identify Funding and Financing Options**: As part of the Blueprint, the Port has identified the most promising public and private financing options. Given the highly dynamic nature of the zero-emissions financing space, the Port Community must continue to monitor the options and to work with regulatory agencies and private financing firms to develop programs supportive of the Port's transition to zero emissions.

- **Step 3 - Address Key Barriers**: The Port has identified key barriers to financing the zero-emissions transition. In the near-term, more educational forums, such as workshops and meetings, can help improve the Port Community's awareness of the opportunities. Additionally, regular communication with regulatory agencies and joint advocacy efforts may help communicate barriers to the public funding programs, and the Port should evaluate lease terms and other guiding documents to ensure they do not preclude private investment, if desired.

- **Step 4 – Develop Project Funding Plans:** For every zero-emissions project, the Port should work closely with its operator partner to develop a funding plan that considers project cost, timeline, and source of funding as well as any other factors that could impact successful financing.

7 Workforce Development

The transition to zero-emissions equipment and vehicles is expected to create significant workforce development challenges in the port environment. From operations and maintenance to the installation of charging and energy management systems, new career pathways will be required to plan for, support, and maintain the future fleet of zero-emissions equipment and vehicles.

Incumbent workers may need retraining, and new employees will need to acquire the skills necessary for success in a zero-emissions port environment. Importantly, the Port does not have a direct role in workforce development; thus, the Port must work closely with its partners in organized labor, educational institutions, and professional certification programs to ensure a rapid workforce transition to support zero emissions.

7.1 Current Workforce

Workforce opportunities generally include these classifications:

- **Terminal equipment operators:** Terminal equipment, such as RTG cranes, yard tractors, and forklifts, are operated by members of ILWU;

- **Terminal equipment mechanics:** Terminal equipment is maintained at each terminal by either ILWU or the International Association of Machinists (IAM);

- **Truck drivers:** Drayage truck drivers are either independent owner-operators or employees of trucking companies;

- **Truck mechanics:** Drayage trucks are maintained by in-house mechanics at large trucking companies or at off-site maintenance facilities;

- **Fleet mechanics:** The Port has mechanics to service its own fleet of vehicles. These mechanics are City employees represented by IAM; and

- **Infrastructure engineers and installers:** The Port is responsible for developing and maintaining the landside infrastructure at each port terminal. The Port has a large staff of engineers that oversees the design and execution of major infrastructure projects, including those related to zero emissions. The actual construction and installation of charging outlets is largely bid to outside contractors.

Each of these workforce opportunities may require its own certifications or educational credentialing.

7.2 Workforce Projections and Potential Impacts

To support the Blueprint, the Port worked with CITT at California State University, Long Beach, to project workforce development impacts and to identify the necessary career pathways to support the transition to zero emissions. The complete report can be found in Appendix I. Additionally, this section incorporates findings and recommendations from the "Zero-Emission Port Equipment Workforce Assessment" developed by Long Beach City College (LBCC) under a separate CEC contract.[30]

CITT found there is likely to be a high demand for the following job titles:

- Electrician;
- Solar Photovoltaic Installer;
- Automotive Specialty Technicians;
- Electrical Engineer;
- Electrical Power-Line Installer and Repairer (Lineman); and
- Maintenance Technician.

Additionally, CITT found that many of these classifications will require skills beyond what is currently expected. Electrical engineers, for example, will require not only traditional electrical engineering skills but also experience in energy management systems integration and even energy policy. The LBCC workforce assessment concurred with this finding and recommended the need for more cross-disciplinary programs.

7.2.1 Safety Certifications and Specialized Credentials

CITT identified the following professional certification programs and credentials that may be relevant to incumbent workers seeking to obtain the necessary skills for a zero-emissions future:

- **Electric Vehicle Infrastructure Training Program (EVITP)**: A certification for professional electricians to learn how to install charging equipment. The Port is partnering with EVITP on one of its zero-emissions technology demonstrations, which involves the installation of nearly 40 electrical charging outlets. The Port will evaluate the benefits and potential challenges of requiring EVITP-certified contractors on a port infrastructure project. The California Public Utilities Commission requires EVITP-certified contractors on all transportation electrification projects, and the City of Long Beach is exploring the possibility of making EVITP a requirement on city projects.

- **Energy Storage and Microgrid Training and Certification (ESAM-TAC)**: A certification for professional electricians to learn how to install and maintain energy storage systems and microgrids.

- **Certified Electric Vehicle Technician Training Program (CEVT)**: A certification for automotive service technicians to learn how to produce, maintain, and repair electric vehicles.

The Port Community should evaluate these programs to see if requirements for these certifications on port-related projects could enhance the safety or effectiveness of our zero-emissions transition. Additionally, as identified in the LBCC workforce assessment, community colleges may need to ramp up non-credit training programs, such as EVITP, for incumbent workers in partnership with labor unions.

[30] Long Beach City College, "Zero-Emission Port Equipment Workforce Assessment." Funded by the California Energy Commission contract no. ARV-16-024. Available at www.polb.com/zeroemissions.

7.3 Workforce Development Actions

The following sections describe ways in which the Port Community can prepare its incumbent and future workforce for widespread zero-emissions deployment. These actions have been informed by the CITT report, the LBCC report, and conversations with other relevant stakeholders in the Port Community.

7.3.1 Equipment and Vehicle Operations

The ILWU represents the more than 8,000 longshore workers who drive and operate zero-emissions terminal equipment. PMA provides training for longshoremen on skills universally required at all terminals, such as lashing. Terminals are responsible for on-the-job longshore training when introducing a new piece of equipment.

Conventionally-operated zero-emissions equipment should not require new operating skills, and most of the training is expected to take place at the worksite, between the terminals and the longshoremen, as needed; however, the Port should work closely with PMA and ILWU to monitor whether there is a need for new universal training modules related to zero emissions.

Similarly, there is not expected to be a significant need for new skills in driving a battery-electric or fuel cell drayage truck outside of fueling, but the Port should continue to monitor potential operational impacts with partners such as LBCC and the Harbor Trucking Association.

7.3.2 Equipment Maintenance

The switch to zero-emissions equipment and trucks is likely to have a significant impact on mechanics, whose experience is built around combustion engines, not batteries or fuel cells. At the terminals, training is likely to occur through a model by which the equipment manufacturers or technology developers instruct a lead mechanic, who in turn, trains the maintenance team. This "train the trainer" model is the model currently used at terminals to teach and apply maintenance skills for a new piece of equipment.

> CASE STUDY
>
> Workforce Partnerships to Advance Clean Air Goals
>
> When the Port adopted its first Clean Trucks Program in 2007, it recognized an immediate need for mechanics who could service the emerging natural-gas drayage trucks. The Port partnered with LBCC to develop an alternative fuels technician certification program to do just that. LBCC worked closely with engine manufacturers, industry experts, Harbor Trucking Association, and Port staff to design and implement the curriculum.
>
> LBCC also forged a partnership with Cabrillo High School in West Long Beach, a port-adjacent disadvantaged neighborhood, to link the community college curriculum to the high school. Cabrillo High students were able to take college-level courses through their on-campus automotive program. Upon high school graduation, these students needed only two additional classes at LBCC to obtain their professional certification.
>
> Today, the Alternative Fuels Program at LBCC continues to thrive and could be expanded to encompass zero emissions. The effort offers exemplifies how the Port can partner with educational institutions to support local workforce development and its own clean-air policy goals.

Recently, PMA and LBCC piloted a program by which longshoremen could receive training to become terminal equipment mechanics; this program should continue to be evaluated and may need to be expanded to accommodate the increasing demand for highly trained electric-automotive technicians, who could be sourced from the existing longshore workforce.

Trade schools and community colleges, including LBCC, provide technician training certifications and coursework for truck mechanics. These programs have evolved in the past to suit changing technologies and policy shifts – as was the case during the Port's first Clean Trucks Program (see case study: "Workforce Partnerships to Advance Clean Air Goals") – and are poised to adapt again to zero emissions.

The Port should work closely with LBCC to align curriculum and training programs for the zero-emissions transition, evaluating the need to create cross-disciplinary programs,[31] to extend these training programs into the Long Beach Unified School District in order to generate early interest in zero-emissions workforce opportunities, and to identify and address potential barriers to entry for the incumbent workforce, which may include financial assistance. Additionally, the Port should work with LBCC and other workforce partners to advocate for more funding for zero-emissions workforce development and curriculum development.

As the Port and City introduce more electric vehicles into our own fleets, we should evaluate our job classifications to ensure that our workers have skills in electric vehicle maintenance, potentially by providing access to nationally recognized credentialing programs, such as CEVT.

7.3.3 Infrastructure Engineering and Installation

CITT projected a significant need for electricians with experience in high-voltage electrical work as well as electrical engineers. As noted above, the Port should evaluate the need for safety requirements or additional credentials for the contractors likely to install the charging or fueling equipment and should consider additional training requirements for its own employees, who may be tasked with maintaining or deploying high-voltage charging units.

Also, the Port must gear up to expand its own electrical engineering staff, which plays a critical role in designing terminal and potentially truck infrastructure within the Harbor District. The Port should evaluate job classification specifications to ensure that engineers have the requisite skills in electrical design, hydrogen, energy systems integration and energy policy and should prioritize additional training for the incumbent port workers.

7.4 Actions

The Port has identified the following actions to support workforce development:

- **National Certifications.** Evaluate national certification programs, such as EVITP, ESAM-TAC, and CEVT, to see if requirements for these certifications on port-related projects or inclusion within job classifications could enhance the safety or effectiveness of the zero-emissions transition or the preparedness of our workforce for zero-emissions vehicle maintenance and infrastructure installation. Work with community colleges to offer certification trainings.

- **Incumbent Workforce Training.** Continue to evaluate and potentially expand programs that train the existing longshore workforce for electric-automotive mechanic positions and continue to

[31] LBCC, Workforce Assessment. See Appendix I of this document.

work with PMA, LBCC, and industry groups to monitor the need for new skills for equipment operators and truck drivers and for any associated training.

- **Local College Curriculum Alignment with Zero Emissions**. Work closely with LBCC to align curriculum and training programs for the zero-emissions transition.

- **Identification of and Solutions for Barriers**. Identify and address potential barriers to entry for the incumbent workforce, which may include financial assistance.

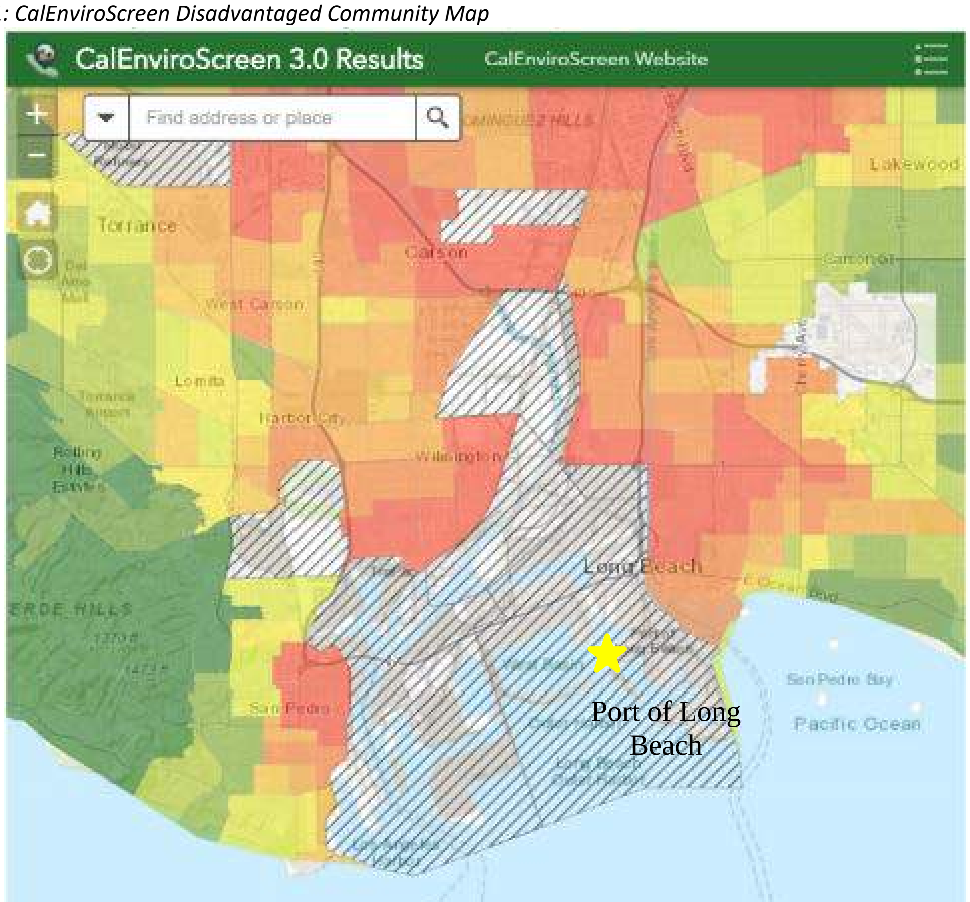
8 Community Benefits

The community surrounding the Port, which is one of the state's most disadvantaged areas, stands to benefit greatly from the transition to zero emissions. The obvious benefits are less air pollution and improved public health. Less obvious is the potential to expand job opportunities for local residents and to leverage zero-emissions investments for community benefit. This section describes the potential community benefits associated with zero emissions and includes action steps to maximize these benefits.

8.1 About the Community

The area around the Port is ranked in the 99th percentile for statewide air quality and is considered "disadvantaged," according to CalEnviroScreen, the state's disadvantaged-community screening tool, as shown in Figure 31. Poor air quality means higher health risk for local residents, a fact that has driven the Port's push toward zero emissions.

Figure 31: CalEnviroScreen Disadvantaged Community Map



8.2 Air Quality and Public Health Benefits

The air quality and public health benefits of zero emissions are likely to be significant, and most stakeholders agree these benefits are the primary driver for a transition. As part of the Annual Air Emissions Inventory, the Port reports emissions contributions by equipment and vehicle type. Based on 2017 emissions, the successful transition to zero-emissions terminal equipment and drayage trucks would result in the elimination of these emissions sources, totaling more than 400,000 metric tons of GHG, nearly 1,500 tons per year of NOx, and nearly 11 tons per year of particulate matter (PM) per year.

As noted earlier, yard tractors, top handlers, and RTG cranes generate more than 91% of the terminal fleet's NOx emissions and 95% of GHG emissions while representing only 74% of the fleet. In light of this, the Port should prioritize the transition of these pieces of equipment in order to accelerate emission reductions for community benefit.

Emission reductions, particularly PM reductions, are expected to generate substantial public health benefits for the community; however, more work could be done to validate these benefits by measuring actual health outcomes. Long Beach has an extensive collaborative network of health agencies and nonprofit organizations working to reduce port-related health impacts, such as asthma and cardiopulmonary ailments, and the Port has funded many of these organizations through its Community Grants Program. This network could benefit from better data aggregation of health outcomes to identify the on-the-ground community health improvements associated with zero emissions.

8.3 Community Hire Programs

As described in Section 7, the zero-emissions transition could open up new job opportunities around infrastructure installation, equipment development and maintenance, and energy system installation. The Port Community should work to ensure that local residents, particularly those in disadvantaged communities, have access to these new jobs. Community hire programs are one way to make sure that jobs in the zero-emissions space are available to Long Beach residents and workers that have traditionally struggled to find placement.

CASE STUDY

Community Hire Programs in Action

Community hire programs, both formal and informal, can help ensure that our most disadvantaged community members and local residents have access to the zero-emissions workforce benefits likely to occur. The Port and several zero-emissions equipment manufacturers already have such programs in place.

BYD Motors, a major zero-emissions equipment manufacturer, has a contractual agreement with Jobs to Move America, a coalition of community-based organizations and trade unions, to recruit and hire 40% of its workforce from populations facing significant barriers to employment, such as veterans, returning citizens, women, and African-Americans.

Another zero-emissions equipment manufacturer, TransPower, uses informal outreach programs and partnerships with local colleges to fill entry-level and internship positions. The company also recruits veterans from the nearby military bases, and today, employs eight veterans.

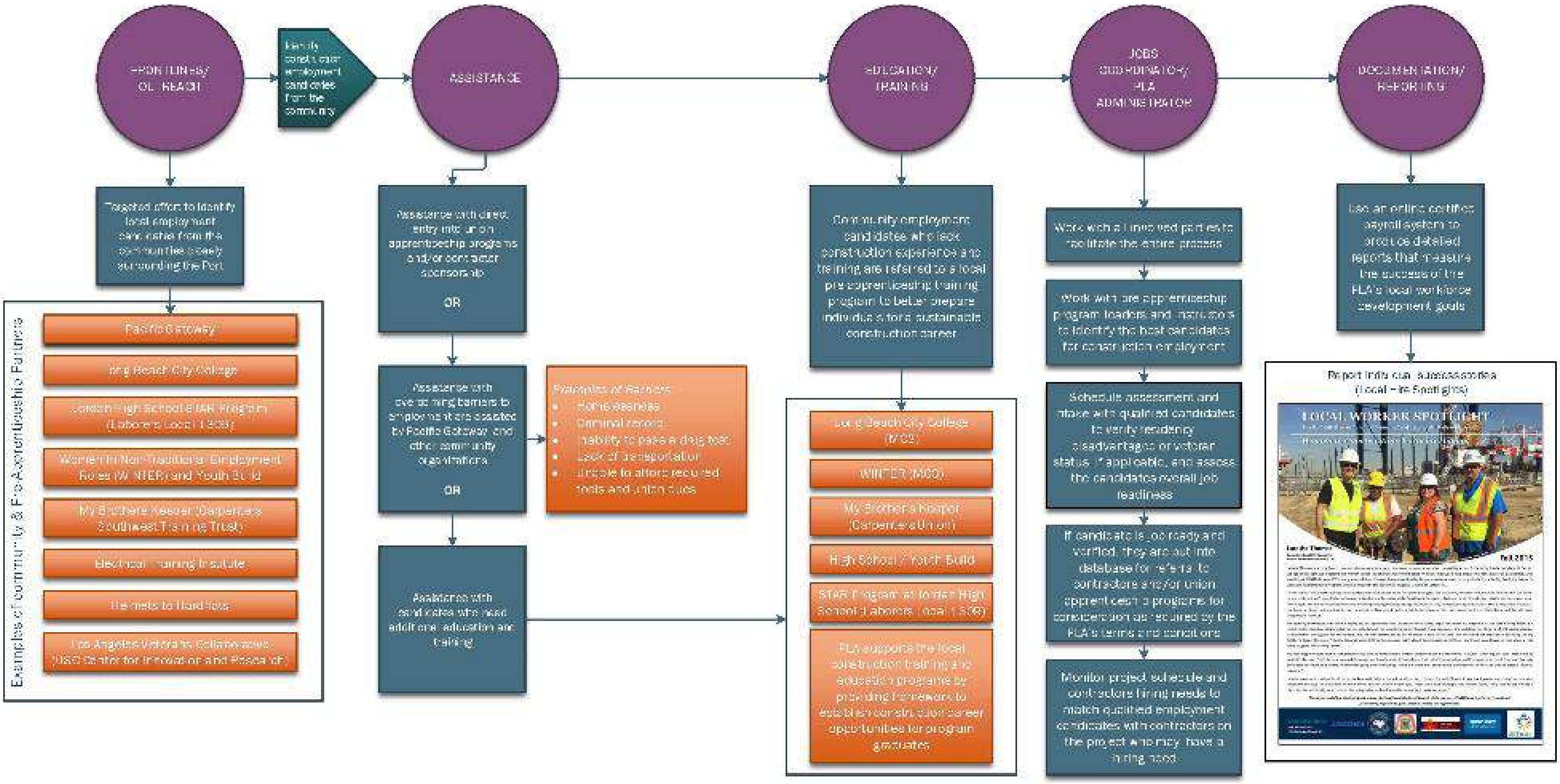
For major infrastructure projects, the Port has project labor agreements, which are formal contracts that require union labor and define recruitment and hiring priorities for Long Beach residents, disadvantaged populations, and veterans. On the largest and most active infrastructure projects, Gerald Desmond Bridge Replacement and Middle Harbor, roughly 1 in 8 construction workers came from Long Beach, and 16% were veterans or from a disadvantaged population.

Community hire programs can be formal, as in the case of the Port's project labor agreements, or informal, as in the case with TransPower, a technology developer. The level of commitment and success varies. The accompanying case study ("Community Hire Programs in Action") describes a few such models. The Port should continue to evaluate zero-emissions infrastructure projects on a case-by-case basis to determine whether each project should be subject to local hire provisions.

Importantly, as noted in Section 7, the Port Community in Long Beach has a framework in place to support the local community workforce with partnerships beginning in high school, continuing through pre-apprenticeship programs at community colleges, and ending in job-hire programs for major Port infrastructure projects (see Figure 32). As the demand for jobs in the zero-emissions space increases, the Port may need to expand awareness of these educational and career pathways to make sure local residents take advantage.

Working with LBCC, community-based organizations, and its partners in the building trades, the Port should host workshops in the local community and participate actively in local job fairs to boost the number of qualified students entering pre-apprenticeship programs at LBCC and ultimately the pool of Long Beach-based electrical workers, who have priority access to Port infrastructure projects governed by project labor agreements. The Port should work with these partners to identify barriers that may prevent local residents from accessing these pathways, which may include lack of transportation to work sites or lack of money to purchase necessary training materials.

Figure 32: Port of Long Beach Community Workforce Development Program



8.4 Leveraged Energy and Infrastructure Investments

The Port and its operators are poised to invest millions of dollars in zero-emissions infrastructure and equipment, which could have value beyond the Harbor District. For example, the battery inside an electric or fuel-cell drayage truck or yard tractor will one day reach the end of its useful life and will no longer be suitable for the demanding port duty cycles; however, this battery still has useable hours for less demanding applications. As identified by the Port Community stakeholders, these "second life batteries" could be used as back-up power systems or microgrids in community centers, particularly during emergencies or power outages.

The Port should work with the City and community-based organizations to identify opportunities to demonstrate such second-life battery applications. These types of demonstrations could enhance the resale value of early zero-emissions equipment investments, which has been identified as a barrier to greater market acceptance, while bolstering the community's resiliency.

8.5 Advocacy

Seaports and community groups can – and should – work together to advance the move toward zero emissions. The Port has been very successful partnering with environmental-justice groups and community-based organizations to strengthen grant applications and to advocate for policies that support zero emissions (see case study: "Community Advocacy for Zero Emissions"). Although Ports and community groups do not always agree on exact approaches, we should work to identify our commonalities in order to coordinate advocacy efforts and opportunities to expand zero emissions across the country.

> CASE STUDY
>
> **Community Advocacy for Zero Emissions**
>
> Community-based organizations and environmental-justice groups can accelerate zero emissions through policy and funding advocacy.
>
> Most simply, community groups can provide seaports with support letters for grant applications, which may lead to the successful demonstration and deployment of zero-emissions equipment. In 2016, the Port worked with Coalition for Clean Air and East Yard Communities for Environmental Justice to signal broad support for a nearly $10 million demonstration of zero-emissions trucks and terminal equipment; the Port secured the grant and the demonstration is underway.
>
> Community groups also have inspired policy changes to advance zero-emissions deployment in California. Earthjustice and East Yard Communities for Environmental Justice successfully advocated for a provision in Senate Bill 350 that required private utilities to invest in transportation electrification infrastructure. The Port worked in tandem with these organizations to propel the effort, and now, SCE is poised to invest more than $300 million in electric charging infrastructure.
>
> These examples demonstrate the benefit of seaports and community groups working closely together to advance our shared zero-emissions goals.

8.6 Actions

The Port has identified the following actions to support community benefits:

- **Air Quality Benefits and Public Health:** Continue to monitor emissions benefits associated with zero emissions and support ways to better aggregate health outcome data to identify on-the-ground community health improvements;

- **Community Hire Programs:** Continue to support programs that hire Long Beach residents and disadvantaged workers;

- **Awareness of Workforce Pathways for Local Residents**: Expand awareness of educational and career pathways to make sure local residents take advantage of workforce training and community hire programs;

- **Leveraged Investments:** Work with the City and community-based organizations to identify opportunities to demonstrate second-life battery applications for community resiliency; and

- **Advocacy for Zero Emissions:** Continue to partner with community groups to jointly advocate for zero-emissions policies and funding, where it makes sense.

9 Actionable Steps to a Zero-Emissions Future

The actions defined in this Blueprint require a concerted, collaborative effort from the entire Port Community and every Port division, from Engineering and Finance to Environmental Planning and Security. To be successful, the Port must integrate these actions seamlessly into our organizational structure and processes. The Blueprint outlines the key steps for technology, infrastructure, finance, workforce, and community and the many related actions needed to be successful.

At this stage, the actions toward zero emissions are not likely to proceed in linear, sequential steps. The process is more likely to be dynamic and iterative. To that point, today's incentives for market acceptance are being offered in parallel to the technology's development. Infrastructure construction is occurring before design standards have been finalized. Workforce training is being identified before we even know the full implications of zero emissions.

In time, the Blueprint actions will coalesce around a sequential progression for a future, fully-commercialized zero-emissions future; today, as we continue to learn more and grapple with the uncertainty, adjustments are likely to be needed along the way.

9.1 Organizational Integration

The move toward zero emissions is not an ancillary effort. When our Board of Harbor Commissioners adopted the CAAP, it made zero emissions a cornerstone of how we operate, and the Port must internalize these actions throughout the organization and in the broader Port Community.

9.1.1 Internal Integration

The following Port committees provide an **internal** venue for executing the Blueprint actions and monitoring progress, and it is recommended that the EV Blueprint become a standing item on these committee agendas:

- **Planning, Environmental, Administration, Commercial, and Engineering (PEACE) Committee:** The PEACE Committee involves the highest levels of management from all of the Port's core areas to discuss capital project priorities, environmental and planning initiatives, business opportunities, the budget and cash flow. The Committee meets monthly.
- **CAAP Executive Committee**: This committee meets quarterly to discuss progress toward zero emissions and implementation of the other CAAP strategies. It is comprised of the Executive Director, Deputy Directors, Managing Directors, and Director of Environmental Planning.
- **Grants Strategy Committee:** This committee meets monthly to discuss funding priorities and grant opportunities and to develop strategic approaches to securing funds to support Port projects. It is comprised of the Executive Director, Deputy Directors, Managing Directors, and division directors involved in grant management.

9.1.2 External Integration

The following groups and forums provide an **external** venue to share progress on zero-emissions technology and infrastructure advancement with the broader Port Community:

- **TAP Advisory Committee:** The TAP Advisory Committee is comprised of representatives from both Ports, SCAQMD, CARB, and the CEC. This committee meets every six weeks to provide updates on technology demonstrations – many of them zero-emissions – and to consider proposals for new funding. This committee can help monitor the progress on zero-emissions equipment and vehicle advancement.

- **CAAP Stakeholder Implementation Advisory Group**: This group, which is open to the public and does not have a formal membership, meets quarterly to hear progress on achieving the CAAP goals. The Port should plan to provide updates on zero-emissions technology demonstrations, feasibility assessments, and infrastructure installations.
- **CEC Ports Collaborative**. Led by the CEC, the Ports Collaborative brings the state's seaports together on a monthly basis to discuss technology demonstrations, funding, and zero-emissions and energy management advancement. The Port should plan to share its Blueprint and provide regular updates through this forum.
- **EPA Ports Initiative**. The EPA has spearheaded a national conversation around environmental justice in seaport communities. The Port should share its EV Blueprint with this initiative in order to communicate the community benefits of zero emissions more broadly.

In addition to these standing committees and forums, the Port should strive to keep the Guidance Committee and the broad stakeholder advisory group engaged in its efforts. To that end, the Port should provide an annual update to these stakeholders during which the Port will review progress, describe lessons learned, and assess the need for changes in order to achieve the zero-emissions goals. As stated earlier, the Blueprint is a dynamic, iterative framework, and the Port must have space to evaluate, reassess, and refine our actions.

9.2 Summary of Near-Term Actions

Table 20 summarizes the near-term actions for advancing the Port Community's zero-emissions future as identified throughout the Blueprint. Actions in **bold** require leadership from a stakeholder other than the Port itself, suggesting the need for collaboration across the Port Community.

Table 20: Summary of Near-Term Steps to Advance the Blueprint Goals

Zero-Emissions Equipment/Vehicles	
Inventory	Conduct annual equipment inventories to assess zero-emissions transition progress.
Baseline	Further develop specific duty and drive cycle information to better understand when one-to-one zero-emissions replacement of traditional technology can be achieved.
Demonstrate	Validate new technologies as they emerge in real-world testing.
Assess	Continue technology feasibility assessments on a regular basis as part of the CAAP.
Synthesize	**Develop and maintain, in partnership with other agencies, a library of port-specific data and synthesized analyses associated with zero-emissions port technologies.**
Accelerate	Work with major manufacturers to accelerate commercialization with standard warranties, parts replacement, and customer service.
Experience	Facilitate short-term demonstrations, ride-and-drive events, and tours for operators.
Scale	Explore bulk purchasing programs to scale production and reduce unit costs.
Engage	**Collaborate with other seaport communities in order to spur greater market acceptance.**
Drive	Implement the CAAP and monitor regulatory efforts to drive market acceptance.

Charging/Refueling Infrastructure	
Catalog	Maintain a detailed inventory of existing charging and fueling infrastructure.
Forecast	Update high-level assessments of new energy needs based on equipment performance and energy consumption learned through technology demonstrations.
Evaluate	Organize infrastructure providers to help stakeholder evaluate cost-effective solutions and demonstrate innovative charging options.
Standardize	**Work with associations and state agencies to drive the adoption of heavy-duty charging standards through funding eligibility requirements or other mechanisms.**
Adopt	As standards are developed, adopt these standards into the Port's design process.
Collaborate	**Collaborate on regional infrastructure plans for zero-emissions drayage trucks.**
Integrate	Continue to execute the Energy Initiative Roadmap and integrate zero emissions into the Port's Business Continuity Plan and Coastal Resiliency Planning efforts.
Secure	Engage security and law enforcement agencies to address cybersecurity concerns.
Design	Develop design plans with terminal operators for the zero-emissions transformation.
Execute	Execute design plans as lease opportunities arise and identify funding mechanisms or incentives to bring terminal operators to the table prior to a lease expiration.

Financial and Business Model Considerations	
Refine	Refine cost estimates as equipment matures and terminal design efforts are conducted.
Relate	**Support the development of more refined TCO calculations to better compare zero-emissions technologies to diesel technologies.**
Incentivize	Encourage the use of public funding programs, including LCFS, where necessary to promote early adoption of high-risk, initial-stage technologies.
Guide	Work with funding agencies to minimize barriers associated with grant funding programs.
Iterate	**Conduct outreach to the private and public finance stakeholders to ensure awareness of the opportunities and challenges associated with port projects.**
Innovate	**Identify innovative financing options and tools to help stakeholders calculate the benefits.**
Fund	Develop funding plans for each project in collaboration with operators.

Workforce Development	
Certify	Evaluate national certification programs for applicability to port-related projects and work with community colleges to offer certification trainings.
Train	Review and potentially expand programs that train the existing longshore workforce for electric-automotive mechanic positions.
Align	Align curriculum and training programs for the zero-emissions transition.
Champion	**Champion more funding for workforce education, training, and curriculum development.**
Support	Identify and address potential barriers to entry for the incumbent workforce, which may include financial assistance.

Community Benefits	
Document	Continue to monitor emissions benefits and support ways to better aggregate health outcome data to identify on-the-ground community health improvements.
Cultivate	Continue to support programs that hire Long Beach residents and disadvantaged workers to cultivate the local workforce.
Educate	Expand awareness of educational and career pathways to make sure local residents take advantage of workforce training and community hire programs.
Partner	Work with the City and community groups to identify opportunities to demonstrate second-life battery applications for community resiliency.
Advocate	Continue to partner with community groups to jointly advocate for zero-emissions policies and funding, where it makes sense.

9.3 Accelerating the Actions

The Port Community must move expeditiously to advance its 2030 and 2035 zero-emissions goals. Although some of the Blueprint actions involve better communication and coordination of existing resources, it is clear, as noted in Section 6, that funding will play a critical role in the Port Community's ability to execute – and where possible, accelerate – many of the Blueprint activities.

In the near term, the Port sees an opportunity to significantly advance the following actions, particularly if funding sources can be identified:

- **Develop design plans** with terminal operators to evaluate the opportunities and costs associated with retrofit and redevelopment pathways. This detailed design and engineering effort will consider short- and long-term implications of terminal operations, allowing terminal operators on a site-by-site basis to create a customized vision that fits their geographic, business, operational, and infrastructure constraints. Based on the design plans and regional infrastructure plans, the Port will be able to update ROM costs and plan for construction.

- **Develop regional truck infrastructure plans** to thoughtfully and carefully create a local and regional vision for zero-emissions drayage truck hydrogen refueling stations and battery recharging stations. This effort would include close collaboration with many key stakeholders, including the Port of Los Angeles, SCAQMD, SCE, and major hydrogen fuel providers.

- **Refine TCO models** for terminal equipment and drayage trucks that can be developed in an open-source platform with clear and transparent assumptions. This effort would create a customizable model for relevant stakeholders across California and the world to evaluate their own specific equipment and technology needs.

- **Evaluate and expand incumbent workforce training**, including curriculum development, for longshore workers and truck drivers to gain the skills necessary for zero emissions operations and maintenance, and potentially, to move into new, higher-need jobs, such as mechanic positions.

- **Align local college curricula** with the zero-emissions transition, including the development and roll-out of curriculum and training programs for these emerging technologies.

- Launch a community campaign to **expand awareness of educational and career pathways**, ensuring that local residents take advantage of workforce training and community hire programs in support of zero emissions.

9.4 Sharing the Blueprint

The Port's ability to transition to zero emissions hinges on broader acceptance of these Blueprint actions, particularly in other port communities. Equipment manufacturers need higher quantities in order to scale up production and bring down costs for everyone. Finance organizations need larger markets to create better investment opportunities. The entire ecosystem would benefit from sharing lessons learned from technology demonstrations, infrastructure installations, and workforce challenges. Thus, the Port must actively engage stakeholders – including other seaport communities – to share the Blueprint actions and our progress in furtherance of the CAAP's zero-emissions goals.

This section describes the Port's actions to share the Blueprint with the following stakeholders:

- Seaports and the shipping industry;
- Engineers and technology developers;
- Regulatory agencies; and
- Environmental and community organizations.

9.4.1 Seaports and Industry

The Port will distribute the final Blueprint to other seaports, present findings at port-related conferences and meetings, and work with seaport and industry associations to communicate the Port's efforts. These forums include conferences and seminars as well as regular meetings of the following associations:

- American Association of Port Authorities;
- California Association of Port Authorities;
- PMSA;
- West Coast MTO Agreement;
- Harbor Trucking Association; and
- California Trucking Association.

9.4.2 Engineers and Technology Developers

The Port can help advance knowledge about zero emissions by sharing lessons learned around design, infrastructure development, and equipment. The following organizations offer forums to do so:

- American Society of Civil Engineers;
- Institute of Electrical and Electronics Engineers;
- Association of Energy Engineers;
- California Hydrogen Business Council;
- CALSTART; and
- Advanced Clean Transportation Expo.

9.4.3 Regulatory Agencies

Regulatory agencies can benefit greatly from understanding the challenges and potential solutions associated with transitioning to zero emissions. These agencies include the EPA, CARB, CEC, and SCAQMD.

These agencies offer forums for sharing lessons learned, such as those below:

- EPA West Coast Collaborative;
- EPA Ports Initiative;
- CEC Ports Collaborative; and
- SCAQMD Clean Fuels Advisory Committee.

9.4.4 Environmental and Community Groups

The Port has an extensive community relations program, offering free public boat tours, distributing a port newsletter, and "Let's Talk Port" community meetings. The Port also committed to regular community updates as part of the CAAP. The Port plans to share progress on the Port EV Blueprint at the CAAP Quarterly Stakeholder meetings, “Let’s Talk Port” meetings, and other community events. Additionally, the Port meets regularly with environmental organizations and community-based groups for informal discussions on Port programs. These smaller forums provide an opportunity to share lessons learned and next steps.

10 Conclusions

The Port of Long Beach has adopted some of the world's most aggressive goals for zero emissions, including a goal of up to 100% zero-emissions terminal equipment by 2030 and up to 100% zero-emissions trucks by 2035. To support these goals, the Blueprint identifies more than three dozen actions to be taken over the next few years to ensure the Port Community has the necessary zero-emissions equipment, infrastructure, financing, workforce, and community benefits to be successful.

These actions have been informed by substantial input from a broad cross-section of Port stakeholders; these stakeholders will be instrumental in helping to execute many of the actions identified. Over the next few years, the Port will continue to monitor our progress toward meeting the CAAP's zero-emissions goals, working closely with the Port Community to refine, reassess, and adjust as necessary.

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Appendix A: Port Community Electric Vehicle Blueprint Research Report

PCEVB Research Report

1 Introduction

California's interconnected system of ports, railroads, highways, and roads are responsible for one-third of the State's economic activity, with freight-dependent industries accounting for over $740 billion in gross domestic product and over five million jobs.[1] Maintaining the competitiveness of this economic engine is vital. Yet, freight transportation in California also generates a high portion of air emissions in parts of the state with poor air quality. Reducing these pollutants are important local, regional, and State priorities, as well as a matter of compliance with the federal Clean Air Act. Seaports, however, are faced with unique constraints when deploying zero-emissions vehicles and equipment due to, among other factors, high energy demand, restrictive duty cycle requirements, and diverse tenant and operational interests. Even more, at most California seaports including the Port of Long Beach (POLB or Port), the port authorities do not own or operate the equipment targeted for zero-emissions transformation and thus must work with private operators to turn over equipment and vehicles and to install infrastructure suitable for a company's individual operations. Further complicating matters in this dynamic, 24/7 port environment, everything is interdependent, with an astonishingly broad array of light-, medium-, and heavy-duty equipment and vehicles in operation.

To address this challenge, the Port of Long Beach is initiating the Port Community Electric Vehicle Blueprint (PCEVB) to establish a comprehensive strategy to assist in the identification of the most cost-effective technologies, financial incentives, and infrastructure upgrades for creating the model sustainable, zero-emission port ecosystem of the 21st century. The PCEVB is designed to accelerate the deployment of electrified transportation at local and regional levels with a holistic and futuristic view of regional transportation planning. The PCEVB Research Report is designed to organize the process of transitioning one of the world's busiest seaports to zero-emission operations by creating a baseline

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[1] "California Sustainable Freight Action Plan," Brown Jr., Governor Edmund G., p. 1.

status of existing zero-emission transportation and cargo-handling activities within the Port, adjacent visitor-serving areas, and the surrounding communities directly impacted by port-related activities.

2 Project Background

2.1 Project Scope: The Port Community

The Port of Long Beach is the second busiest port in the United States. The Port provides economic benefits at the local, regional, state, and national levels by supporting 30,000 jobs in Long Beach, 316,000 jobs throughout Southern California, and 1.4 million jobs throughout the United States. The Port's robust economic activity, however, has an impact on the communities surrounding these operations. While the Port has a positive effect on neighboring communities by providing high-paying jobs and generating significant local tax revenues, it also has environmental and public health impacts on the surrounding communities through increased air, noise, light, and water pollution, as well as the disruption of local transportation systems.[2]

Figure 1: Map of the Harbor District of the Port of Long Beach

[2] ICF International. 2016. Port of Long Beach Community Impact Study. April. (ICF 683.15.) San Diego, CA. Prepared for Port of Long Beach, Long Beach, CA. p. 1-1.

The Port has made important strides to mitigate these negative environmental impacts through its Green Port Policy, as well as through project-specific mitigation measures implemented as requirements of the California Environmental Quality Act (CEQA). Over the last decade, the Port has been a leader in addressing its environmental and public health impacts through such groundbreaking efforts as the CAAP and the Water Resources Action Plan (WRAP), which contain numerous aggressive and innovative pollution-reduction strategies.

The Port's success is evident. Since 2005, Port-related air pollution is down 85%, and the San Pedro Bay is home to a thriving array of plant and animal life. The Port recognizes, however, that its environmental impacts have had years to accumulate, and even the Port's cutting-edge and aggressive mitigation efforts do not fully address the cumulative effects of Port operations on neighboring communities.[3]

To identify both the direct impacts of Port-related operations on the local community and community-based mitigation measures to relieve these impacts, the Port conducted a Community Impact Study (CIS) in 2016. The CIS identified Port-related community impacts through a CEQA-like analysis that used quantitative and qualitative, industry-accepted technical methodologies to demonstrate a connection between Port operations, the impact on the community, and possible ways to reduce these impacts. The CIS examined four key areas: air quality, traffic, noise, and water quality. These resource areas are most strongly associated with community impacts outside the Harbor District.[4] Some key findings of the report include:

- Port-related operations have a direct impact on criteria pollutant and greenhouse gas (GHG) emissions in the community.
- Population-weighted cancer risk associated with operations at the Port of Long Beach… averages 66 in a million, rising to an average of 143 in a million for residents living within approximately 1.25 miles of the port and major goods movement routes.[5]
- The area experiencing the most significant Port traffic impact encompasses areas within about 10 miles of the Port. These areas experience approximately 371,939 daily vehicle miles traveled (VMT), equating to 102,283,225 VMT over the course of a year.[6]
- Noise from Port-related trucks exceeds 65 dBA L_{dn} (a common threshold for excessive noise) at land uses directly adjacent to many of the roadways in the affected region.[7]
- Locations where Port trucks make a perceptible or noticeable increase to the overall traffic noise levels are generally located within about 5 miles of the Port.[8]
- The Port comprises roughly 3,200 acres out of the 1,060,400 acres of watershed discharging into San Pedro Bay, which is considered an "impaired water body."[9]

For these reasons, the Port determined that its EV blueprint had to include the Harbor District (Figure 2), which includes hotels and the Long Beach Carnival Cruise Ship Terminal, and must also consider the possible impacts on and benefits to adjacent residential, commercial, and industrial areas—including many census tracts categorized as DACs—and the immediate vicinity of driving routes into the Port.

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[3] ICF International. 2016. Port of Long Beach Community Impact Study. April. (ICF 683.15.) San Diego, CA. Prepared for Port of Long Beach, Long Beach, CA. p. 1-1.
[4] Id.
[5] Id. at 2-8.
[6] Id. at 3-6.
[7] Id. at 4-6.
[8] Id.
[9] Id. at 4-5.

2.2 Project Team

The Project Team supporting the development of the PCEVB, including the Research Report, consists of highly-qualified industry experts.

Table 1: PCEVB Project Team

Roles	Responsibility
Port of Long Beach (POLB)	Project oversight and strategy
Grant Farm	Management of the EV Blueprint planning, outreach, team building, and lead PCEVB development
National Renewable Energy Laboratory (NREL)	Evaluation of power demand and impact analysis, identification of relevant analytical tools and models
Tetra Tech & Gladstein Neandross & Associates (GNA)	Assessment of zero emission on-road trucks and terminal equipment
Southern California Edison (SCE)	Consultation on impact of the EV Blueprint on grid and utility rates, accounting for behavior and increasing loads from vehicle electrification while achieving community energy savings and zero net energy community status
Zero Net Energy (ZNE) Alliance	Identification of innovative financing approaches
Center for International Trade and Transportation (CITT)	Identification of workforce development opportunities
Pacific Merchant Shipping Association (PMSA)	Consultation on technology selection, charging infrastructure location, and needs of terminal operators and shipping companies in relation to transportation electrification

3 State of Zero-Emission Transformation

3.1 Regional and Local Planning Documents

California has provided global leadership for zero-emission vehicle and equipment adoption and deployment at the state, regional, and local level. Critical state, regional, and local planning documentation is available from the California Air Resources Board (CARB), California Department of Transportation (Caltrans), the Governor's Office of Business and Economic Development (GO-Biz), the South Coast Air Quality Management District (SCAQMD), and the San Pedro Bay Ports. Guidance documents are published for each organization, detailing the mechanisms and manner by which public funding is intending to support zero-emission technology deployment. A summary of these planning documents, and its relevance to the PCEVB are provided within this section.

3.1.1 California Sustainable Freight Action Plan & Executive Order (EO) B-32-15

In 2015, Governor Brown issued EO B-32-15 to provide a vision for California's transition to a more efficient, more economically competitive, and less polluting freight transport system. The first step of EO B-32-15 directed Caltrans, California Environmental Protection Agency (CalEPA), California Department of Natural Resources (CalDNR), CARB, and GO-Biz to develop the California Sustainable Freight Action Plan. Published in July 2016, the CA Sustainable Freight Action Plan provides recommendations on a high-level vision and broad direction for state agencies to utilize when developing specific investments, policies, and programs related to the freight transport system. Recommendations include three important targets:

1. **System Efficiency Target**: Improve freight system efficiency 25 percent by increasing the value of goods and services produced from the freight sector, relative to the amount of carbon that it produces by 2030.
2. **Transition to Zero Emission Technology Target**: Deploy over 100,000 freight vehicles and equipment capable of zero emission operations and maximize near-zero emission freight vehicles and equipment powered by renewable energy by 2030.
3. **Increased Competitiveness and Economic Growth Targets**: Establish a target or targets for increased state competitiveness and growth metrics and models developed by a working group comprised of economists, experts, and industry.

The CA Sustainable Freight Action Plan is currently under development with the goal of finalizing the targets in 2019. These targets will be an important guide to investments, policies, and programs developed to leverage public funding for port-related projects. Participation by the port community is essential to optimizing the value of this initiative.

3.1.2 Emissions Reduction Plan for Ports and Goods Movement in California (2006)

The Emission Reduction Plan for Ports and Goods Movement in California, developed by CARB, is one of the most critical planning documents developed to specifically address how CARB will engage in the port and freight ecosystem to support the movement to zero- and near-zero-emission vehicles and equipment across California. The Emission Reduction Plan for Ports and Goods Movement in California set agency goals including:

1. To reduce total statewide international and domestic goods movement emissions to the greatest extent possible and at least back to 2001 levels by year 2010.
2. To reduce the statewide diesel PM health risk from international and domestic goods movement 85 percent by year 2020.
3. To reduce NOx emissions from international goods movement in the South Coast 30 percent from projected year 2015 levels, and 50 percent from projected year 2020 levels based on preliminary targets for attaining federal air quality standards.
4. To apply the emission reduction strategies for ports and goods movement statewide to aid all regions in attaining air quality standards.
5. To make every feasible effort to reduce localized risk in communities adjacent to goods movement facilities as expeditiously as possible.

This planning effort has resulted in critical rulemaking activity, including those for commercial marine vessels, commercial harbor craft, vessel speed reduction, ship onboard incineration, cargo-handling equipment at ports and intermodal rail yards, locomotives, port trucks, and other privately-owned trucks. POLB is actively engaged in these rulemaking activities and closely monitors the proposals and findings to evaluate impacts on the port-community.

3.1.3 Zero Emission Vehicle (ZEV) Action Plan (2013 & 2016) and Executive Order (EO) B-16-12

In 2012, Governor Brown issued EO B-16-12 to accelerate the market for ZEVs, calling for 1.5 million ZEVs in California by 2025. In 2013, the ZEV Action Plan was developed to identify specific actions state government would take to meet the milestones of the EO and in 2016, the ZEV Action Plan was updated. The 2016 ZEV Action Plan introduces new actions to meet four stated priorities and to build California's ZEV market and remove barriers to future market growth. The four priorities include:

1. Raising consumer awareness and education about ZEVs
2. Ensuring ZEVs are accessible to a broad range of Californians
3. Making ZEV technologies commercially viable in targeted applications in the medium-duty, heavy-duty, and freight sectors
4. Aiding ZEV market growth beyond California

The 2016 ZEV Action Plan identifies a detailed series of goals and objectives and assigns responsibility for these actions across agencies.

3.1.4 Executive Order (EO) B-48-18

Through EO B-48-18 (January 2018), Governor Brown set a new target for 5 million ZEVs in California by 2030 and established a new eight-year initiative to continue the state's clean vehicle rebates. This $2.5 billion initiative will help bring 250,000 vehicle charging stations and 200 hydrogen fueling stations to California by 2025. EO B-48-18 builds upon the ZEV Action Plan and EO B-16-12.

3.1.5 Senate Bill 350

On October 7, 2015, Senate Bill 350: Clean Energy and Pollution Reduction Act (de León, Chapter 547, Statutes of 2015) (SB 350) was signed into law, establishing new clean energy, clean air and GHG reduction goals for 2030 and beyond. SB 350 established California's 2030 GHG reduction target of 40 percent below 1990 levels. To achieve this goal, SB 350 sets ambitious 2030 targets for energy efficiency and renewable electricity, among other actions aimed at reducing GHG emissions across the energy and transportation sectors. SB 350 greatly enhances the state's ability to meet its long-term climate goal of reducing GHG emissions to 80 percent below 1990 levels by 2050.

SB 350 requires California's six investor-owned utilities (IOUs) to develop programs and investments to support "widespread transportation electrification" to reduce petroleum use and to meet air quality standards. The California Public Utilities Commission was given authority to approve these programs and investments in transportation electrification, including charging infastructure, provided the programs and investments minimize costs and maximize benefits. Additionally, SB 350 requires publicly owned utilities (POUs) with annual electricity demand exceeding 700 gigawatt-hours to develop and adopt integrated resources plans (IRPs) by January 1, 2019. The IRPs must discuss how each POU plans to meet GHG reduction targets established by the ARB and identify procurement plans of at least 50 percent renewable energy resources by 2030. SB 350 requires that the POU IRPs also address their procurement plans for electrification of the transportation sector within their service territory.

3.1.6 South Coast Air Quality Management District 2016 Air Quality Management Plan (AQMP)

The 2016 AQMP is a regional plan for achieving the federal air quality standards. While regional air quality has improved over the years, the South Coast Air Basin still exceeds federal public health standards for both ozone and particulate matter (PM) and experiences some of the worst air pollution in the nation. 2016 AQMP objectives include:

1. Eliminate reliance on future technologies to the maximum extent possible
2. Calculate and take credit for co-benefits from other planning efforts with parallel and complementary programs
3. Develop a strategy with fair-share emission reductions at the federal, state, and local level with a focus on mobile sources that are not exclusively within the South Coast Air Basin

4. Invest in strategies and technologies meeting multiple objectives regarding air quality, climate change, air toxics exposure, energy, and transportation
5. Identify and secure significant funding for incentives to implement early deployment and commercialization of zero- and near-zero emission technologies
6. Enhance the socioeconomic analysis and pursue the most efficient and cost-effective path to achieve multi-pollutant and multi-deadline targets
7. Prioritize enforceable regulatory measures as well as non-regulatory, innovative, and "win-win" approaches for emissions reductions.

The 2016 AQMP identifies the need for approximately $11-$14 billion in total funding over a seven to 15-year period to meet the federal air standards.

3.1.7 San Pedro Bay Ports Clean Air Action Plan (CAAP) 2017

In 2017, the Port of Long Beach and Port of Los Angeles developed the San Pedro Bay CAAP as a result of extensive public outreach over the previous two years in combination with recent regulatory and statutory changes. The 2017 CAAP Update details four strategies aligned with the Sustainable Freight Action Plan:

- Clean Vehicles and Equipment Technology and Fuels
- Freight Infrastructure Investment and Planning
- Freight Efficiency
- Energy Resource Planning

Important activities called out in the CAAP that are relevant to the PCEVB include:

- **Clean Trucks Program**: Adopted in 2007 and launched in 2008, the Clean Trucks Program was designed to phase out the oldest, dirtiest trucks serving port terminals by banning trucks older than 2007 engine model year, between two and six years in advance of the State Drayage Truck Regulation. In 2017, the ports established a goal for 100 percent zero-emission drayage truck operations by 2035. The CAAP outlines a strategic pathway, including interim near-zero deployments to achieve this goal.
- **Terminal Equipment**: The ports, along with the Mayors of Long Beach and Los Angeles, have adopted a goal of zero emissions for all terminal equipment by 2030. This ambitious goal requires the development of new zero-emission technologies and upgrade of existing, yet inadequate, infrastructure. To help achieve this goal, starting in 2019, terminal operators will be required to submit equipment inventories and a 10-year procurement schedule for new cargo handling equipment that will be updated annually. Additionally, any equipment purchased after 2020 must be zero-emissions, if feasible, or the cleanest available technologies.
- **Vessel At-Berth Emission Reductions**: CARB's current regulation requires at-berth emission reductions from container, cruise, and refrigerated cargo vessels, generally by plugging the ship into the electrical grid (shore power) and turning off the auxiliary engines. The Ports are currently working with CARB to achieve up to 100 percent compliance with the At-Berth Regulation by 2030. Additionally, the Ports have committed to evaluating new technologies necessary for expanding to non-regulated vessels where possible.

- **Expanding the Use of Rail**: The Ports have established a goal of accommodating 35 percent of all cargo leaving the port complex by rail, up from 23.5 percent in 2016. Over the long term, the Port seeks to handle up to 50 percent of all cargo leaving the port complex by rail.
- **Charging Standards for Electric Terminal Equipment**: Since 2015, the Ports have been working with regulatory agencies, technology developers, and equipment operators to establish charging standards for yard tractors and other pieces of terminal equipment. These standards include technical specifications that consider design, cost, and the complexity of charging a large fleet of equipment simultaneously.
- **Green Terminal Program**: The Ports are developing a voluntary recognition program to highlight the achievements of terminals working to enhance productivity while minimizing air quality impacts. Relevant programs that can be used as a model include the Container Terminal Quality Index and Green Marine.
- **Port Truck Reservation System**: Individual terminals and trucking companies use their own software systems to manage their gate operations, with most terminals offering expedited access to the terminal based on a reservation system or pre-arrival requirements. Without a universal system, further efficiencies are difficult to realistically obtain. The Ports are pursuing the use of a universal systematic integration of the reservation systems for all marine terminals to be implemented by January 1, 2020.
- **Energy Island Initiative**: An innovative compilation of strategies that are designed to provide reliability, resiliency, and economic competitiveness to the POLB complex and its marine terminal tenants. Renewable energy technologies, other self-generation systems, controls, and energy storage will allow POLB to operate as an island from the local energy grid during times of emergency or outage.

The 2017 CAAP is a foundational document for the PCEVB, detailing more than a decade of thought-leadership regarding how to implement and execute programs to achieve zero-emission goals.

3.2 Zoning and Parking Policies

The City of Long Beach Municipal Code governs zoning and parking policies within the City of Long Beach jurisdiction, including at the Port of Long Beach. These parking codes are largely relevant for passenger cars. Specific parking codes relevant to EV charging include:

- Section 18.47.040: Where hotels are constructed on a building site, 30 percent of the total number of parking spaces, but in no case less than one, shall be EV spaces capable of supporting future EVSE and 10 percent of the total number of parking spaces, but in no case less than one, shall have EV chargers installed. Construction documents are intended to demonstrate the project's capability and capacity for facilitating future EV charging
- Section 18.47.050: Where nonresidential buildings or structures are constructed on a building site, 25 percent of the total number of parking spaces, but in no case less than one, shall be EV spaces capable of supporting future EVSE and five percent of the total number of parking spaces, but in no case less than one, shall have EV chargers installed.
- Chapter 18.76: Provides an expedited and streamlined permitting process for electric vehicle charging stations

- Chapter 21.41: Provides general guidance for parking space requirements for various zoning classifications and specifications but does not address EV parking spaces directly as those are referenced to Chapter 18.47.

POLB does not have an additional unique set of parking policies addressing zero-emission charging or re-fueling for passenger cars, which would include employee cars at terminal administrative offices. Bulletin information is provided by City of Long Beach (BU-050) for EV Charging for new construction which summarizes the code rules relevant to EV parking. These excerpts are not intended to represent a comprehensive list of all information pertinent to an installation related to the PCEVB.

3.3 Local Building Codes

The City of Long Beach building code generally references the California Green Building Codes for information regarding electric vehicle charging and renewable energy requirements. Specific relevant sections within the City of Long Beach building code include:

- Section 21.45.400: Among a number of other aspects, this code section requires that all roofs shall be designed to be solar-ready by allowing for an additional eight pounds per square foot of dead load and providing a conduit from the electrical panel to the roof.

Within the California Green Building Code, specific relevant sections include:

- Section 5.106.5.2: Specifies the space requirements for clean air vehicles (low-emitting, fuel-efficient, and carpool/van pool vehicles).
- Section 5.106.5.3: Specifies the electric vehicle charging space requirements, calculation methodology, identifications, and future charging space requirements.
- Section A5.211.1: Specifies requirements for the use of on-site renewable energy sources, such as solar, wind, geothermal, low-impact hydro, biomass, and biogas, for at least one percent of the electric power calculated as the product of the building services voltage and the amperage specified by the electrical service overcurrent protection device rating, or 1 kW, whichever is greater.
- Section A5.211.3: Specifies that if offered by the local utility provider, building owners should participate in a renewable energy portfolio program that provides a minimum of 50 percent electrical power from renewable sources.

Bulletin information is provided by City of Long Beach (BU-050) for EV Charging for new construction which summarizes the code rules relevant to construction and EV charging infrastructure. These excerpts are not intended to represent a comprehensive list of all information pertinent to an installation related to the PCEVB.

3.4 Permitting and Inspection Processes

POLB maintains a series of guidelines, standards, and design manuals to support the development of infrastructure within the Port boundaries. Relevant guidelines include:

- 2003 Architectural Guidelines
- 2013 Quality Management Standards
- 2014 Design Criteria Manual
- 2014 Standard Plans

- 2016 CADD Standards
- 2016 Electrical Standard Plans
- 2017 Electrical Design Criteria Manual

These documents are provided to engineering, design, and construction contractors to ensure that the documentation provided for each activity is consistent with existing engineering specifications. These standards will guide all future zero-emission vehicle infrastructure deployments.

3.5 Utility Interconnection Process

3.5.1 Utility Rules Relating to PCEVB

Southern California Edison is the electric service provider for the Port of Long Beach. Five processes are directly related to electric vehicle charging infrastructure:

- Rule 2: Processes pertaining to the additions of new load
- Rule 15: Processes pertaining to distribution line extensions
- Rule 16: Processes pertaining to service extensions
- Rule 18: Processes pertaining to separate premises and use by others
- Rule 21: Processes pertaining to generating facility interconnections

3.5.2 Existing Port Rate Tariffs

In 2014, SCE and the Port completed a multi-year process to establish a Maritime Entity (ME) Rate. This rate schedule provides electric infrastructure and discounted rates to applicable maritime entities at the Port. The rate option was established to facilitate expansion of SCE's electric distribution facilities to serve projected load growth at the Port. Eligible customers must be engaged in container, stevedoring, or shipping activities and have a service account that is located within the real property instead of the City of Long Beach within or adjacent to the Harbor District, with the exception of Pier H. In general, the rate offers:

- A Contribution to Margin (CTM) discount for certain types of New Load
- Accounts Served at less than or equal to 50kV and Below: Option to pay Existing Load at sub-transmission rates, plus Imputed Added Facilities (IAF) amount in lieu of the served voltage rates (i.e., secondary or primary)
- Accounts Served at greater than 50kV with Previously Existing Added Facilities Agreements: Option to pay IAF amount in lieu of existing Added Facilities Agreements (AFA) charges
- Under certain conditions, SCE will install and pay for 66kV electric facilities.

It is important to understand the difference between Existing Load vs. New Load, CTM, and IAF to understand the opportunities created with the Maritime Entity Rate.

- Existing Load vs. New Load: Existing Load, also known as Base Period Usage (BPU), is the installed service's average usage, demand, and kVAR by season and time of use (TOU) period for the 24 months immediately preceding the effective date of the rate (April 14, 2014). New Load is any usage, demand, and kVAR exceeding the BPU.
- Contribution to Margin (CTM): Calculated each monthly billing period, and only applicable to New Load, the CTM is the difference between the Otherwise Applicable Tariff (OAT) bill (as defined in the tariff) for New Load and the Marginal Cost of Services for the New Load of

Maritime Entities. When the CTM is positive, a discount of 50 percent of the CTM is applied to the bill.

- Imputed Added Facilities (IAF): The IAF amount is calculated by multiplying the monthly metered demand by the IAF charge ($2.84./kW). For > 50 kV customers that elect to have their existing AFA billed based on the IAF charge, the IAF amount is capped at the seasonal FRD BPU, meaning these customers will never pay more than $2.84/kW times the seasonal FRD BPU.

3.5.3 Utility Rate Tariffs Relating to PCEVB

Existing rate structures relevant to electric vehicle operations include time of use (TOU) and pilot rates: TOU-EV-3, TOU-EV-4, TOU-EV-6, Charge Ready Program Demand Charges Explanation, and Charge Ready Demand Response Pilot. A summary of the existing rate structures is shown in Table 2.

Table 2: Comparison of Existing Rate Structures Available to EV Operators

RATE FACTORS EFFECTIVE JANUARY 1, 2018	Customer Charge	Facilities Related Demand (FRD) Charges	Summer Season Energy Charges			Winter Season Energy Charges		
Rate Schedule	$/month	$/kW	On-Peak kWh	Mid-Peak kWh	Off-Peak kWh	On-Peak kW	Mid-Peak kW	Off-Peak kW
Demands 20 kW and below								
TOU-EV-3 (Option A)	80.6 ¢/Day	N/A	$0.34947	$0.15088	$0.10594	$0.14528	$0.13420	$0.11059
TOU-EV-3 (Option B)	80.6 ¢/Day	$10.06	$0.29979	$0.10120	$0.05626	$0.09560	$0.08452	$0.06091
$ Differential	$0.00	$10.06	$0.04968	$0.04968	$0.04968	$0.04968	$0.04968	$0.04968
% Differential	0%	100%	17%	49%	88%	52%	59%	82%
Demands between 20 kW to 500 kW								
TOU-EV-4	$228.58	$15.89	$0.28229	$0.09598	$0.05546	$0.09211	$0.07732	$0.06010
Demands above 500 kW by Voltage	$/month	$/kW	On-Peak kWh	Off-Peak kWh	Super-Off Peak kWh	On-Peak kWh	Off-Peak kWh	Super-Off Peak kWh
Below 2 kV								
TOU-EV-6	$658.17	$11.81	$0.45828	$0.09337	$0.07247	$0.08850	$0.08449	$0.07682
From 2 kV to 50 kV								
TOU-EV-6	$314.30	$11.68	$0.45070	$0.08916	$0.06905	$0.08476	$0.08083	$0.07332
Above 50 kV								
TOU-EV-6	$2,110.04	$4.79	$0.39765	$0.07471	$0.05598	$0.07166	$0.06773	$0.06024

SCE indicated that a series of new rate structures would be available to EV operators in the near-term.[10] Specifically, TOU-EV-3, TOU-EV-4, and TOU-EV-6 will be replaced with TOU-EV-7, TOU-EV-8, and TOU-EV-9 respectively. These new rates are expected to be effective by Q2 2019. These new rate structures will not include any Facilities Related Demand (FRD) charges during the first five years with demand charges phased in during years six to ten per the schedule in Table 3. Customers with existing TOU-EV-3, TOU-EV-4, or TOU-EV-6 service accounts with Demand Neutralization will have the FRD demand offset grandfathered in perpetuity. Additionally, it remains to be seen how the ME Rate will align with these new TOU rates for port terminals.

Table 3: Phased Approach to Facilities Related Demand Charges for New Proposed EV Rate Tariffs

Calendar Year	2019-2023	2024	2025	2026	2027	2028	2029+
Rate Year	1 - 5	6	7	8	9	10	11
% of Final FRD	0%	17%	33%	50%	67%	83%	100%

[10] Communication with Katie Sloan, SCE, part of the PCEVB Guiding Committee

The new EV rate schedules are also expected to have new TOU periods as presented in Figure 2.

Figure 2: Proposed Time of Use Periods for New Proposed EV Rate Tariffs

3.6 EV Registration Data

3.6.1 Equipment at the Port

The Port Community has unique freight handling equipment and distinguishes the ports from other transportation and freight movement sectors. A selection of relevant, port-specific equipment types are described in Table 4 to ensure a common understanding of the equipment across the PCEVB.

Table 4: Common Port-Specific Equipment Descriptions

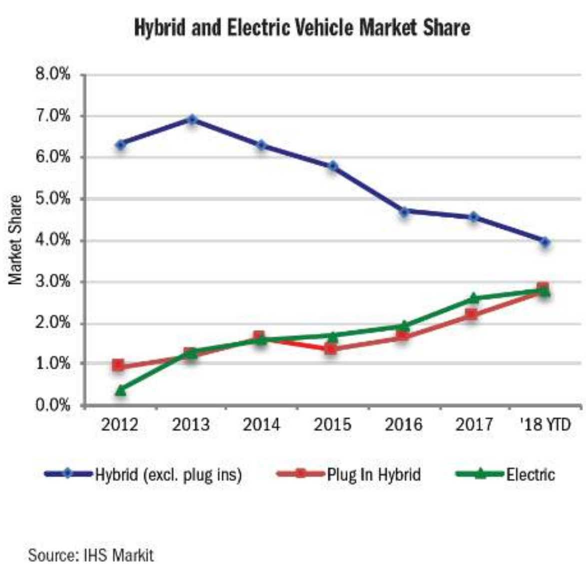
Equipment Description	Equipment Image
Forklifts Forklifts are used to handle various types of cargo at both container and non-container terminals.	
Rubber-tired gantry cranes Also known at RTGs, these cranes move containers to and from container stacks.	
Side Handlers Side handlers, in general, move and stack the empty containers within a terminal. They are often also referred to as side picks or side loaders.	

Equipment Description	Equipment Image
Top handlers Top handlers move, stack and load containers using an overhead telescopic boom. They can be used in place of or in conjunction with RTGs to lift heavy containers within a terminal.	
Yard tractors Also known as yard hostlers or utility tractor rigs (UTRs); yard tractors are designed to move cargo containers on a terminal.	

3.6.2 Light-Duty Deployments

EV registration for electric and plug-in vehicles in California have continued to increase in 2018, with new registrations for EVs, plug-in hybrids, and conventional hybrids totaling 9.6 percent of new car registrations in Q1 2018 (Figure 3).[11]

Figure 3: Hybrid and Electric Vehicle Registrations and Market Share for the State of California

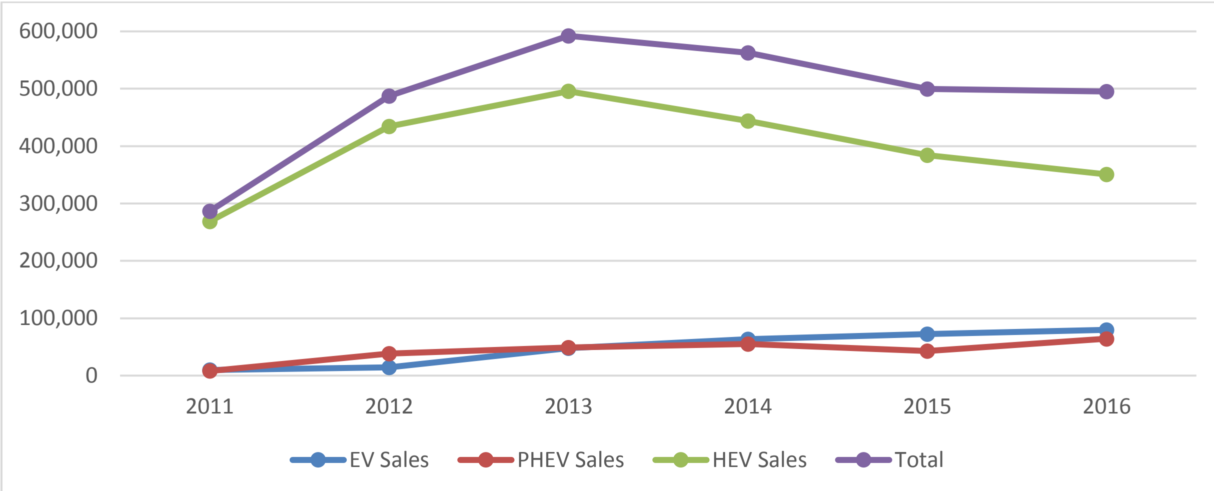


Hybrid and Electric New Vehicle Registrations and Market Share					
	2014	2015	2016	2017	YTD 2018
Hybrid regs.(excl. plug ins)	116217	118981	98083	93254	19416
Hybrid share(excl. plug ins)	6.3%	5.8%	4.7%	4.6%	4.0%
Plug in hybrid regs.	29949	27740	34727	45012	13534
Plug in hybrid share	1.6%	1.4%	1.7%	2.2%	2.8%
Electric regs.	29536	34477	40347	53499	13657
Electric share	1.6%	1.7%	1.9%	2.6%	2.8%

[11] California Auto Outlook: Comprehensive information on the California Vehicle Market. Covering First Quarter 2018. Volume 14, Number 2. Released May 2018.

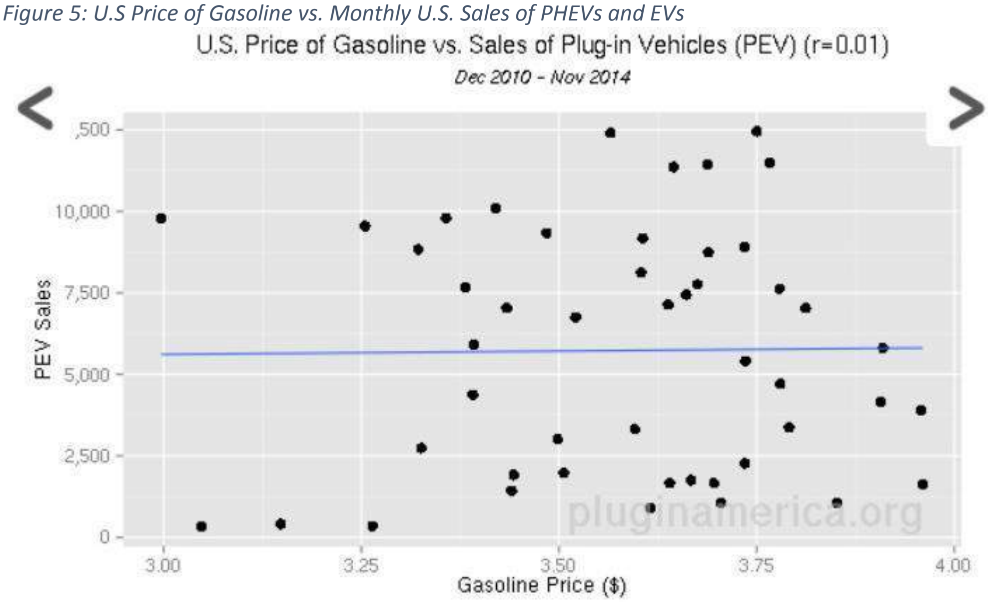
Interestingly, the share of conventional hybrids has decreased as plug-in hybrids and EVs have increased, leaving the total market share of all conventional hybrids, plug-in hybrids, and EVs relatively stable over the past five years. This trend is also reflected in the overall U.S. market (Figure 4).[12]

Figure 4: US Sales of Conventional Hybrids, PHEVs, and EVs



While this trend of decreasing HEV sales and increasing PHEV and EV sales is visible in the US and California markets, there are many factors contributing to that outcome. One of several important factors is that consumers were not statistically impacted by gasoline prices (Figure 5),[13] likely due to the influx of high-cost or luxury vehicles (led recently by the Tesla Model S). With the focus of the PCEVB on medium- and heavy-duty vehicles and equipment used in a business setting, there may be limited consumer insights that can be gained from evaluating trends in the more established light-duty sector.

Figure 5: U.S Price of Gasoline vs. Monthly U.S. Sales of PHEVs and EVs



[12] Alternative Fuels Data Center: Hybrid Electric Vehicle Sales by Model and U.S. Plug-in Electric Vehicle Sales by Model
[13] Green Car Reports. Hybrid market share peaked in 2013, down since then. https://www.greencarreports.com/news/1108483_hybrid-market-share-peaked-in-2013-down-since-then Accessed 8/22/18

The Port has initiated a green fleet policy to guide the transition of its light-duty vehicle fleet to zero-emission vehicles.

3.6.3 Medium- and Heavy-Duty Deployments

Within California's port sector, the most recent California Energy Commission report tracking progress on zero-emission vehicles and infrastructure[14] identified funded zero-emission vehicle pilot projects for 28 yard tractors, three top handlers, 50 drayage trucks, and nine gantry cranes combined across the POLB, Port of Los Angeles, and Port of San Diego. In addition, CARB's 2017-18 Funding Plan indicates past investments to deploy 40 zero-emission drayage trucks and 40 zero-emission pieces of cargo-handling equipment at Port of Los Angeles and three facilities in San Bernardino County. At POLB in 2017, there were a total of 178 electric vehicles out of the Port's 1,408 total vehicles. A summary of these vehicles is shown in Table 5.

Table 5. 2017 Population of Zero-Emission Vehicles at the Port of Long Beach

Vehicle Type	Fuel	Count
Automated Guided Vehicle	Electricity	56
Automatic Stacking Crane	Electricity	32
Crane	Electricity	4
Electric Pallet Jack	Electricity	2
Forklift	Electricity	9
Material Handler	Electricity	1
Miscellaneous	Electricity	3
STS Crane	Electricity	64
Sweeper	Electricity	1
Truck	Electricity	6
N/A	Hydrogen	0

3.7 Equipment and Vehicle Usage

Understanding baseline equipment and vehicle usage is critical to identifying the opportunities and priorities for transitioning to electric equipment. As part of its Annual Emissions Inventory, POLB works with its terminal operators to track cargo-handling equipment usage throughout the port. These data provide high-level insight into the means by which cargo-handling equipment is utilized across the port.

Figure 6, Figure 7, and Figure 8 show the equipment population count (blue) along with operational data (hours per year) including minimum, maximum, and the range within the first standard deviation (black).

[14] California Energy Commission – Tracking Progress. Zero-Emission Vehicles and Infrastructure. Last Updated 7/5/17 www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf Accessed 8/22/18

Figure 6. 2017 Usage of Existing Electric Equipment at POLB

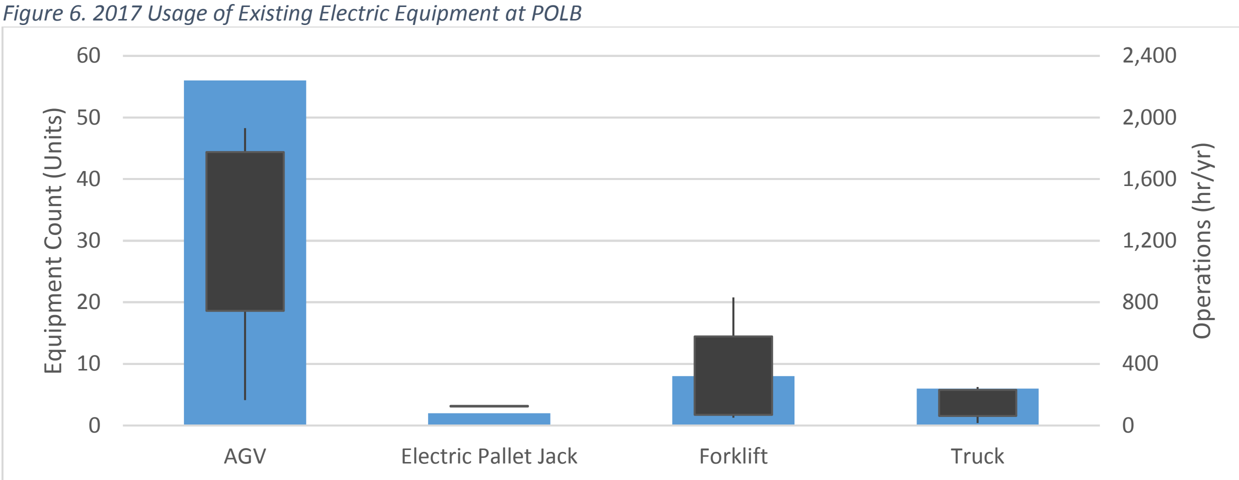


Figure 6 does not include automatic stacking cranes because no operational data is available for this equipment type in the 2017 CHE database.

Figure 7. 2017 Usage of Existing Propane Equipment at POLB

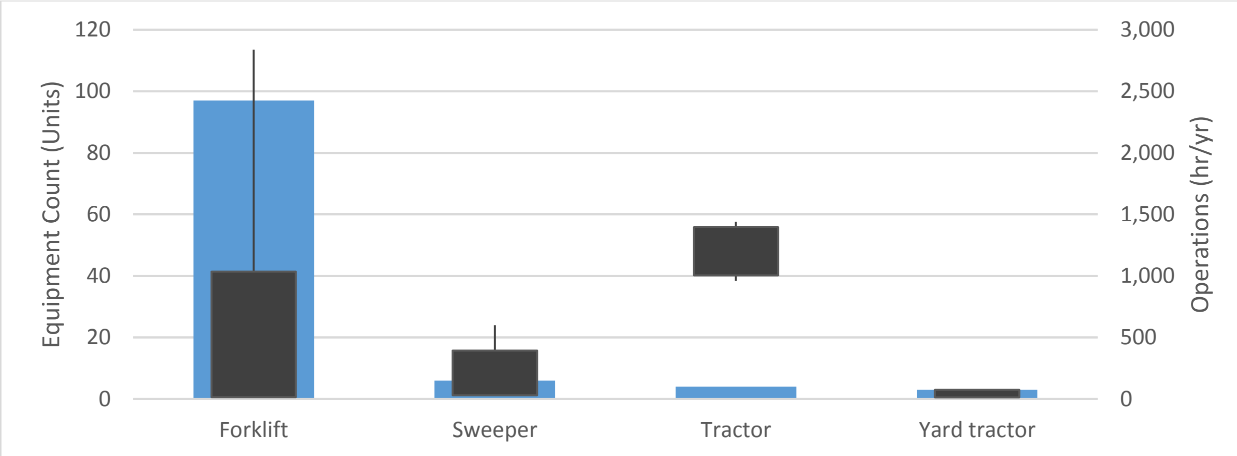
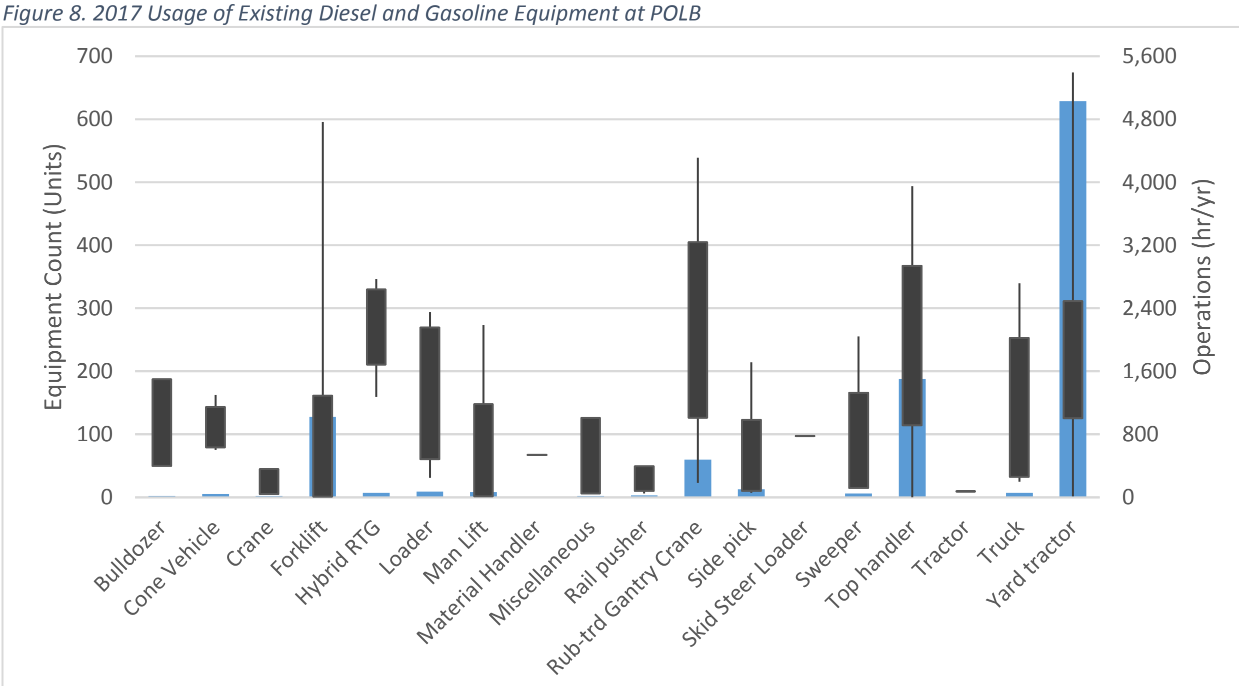


Figure 8. 2017 Usage of Existing Diesel and Gasoline Equipment at POLB



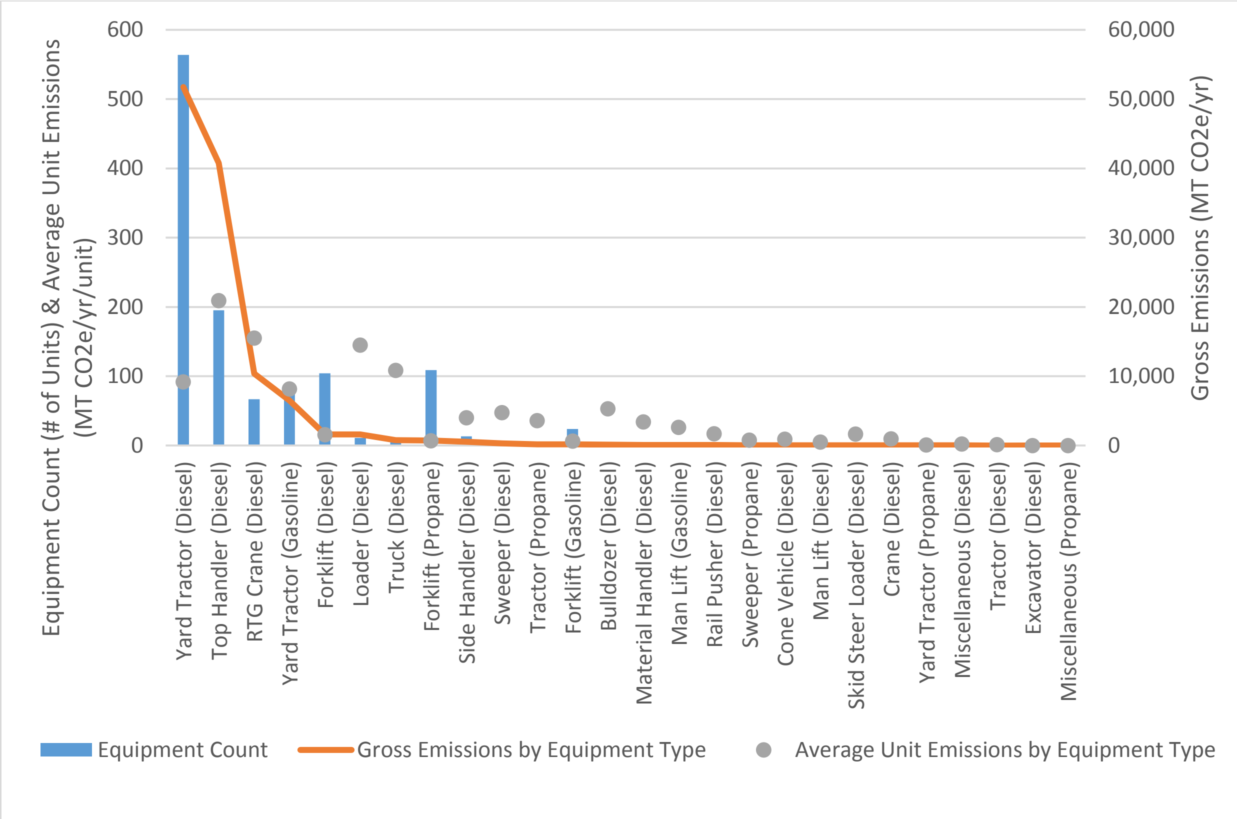
As part of the Annual Air Emissions Inventory, the Port reports emissions contributions by equipment type is calculated (Table 6).

Table 6. 2017 Cargo Handling Equipment Emissions by Equipment Type

Port Equipment	Engine Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e MT
Bulldozer	Diesel	0.0	0.0	0.0	0.9	0.0	0.3	0.1	106
Cone vehicle	Diesel	0.0	0.0	0.0	0.2	0.0	0.3	0.0	45
Crane	Diesel	0.0	0.0	0.0	0.1	0.0	0.1	0.0	19
Excavator	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Forklift	Diesel	0.2	0.1	0.2	6.5	0.0	9.3	0.6	1,602
Forklift	Gasoline	0.0	0.0	0.0	0.3	0.0	4.2	0.1	151
Forklift	Propane	0.1	0.1	0.0	6.8	0.0	28.2	2.4	739
Loader	Diesel	0.1	0.1	0.1	2.0	0.0	3.6	0.4	1,594
Man lift	Diesel	0.0	0.0	0.0	0.2	0.0	0.2	0.0	39
Man lift	Gasoline	0.0	0.0	0.0	2.3	0.0	34.3	1.7	52
Material handler	Diesel	0.0	0.0	0.0	0.5	0.0	0.1	0.0	68
Miscellaneous	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4
Miscellaneous	Propane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rail pusher	Diesel	0.0	0.0	0.0	0.2	0.0	0.2	0.0	50
RTG crane	Diesel	1.0	0.9	1.0	86.6	0.1	22.6	5.3	10,391
Side handler	Diesel	0.0	0.0	0.0	5.1	0.0	1.1	0.3	520
Skid steer loader	Diesel	0.0	0.0	0.0	0.2	0.0	0.2	0.0	33
Sweeper	Diesel	0.0	0.0	0.0	1.0	0.0	0.6	0.1	284
Sweeper	Propane	0.0	0.0	0.0	0.3	0.0	1.5	0.1	47
Top handler	Diesel	1.2	1.0	1.2	165.4	0.5	86.7	15.5	40,766
Tractor	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
Tractor	Propane	0.0	0.0	0.0	0.5	0.0	16.3	0.3	179
Truck	Diesel	0.1	0.1	0.1	2.1	0.0	1.6	0.2	757
Yard tractor	Diesel	0.9	0.8	0.9	60.6	0.7	126.8	7.7	51,736
Yard tractor	Gasoline	0.6	0.5	0.0	3.3	0.1	201.3	0.3	6,511
Yard tractor	Propane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6
Total		**4.2**	**3.8**	**3.5**	**345.2**	**1.4**	**539.7**	**35.0**	**115,792**

Using the emissions data and the equipment population, priority equipment can be identified based on several metrics for evaluating impact: gross emissions by equipment type, average unit emissions, and population size (Figure 9).

Figure 9. Emission Profile of Cargo Handling Equipment: Gross Emissions and Average Unit Emissions



The first four equipment types, yard tractors (diesel and gasoline), top handlers, and RTG cranes generate 94.5 percent of cargo-handling equipment emissions while only representing 73.7 percent of the fleet. To better understand the use case for these equipment types, POLB has conducted detailed evaluations of duty cycles for yard tractors and RTG cranes.

A study of the yard tractor duty cycle was conducted by CALSTART with assistance from the Center for Alternative Fuels, Engines, and Emissions at West Virginia University. The study was completed in 2009 with Long Beach Container Terminal (LBCT) at POLB. The study identified duty cycles for medium-heavy and heavy-heavy duty applications. Findings are presented in Table 7 and Table 8.

Table 7. Overall Statistics Associated with Medium-Heavy Duty Sub-Cycles for Yard Tractors

Parameter	Medium-Heavy Rail	Medium-Heavy Ship	Medium-Heavy Combined
Duration	300 sec.	900 sec.	1200 sec.
Avg. Speed	6.1 mph	5.0 mph	6.8 mph
Std. Dev. Speed	7.8 mph	6.4 mph	6.8 mph
Creep	13.7%	16.9%	16.1%
Idle	44.5%	41.2%	42.0%
Creep + Idle	58.2%	58.1%	58.1%

Table 8. Overall Statistics Associated with Heavy-Heavy Duty Sub-Cycles for Yard Tractors

Parameter	Heavy-Heavy Rail	Heavy-Heavy Ship	Heavy-Heavy Combined
Duration	300 sec.	900 sec.	1200 sec.
Avg. Speed	7.1 mph	7.1 mph	7.1 mph
Std. Dev. Speed	5.2 mph	6.9 mph	6.5 mph

Creep	17.6%	13.9%	14.9%
Idle	13.3%	28.4%	24.6%
Creep + Idle	30.9%	42.3%	39.5%

Additionally, a study of RTG crane load factors was conducted by Starcrest Consulting Group, completed in 2009. The study evaluated three methodologies for estimating load factors for RTGs. The CARB methodology found a low range of 15 percent and a high range of 43 percent. However, the remaining two methodologies, utilizing actual usage data, suggest 15 percent to 20 percent to be more representative of actual average usage. The findings are a significant departure from the default value used by CARB (43 percent). Given the power demand from these large pieces of equipment, understanding RTG operations is important to developing the grid-tied infrastructure needed to support their zero-emission transition across the Port.

3.8 EV and Zero-Emission Cargo-Handling Deployments

POLB operators have already initiated the process of deploying zero-emission technologies. As shown in Table 5, 178 pieces of terminal equipment have been electrified at the Port. The major deployments at this point, include ship-to-shore (STS) cranes, autonomous guided vehicles (AGV), and automatic stacking cranes. STS Cranes have been prime candidates for electrification as they are fairly stationary units that can be grid-tied, and the Port's full fleet of STS cranes is electrified. The AGVs and automatic stacking cranes are predominantly located at the LBCT terminal, which has been substantially redeveloped over the last 5 years to include the necessary infrastructure for nearly 100 percent electrification. The automatic stacking cranes are rail-mounted and operate in a well-defined geographic area of operation, easing the infrastructure demands for grid-tied electrification. The AGVs are lead-acid battery operated and have piloted a battery-swap system to efficiently refuel.

In addition to these major deployments of electric CHE, POLB is currently implementing several programs to continue zero-emission CHE testing and pre-commercial deployment:

- **Zero Emission Terminal Transition Project**: Deployment of 21 new or repowered zero-emission CHEs for three terminal operators (LBCT, ITS, SSA). Deployments will include 12 battery-electric yard tractors and nine repowered electric RTG cranes.
- **C-PORTS**: Deployment of five new zero-emission CHE for two terminal operators (LBCT and SSA). Deployments will include one battery-electric top handler, one battery-electric yard tractor, one hydrogen fuel cell electric yard tractor, and two battery-electric top handlers.
- **Project RIZE**: Deployment of a microgrid, including a 300-kW photovoltaic (PV) array, 330 kW/670 kWh stationary battery, and 250 kW/220 kWh mobile battery storage system to serve the Joint Command and Control Center.
- **PAVE Project**: Upgrade the electrical distribution at POLB to support the operation of 27 electric yard hostlers and 10 electric forklifts. The PAVE Project will also develop and test a Dynamic Energy Forecasting Tool to predict costs of converting freight facilities to support zero-emission vehicle operations.
- **START Phase 1**: Deployment of 102 zero- and near-zero-emission vehicle at POLB, Port of Oakland, and Port of Stockton. The POLB deployments will include 33 battery-electric yard tractors, one battery-electric top handler, and five battery-electric class 8 trucks, along with three near-zero-emission marine vessels.

Figure 10 and Table 9 show the existing and planning zero-emission fueling infrastructure and renewable energy projects at the Port.

Figure 10. Map of Existing and Planned Zero-Emission Infrastructure and Renewable Energy Projects

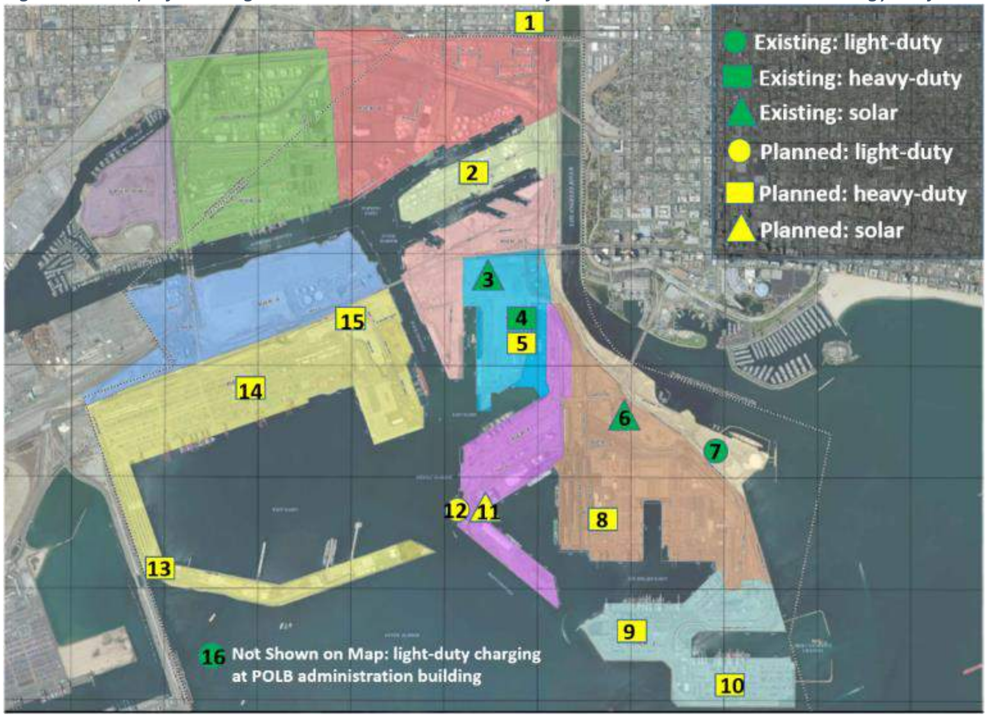


Table 9. Description of Existing and Planning Zero-Emission Infrastructure and Renewable Energy Projects

	Description	Availability
1	5 charging units for heavy-duty trucks at a trucking facility, including 2 publicly accessible charging units at the Clean Trucks Program Center	Q3 2020
2	36 charging units for yard tractors and 1 charging unit for a top handler at a container terminal	Q3 2020
3	905 kW solar carport at a container terminal	Existing
4	Battery exchange building for automated guided vehicles to enable battery swapping; full electrification of yard cranes at a container terminal	Existing
5	6 charging units for non-automated yard tractors at a container terminal	Q2 2019
6	320 kW solar rooftop installation at the POLB Maintenance Yard	Existing
7	2 charging units for passenger cars at the Queen Mary	Existing
8	20 charging units for yard tractors at a container terminal	Q3 2019
9	2 charging units for top handlers at a container terminal	Q2 2019
10	Electrical tie-ins for 9 grid-based electric rubber-tired gantry cranes at a container terminal	Q3 2019
11	300 kW solar carport at the POLB security center	Q1 2020
12	Charging units for passenger cars at the POLB security center; quantity undefined	TBD
13	27 charging units for yard tractors at a container terminal	Q2 2021
14	10 charging units for heavy-duty forklifts at a container terminal	Q2 2021
15	2 charging units for yard tractors at a container terminal	Q2 2021
16	2 charging units (4 plugs) for passenger cars at the POLB administration building	Existing

3.9 Available Analytical Tools and Software Applications

This section includes a summary of major tools that have been developed to support the deployment of zero emission vehicles. Evaluation of the effectiveness of these tools will be conducted during the development of the PCEVB.

3.9.1 Southern California Edison Tools and Services

SCE has developed a suite of tools and services to help educate users and raise awareness for interested stakeholders. Two specific tools that are available online for stakeholders are the Charge Port Estimator and the Business Rate Analysis Tool.

The Charge Port Estimator provides a suggested number of charge ports for potential deployment based on estimated current and near-term EV adoption, the number of charge ports already deployed, and a ratio of EVs per charge port. A visual of the online tool and its output are shown in Figure 11 and Figure 12. Figure 12 uses information associated with the Queen Mary Cruise Terminal at POLB, which has 1,450 parking spaces and three EV chargers currently.

Figure 11: SCE's Charge Port Estimator Online Tool Input Page

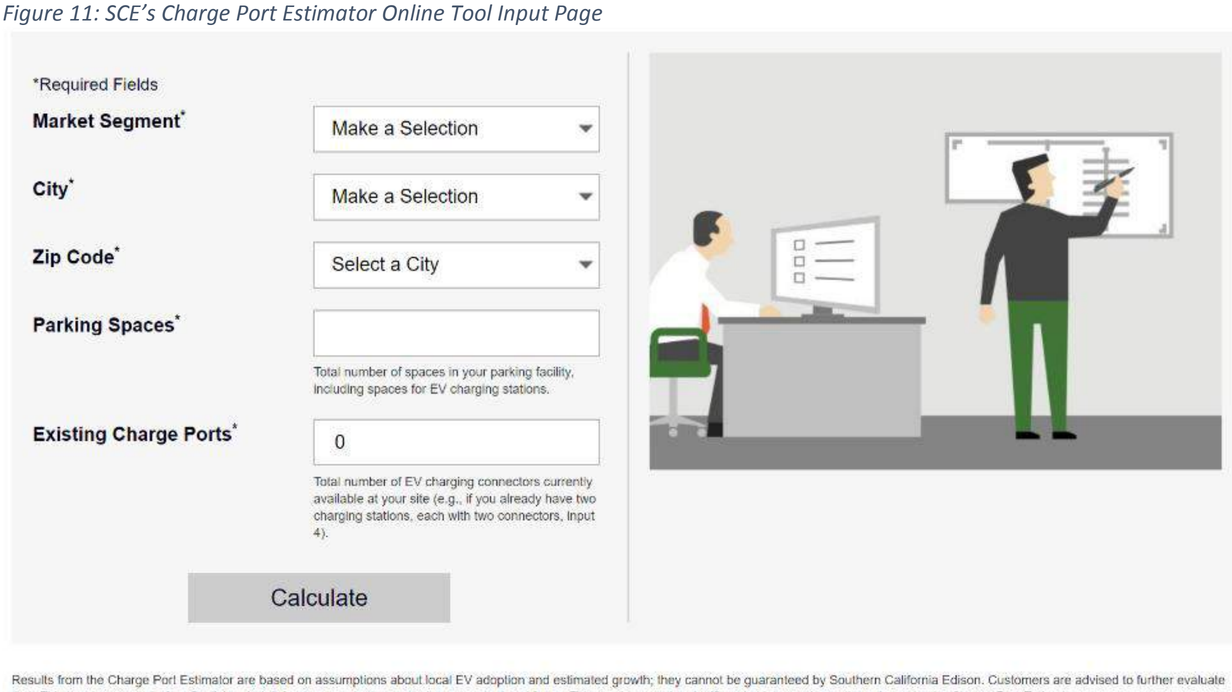
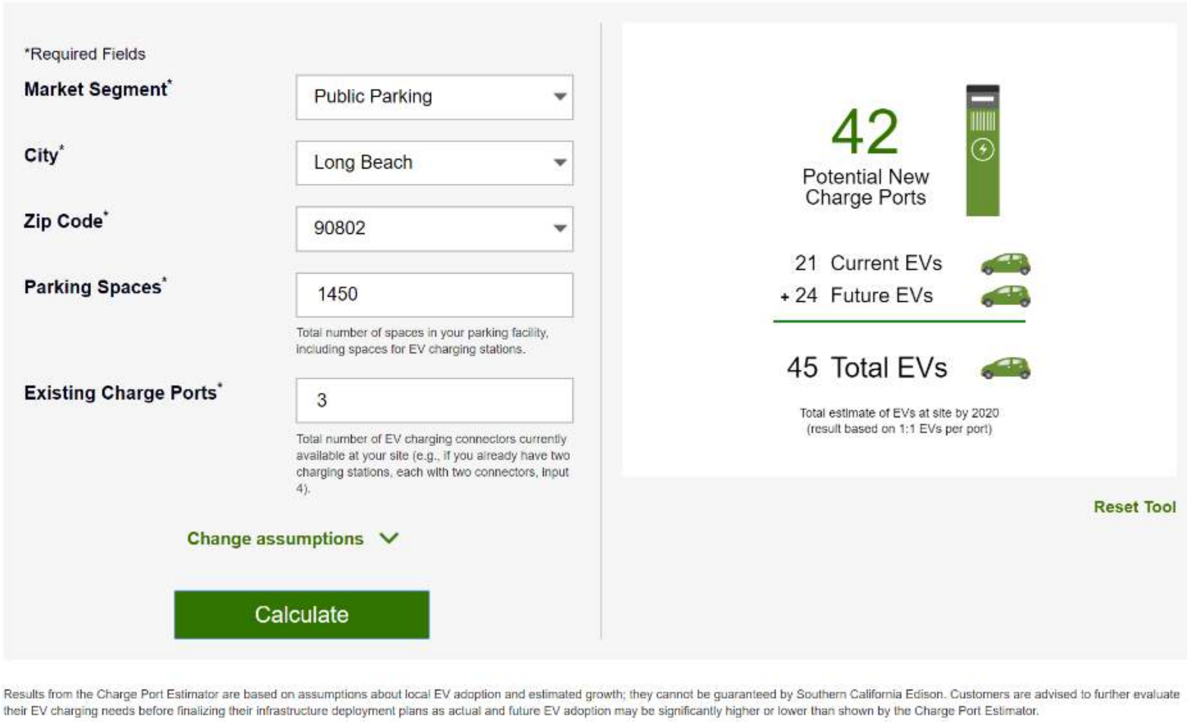


Figure 12: SCE's Charge Port Estimator Online Tool Output Page



The Business Rate Analysis Tool is designed to help stakeholders understand the potential costs associated with EV charging infrastructure. Figure 13 and Figure 14 show the type of information available through this tool. Figure 14 shows the results for an arbitrary number of charge ports, 14 Level 1 and 6 Level 2 charge ports.

Figure 13: SCE's Business Rate Analysis Tool Input Page

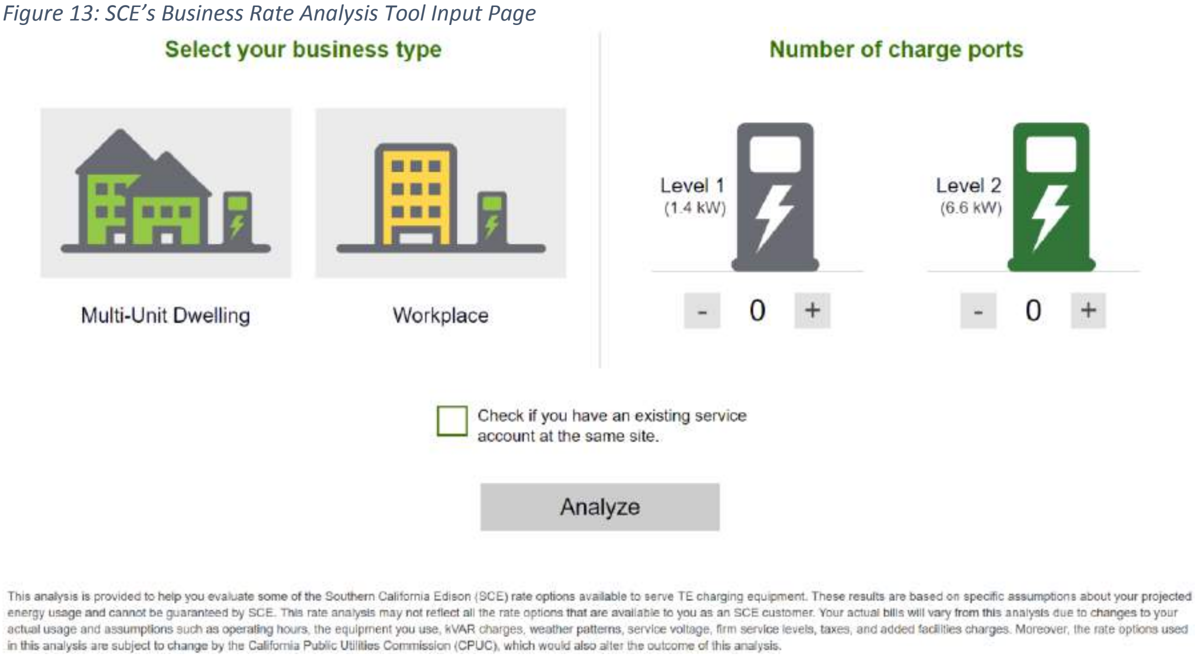


Figure 14: SCE's Business Rate Analysis Tool Output Page

Your Results

20
Total # of Charge Ports

33,400
Estimated Total Annual kWh

59
Estimated Annual Max kW Demand

Estimated Annual Cost

Rate Plans	Total
TOU-EV-4	$16,410
TOU-GS-2-A	$16,680
TOU-GS-2-B	$16,720

*****FRD Offset:** Assumes that the Facilities Related Demand (FRD) for the EV account does not exceed the FRD for the General Service account if located at the same premises (i.e., no FRD charge for the EV account).

3.9.2 EVI-Pro

Developed by NREL and the California Energy Commission, the Electric Vehicle Infrastructure Projection (EVI-Pro) computer simulation tool quantifies the types of charging infrastructure needed to ensure that plug-in electric vehicle drivers can meet their transportation needs. EVI-Pro takes input information about vehicle attributes, infrastructure attributes, and travel data to produce driving/charging simulations to generate forecasts for participation rates, charging load profiles, consumer benefits and individual charging session utilization. With this information, spatial/temporal post processing is modeled to identify EVSE density and utilization, ultimately reaching recommendations for plug counts and consumer demand. While EVI-Pro was developed to understand charging infrastructure needs at the state, regional, and local levels, it has the potential to be a powerful tool to adapt to the Port community.

3.9.3 StorageVET

StorageVET was developed by EPRI and the California Energy Commission to help evaluate the financial model opportunities for energy storage. StorageVET was designed to provide a consistent platform for communication of site-specific storage value between stakeholders of utilities, regulators, and vendors. The tool will be useful to evaluate the potential benefits associated with microgrid deployments across the Port.

3.9.4 UC Davis GIS EV Planning Toolbox

The GIS EV Planning Toolbox was developed by UC Davis and the California Energy Commission targeting Metropolitan Planning Organizations in California. The toolbox is intended to be used for planning the location of plug-in electric vehicle charging infrastructure in California. The tool has two main uses. The first use suggests the location of demand based on market size input from the user. The second use provides the location and magnitude anticipated demand for infrastructure given a market location. The tool does not provide guidance for implementation (permitting, construction, costs, and placement). The tool outputs the number of anticipated charging events and number of kWh by location.

3.10 Local and Regional Efforts to Promote Zero-Emission Infrastructure

3.10.1 Southern California Edison

SCE currently implements Charge Ready and Market Education programs to support California's policies to reduce GHGs and air pollutant emissions to help meet the state's zero-emission vehicle goals. The Market Education program targets car buyers to help them gain awareness of EVs and the benefits of fueling from the grid. This program also includes SCE's advisory services, providing education and support related to electrifying fleets, EV charging, reducing GHG footprints, and other transportation electrification areas for business customers. SCE has indicated that it is looking to expand its Market Education program to medium- and heavy-duty fleet operators, which would be of particular relevance to the PCEVB.

As part of its existing Market Education program, SCE has developed an Electric Vehicle landing page that provides a central location for information directed to five topic areas: workplace charging, public parking, fleets, multi-unit dwellings, and the Charge Ready program. These pages have valuable information about vehicle types, charging infrastructure, SCE's EV rates, and links to additional tools, resources, and fact sheets. SCE is working to modify the Charge Ready program, which focuses on the light-duty sector, to target the heavy-duty sector. The Port is working with SCE to refine the Charge Ready Heavy Duty program.

In addition to its online presence, SCE offers in-person services that include Initial Fleet Assessments that include GHG savings calculations to help customers evaluate the business case for converting a fleet of vehicles to transportation electrification technologies and Infrastructure Assessments to assist customers in evaluating a potential deployment of charging equipment.

3.10.2 South Coast AQMD

The South Coast AQMD has enacted a series of incentive programs to support the deployment of zero-emission vehicles and charging infrastructure residentially and at the workplace. Relevant programs to PCEVB are discussed in the Existing Incentives and Financing Sources section.

3.10.3 San Pedro Bay Ports

The 2017 San Pedro Bay Ports CAAP details plans for the Port of Long Beach and Port of Los Angeles to transition to zero-emission technologies. The PCEVB will advance the goals and objectives identified in the CAAP. Details about the CAAP are presented in the San Pedro Bay Ports Clean Air Action Plan (CAAP) 2017 section.

3.11 Key Local Champions

POLB has identified several key local champions that have been instrumental in support of POLB's zero-emission goals. SCE, SCAQMD, Port of Los Angeles, and Port container terminal operators—SSA Marine, LBCT, International Transportation Service, and Total Terminals International—have been instrumental in the early deployments and will be critical to the continued progress. The contributions of these local leaders are documented throughout this report.

4 Existing Incentives and Financing Sources

4.1 Port and Tenant Relationship

The Port is a landlord port, meaning that it leases its land to private terminal operators, which own and operate all of the equipment and run the business of moving cargo. These leases are typically long in duration—15 to 20 years—and include payment structures, financial guarantees, an assessment of any existing or planned physical improvements to the site, and environmental covenants, which may include provisions to upgrade equipment. Site improvements, which would include electrical infrastructure installations, are generally capitalized in the Port's budget and amortized back to the leaseholder over the course of the lease obligation. The interplay between Port and terminal operators can be challenging as the terminal operator owns and operates the equipment while the Port owns the infrastructure.

4.2 The Port's Budget Process

4.2.1 Basis for Budget Development

The Port of Long Beach is a public agency managed and operated by the City of Long Beach Harbor Department. The Port is governed by the Long Beach Board of Harbor Commissioners, whose five members are appointed by the mayor of Long Beach and confirmed by the City Council.

The Port's budget serves as a financial plan for delivering effective services and efficiently managing the revenues which support those services. The Fiscal Year 2018 (FY18) Budget covers the period of October 1, 2017 through September 30, 2018. Long Beach City Charter, Section 1210, requires that the Board of Harbor Commissioners adopt and transmit a departmental budget that conforms to the general City budget "not later than sixty (60) days prior to the beginning of each fiscal year." The City's Charter and municipal code provide broad governance for preparation of the operating and capital budgets. The budget is also developed based on the following:

- The Port's top priorities and other Board of Harbor Commissioners' directives
- The Port's Long Range Financial Plan, which is updated annually and presented to the Finance Sub-Committee and the Board prior to the release of the budget
- The Port's commitments to the Strategic Goals and Six-Month Strategic Objectives outlined in the Fiscal Year 2017 Strategic Plan:
    - Financial Strength
    - Ten-Year Capital Plan
    - Diverse Workforce
    - Green Port of the Future
    - Market Share Growth

4.2.2 Operating and Capital Budgets

The Port's budget processes is completed throughout the year. A calendar of activities is summarized in this section.

- December/January – Budget guidelines and timeframes for development of the operating and capital budgets are developed. The budget development process begins when budget instructions and budget templates (personnel, non-personnel, and budget forms) are distributed to divisions for budget preparation.
- January/February - Divisions complete and submit requests to reallocate staffing and non-personnel resources for the upcoming year to meet changing operational needs. The Finance Division reviews the submissions and requests explanations for any major variances or unusual items from prior year activity or prior budget amounts.
- March/April - The proposals are then integrated with the revenue forecast, the 10 year capital program resiliency plan, and debt service, into a preliminary budget document that is presented to the senior management and the Finance Sub-Committee for guidance and review.
- May/June - The Finance Director and the Managing Director of Finance and Administration, guided by the direction of the Finance Sub-Committee and other members of senior management, then present a Proposed Budget that conforms to the strategic goals of the Port to the full Board of Harbor Commissioners for adoption.

- May/June - Upon approval by the Board of Harbor Commissioners in, the Harbor Department's budget is transmitted to the City Clerk and City Auditor's office for inclusion into the City's overall budget.
- August/September - The City Manager and Mayor present the City of Long Beach's budget to the City Council for final approval.

4.2.3 Traditional Debt

Due to its dominant West Coast market position, naturally deep water, state-of-the-art facilities, diverse revenue stream, and stable finances, the Port's debt continues to be highly rated by all three major rating agencies: Standard and Poor's (AA); Fitch (AA); and Moody's (Aa2) – all with stable outlook.

The Port in FY 2018 will continue to effectively manage the $995.2 million debt portfolio anticipated to be in place at the beginning of the fiscal year, with $97.2 million in scheduled principal and interest payments. It is projected that $225 million in new debt will be issued in FY 2018 in order to support the continuation of the Port's capital program. This is in addition to the $200 million in new debt that was issued in June 2017. For the 2017 Series Revenue Bonds, the Port issued "Green bond" to finance the "Green Projects" including the intermodal railyard and the wharf and the backlands redevelopment as part of the Middle Harbor Terminal Redevelopment Projects which the Board believes environmentally beneficial.

The Port's FY 2016 year-end Debt Service Coverage Ratio (DSCR) was 2.47, which is well above the ratio of 1.25 required by its bond covenants. In October 2011, the Board of Harbor Commissioners passed an ordinance which requires the Port to maintain a minimum DSCR of 2.0 and a minimum unrestricted cash balance equivalent to 600 days of the prior year's operating expenses before depreciation and amortization. The Port anticipates the DSCR will be 2.67 and 2.37 at the end of FY 2017 and FY 2018, respectively. In order to fund the Port's Harbor Department Annual Budget - FY 2018 – which includes substantial investments in capital and environmental programs, an additional $800 million debt issuance is expected in 2018, and beyond.

4.3 Public Funding

4.3.1 CARB: Clean Transportation Incentives

CARB administers a variety of funding programs to meet the agency's goals, including those from the Emission Reduction Plan for Ports and Goods Movement in California. Relevant programs include the Clean Transportation Incentives Program, the Carl Moyer Program, and the VW Mitigation Trust. The Clean Transportation Incentives Program includes Low Carbon Transportation Incentives (annual program), Air Quality Improvement Program (annual through 2023), the Zero-Emission Warehouse Program (one-time funding), and VW 2.0- and 3.0-Liter Settlement Program (one-time, decennial funding). In fiscal year 2017-18, the Clean Transportation Incentives Program allocations include:

- Low Carbon Transportation Investments (LCT): $560 million
- Air Quality Improvement Program (AQIP): $28.64 million
- Volkswagen (VW) 3.0-Liter Settlement Program: $25 million
- Zero- and Near-Zero Emission Warehouse Program: $50 million

In 2018, the funding between these four programs was divided among a number of programs.

Project Category	Proposed Allocation by Funding Source (millions)				
	Low Carbon Transportation[1]	AQIP[2]	VW Settlement[2]	Warehouse Program[3]	Total
LIGHT-DUTY VEHICLE AND TRANSPORTATION EQUITY INVESTMENTS					
CVRP (standard rebates)	$140				$140
Transportation Equity Projects	$100		$25		$125
EFMP Plus-Up	$10		$10		$20
Financing Assistance for Lower-Income Consumers	$10		$10		$20
Clean Mobility Options in Disadvantaged Communities	$22				$22
Agricultural Worker Vanpools	$3				$3
Rural School Bus Pilot	$10				$10
CVRP Rebates for Low-Income Applicants	$25				$25
To Be Allocated in Spring 2018 Based on Demand	$20				$20
One-Stop-Shop for CARB's Equity ZEV Replacement Incentives *(new)*			$5		$5
Light-Duty Vehicle and Transportation Equity Investment Total	**$240**		**$25**		**$265**
HEAVY-DUTY VEHICLE AND OFF-ROAD EQUIPMENT INVESTMENTS					
Advanced Freight Equipment Demonstration and Deployment	$140			$50	$190
Zero- and Near Zero-Emission Freight Facilities[3] *(new)*	$100			$50[3]	$150
Zero-Emission Off-Road Freight Voucher Incentive Project *(new)*	$40				$40
Clean Truck and Bus Vouchers (HVIP + Low NOx Engine Incentives)	$180	$8			$188
Truck Loan Assistance Program		$20			$20
Heavy-Duty Vehicle and Off-Road Equipment Investment Total	**$320**	**$28**		**$50**	**$398**
TOTAL	**$560**	**$28**	**$25**	**$50**	**$663**

Relevant programs to PCEVB include:

- Clean Mobility Options for Disadvantaged Communities: This program supports small, simple car sharing projects serving disadvantaged communities using new or used battery-electric, fuel cell electric, or plug-in hybrid vehicles, along with support for outreach, a reservation system, charging infrastructure, and ridesharing. Funding will first be allocated to a statewide administrator, but upon award, the port communities may anticipate piloting this type of program to ease the commute for local workers.
- Zero- and Near-Zero-Emission Freight Facilities: This program supports the holistic reduction of GHG and criterial pollutant emissions in freight facilities and to help achieve additional benefits, such as providing economic, environmental, and public health benefits to disadvantaged communities and/or low-income communities. POLB spearheaded a successful multi-port initiative: *Sustainable Terminals Accelerating Regional Transformation (START) Phase 1*.
- Zero-Emission Off-Road Freight Voucher Incentive Program (FVIP): This program is intended to be a new program analogous to the existing Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) for off-road freight equipment. The program is targeted toward commercialized products and is designed to accelerate deployment of cleaner technologies by providing a streamlined way for fleets ready to purchase specific zero-emission equipment to receive funding to offset the higher cost of such technologies. Similar to the Clean Mobility Options program, an administrator will be selected for the FVIP program. Port of Long Beach has been engaged in public workshops and comments associated with this program.
- Clean Truck and Bus Vouchers (HVIP and Low NOx Engine Incentives): HVIP and Low NOx Engine Incentives are intended to encourage and accelerate the deployment of zero-emission trucks and buses, vehicles using engines that meet the optional low-NOx standard, and hybrid trucks and buses in California. HVIP provides vouchers of up to $110,000 for California purchasers and lessees of zero-emission trucks and buses, and up to $30,000 for eligible hybrid trucks and buses on a first-come, first-served basis. HVIP is currently administered by CALSTART. HVIP is a critical funding opportunity for POLB to achieve its zero-emission drayage truck goals by 2035.
- Truck Loan Assistance Program: Launched in 2009, the Truck Loan Assistance Program is designed to help small business fleet owners affected by CARB's In-Use Truck and Bus Regulation to secure financing for upgrading their fleets with newer trucks or diesel exhaust

retrofits. The program is implemented in partnership with the State Treasurer's Office's California Pollution Control Financing Authority (CPCFA) through its California Capital Access Program (CalCAP) and leverages public funding with private funding from participating lending institutions. This financing program may be an asset for POLB to achieve its zero-emission drayage truck goals by 2035.

The 2018-19 Funding Plan is expected to be released imminently. Funding priorities include $70-$135 million for demonstration of zero-emission and plug-in hybrid drayage trucks, advanced powertrains, and zero-emission and hybrid heavy CHE. An additional $110-$225 million is expected to be directed towards zero-emission medium- and heavy-duty delivery trucks, fuel cell transit buses, and CHE. Lastly, a heavy-duty off-road voucher program, structured similarly to the existing HVIP program is expected to support zero-emission and hybrid yard hostlers and CHE.

4.3.2 CARB: Volkswagen Environmental Mitigation Trust

The VW Settlement provides $423 million for California—through CARB—to mitigate the excess NO_X emissions caused by VW's use of illegal defeat devices in certain diesel vehicles with a focus on "scrap and replace" projects, which include commercial marine vessels, CHE, and heavy-duty on- and off-road vehicles and equipment. A Beneficiary Mitigation Plan must be developed and submitted to the Trustee, Wilmington Trust, prior to expending any funds. The Beneficiary Mitigation Plan is currently being developed through a public process that began on September 20, 2017. The State of California's Proposed Beneficiary Mitigation Plan (April 20, 2018) recommended:

- $130 million for zero-emission transit, school, and shuttle buses and specifically identified funding allocations up to $100,000 for battery-electric shuttle buses
- $90 million for class 8 zero-emission freight and port drayage trucks and specifically identified funding allocations up to $200,000 for class 8 trucks, targeting 2009 or older model year replacements
- $70 million for zero-emission forklifts, port CHE, airport ground service units, and shorepower and specifically identified funding allocations up to $175,000 for forklifts and port CHE and up to $2.5 million for shorepower
- $60 million for combustion freight/marine projects and specifically identified funding allocations up to $1 million in funding per Ferry, Tug, and Tow Tier 4 or Hybrid Repower, up to $60,000 for low NOx class 7-8 truck repowers or replacements, and up to $1.35 million for switcher locomotive Tier 4 repowers or replacements.
- $10 million for light-duty ZEV infrastructure funding up to 100 percent of public charging at government property, up to 80 percent of public charging on private property, and up to 33 percent of hydrogen fueling infrastructure.

The program is expected to be fully funded by November 2018.

4.3.3 CARB: Supplemental Environmental Projects

The Supplemental Environmental Project (SEP) Policy permits community-based projects to be funded from penalties received during ARB's settlement of enforcement actions. The ARB is instructed to solicit, compile, and maintain a library of eligible projects that violators may choose from during the settlement process. The SEP Policy permits CARB to allocate up to 50% of penalties obtained from violators towards eligible SEPs that have some nexus to the violation, either by location or type of pollutant to be addressed. Funds may cover all phases of the selected SEP, including capital, operational, and administrative costs. Examples of potential projects include air monitoring studies, vehicle and equipment upgrades, workforce training and awareness campaigns, projects reducing exposure to air pollutants, and projects achieving direct and indirect emissions reductions beyond regulatory requirements. This funding mechanism is intended for projects that do not have an alternative avenue for funding. A pre-application process is used to evaluate CARB's level of interest in the project.

4.3.4 CARB: Low Carbon Fuel Standard

The Low Carbon Fuel Standard (LCFS) was developed to address long-term operational challenges associated with alternative fuel adoption through incentives for actual alternative fuel utilization and disincentives for the use of dirtier fossil fuels. The LCFS program is well-established and was recently (2015) readopted in the California legislature, overcoming significant opposition from regulated industries (e.g. oil and gas). Additionally, the LCFS program is currently (2018) undergoing amendments and updates that will expand the program and authorize its continued operations through 2030. The LCFS program awards credits for emissions reductions achieved by providing lower carbon intensity transportation fuels in California, allowing participants to gain value for these emission reductions in the LCFS credit marketplace where regulated entities can purchase credits to offset the higher carbon intensity of their fuels.

There are two major components to the LCFS program: 1) the fuel pathway carbon intensity (CI) and 2) the energy economy ratio (EER). The CIs for diesel fuel and California grid electricity are well established in the program; the operator of an electric fleet could be eligible to use the existing pathway for electricity. The EER ratio establishes the relative efficiency of an alternative fuel engine compared to the diesel or gasoline baseline.

The LCFS program is currently undergoing an amendment and rulemaking process that is poised to dramatically increase the value of the program to the Port community. Relevant changes include:

- Owner of the fuel-supplying equipment (FSE) is first owner of the credits, if they opt in. If the FSE owner does not claim them, then they go to the electrical distribution utility (SCE) by default.
- Owners of the FSE can transfer status to a third-party if agreed by written contract.
- Change to EER values, including shore power to ocean-going vessels (EER of 2.6), other mobile equipment (generic EER of 2.7), and electric transport refrigeration units (eTRUs) (EER of 3.4) qualify for crediting.
- FSE owner can apply for an EER specific to particular equipment.
- Third party verifier is required to audit projects annually.
- FSE owners can claim that their charging came from any renewable energy (with a carbon intensity value of 0.0 gCO_2/MJ) put into the California balancing authority that is not used for the state RPS
- ZEV charging stations can accrue LCFS credits for capacity, instead of delivered energy

POLB has been actively engaged in the rulemaking process in 2018. Final rulemaking is expected in September/October 2018 and implementation of the new rules are expected to take effect on January 1, 2019.

4.3.5 CARB/SCAQMD: Carl Moyer Memorial Air Quality Standards Attainment Program

The Carl Moyer Program seeks to cost-effectively reduce smog-forming and toxic air contaminant emissions. To achieve these goals, the Carl Moyer Program focuses on vehicle or equipment replacement, repower, or retrofit; vehicle retirement; and, alternative fuel infrastructure. The program is focused on commercially-available (not demonstration) technologies. Carl Moyer funds are organized by CARB and annually CARB will send a solicitation to each air district, which will apply for funding through a competitive solicitation. The funding is intended to support a wide range of mobile equipment, including heavy-duty trucks, drayage trucks, off-road equipment, locomotive equipment, and marine vessels.

4.3.6 CEC: Electric Procurement Investment Charge

Administered by the California Energy Commission, the EPIC program supports the development of non-commercialized new and emerging clean energy technologies in California and provides assistance to commercially viable projects. Most of the funding procured through this mechanism (80%) is administered by the California Energy Commission as directed through its Triennial Investment Plan.[15] The Triennial Investment Plan consists of eight themes, of which three are considered targets for the PCEVB (Theme 2, Theme 3, and Theme 5). The remaining themes—Theme 1, Theme 4, Theme 6, Theme 7, and Theme 8—are considered tangential to the long-term zero-emission CHE and trucking goals of the Port. EPIC funding allocations are categorized by investment type: 1) applied research and development ($159.8 million), 2) technology deployment and demonstration ($173.2 million), and 3) market facilitation ($66.6 million). In the Investment Plan, allocations are not made by theme.

Theme 2: Accelerate Widespread Customer Adoption of Distributed Energy Resources

The funding priorities of this theme focus on the transition to a more decentralized and decarbonized electric economy. Specifically, the relevant objective is to identify optimal technology packages for specific uses and applications that can drive down costs for distributed energy resources (DER). Specific initiatives that directly address goals of the PCEVB include:

- **Initiative 2.2.1**: Advance Microgrids to the Tipping Point of Broad Commercial Adoption

Theme 3: Increase Grid System Flexibility and Stability from Low-Carbon Resources

The funding priorities of this theme focus on the enabling system flexibility and stability from low-carbon resources including demand response, energy storage, smart inverters, and balancing supply and demand over larger geographic areas. Specific initiatives that should directly address goals of the PCEVB include:

- **Initiative 3.1.1**: Pilot Test for the Next Generation Demand Response Landscape
- **Initiative 3.1.2**: Assess Performance of Load Control Systems
- **Initiative 3.1.3**: Assess iDERs and Load Management Systems
- **Initiative 3.2.1**: Grid-Friendly PEV Mobility
- **Initiative 3.2.2**: Battery Second Use

[15] http://docketpublic.energy.ca.gov/PublicDocuments/17-EPIC-01/TN217347_20170428T145448_The_Electric_Program_Investment_Charge_Proposed_20182020_Trienn.pdf

Theme 5: Create a Statewide Ecosystem for Incubating New Energy Innovations

The funding priorities of this theme focus on transforming California's electricity sector and reimagining the current model for delivering clean energy technologies to the market. Specifically, the relevant objective is to overcome barriers to broader and more diverse clean energy entrepreneurship Specific initiatives that should directly address goals of the PCEVB include:

- **Initiative 5.1.3**: Cost Share for Private, Non-Profit Foundation, or Federal Clean Energy Funding Opportunities

4.3.7 CEC: Alternative and Renewable Fuel and Vehicle Technology Program

Administered by the California Energy Commission, the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) is a result of AB 118 (Núñez 2007). AB 118 created the ARFVTP to provide funding for projects that will "transform California's fuel and vehicle types to help attain the state's climate change policies." This program targets projects that:

- Reduce criteria and toxic air pollutant emissions from vehicles;
- Reduce the use of 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 available to the public, existing fleets, public transit, and along transportation corridors;
- Improve the efficiency, performance, and market viability of alternative light-, medium-, and heavy-duty vehicle technologies;
- Retrofit medium- and heavy-duty on-road fleet and off-road freight vehicles to alternative technologies or fuel use;
- Offer incentives for the purchase of alternative fuel vehicles;
- Establish workforce training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies;
- Support local and regional planning for zero-emission vehicle and fueling infrastructure deployment.

The program is directed by an annual investment plan that guides the program's investment activities for the year. The 2018/2019 Investment Plan has identified several initiatives relevant to the PCEVB. Currently the 2018/2019 Investment Plan is being updated (notice given 9/7/2018). Specifically:

Zero-Emission Vehicle Infrastructure

This initiative focuses on the fueling infrastructure necessary to support widespread deployment of zero-emission vehicle technologies. Specific relevant funding allocations are proposed for electric vehicle charging infrastructure ($134.5 million, now proposed $94.2 million), hydrogen refueling infrastructure ($92 million, now proposed $20 million), and manufacturing and workforce training and development ($8.5 million, now proposed $17.5 million).

- **Electric Vehicle Charging Infrastructure**: This program has been developed in a highly on-road-vehicle-centric manner with direct current fast charging infrastructure and advanced grid integration and management tools. There is a clear opportunity to assert the value of funding off-road charging infrastructure as a specific activity.

- **Hydrogen Refueling Infrastructure**: This program has been developed to support a network of stations needed to support the initial deployment of hydrogen fuel cell vehicles.
- **Manufacturing and Workforce Development**: This program had been two separate programs, one for manufacturing and one for workforce development. In the current investment plan, these topic areas have been combined with a clear indication that ARFVTP's investment in manufacturing will be expected to be in conjunction with workforce development efforts.

Advanced Technology Vehicle Support

This initiative is focused on advanced freight and fleet technologies and has been allocated $17.5 million. There is a single programmatic effort in this year's Investment Plan.

- **Advanced Freight and Fleet Technologies**: This funding initiative will fund both demonstration and deployment projects. The 2017/2018 investment portfolio included $24 million for advanced vehicles at California seaports. Given the high priority of ports for GHG reductions, additional emphasis should be placed on funding activities at the ports.

4.3.8 Southern California Edison: SB 350 Funding

On August 31, 2018, the California Public Utilities Commission approved $738 million in transportation electrification projects for the state's electric utilities. SCE had $356.3 million approved across two programs:

Medium- and Heavy-Duty Make-Ready Program

- Authorizes $343 million for SCE to support make-ready installations at a minimum of 870 sites to support the electrification of at least 8,490 medium- or heavy-duty fleet vehicles.
- Requires a minimum of 15% of the infrastructure budget to serve transit agencies.
- Requires a maximum of 10% of the infrastructure budget to serve forklifts.
- Requires a minimum of 25% of the infrastructure budget to serve vehicles operating at ports and warehouses.
- Requires SCE to spend a minimum of 40% of its program budget in DACs.
- Requires SCE to offer rebates of up to 50% of the cost of the EVSE for sites in DACs and sites that support electric transit and school buses.

Commercial Rate Proposal

- Authorizes SCE to establish three new, time-of-use rates for commercial customers with electric vehicles under which, for the first five years the rates are available, they would not include a demand charge, and costs would instead be recovered through a volumetric energy charge.
- Allows SCE to update its definition of "electric vehicle" for the purposes of rate eligibility to include all forms of transportation electrification described in SB 350.
- No incremental funding will be incurred associated with this rate.

4.3.9 Southern California Edison: Charge Ready and Market Education Program

SCE currently implements Charge Ready and Market Education programs to support California's policies to reduce GHGs and air pollutant emissions to help meet the state's zero-emission vehicle goals. The Charge Ready program deploys electric infrastructure to support light-duty EV charging at customer sites throughout SCE's service area. As of April 2018, SCE had deployed infrastructure to support 941 charge ports at 60 customer sites, including 462 charge ports at 36 sites located in disadvantaged communities, exceeding the Charge Ready program goals of 10% disadvantaged community deployments. The Charge Ready Pilot Program was open to non-residential customers in long dwell-time locations, including workplaces, multi-unit dwellings, fleets, and destination centers. This program is well-suited for the customer-centric locations within the Port Communities, including cruise terminals, the Queen Mary, and nearby hotels. Additionally, SCE is developing the Charge Ready Heavy Duty program, taking the lessons learned from the existing light-duty-centric Charge Ready program and adapting it for the heavy-duty sector.

4.3.10 South Coast AQMD: Clean Air Plans

SCAQMD has developed extensive inventories and planning tools for reducing air emissions in non-attainment zones within its district. These plans are regularly updated through amendments and comprehensive new plans. POLB is located in areas targeted for emission reductions. In the SCAQMD Clean Air Plan, a minimum of $448 million is expected to be invested from 2017-2024 from a variety of funding sources.

4.3.11 US Environmental Protection Agency: Diesel Emissions Reduction Act

The Diesel Emissions Reduction Act (DERA) directs the U.S. Environmental Protection Agency (EPA) to annually distribute competitive grant moneys for the retrofit or replacement of diesel engines to achieve emissions reductions above and beyond regulatory requirements. The EPA Office of Transportation and Air Quality anticipates awarding funds to retrofit or replace older diesel engines in school buses, class 5–8 heavy-duty on-road vehicles, locomotives, marine engines, off-road equipment and vehicles, and diesel generators and pumps.

4.3.12 US Environmental Protection Agency: Targeted Air Shed Grant Program

Funded through congressional appropriations, the Targeted Air Shed Grant Program aims to reduce air pollution in nonattainment areas that the Agency determines are ranked as the top five most polluted areas relative to ozone, annual PM2.5, or 24-hour PM2.5 standards. The Los Angeles South Coast Air Basin ranks as the highest ozone nonattainment area and third highest PM2.5 nonattainment area in the county. Funding for this program has been appropriated in 2010, 2015, 2016, and 2017.

4.3.13 US Department of Transportation: Better Utilizing Investments to Leverage Development

The Better Utilizing Investments to Leverage Development (BUILD) Transportation Discretionary Grant program, provides a unique opportunity for the Department of Transportation to invest in road, rail, transit, and port projects that promise to achieve national objectives. Previously known as Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grants, Congress has dedicated nearly $5.6 billion for nine rounds of National Infrastructure Investments to fund projects that have a significant local or regional impact. The eligibility requirements of BUILD allow project sponsors at the State and local levels to obtain funding for multi-modal, multi-jurisdictional projects that are more difficult to support through traditional DOT programs. BUILD can fund port and freight rail projects, for example, which play a critical role in our ability to move freight, but have limited sources of Federal and local funds. BUILD can provide capital funding directly to any public entity, including municipalities, counties, port authorities, tribal governments, MPOs, or others in contrast to traditional Federal programs which provide funding to very specific groups of applicants (mostly State DOTs and transit agencies).

4.4 Traditional Private Funding

Across the industry, there are several types of investment classes, each requiring different returns apportioned to perceived level of risk. A summary of equity considerations is presented in Table 10.

Table 10. Equity Risk-Return Profiles

	Investment Grade Debt	Junior Debt	Core Equity	Core + Equity	Value-Added Equity	Opportunistic Equity
Return Assumptions[1]	3.5-5.5%	5.5-9%	5-9%	8-12%	11-15%	15-17%
Key Risks	Operating Assumptions, Investment Structure	Market Risk, Operating Assumptions, Strategy Implementation	Operating Assumptions, Leverage Levels, Regulatory	Construction	Strategy Implementation	Market Risk, Political Risk and Currency Risk
Revenue Certainty (contracted)	Yes	No	Yes	Yes	No	In Some Cases
Already Revenue Generating?	N/A	N/A	Yes	No	In Some Cases	In Some Cases
Main Return Driver	Income	Income and Appreciation	Income	Income and Appreciation	Appreciation	Appreciation
GDP Sensitivity	Low	High	Low	Low	High	High
Greenfield or Brownfield	Both	Both	Brownfield	"Dark Green"	Both	Both
Development Risk	In Some Cases	In Some Cases	No	No	In Some Cases	In Some Cases
Return Driven by Exit?	No	No	No	No	Yes	Yes
Operating Complexity	Low	Low	Medium	Medium	High	Medium/High

Source: BlackRock, February 2015. 1 These ranges are BlackRock's return assumptions for infrastructure assets. BlackRock has arrived at these long-term, project-level return assumptions by applying the cost of capital and a discounted cash flow methodology, taking into account anticipated revenues and operational factors, to projects currently available in the market. The upper end of each targeted return range assumes the use of leverage and/or manager skill. The estimates are as of March 2015, may change as subsequent conditions vary and are presented for informational purposes only. No guarantee is made regarding the ability of investors to obtain returns within these ranges, either now or in the future.

4.5 Innovative Strategies

As the zero-emission vehicle market is growing, there is increased interest in public and private financing to move the market. Critical market mechanisms that are being evaluated at the state and national level for infrastructure include:[16]

<u>Public Sector</u>

1. **Investment tax credits**: Federal tax credits for EVSE infrastructure have been around for several years. Historically, $30,000 has been available for commercial developers. The Investment Tax Credit includes tax credits for battery storage technology that could support vehicle to grid (V2G) or next generator battery applications. The investment tax credit for zero-emission infrastructure is currently being considered for reauthorization by Congress.
2. **Loan loss reserve funds (LLRF)**: The goal of the LLRF is to help reduce the actual or perceived risks that banks see in making loans into a new or poorly understood sector. The LLRF repays the first 5-10 percent of a bank's losses in a loan portfolio and can be used to leverage private capital. LLRFs were instrumental in creating the Property Assessed Clean Energy (PACE) financing programs across the U.S.

[16] http://www.ironoakenergy.capital/uploads/3/2/5/1/3251407/ev_leveraged_financing_-_by_ironoak_energy_for_vulcan_philanthropy.pdf

3. **Interest rate buy-downs**: Agreements to subsidize high interest rates that private investors may require as compensation for lending in the less-established zero-emission vehicle markets. This program type is generally distributed as a grant program without expectation of capital return.
4. **Low-interest revolving loan funds**: Revolving loan funds are pools of capital from which loans can be made for EVSE projects. Assuming that defaults remain low, a revolving loan fund renews as capital is repaid with interest and fees sufficient to cover administrative costs. This mechanism has been widely established for energy efficiency improvements.
5. **Loan guarantees**: Often used with early-stage industries, a loan guarantee program allows public funding to assume debt obligation in the event of default, leading to market-rate loans for technologies considered high risk.
6. **Green bonds**: Green bonds allow public issuers to access low cost capital for public infrastructure projects and are a relatively new mechanism. Since 2005, the transportation sector has seen $546 billion in bonds, largely directed towards rail projects.
7. **Carbon credit funding**: Cap-and-Trade policies are designed to regulate emissions and create a market in which carbon credits are generated and traded. California's Cap-and-Trade program (AB 32) is a model for how to successfully implement carbon credit funding.

A summary of the advantages and challenges of these public funding mechanisms are presented in Table 11. The primary participants in these programs are presented in Table 12.

Table 11: Advantages and Challenges of Public Sector Financing Solutions

Public Sector Financing Solutions	Pros	Cons
Investment Tax Credits	Creates simple financial incentives for EVs and EVSE to offset initial capital costs	Requires EV purchasers or EVSE developers to have sufficient tax liability to monetize the tax credit -- necessitates syndication or monetization strategies
Loan Loss Reserve Funds	Reduces the risks that banks perceive in making many small loans into the EV sector by covering the first 10% of a bank's losses in a loan portfolio	Does not cover 100% of the bank's risks, so they still need to take some risk in order to justify the return on their capital
Interest Rate Buydowns	Subsidizes high interest rates that investors require as compensation for lending in uncertain markets	Uses public money in order to make private loans marginally more attractive to borrowers
Low-Interest Revolving Loan Funds	Provides "evergreen" sources of capital that are recycled to fund EVSE projects on a continual basis	Depends on revenues generated from the EVSE project -- tends to fund only very low risk projects
Loan Guarantee	Assumes the debt obligation in the event of default, and addresses a huge pain point for the EV industry	Requires application to a competitive federal program offered to a wide range of energy projects
Green Bond Financing	Gives access to low-cost capital for clean infrastructure projects/investments for both public and private sector	Requires high transaction costs associated with issuing a large bond
Carbon Credit Funds	Provides a mechanism to generate large quantities of incentive funding from emitters	Requires the creation of a cap-and-trade or other carbon regulatory structure in order to create the market structure for carbon credits
Zero Emissions Vehicles Credits	Incentivizes car manufacturers to design and sell more EVs -- creates a revenue stream for leading edge EV car manufacturers	Creates a complex trading market for ZEV credits between car manufacturers, which has resulted in backlash from the penalized companies

Table 12: Primary Participants of Public Sector Financing Solutions

Public Sector Financing Solutions	Angels	Venture Capital	Private Equity	Infra. Investors	Banks	Retail Investors	Corporate Finance	EV Consumer	EV Car Co.	EVSE Developer	Utilities
Investment Tax Credits		X	X	X	X		X	X	X	X	
Loan Loss Reserve Funds				X	X						
Interest Rate Buydowns				X	X					X	X
Low-Interest Revolving Loan Funds				X	X					X	X
Loan Guarantee		X	X	X	X		X		X	X	
Green Bond Financing			X	X	X		X				X
Carbon Credit Funds								X		X	
Zero Emissions Vehicles Credits							X		X		

<u>Private Sector</u>

1. **Securitization of EV loans/leases**: Securitization is the financial practice of pooling various types of contractual debt, including EV or EVSE loans or leases, and selling their related cash flows to third party investors. This asset-based security tool can be used to increase available capital secured through energy savings or loan repayments.
2. **YieldCos**: YieldCos are publicly traded corporations that provide stable and growing distributions for investors from operating assets that generate a predictable stream of cash flow. Combined

with the potential certainty of LCFS credits generation and the predictability of port operations, yieldcos may be a viable option for zero-emission fueling infrastructure.

3. **Tax credit syndication**: Syndication allows third-party investors to become project owners as limited partners to monetize tax credit values when the developer does not have sufficient tax liability to utilize the available credits.
4. **Tax credit monetization**: Provides a mechanism for tax credits to be transferred by the credit generator, often a financial lender, to receive a discounted cash flow that can be applied to the capital investment at the time of purchase.
5. **On-bill financing**: On-bill financing amortizes capital costs of infrastructure across existing payments, such as monthly utility bill, leases, or taxes (PACE Program). This practice has been used extensively to finance common goods, including energy efficiency projects and solar energy.
6. **Fleet management company**: Third-party fleet management companies have been a stable in the zero-emission vehicle markets where consumer confidence is weak in the long-term performance of the new technologies. Fleet management companies, often owned and operated by the technology provider, lease the vehicle/equipment and therefore assume the risks with operational performance.
7. **Bundling EV/EVSE investment**: Bundling the vehicle and infrastructure procurement has been common consideration at POLB, where there is a highly-defined infrastructure user. However, the nature of ownership has created challenges when bundling outside of a grant process because the terminal operator owns the equipment while POLB owns the infrastructure.
8. **Power purchase agreements (PPA)**: PPA financing combines the capital expense and operational expense into one structured payment, which reduces the first-cost burden of zero-emission vehicle/equipment investment and treats the zero-emission technology as a service, not a piece of equipment. This approach has been widely used in the solar industry where third-party ownership was critical to the rise of the industry.

A summary of the advantages and challenges of these private funding mechanisms are presented in Table 13. The primary participants in these programs are presented in Table 14.

Table 13: Advantages and Challenges of Private Sector Financing Solutions

Private Sector Financing Solutions	Pros	Cons
Loan/Lease Securitization	Attracts large amounts of capital into the EV space and helps finance EV manufacturers/financiers	Generates high transaction costs due to complicated financial structure and large investment scale
YieldCos	Bundles revenue generating assets into an investable product that shields investors from corporate solvency risk	Must be backed by stable cash flows -- may be challenging given EVSE business models; YieldCo model currently undergoing a market reset due to past structural flaws
Tax Credit Syndication	Allows developers with insufficient tax liabilities to fully utilize tax credits for EVSE development	Requires higher transaction costs to create a tax credit syndication structure -- limited by tax equity investor
Tax Credit Monetization	Allows EV purchasers to take advantage of the full tax credit at the point of purchase	Has limits to the degree to which lenders can and want to utilize tax credits
On-Bill Financing	Allows developers to amortize the cost of shared amenities like EVSE onto bills -- simple and proven approach	Forces shared cost model onto non-EV drivers
Fleet Management Company	Represents a large-scale opportunity to transition fleets through a single point of purchase/lease with companies that have a long-term economic view of vehicle investment	Remain skeptical about EVs and are conservative in their approach to investment
Bundled EV/EVSE Financing	Solves "chicken and egg" dilemma of financing EVs + EVSE simultaneously by creating investment opportunities of the necessary scale to attract larger investors	Complicated public-private partnerships and financial structures required to bundle EVs and EVSE assets with different return expectations
Power Purchase Agreements	Solves the first cost barrier for EVs by bundling CapEx and OpEx into a single contract	Requires organizations or consumers to get CapEx and OpEx out of their typical "silos" as distinct budget categories

Table 14: Primary Participants of Private Sector Financing Solutions

Private Sector Financing Solutions	Angels	Venture Capital	Private Equity	Infra. Investors	Banks	Retail Investors	Corporate Finance	EV Consumer	EV Car Co.	EVSE Developer	Utilities
Loan/Lease Securitization			X	X	X	X	X		X		
YieldCos						X	X			X	
Tax Credit Syndication			X	X	X					X	
Tax Credit Monetization							X	X	X		
On-Bill Financing							X	X		X	X
Fleet Management Company							X		X		
Bundled EV/EVSE Financing		X	X	X	X		X		X	X	X
Power Purchase Agreements			X	X			X	X	X	X	X

Equipment Operators

The electricity market is dynamic with significant opportunity for arbitrage, creating value through demand response and system capacity optimization and duty cycle adjustments. Ancillary grid services can be monetized, however, require flexibility in vehicle and equipment operations, which may not be feasible within the Port community context. However, battery swapping configurations may have more flexibility to provide these services than direct charging. The hydrogen market is not as dynamic, however, power to gas technologies could allow fuel cell technologies to engage in these ancillary grid service markets.

5 How Port of Long Beach Relates to Other California Seaports

POLB is one of the world's busiest seaports, supporting over one million jobs nationally and generating billions of dollars in economic activity each year. Each year, POLB handles more than 6.8 million 20-foot container equivalent units (TEUs), 82.3 million metric tons of cargo, and handles 2,000 vessel calls. The Port's loaded containers account for one-third of all containers moving through California ports, one-quarter of containers moving through all West Coast ports, and nearly one fifth of containers moving through all U.S. ports. POLB spans 3,000 acres of land and 4,600 acres of water with 10 piers, 66 berths, and 22 shipping terminals (5 break bulk, 6 bulk, 6 container, and 5 liquid bulk). POLB is one of California's three mega-ports, including the Port of Los Angeles and the Port of Oakland. The state has an additional eight niche ports (Hueneme, Humboldt Bay, Redwood City, Richmond, West Sacramento, San Diego, San Francisco, and Stockton) and one private port (Benicia). POLB is an excellent model for zero-emission technology deployments as it has a mix of terminal types (break bulk, bulk, container, and liquid bulk). The lessons learned at POLB will be relevant to all zero-emission deployments in California.

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Appendix B: Port Community Electric Vehicle Blueprint Engagement Report

PCEVB Engagement Report

1 Introduction

California's interconnected system of ports, railroads, highways, and roads is responsible for one-third of the State's economic activity, with freight-dependent industries accounting for over $740 billion in gross domestic product and more than five million jobs.[1] Maintaining the competitiveness of this economic engine is vital. Yet, freight transportation in California also generates a significant portion of air emissions in parts of the state with poor air quality. Reducing these pollutants is an important local, regional, and State priority, as well as a matter of compliance with the federal Clean Air Act. Seaports, however, are faced with unique constraints when deploying zero-emissions vehicles and equipment due to, among other factors, high energy demand, restrictive duty cycle requirements, and diverse tenant and operational interests. Even more, at most California seaports including the Port of Long Beach (POLB or Port), the port authorities do not own or operate the equipment targeted for zero-emissions transformation and thus must work with private operators to turn over equipment and vehicles and to install infrastructure suitable for a company's individual operations. Further complicating matters in this dynamic, 24/7 port environment, everything is interdependent, with an astonishingly broad array of light-, medium-, and heavy-duty equipment and vehicles in operation.

To address this challenge, the Port of Long Beach is initiating the Port Community Electric Vehicle Blueprint (PCEVB) to establish a comprehensive strategy to assist in the identification of the most cost-effective technologies, financial incentives, and infrastructure upgrades for creating the model sustainable, zero-emission port ecosystem of the 21st century. The PCEVB is designed to accelerate the deployment of electrified transportation at local and regional levels with a holistic and futuristic view of regional transportation planning. The PCEVB Engagement activities, as summarized in this Report, are designed to solicit input from relevant stakeholders to understand stakeholder involvement in the transition to zero-emission equipment. Outreach and engagement activities include the establishment of a PCEVB Guiding Committee and identification of target stakeholders from a variety of industries and

[1] "California Sustainable Freight Action Plan," Brown Jr., Governor Edmund G., p. 1.

jurisdictions. The PCEVB Engagement Report builds upon foundational information aggregated and presented in the PCEVB Research Report.

2 PCEVB Guiding Committee

The PCEVB Guiding Committee was established to ensure participation of critical stakeholders that are essential to the successful transition to the electrification of terminal equipment.

2.1 PCEVB Guiding Committee Members

The PCEVB Guiding Committee includes:

- Port of Long Beach
  - Suzanne Plezia, Program Delivery Group, Senior Director/Chief Harbor Engineer
  - Sam Joumblat, Managing Director, Finance & Administration Bureau
- Southern California Edison
  - Katie Sloan, Manager of Renewable and Alternative Procurement Policy
- Pacific Merchant Shipping Association
  - Thomas Jelenić, Vice President
- City of Long Beach
  - Larry Rich, Sustainability Coordinator
- Center for International Trade and Transportation
  - Thomas O'Brien, Executive Director
- National Renewable Energy Laboratory

2.2 PCEVB Guiding Committee Meeting Schedule

The PCEVB Guiding Committee meets on an as-needed basis to review the findings of the PCEVB effort and to provide direction for subsequent efforts, ensuring that the PCEVB addresses critical stakeholder needs throughout the process. Meetings will be scheduled approximately quarterly. The first meeting was conducted on May 30, 2018 to provide an introduction to the PCEVB project. The second meeting was scheduled on October 9, 2018 to review findings from the PCEVB Research Report and to discuss the PCECVB Workshop scheduled for October 24, 2018.

3 PCEVB Questionnaire

3.1 PCEVB Objectives

The PCEVB Questionnaire was developed to attempt to understand many factors impacting the transition to zero-emission operations, including:

- Topic 1: Barriers to Zero-Emission Technology Deployment
- Topic 2: Charging Requirements
- Topic 3: Sustainability Goals
- Topic 4: Existing and Ongoing Zero-Emission Activities
- Topic 5: Limitations and Barriers for Infrastructure
- Topic 6: Recommendations

To facilitate data collection, aggregation, and analysis, the Port of Long Beach developed a Google Form survey to distribute relevant questions. In addition to the Google Form survey, interviews will be conducted with the target stakeholders to further engage in discussions about the specific needs, desires, plans, and challenges that stakeholders possess in relation to the transition to zero-emission operations.

3.2 Target Stakeholders

A target list of stakeholders was developed to span a variety of industries and jurisdictions associated with the transition to zero-emission technologies:

Technology Developers

- BYD
- Cavotec
- Conductix Wampfler
- Dannar
- EDI (Now Cummins)
- GE Transportation
- Lightning Systems
- Nikola
- Plug Power
- Siemens
- Thermo King
- Thor
- TransPower
- Unique Electric Solutions
- US Hybrid

Original Equipment Manufacturers (OEMs)

- Capacity
- Hyster
- Kalmar
- Kenworth
- Nordco
- Peterbilt
- Taylor Machine Works
- Tesla
- Toyota
- Volvo
- Wiggins
- ZPMC

Utilities

- Southern California Edison

Marine Terminal Operators and Tenants

- International Transportation Services (ITS)
- Long Beach Container Terminal (LBCT)
- Pacific Merchant Shipping Association (PMSA)
- SSA Marine
- Total Terminals International (TTI)

Trucking and Warehouse Associations and Owners

- Harbor Trucking Association/Pear Strategies
- Additional stakeholder information will be utilized from a survey conducted in September 2018 by Tetra Tech, Port of Long Beach, and Port of Los Angeles, which was sent to the entire Port Drayage Truck group.

EV Charging Station Manufacturers, Distributers, and Operators

- ABB
- BTCPower
- ChargePoint
- CharIN
- Clipper Creek
- EVgo
- Efacec
- eMotorWerks
- Freewire
- Greenlots
- innogy
- Schneider Electric
- Siemens
- Tritium
- Wave IPT

Hydrogen Fueling Station Manufacturers and Distributors

- Air Liquide
- Air Products
- California Fuel Cell Partnership
- Linde
- NEL Hydrogen
- ITM Power
- Shell
- Stratos Fuel

Labor and Workforce Development

- International Brotherhood of Electrical Workers (IBEW)
- International Longshore Workers Union (ILWU)
- Pacific Maritime Association (PMA)
- Center for International Trade and Transportation

Community-Based Organizations and Environmental Justice Organizations

- East Yard Communities for Environmental Justice
- Earthjustice
- Natural Resources Defense Council
- Coalition for Clean Air

Regulatory Agencies

- South Coast Air Quality Management District
- California Air Resources Board
- California Energy Commission
- California Public Utilities Commission
- US Environmental Protection Agency

Public and Private Funding Authorities

- Amply
- California Pollution Control Financing Authority
- California State Treasurer’s Office
- CALSTART
- Crossroads Financial
- Generate Capital
- Hydrogen Partners

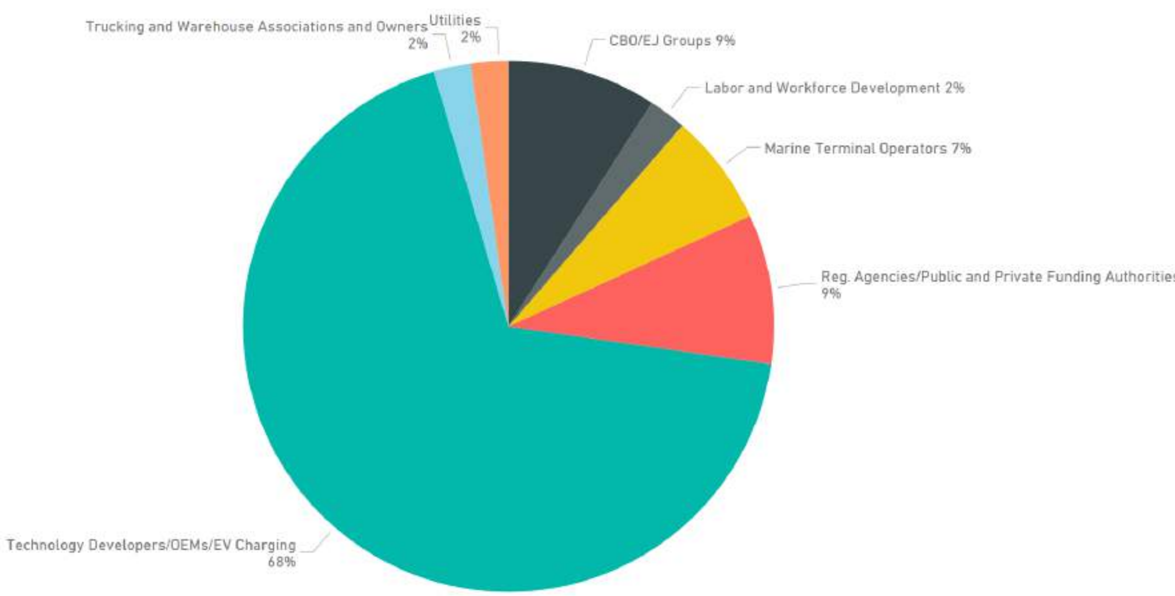
3.3 PCEVB Questionnaire Results

3.3.1 Participants

44 unique responses were collected from nine different organization types, including:

- Technology developers/OEMs
- Marine Terminal Operators
- EV Charging Station & Hydrogen Refueling Station Providers
- Trucking and Warehouse Associations & Owners
- Labor and Workforce Development
- Community-Based Organizations (CBO)/Environmental Justice (EJ) Groups
- Utilities
- Regulatory Agencies
- Public and Private Funding Authorities

Figure 1: Questionnaire Stakeholder Representation

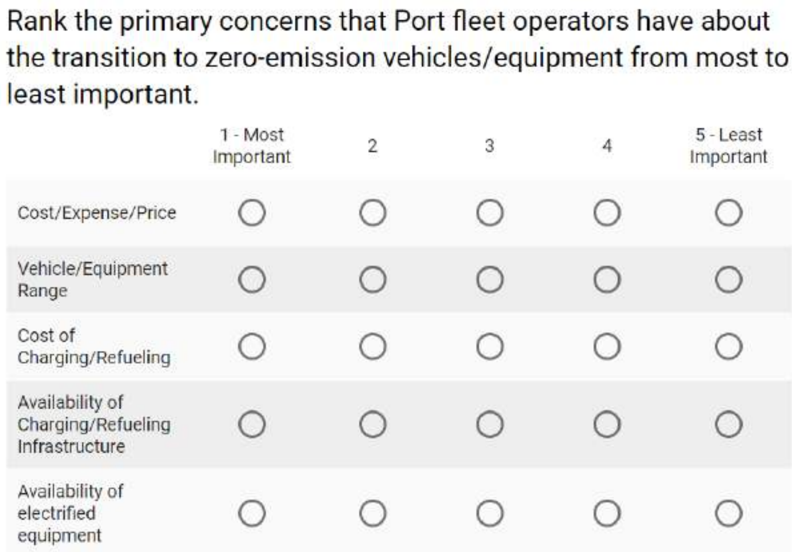


Every organization type was represented by at least one participant; however, to more clearly represent industry trends and to avoid clearly identifying any particular stakeholder, Technology Developers/OEMs were combined with EV Charging companies, and Regulatory Agencies were combined with Public and Private Funding Authorities. The relatively high response rate from technology vendors/OEMs, generally skews the overall data towards the viewpoint of the technology developers and OEMs; however, the intention of the questionnaire is to understand the differences in opinion between respondents across various topics. For this reason, the majority of the findings presented in this report are shown as subcategories.

3.3.2 Topic 1: Barriers to Zero-Emission Technology Deployment

3.3.2.1 Prompt 1

Figure 2: Topic 1, Prompt 1



Rank the primary concerns that Port fleet operators have about the transition to zero-emission vehicles/equipment from most to least important.

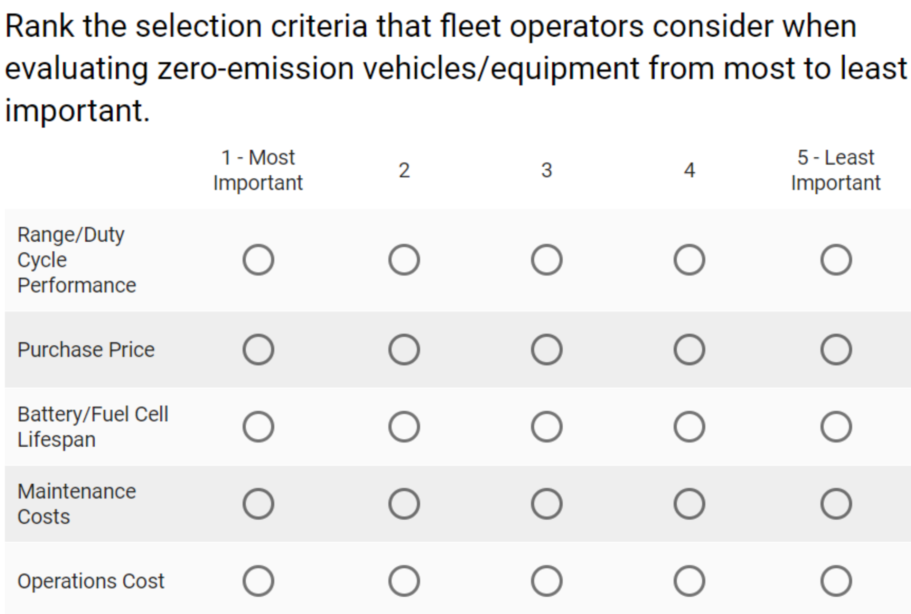
	1 - Most Important	2	3	4	5 - Least Important
Cost/Expense/Price	○	○	○	○	○
Vehicle/Equipment Range	○	○	○	○	○
Cost of Charging/Refueling	○	○	○	○	○
Availability of Charging/Refueling Infrastructure	○	○	○	○	○
Availability of electrified equipment	○	○	○	○	○

Figure 3: Topic 1, Prompt 1 Response – All Respondents

Across the stakeholder groups, the responses were fairly consistent, with indications of concern across all of the identified barriers, with a slightly greater concern about the equipment than infrastructure.

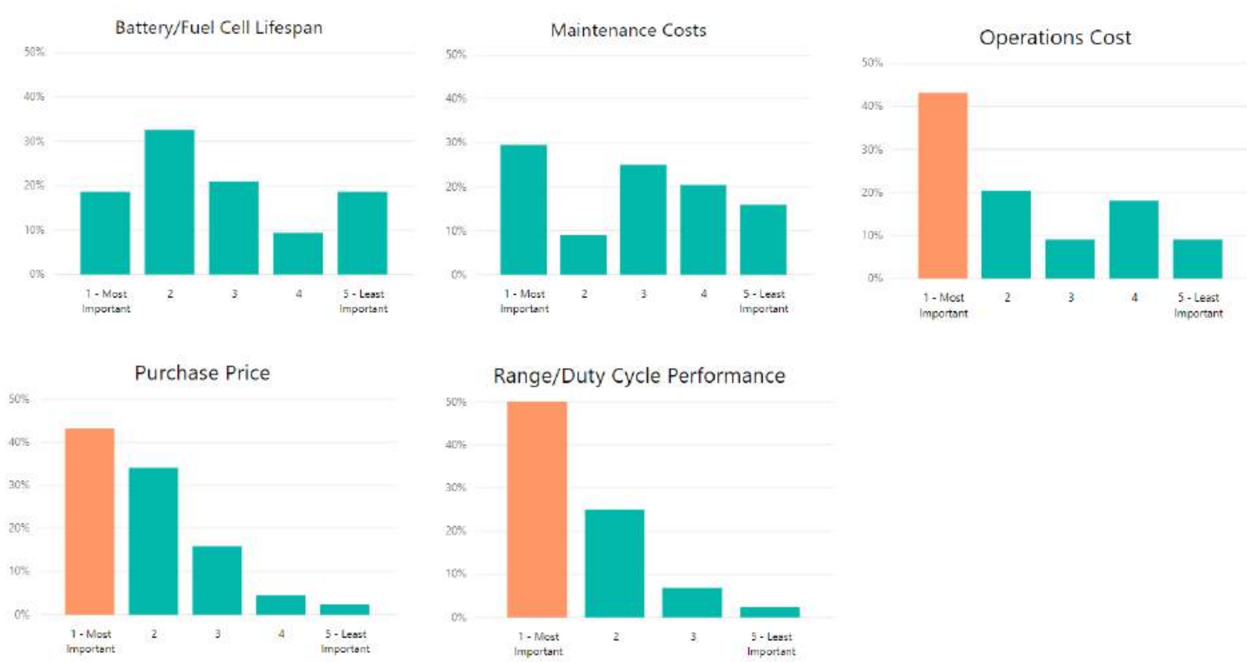
3.3.2.2 Prompt 2

Figure 4: Topic 1, Prompt 2


Rank the selection criteria that fleet operators consider when evaluating zero-emission vehicles/equipment from most to least important.

	1 - Most Important	2	3	4	5 - Least Important
Range/Duty Cycle Performance	○	○	○	○	○
Purchase Price	○	○	○	○	○
Battery/Fuel Cell Lifespan	○	○	○	○	○
Maintenance Costs	○	○	○	○	○
Operations Cost	○	○	○	○	○

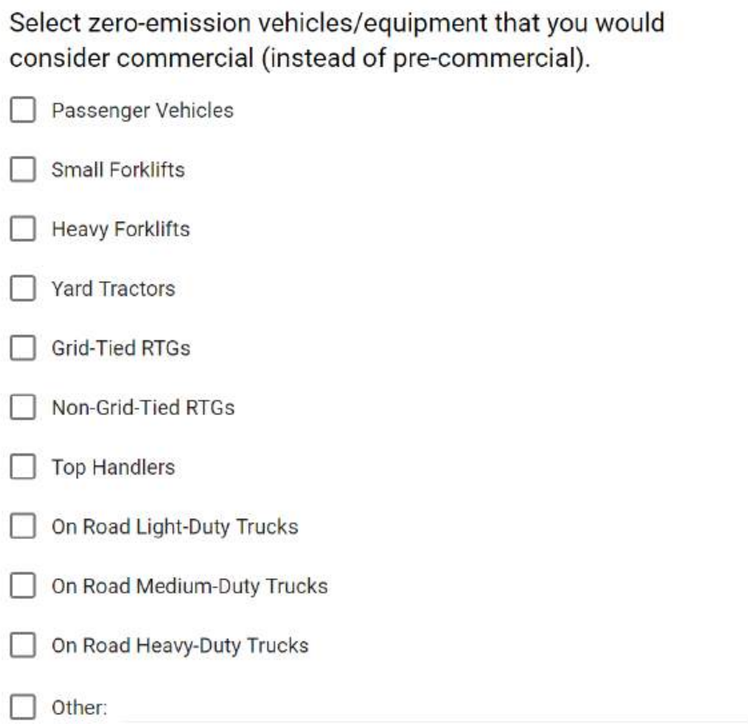
Figure 5: Topic 1, Prompt 2 – All Stakeholder Responses



Across the stakeholder groups, the responses were fairly consistent, with indications of concern across all of the identified equipment attributes, with a slightly greater concern about the range/duty cycle performance, purchase price, and operational costs.

3.3.2.3 Prompt 3

Figure 6: Topic 1, Prompt 3


Select zero-emission vehicles/equipment that you would consider commercial (instead of pre-commercial).

- [ ] Passenger Vehicles
- [ ] Small Forklifts
- [ ] Heavy Forklifts
- [ ] Yard Tractors
- [ ] Grid-Tied RTGs
- [ ] Non-Grid-Tied RTGs
- [ ] Top Handlers
- [ ] On Road Light-Duty Trucks
- [ ] On Road Medium-Duty Trucks
- [ ] On Road Heavy-Duty Trucks
- [ ] Other:

Figure 7: Topic 1, Prompt 3 – Responses from All Stakeholders

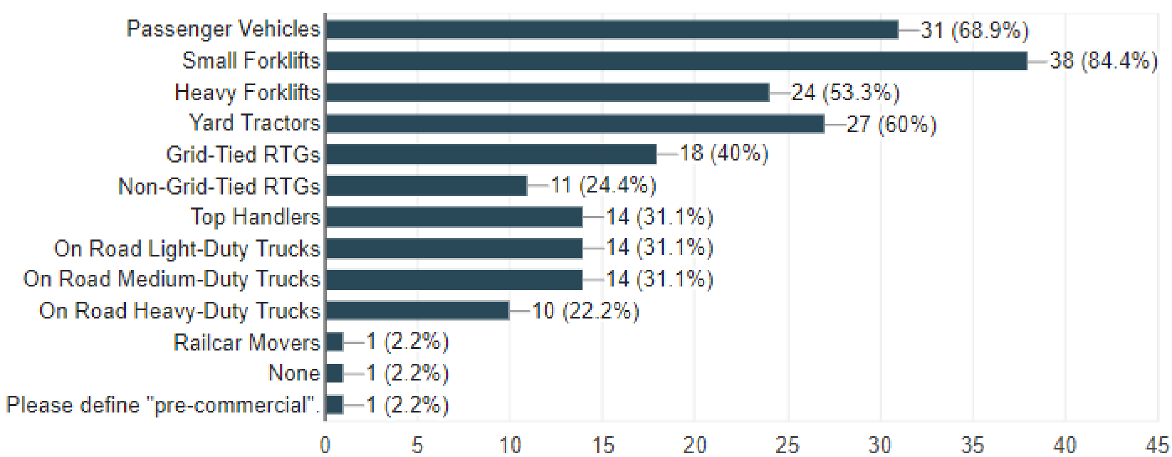
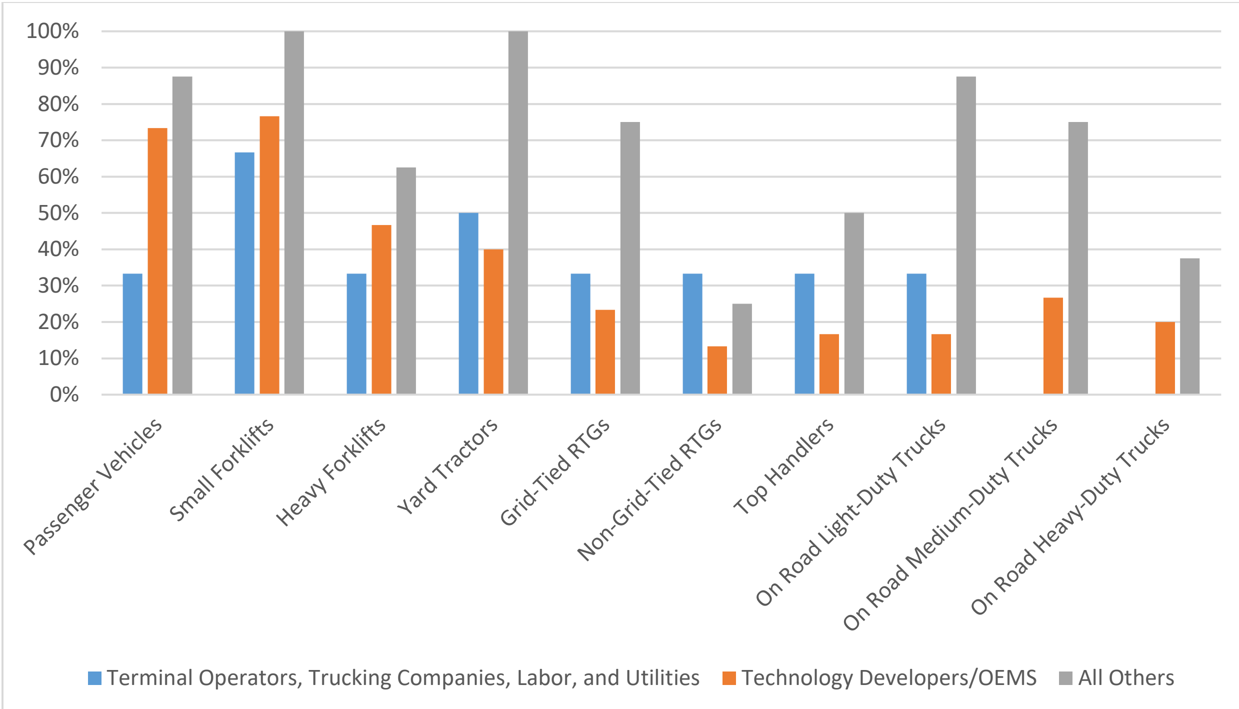


Figure 8: Topic 1, Prompt 3 – Responses from All Stakeholders by Subcategory



It is no surprise that most stakeholders indicated that smaller-scale electric vehicles are considered more commercially available. However, it is useful to note that there appears to be a discrepancy between the subcategories of 1) terminal operators, trucking companies, labor, and utilities, 2) technology developers and OEMs, and 3) all other stakeholders. The first two groups (terminal operators, trucking companies, labor, technology vendors/OEMs, and utilities) have relatively consistent views of zero emission technology commercial availability, while all other stakeholder groups (community-based organizations, environmental justice groups, and regulatory agencies and private finance) believe that the status of technology commercialization is significantly further advanced, particularly with respect to yard tractors, grid-tied RTGs, and on-road trucks. These responses may indicate a difference of opinion of the technology capabilities or simply a difference in definition. Either way, there appears to be value in communication among these groups to solidify a common understanding of the status of relevant technologies.

3.3.2.4 Prompt 4

Figure 9: Topic 1, Prompt 4

What level of operational change will be necessary for Port-related companies to adopt zero-emission vehicles/equipment?

- ○ Complete operational re-organization
- ○ Moderate changes will be necessary
- ○ Minimal changes will be necessary
- ○ No changes will be necessary

Figure 10: Topic 1, Prompt 4 – Responses from Technology Vendors/OEMs

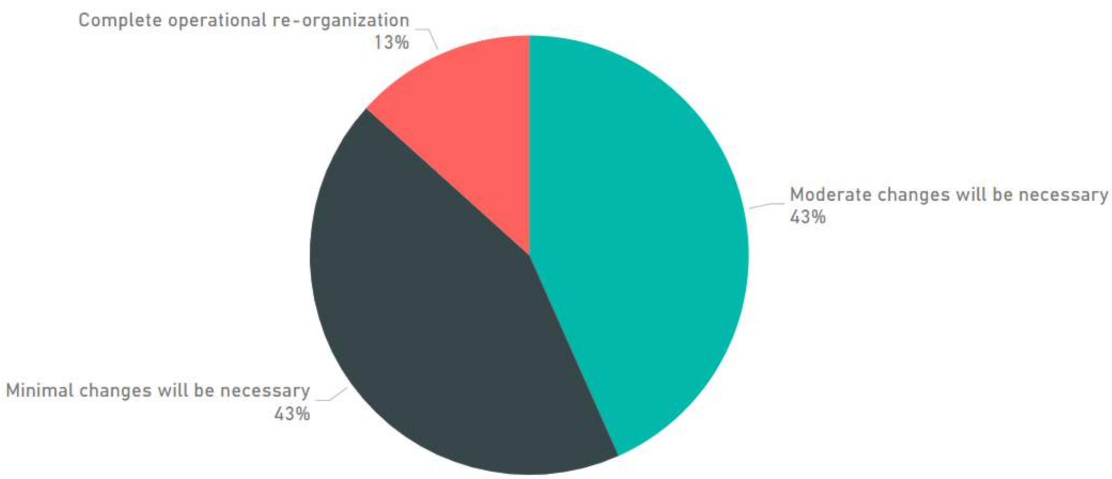
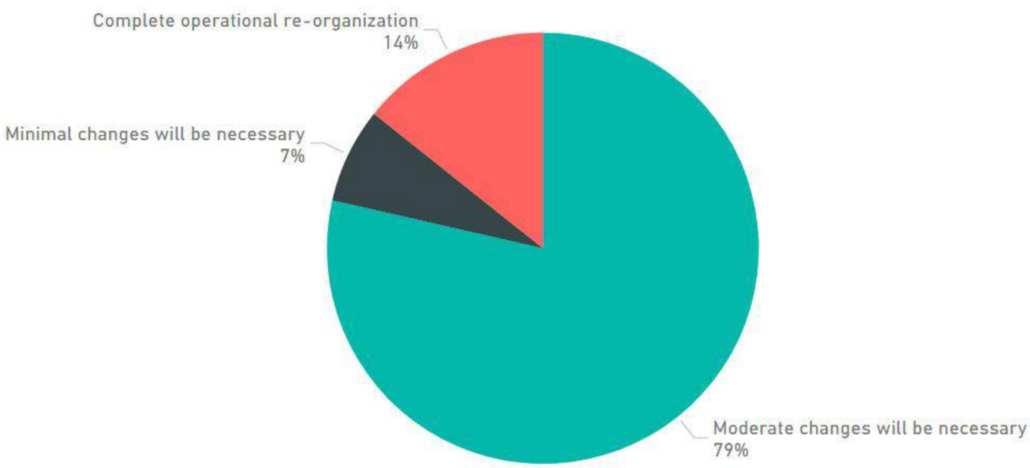


Figure 11: Topic 1, Prompt 4 – Responses from All Other Stakeholders

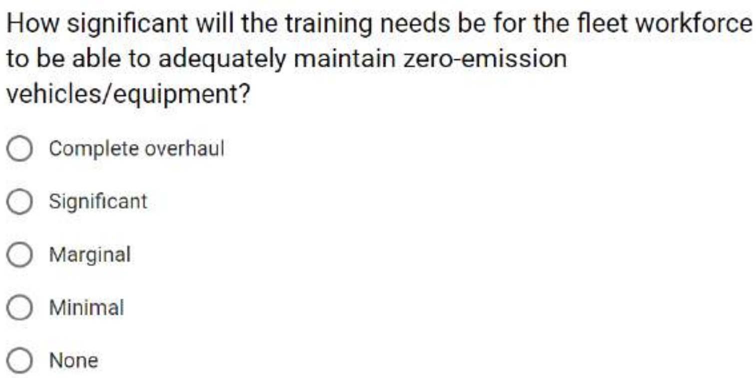


Overall, the responses indicate a perception from technology vendors/OEMs that the operational impacts of the transition to zero-emission equipment will be less significant than is perceived by all other stakeholder groups. The responses to this question suggest that coordination between technology vendors/OEMs with other Port stakeholders should be facilitated to help develop a better understanding of operational changes that may be required and to understand the potential magnitude of the impacts associated these operational changes. As part of this prompt, respondents were asked to describe the changes that would be necessary. One particular written response summarized effectively the concerns of many of the respondents.

> “Starting from the beginning, the operational business case is new (i.e. can my business make money using zero emission equipment), daily review of what equipment is capable of the day’s work, new maintenance procedures, new service procedures, how to charge the equipment efficiently, what are the durability impacts on the business case and resale value?”

3.3.2.5 Prompt 5

Figure 12: Topic 1, Prompt 5


How significant will the training needs be for the fleet workforce to be able to adequately maintain zero-emission vehicles/equipment?

- Complete overhaul
- Significant
- Marginal
- Minimal
- None

Figure 13: Topic 1, Prompt 5 – Responses from Technology Vendors/OEMs

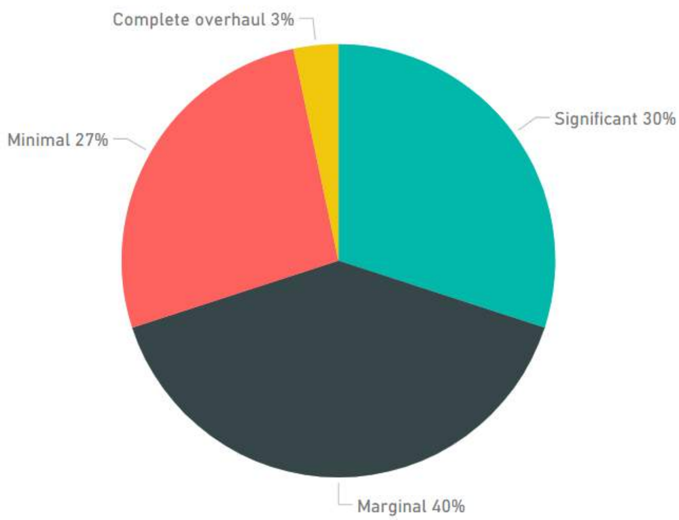
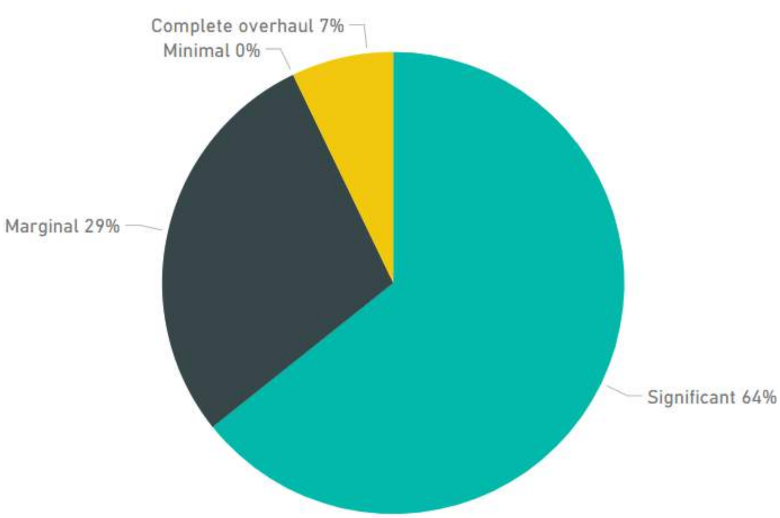
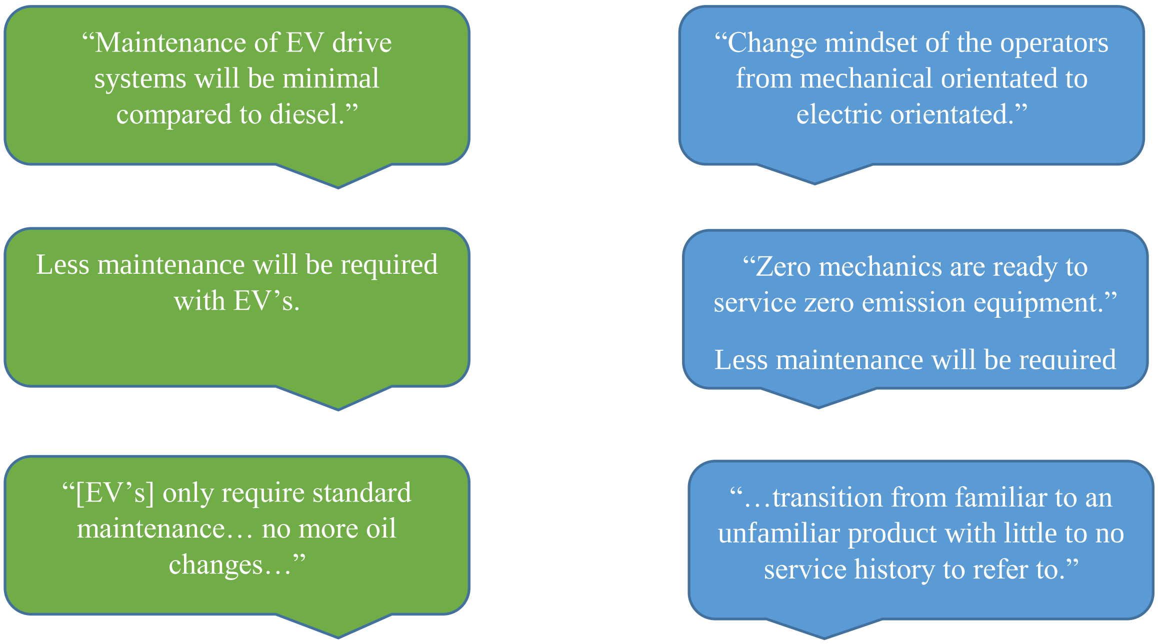


Figure 14: Topic 1, Prompt 5 – Responses from All Other Stakeholders



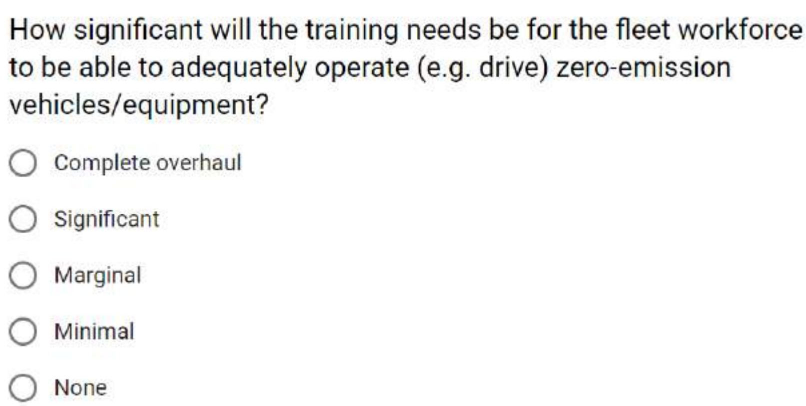
Similar to the results from Topic 1 Prompt 4, responses suggest differing opinions between technology developers/OEMs and the other stakeholders. The relatively large responses for “minimum” from technology vendors/OEMs respondents (27%) is a stark deviation from other stakeholders, 0% of whom reported “minimal.” As part of this prompt, respondents were asked to describe the changes that would be necessary. A selection of responses is presented in Figure 15.

Figure 15: Topic 1, Prompt 5 – Select Short Answer Responses



3.3.2.6 Topic 1, Prompt 6

Figure 16. Topic 1, Prompt 6



How significant will the training needs be for the fleet workforce to be able to adequately operate (e.g. drive) zero-emission vehicles/equipment?

- Complete overhaul
- Significant
- Marginal
- Minimal
- None

Figure 17: Topic 1, Prompt 6 – Responses from Technology Developers/OEMs and Regulatory Agencies/Financing]

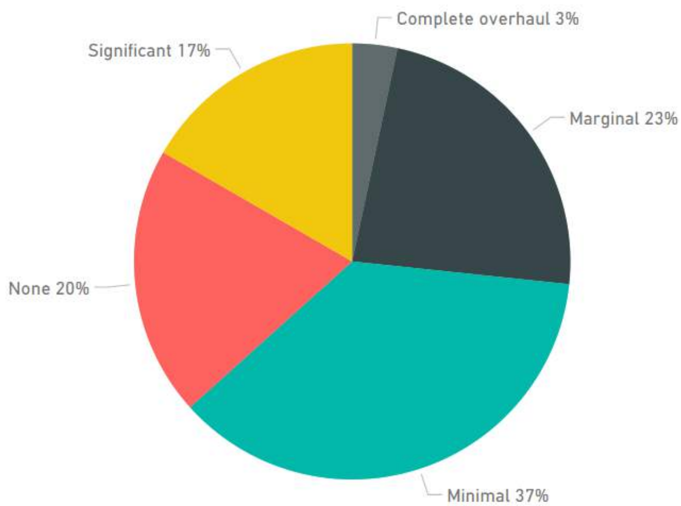
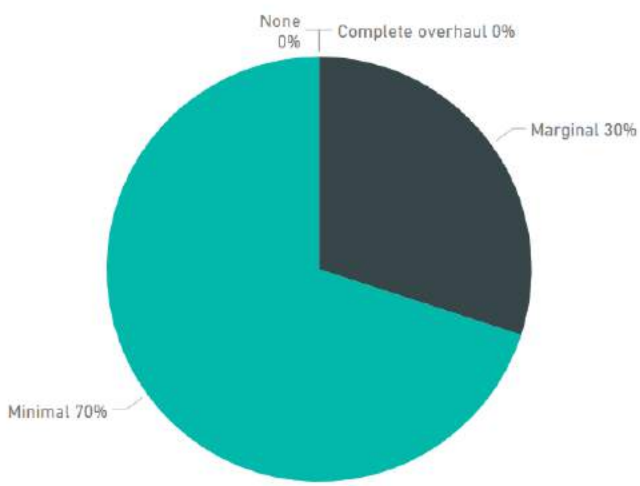


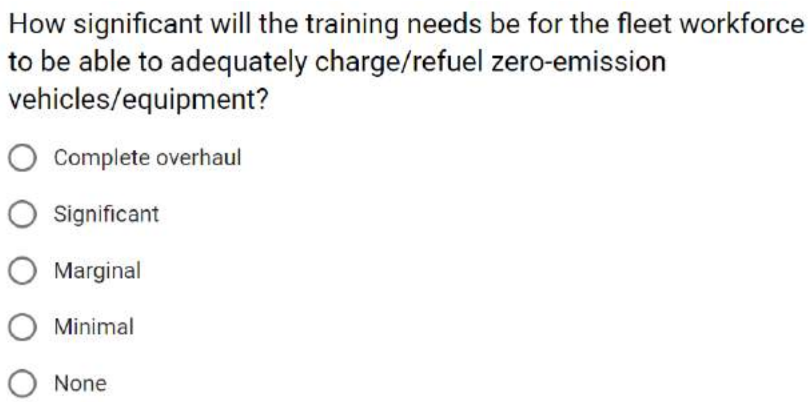
Figure 18: Topic 1, Prompt 6 – Responses from All Other Stakeholders



Surprisingly to the Project Team, the technology developers/OEMs and regulatory agencies/private financing groups identified a greater need for training to operate zero-emission technologies, in addition to a notable fraction (20%) that indicated no training needs. These two groups historically have had significant involvement in the deployment of new technologies (either as the manufacturer or early-stage funder) and communication about the potential "significant" or "complete overhaul" changes to other stakeholders may be important to avoid surprises or unexpected costs associated with zero-emission technology acquisition.

3.3.2.7 Topic 1, Prompt 7

Figure 19: Topic 1, Prompt 7


How significant will the training needs be for the fleet workforce to be able to adequately charge/refuel zero-emission vehicles/equipment?

- Complete overhaul
- Significant
- Marginal
- Minimal
- None

Figure 20: Topic 1, Prompt 7 – Responses from Terminal Operators, Trucking Companies, and Labor

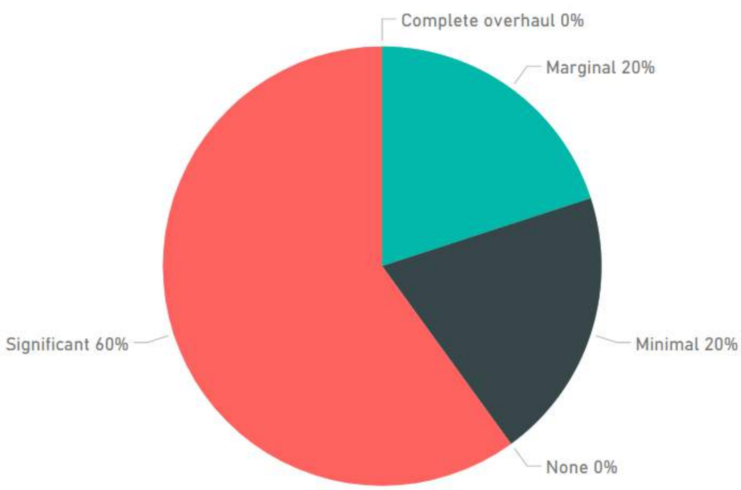
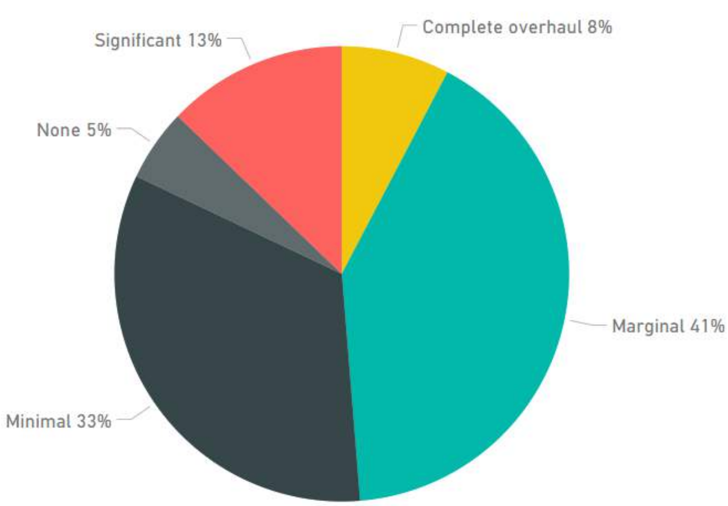


Figure 21: Topic 1, Prompt 7 – Responses from All Other Stakeholders



The responses indicate a wide range of understanding for the need for training around charging and refueling. Generally, the terminal operators, trucking companies, and labor indicated a greater need for training (60% selecting “significant” or “complete overhaul”) than the other stakeholder groups (21% selecting “significant” or “complete overhaul”). Multi-stakeholder discussions and lessons learned from technology developers and regulatory agencies/financing groups may be useful for the Port community operating stakeholders.

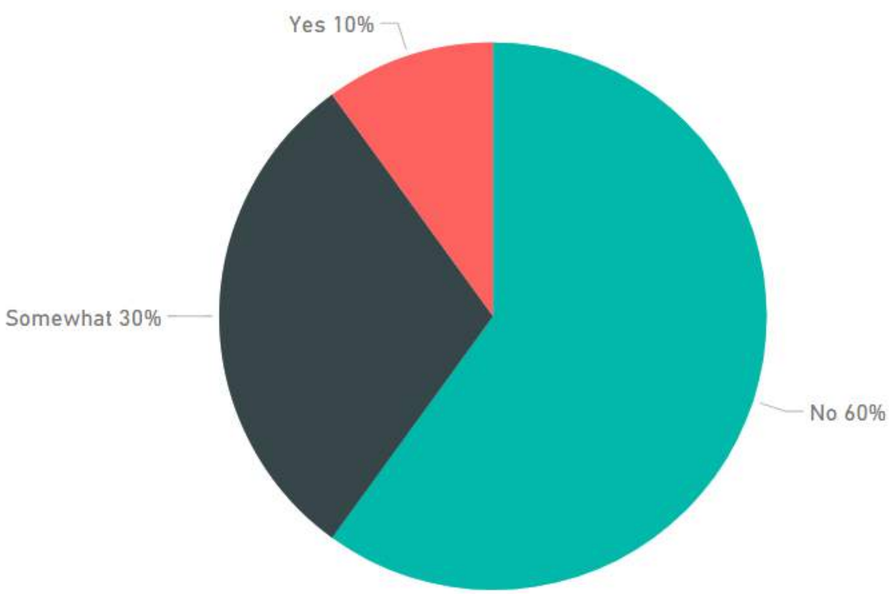
3.3.3 Topic 2: Charging Requirements

3.3.3.1 Topic 2, Prompt 1

Do you believe that charging requirements for port equipment have been standardized?

- Yes
- Somewhat
- No

Figure 22: Topic 2, Prompt 1 – Responses from All Stakeholders



Overall, responses from all stakeholders groups were consistent, with a common understanding that charging standards for Port-centric equipment and vehicles are not standardized. This shared belief underscores the opportunity for standardization to accelerate the deployment of charging infrastructure.

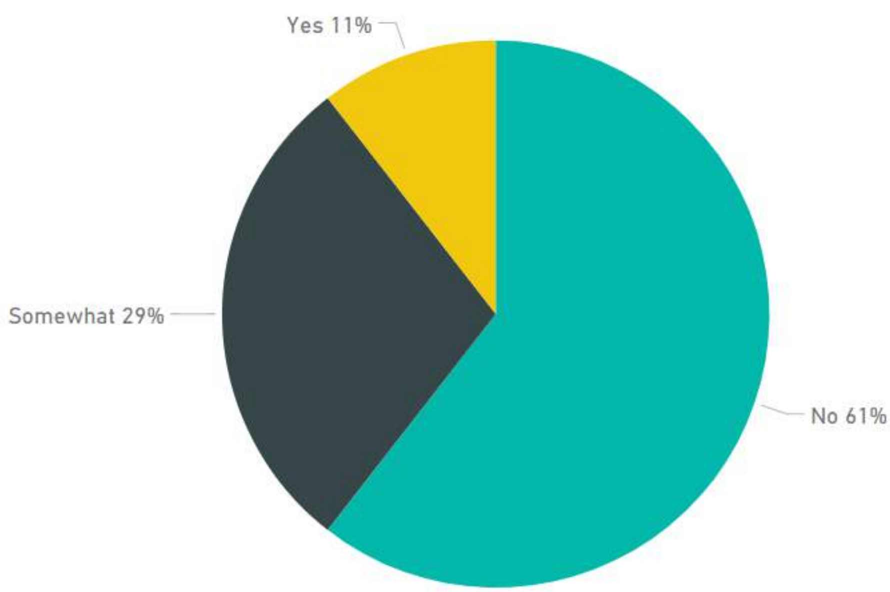
3.3.3.2 Topic 2, Prompt 2

Figure 23: Topic 2, Prompt 2

Do you believe that hydrogen refueling requirements for port equipment have been standardized?

- ◯ Yes
- ◯ Somewhat
- ◯ No

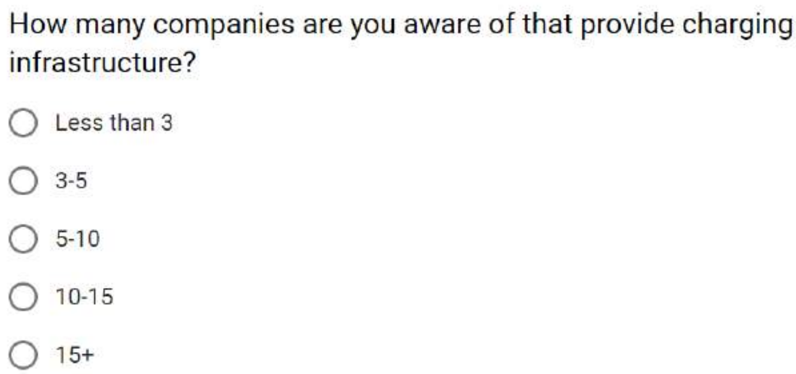
Figure 24: Topic 2, Prompt 2 – Responses from All Stakeholders



As with Topic 2 Prompt 2, responses from all stakeholders groups were generally consistent, with a common understanding that hydrogen refueling standards for Port-centric equipment and vehicles are not standardized. This shared belief underscores the opportunity for standardization to accelerate the deployment of hydrogen refueling infrastructure.

3.3.3.3 Topic 2, Prompt 3

Figure 25: Topic 2, Prompt 3


How many companies are you aware of that provide charging infrastructure?

- Less than 3
- 3-5
- 5-10
- 10-15
- 15+

Figure 26: Topic 2, Prompt 3 – Responses from Terminal Operators, Trucking Companies, and Labor

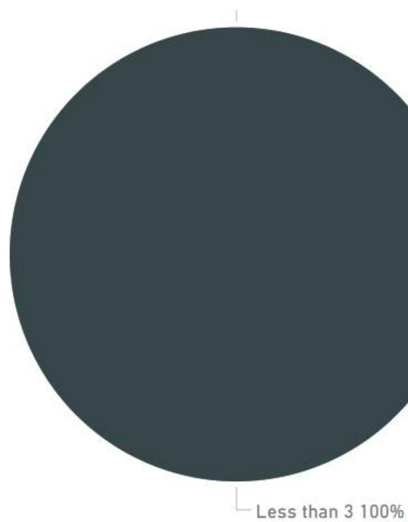
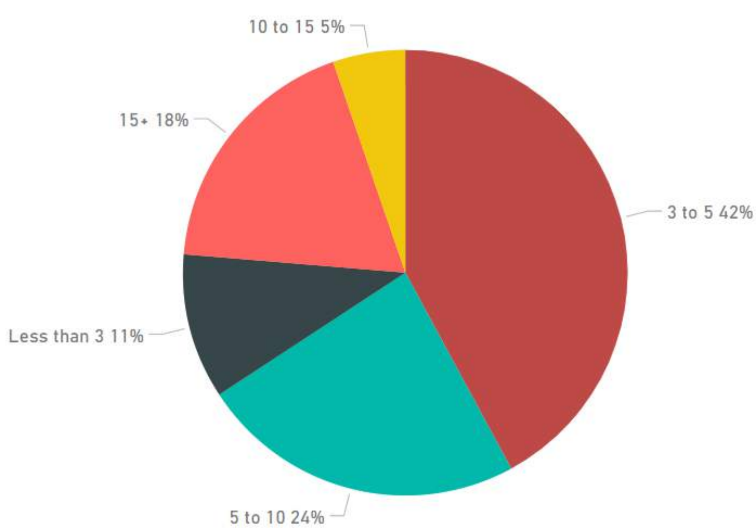


Figure 27: Topic 2, Prompt 3 – Responses from All Other Stakeholders



While there is a considerable spread of awareness between all stakeholder groups, it is notable that the terminal operators, trucking companies, and labor groups all knew fewer than three companies that provide charging infrastructure. This is starkly contrasted by the groups that could identify more than 15 companies, principally regulatory agencies/private funding, technology developers, and utilities. The stakeholders that knew more companies generally participate in the light-duty vehicle markets, which are substantially more mature than the heavy-duty sector. With a dynamic marketplace, it is important to make sure that all stakeholders are aware of the technical and business opportunities that are emerging and to identify opportunities for light-duty charging companies to enter the heavy-duty space.

3.3.3.4 Topic 2, Prompt 4

Figure 28: Topic 2, Prompt 4

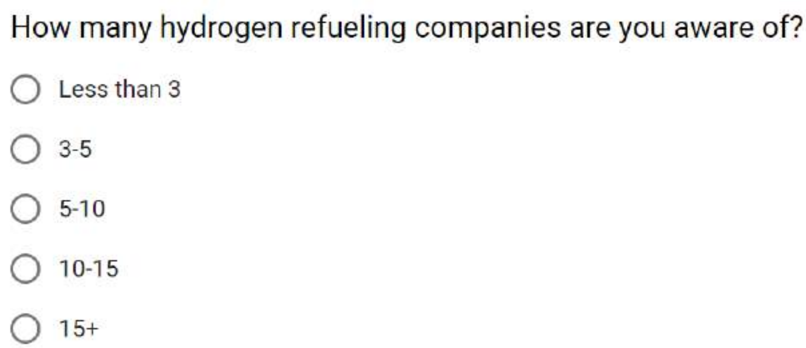
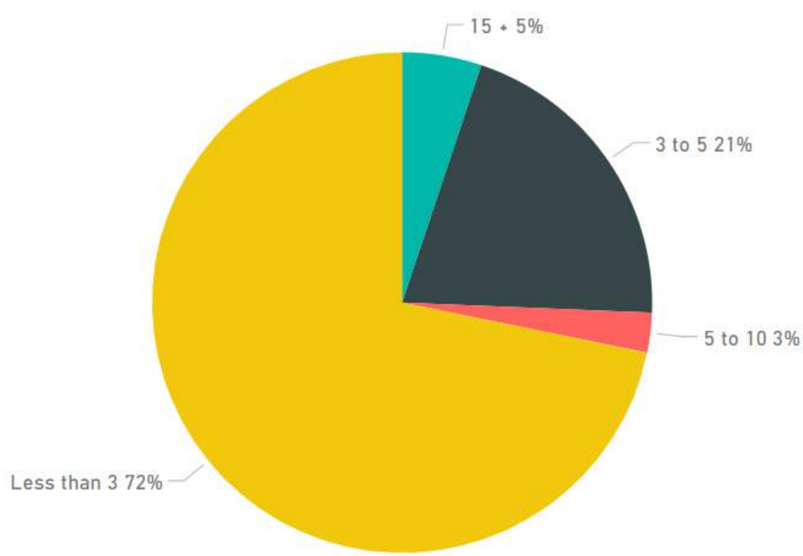


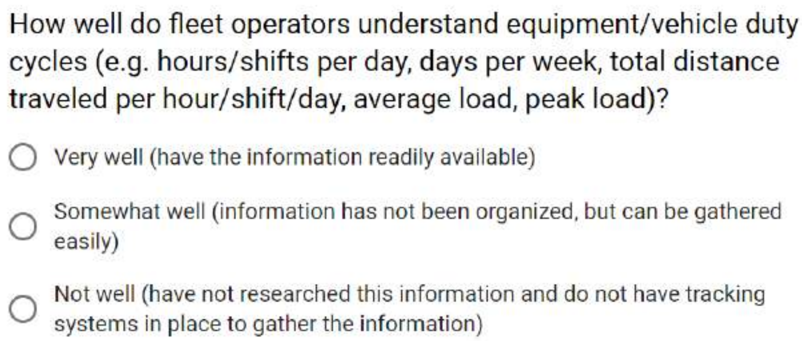
Figure 29: Topic 2, Prompt 4 – Responses from All Stakeholders



Unlike electric charging equipment, almost all stakeholder groups are unaware of three or more hydrogen refueling companies. This lack of awareness may be reflected by the dominance of battery-electric vehicles in the light-duty space. Further education by the industry could help promote the technology as a feasible option within the portfolio of technologies that assist with the Port's zero emission goals.

3.3.3.5 Topic 2, Prompt 5

Figure 30: Topic 2, Prompt 5


How well do fleet operators understand equipment/vehicle duty cycles (e.g. hours/shifts per day, days per week, total distance traveled per hour/shift/day, average load, peak load)?

- Very well (have the information readily available)
- Somewhat well (information has not been organized, but can be gathered easily)
- Not well (have not researched this information and do not have tracking systems in place to gather the information)

Figure 31: Topic 2, Prompt 5 – Responses from Terminal Operators, Trucking Companies, and Labor

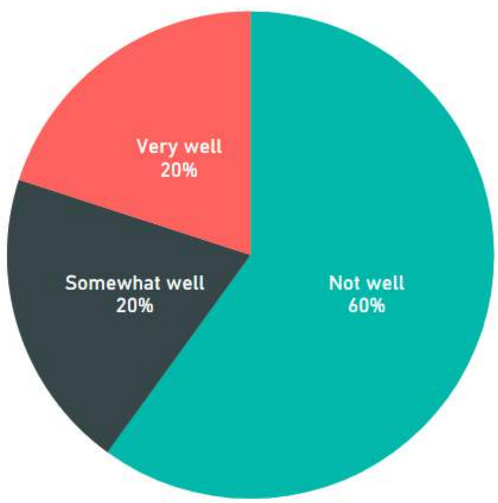
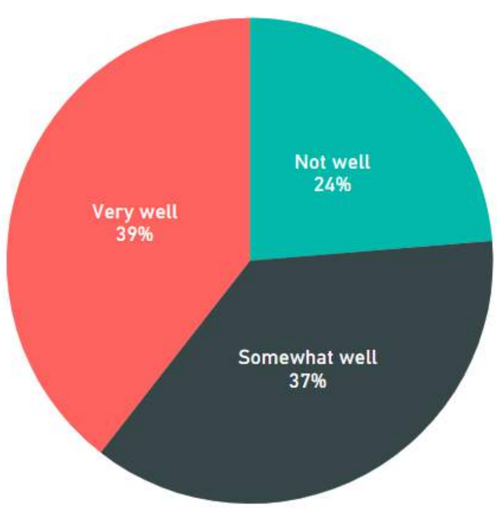


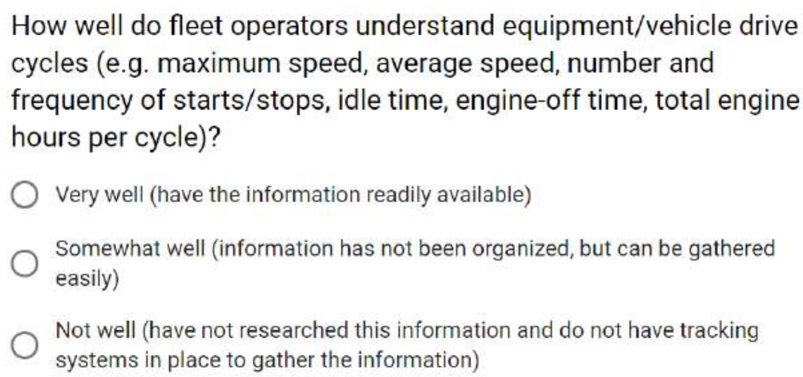
Figure 32: Topic 2, Prompt 5 – Responses from All Other Stakeholders



The responses indicate an important discrepancy between terminal operators/OEMs, trucking companies, and labor and all other stakeholders. Specifically, the equipment users do not believe the data about duty cycle is as readily available as other stakeholders believe it to be. These duty cycle data are important driving factors that dictate comfort with the operational performance of new technologies. Working with these organizations to better help these organizations understand their duty cycle will help accelerate the development and design of technologies that meet the needs of the Port community.

3.3.3.6 Topic 2, Prompt 6

Figure 33: Topic 2, Prompt 6


How well do fleet operators understand equipment/vehicle drive cycles (e.g. maximum speed, average speed, number and frequency of starts/stops, idle time, engine-off time, total engine hours per cycle)?

- Very well (have the information readily available)
- Somewhat well (information has not been organized, but can be gathered easily)
- Not well (have not researched this information and do not have tracking systems in place to gather the information)

Figure 34: Topic 2, Prompt 6 – Responses from Terminal Operators, Trucking Companies, and Labor

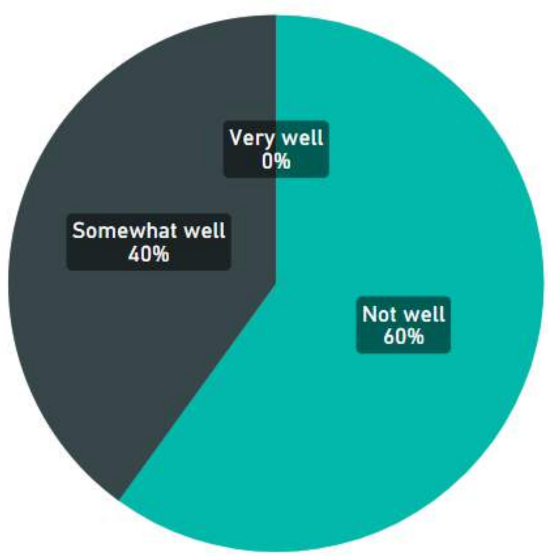
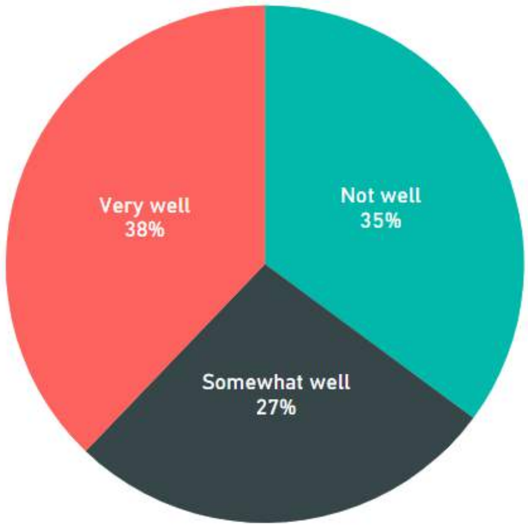


Figure 35: Topic 2, Prompt 6 – Responses from All Other Stakeholders



As with duty cycles, there is a similar and important discrepancy between terminal operators/OEMs, trucking companies, and labor and all other stakeholders. Supporting the acquisition and understanding of this critical operations data will be highly relevant to the accelerated transition to zero-emission equipment.

3.3.3.7 Topic 2, Prompt 7

Figure 36: Topic 2, Prompt 7

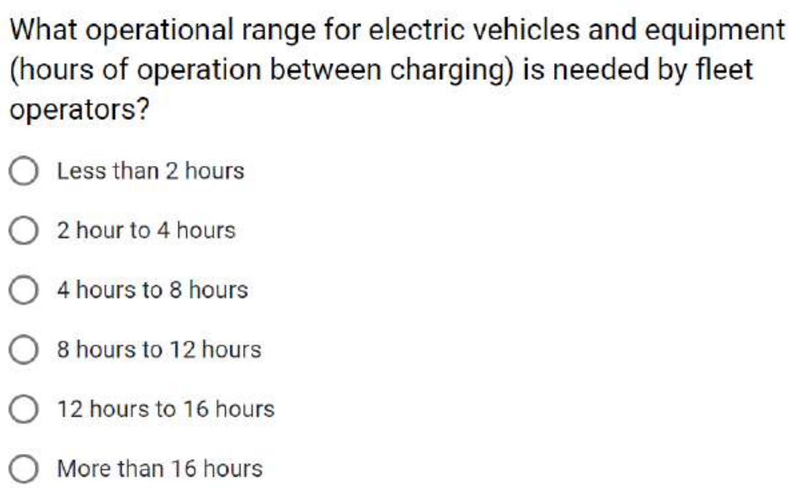


Figure 37: Topic 2, Prompt 7 – Responses from Terminal Operators, Trucking Companies, and Labor

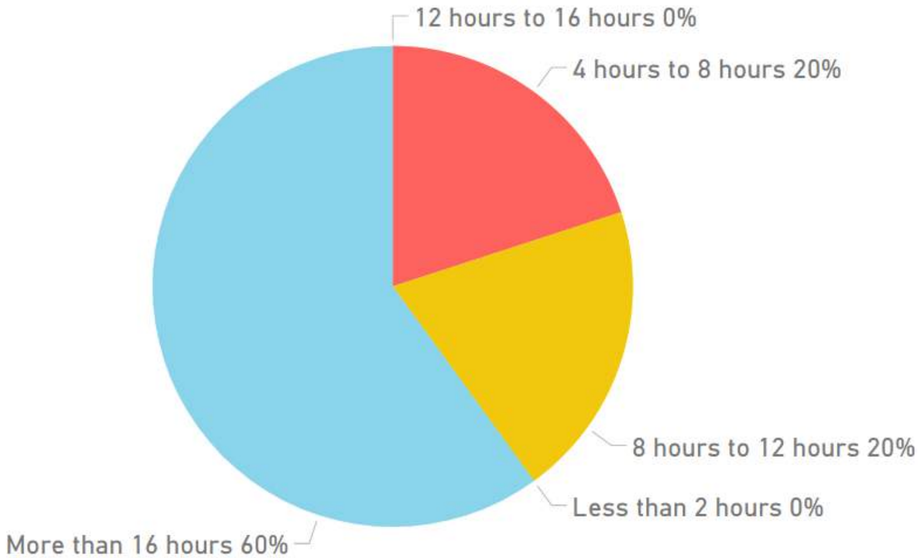
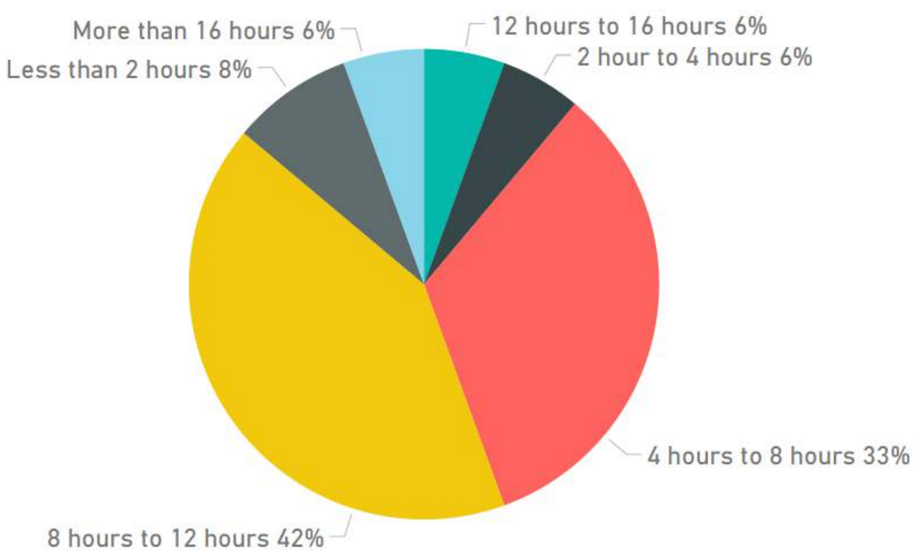


Figure 38: Topic 2, Prompt 7 – Responses from All Other Stakeholders



The responses reveal considerable deviation among stakeholder groups. Terminal operators, trucking companies, and labor expect equipment range to be longer (80% selecting 8+ hours) than other stakeholders (54% selecting 8+ hours). The discrepancy in these responses suggest a need for the equipment operators to better explain the demand of Port operations to the broad stakeholder group and to facilitate quantitative data collection by data logging existing equipment over different periods of time to account for operational variances by day, week, month, and time of year, as some periods of the year are busier than others. As identified in Topic 1 Prompt 2, range/duty cycle performance was noted as one of the most important equipment selection criteria for equipment purchasers.

3.3.3.8 Topic 2, Prompt 8

Figure 39: Topic 2, Prompt 8

What operational range for hydrogen-fueled vehicles (hours of operation between refueling) is needed by fleet operators?

- ◯ Less than 2 hours
- ◯ 2 hour to 4 hours
- ◯ 4 hours to 8 hours
- ◯ 8 hours to 12 hours
- ◯ 12 hours to 16 hours
- ◯ More than 16 hours

Figure 40: Topic 2, Prompt 8 – Responses from Terminal Operators, Trucking Companies, and Labor

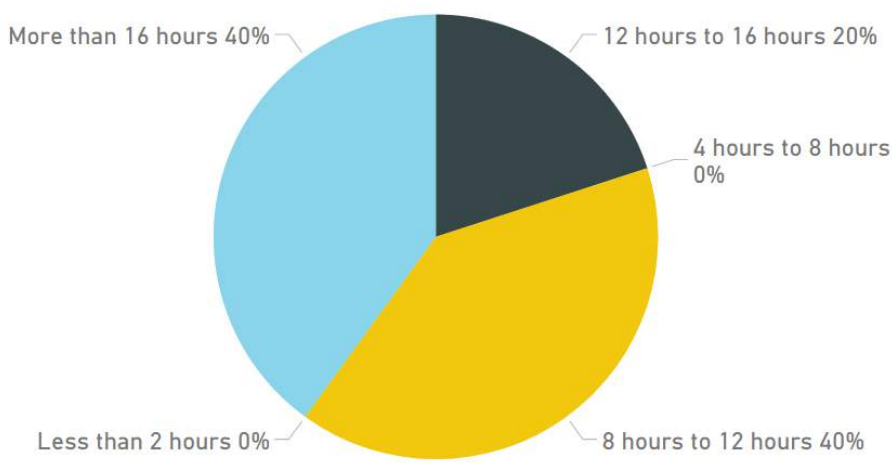
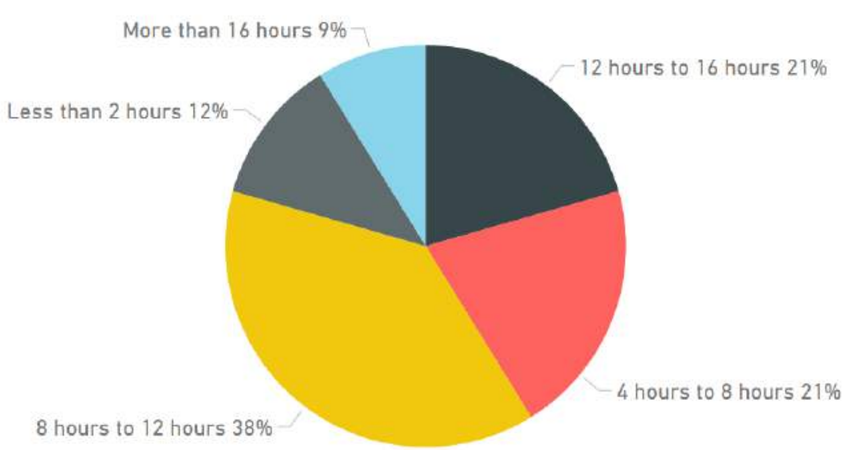


Figure 41: Topic 2, Prompt 8 – Responses from All Other Stakeholders



Similar to Topic 2 Prompt 8, terminal operators, trucking companies, and labor believe there is a greater range needed for hydrogen-fuel equipment (100% selected more than 8 hours) than other stakeholders (68% selected more than 8 hours). If there are notable differences in the refueling requirements between hydrogen-fueled and electric-fueled equipment, this distinction has not been realized by the stakeholders at large.

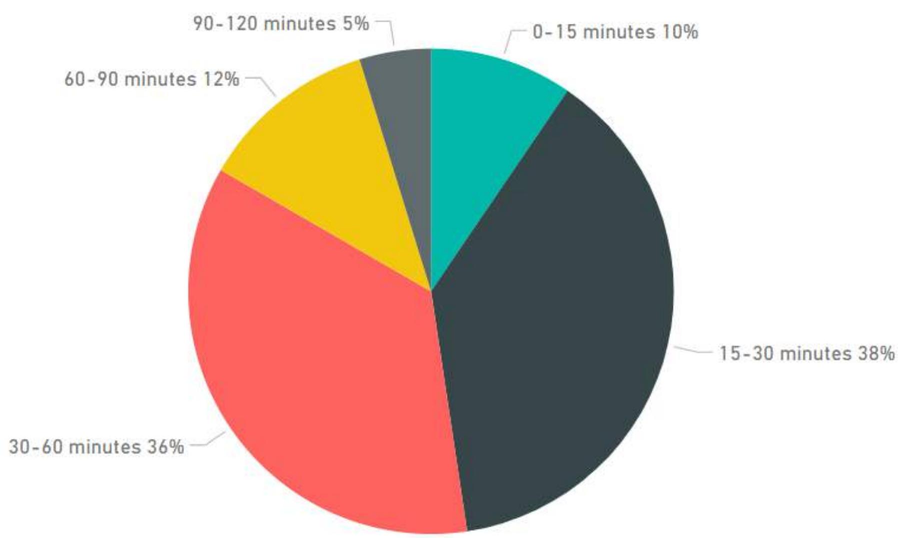
3.3.3.9 Topic 2, Prompt 9

Figure 42: Topic 2, Prompt 9

From an operations perspective, what are tolerable lengths of time for charging/refueling during a lunch-break (as opposed to overnight)?

- ◯ 0-15 minutes
- ◯ 15-30 minutes
- ◯ 30-60 minutes
- ◯ 60-90 minutes
- ◯ 90-120 minutes

Figure 43: Topic 2, Prompt 9 – Responses from All Stakeholders



Overall, responses for this prompt were relatively consistent, with the majority of participants selecting options that included 60 minutes or less. The standout selections, 60 minutes or more, were exclusively from regulatory agencies/financing groups and technology vendors/OEMs. For this select group, additional education about Port operations, particularly around the potential for opportunity charging/refueling during breaks is important. While not specifically captured in the prompts, education around the desired range for equipment of 8+ hours (Topic 2 Prompt 7) and the accessibility of lunch break opportunity charging should be addressed through collaborative dialogue.

3.3.3.10 Topic 2, Prompt 10

Figure 44: Topic 2, Prompt 10

From an operations perspective, what are tolerable lengths of time for charging/refueling overnight?

- ○ 0-4 hours
- ○ 4-6 hours
- ○ 6-8 hours
- ○ 8+ hours

Figure 45: Topic 2, Prompt 10 – Responses from Terminal Operators, Trucking Companies, and Labor

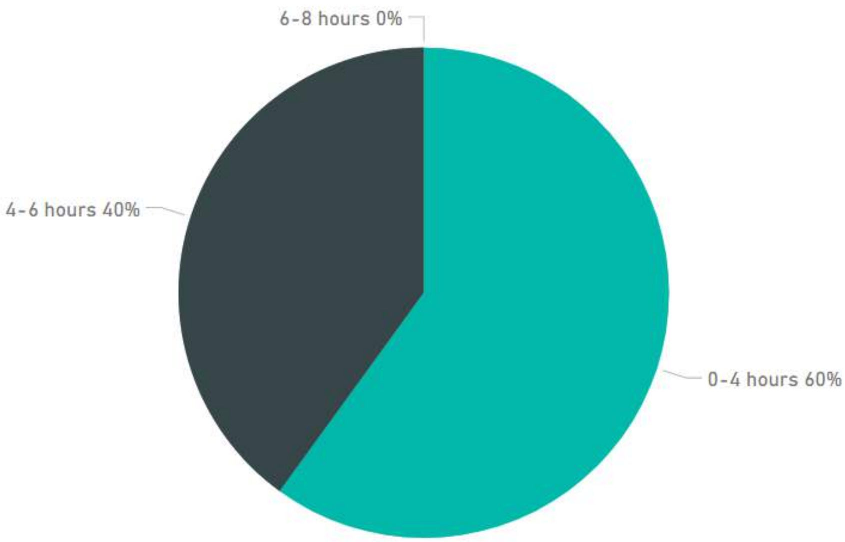


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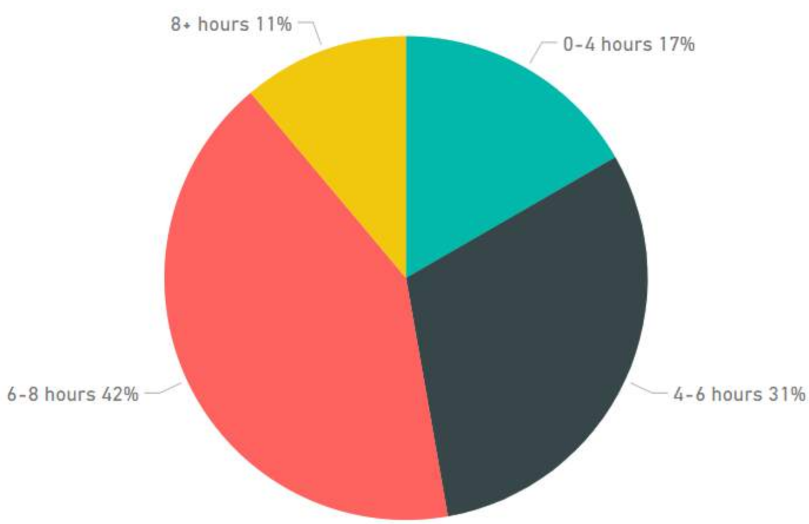
Figure 46: Topic 2, Prompt 10 – Responses from All Other Stakeholders



The responses to this prompt show considerable discrepancy between the terminal operators, trucking companies, and labor (100% selecting fewer than 6 hours) and the other stakeholder groups (48% selecting fewer than 6 hours). Those selecting more than 6 hours were exclusively from the technology vendor/OEM, regulatory agency/finance, or CBO/EJ stakeholder groups. Education around these operating parameters may help better focus technology design and development and pilot programs to better fit the operational needs of the Port community.

3.3.3.11 Topic 2, Prompt 11

Figure 47: Topic 2, Prompt 11

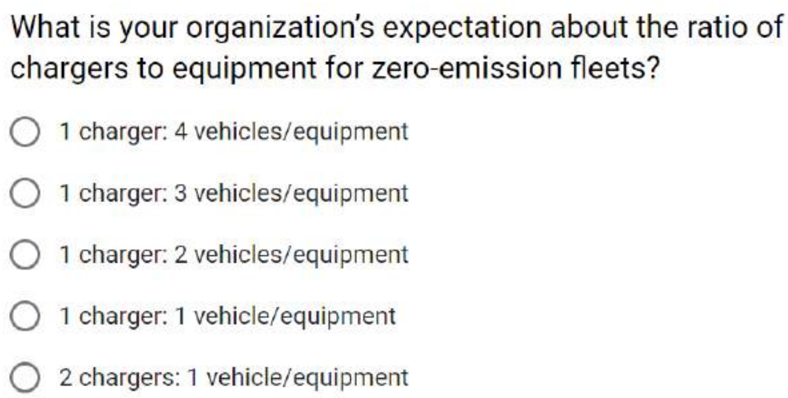
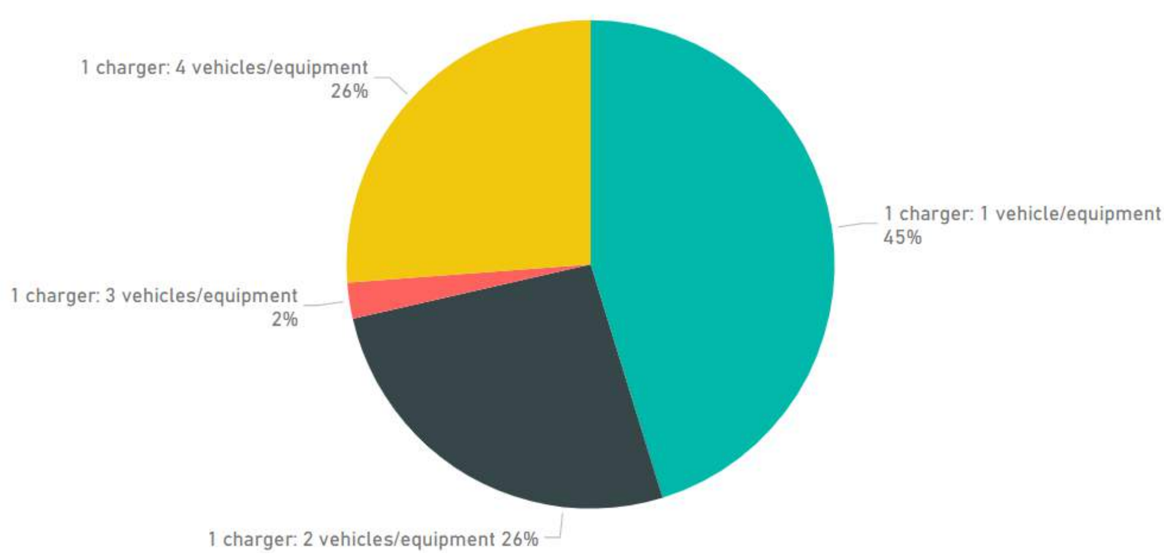


Figure 48: Topic 2, Prompt 11 – Responses from All Stakeholders

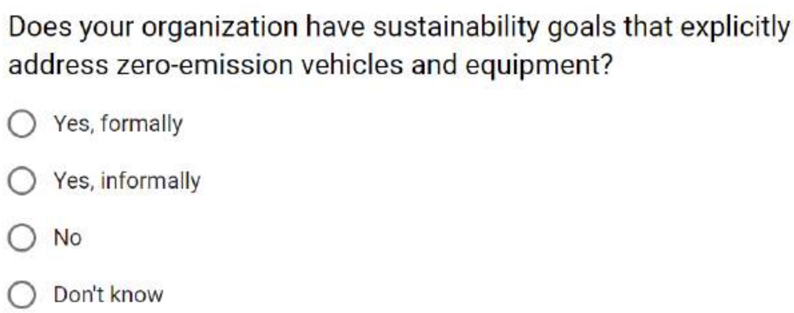


Responses to this prompt were relatively varied but were consistent across stakeholder groups. A slight majority (54%) of respondents indicated that one charger could handle more than one vehicle. It should be noted that the question did not make any distinction between chargers as a unit versus charging port (there may be multiple charging ports on one unit). Notably, the responses from regulatory agencies/financing groups were exclusively that more than one piece of equipment could be served by one charger and 100% of the terminal operators, trucking companies, and labor groups believed a 1:1 ratio was necessary.

3.3.4 Topic 3: Sustainability Goals

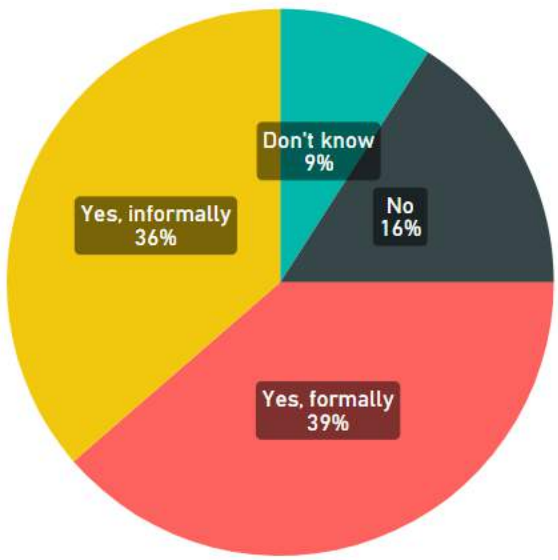
3.3.4.1 Topic 3, Prompt 1

Figure 49: Topic 3, Prompt 1


Does your organization have sustainability goals that explicitly address zero-emission vehicles and equipment?

- Yes, formally
- Yes, informally
- No
- Don't know

Figure 50: Topic 3, Prompt 1 – Response from All Stakeholders



Overall, the majority of the stakeholders have formal or informal zero-emission goals; however, notably several of the respondents did not. This is notable as the stakeholders selected for this survey were pre-identified as actively engaged in the Port's zero-emission efforts. With the Port's extensive efforts to develop measurable, achievable, and actionable zero-emission goals as part of the Clean Air Action Plan, the Port may be a resource for other engaged organizations that have not developed internal zero-emission goals.

3.3.4.2 Topic 3, Prompt 2

Figure 51: Topic 3, Prompt 2

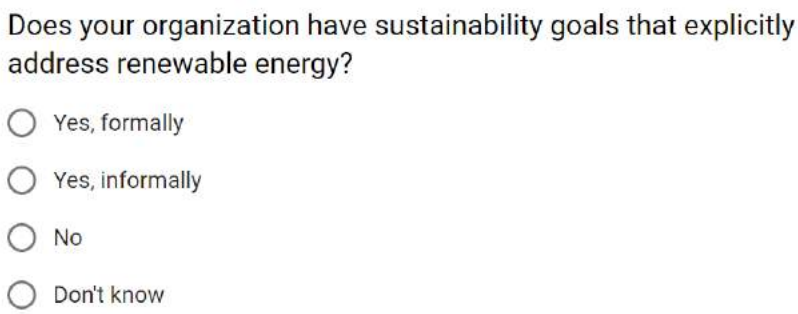
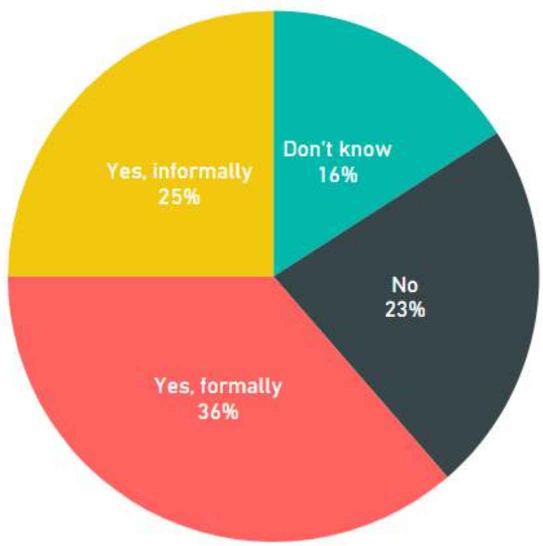


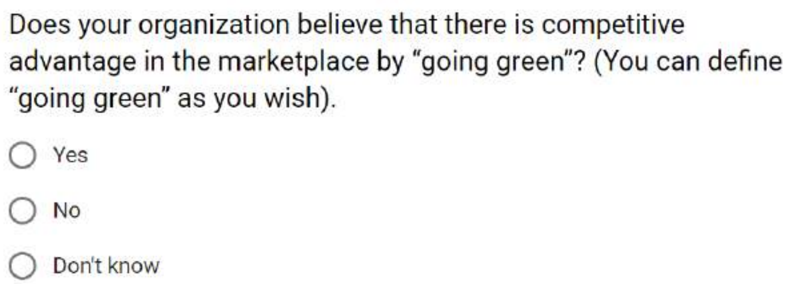
Figure 52: Topic 3, Prompt 2 – Responses from All Stakeholders



Similar to the zero-emission goals, a majority of the respondents indicated having formal or informal renewable energy goals. Interestingly, the overall percentage (61%) of those indicating renewable energy goals is lower than those with zero-emission goals (75%). This trend may reflect the focus of the CAAP on zero-emission technologies. More formal adoption of renewable energy goals by the Port may help move stakeholders towards considerations of renewable energy sources. There is significant overlap between zero-emission technologies and renewable energy sources, which should be considered together, even if ultimately approached in a phased manner or in series.

3.3.4.3 Topic 3, Prompt 3

Figure 53: Topic 3, Prompt 3


Does your organization believe that there is competitive advantage in the marketplace by "going green"? (You can define "going green" as you wish).

Yes

No

Don't know

Figure 54: Topic 3, Prompt 3 – Responses from Terminal Operators and Truck Companies

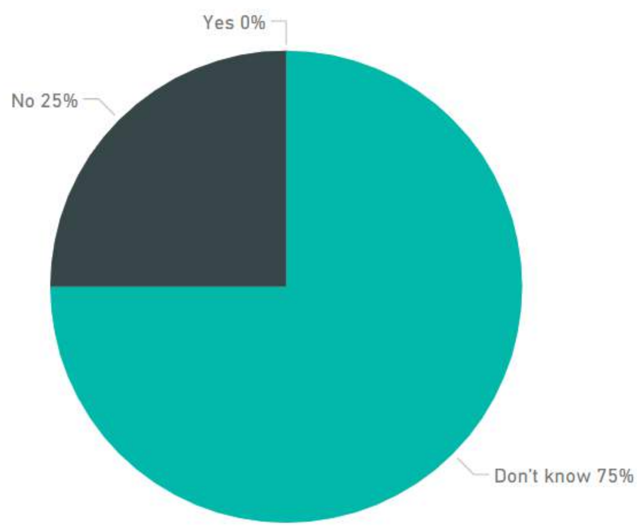
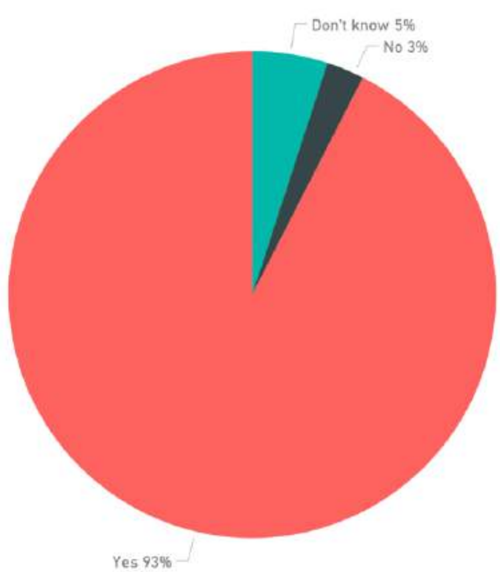


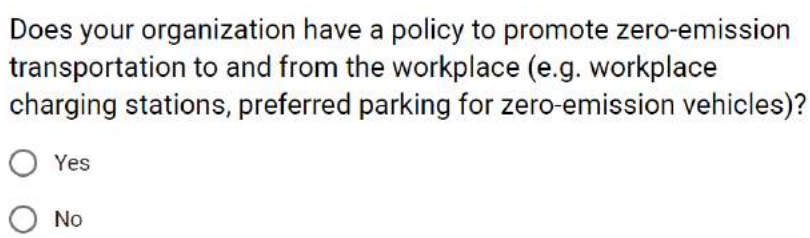
Figure 55: Topic 3, Prompt 3 – Responses from All Other Stakeholders



This prompt addressed an important theme around the zero-emission transition, specifically if the transition is considered to have a competitive advantage. The focus on competitive advantage centers on financial implications of the technologies and specifically excludes external attributes (benefits or costs), such as environmental or health impacts. Interestingly the vast majority of the respondents indicated yes while the terminal operators and trucking companies—those generally responsible for purchasing the equipment all answered with "no" or "don't know." Not surprisingly, the regulatory agency/financing stakeholders unanimously responded "yes." While the definitions of "competitive advantage" and "going green" were left to the respondents' own interpretation, the results indicate a clear need for stakeholders to help terminal operators and trucking companies understand how this transition may be financially beneficial in a highly-competitive marketplace. Information and data sharing will be critical to this knowledge transfer. When 100% of stakeholders agree there is a competitive advantage, the transition to zero-emission technologies will have achieved full commercialization as "going green" will be an integral part of all parties' business models.

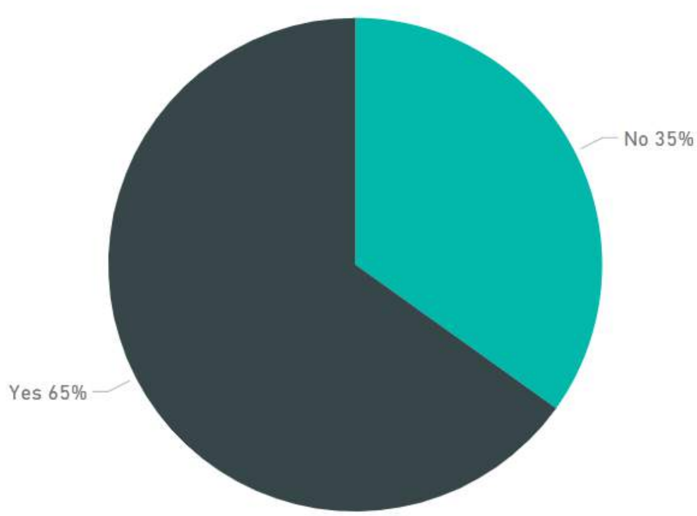
3.3.4.4 Topic 3, Prompt 4

Figure 56: Topic 3, Prompt 4


Does your organization have a policy to promote zero-emission transportation to and from the workplace (e.g. workplace charging stations, preferred parking for zero-emission vehicles)?

- Yes
- No

Figure 57: Topic 3, Prompt 4 – Respones from All Stakeholders



Results show that about two-thirds of participating stakeholder groups have some type of policy in place to promote zero-emission transportation. While not a specifically identified goal in the CAAP, the movement of workers to and from the Port may be an area for future consideration. Supporting workers in the decision to embrace zero-emission technologies in their personal lives can spill over into the business environment.

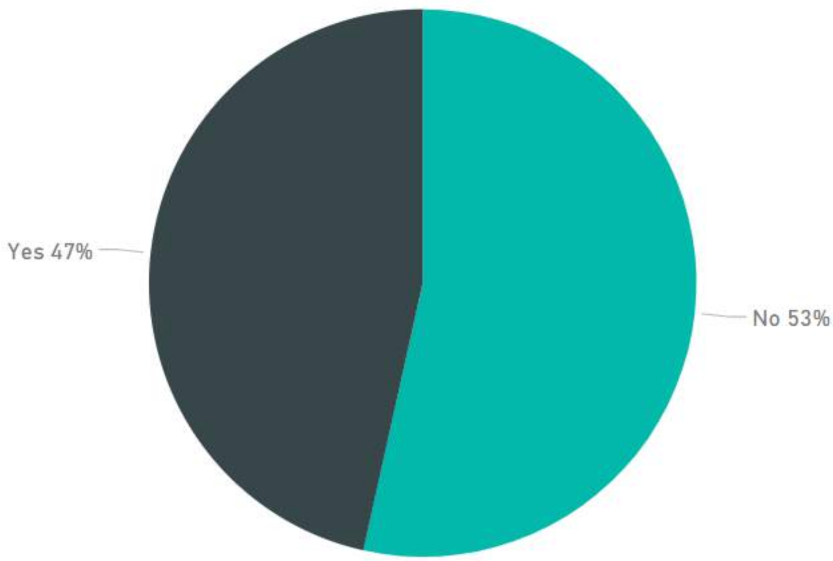
3.3.4.5 Topic 3, Prompt 5

Figure 58: Topic 3, Prompt 5

Does your organization have a policy to promote sustainable transportation to and from the workplace (e.g. carpooling incentives, reduced public transportation costs)?

- ◯ Yes
- ◯ No

Figure 59: Topic 3, Prompt 5 – Responses from All Stakeholders



Surprisingly, unlike Topic 3 Prompt 4, there are fewer organizations that promote sustainable transportation (47%) than zero-emission incentives (65%) for travel to-and-from the workplace. This result may reflect the challenges around mass transportation approaches in the greater Long Beach and Los Angeles region.

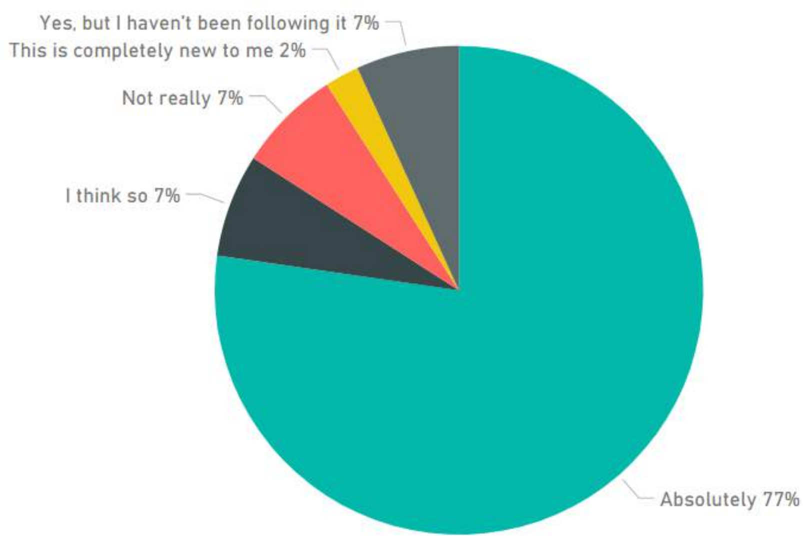
3.3.4.6 Topic 3, Prompt 6

Figure 60: Topic 3, Prompt 6

Is your company aware of the Port of Long Beach's goal for zero-emission terminal equipment by 2030?

- ◯ Absolutely
- ◯ Yes, but I haven't been following it
- ◯ I think so
- ◯ Not really
- ◯ This is completely new to me

Figure 61: Topic 3, Prompt 6 – Responses from All Stakeholders

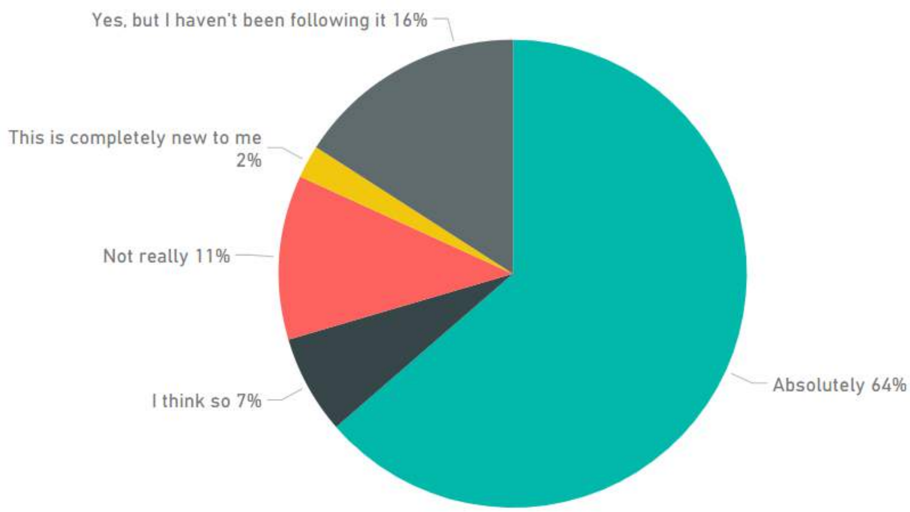


As expected from this stakeholder group, the vast majority (91%) of respondents was aware of the Port's zero-emission terminal equipment by 2030 goal. With a dynamic and emerging market, it is not surprising that there are some participants that are not familiar with the CAAP, particularly if these participants have primarily been engaged in the light-duty sector. Continuing to engage in this market will ensure that the Port is able to reach new participants. Technology developers represented the majority of those unaware of the goal.

3.3.4.7 Topic 3, Prompt 7

Figure 62: Topic 3, Prompt 7

Figure 63: Topic 3, Prompt 7 – Responses from All Stakeholders



As with Topic 3 Prompt 7, most parties are aware of the Port's zero-emission drayage truck goal. Again, the majority of those organization unfamiliar with the goals are technology vendors/OEMs.

3.3.4.8 Topic 3, Prompt 8

Figure 64: Topic 3, Prompt 8

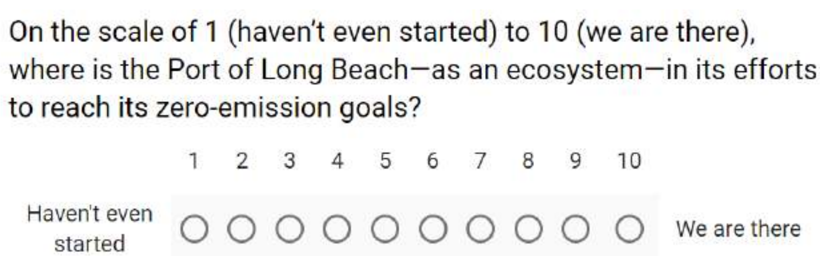
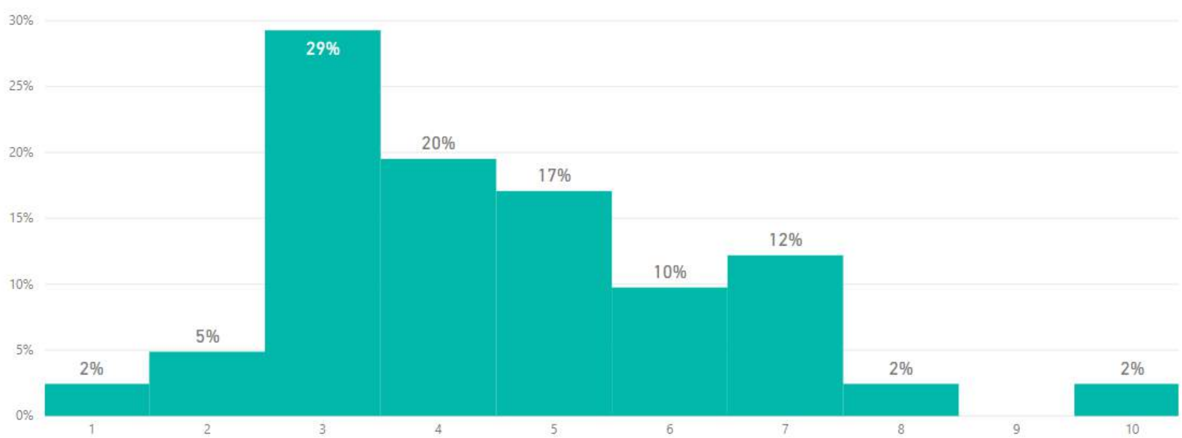


Figure 65: Topic 3, Prompt 8 – Responses from All Stakeholders

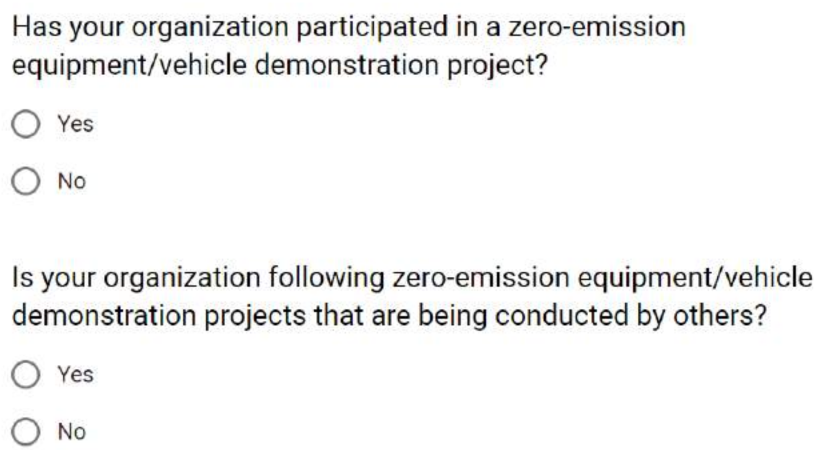


Overall, there is high positivity from the respondents. As indicated in the PCEVB Research Report, nearly 20% of the Port's terminal equipment population is already zero-emissions. With the majority of respondents scoring the Port as a 4.5 on the path to achieving zero emissions, the results indicate that there is a strong belief that beyond the actual deployments, the Port has achieved significant milestones laying the groundwork for its continued efforts.

3.3.5 Topic 4: Existing and Ongoing Activities

3.3.5.1 Topic 4, Prompt 1 and Prompt 2

Figure 66: Topic 4, Prompt 1 and Prompt 2

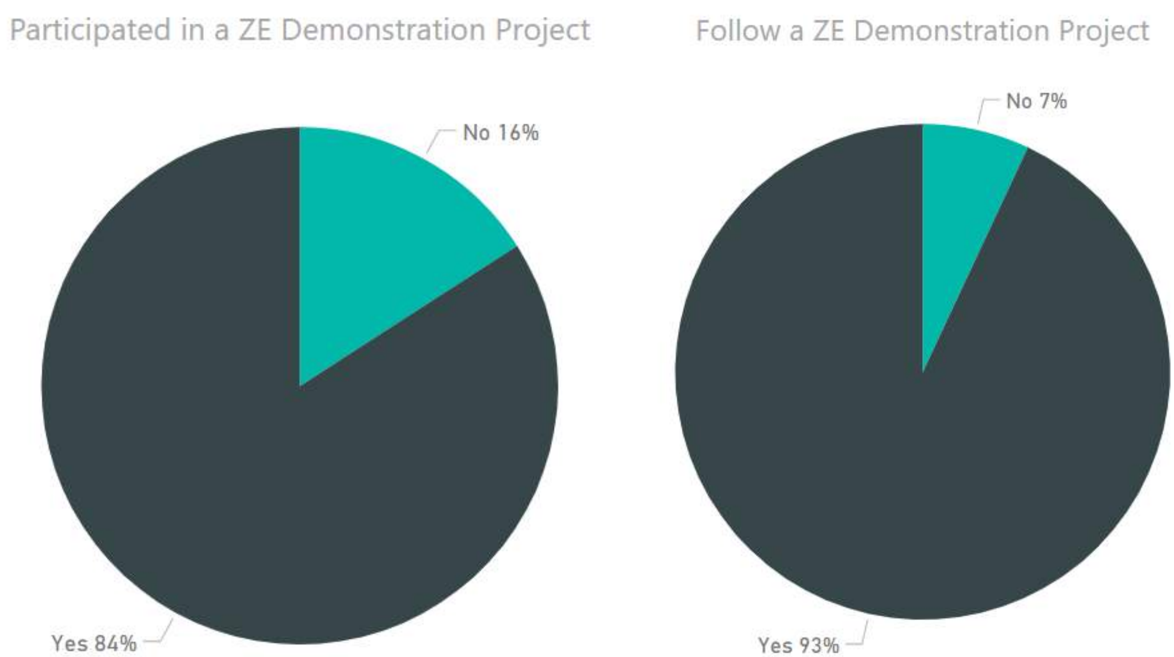

Has your organization participated in a zero-emission equipment/vehicle demonstration project?

- Yes
- No

Is your organization following zero-emission equipment/vehicle demonstration projects that are being conducted by others?

- Yes
- No

Figure 67: Topic 4, Prompt 1 and Prompt 2 – Responses from All Stakeholders



The vast majority of the respondents indicated participation in or monitoring of existing pilot programs. This reflects positively on the Port's significant efforts to bring demonstration and deployment projects for zero-emission equipment to POLB.

3.3.5.2 Topic 4, Prompt 3 and Prompt 4

Figure 68: Topic 4, Prompt 3 and Prompt 4

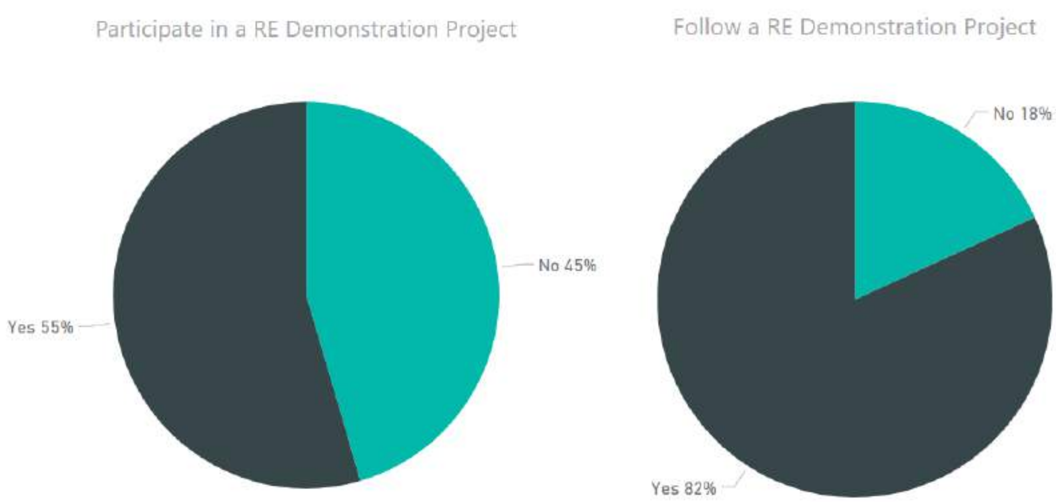
Has your organization participated in a renewable energy demonstration project (i.e., solar, wind, etc.)?

- ◯ Yes
- ◯ No

Is your organization following renewable energy demonstration projects that are being conducted by others?

- ◯ Yes
- ◯ No

Figure 69: Topic 4, Prompt 3 and Prompt 4 – Responses from All Stakeholders



There were fewer organizations that have participated in renewable projects vs. zero-emission projects; however, this question may have been influenced by the inclusion of "solar" and "wind" as examples and the exclusion of "battery storage".

3.3.5.3 Topic 4, Prompt 5

Figure 70: Topic 4, Prompt 5

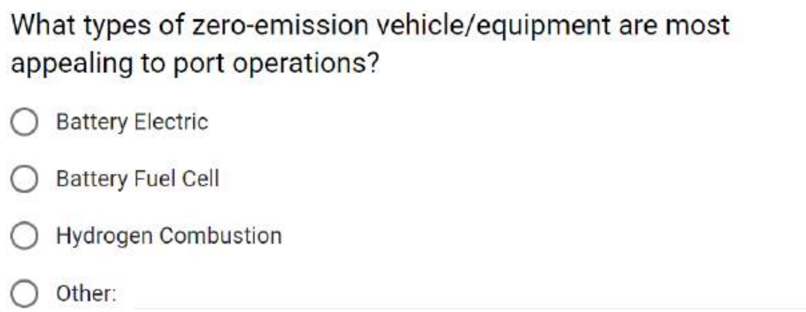
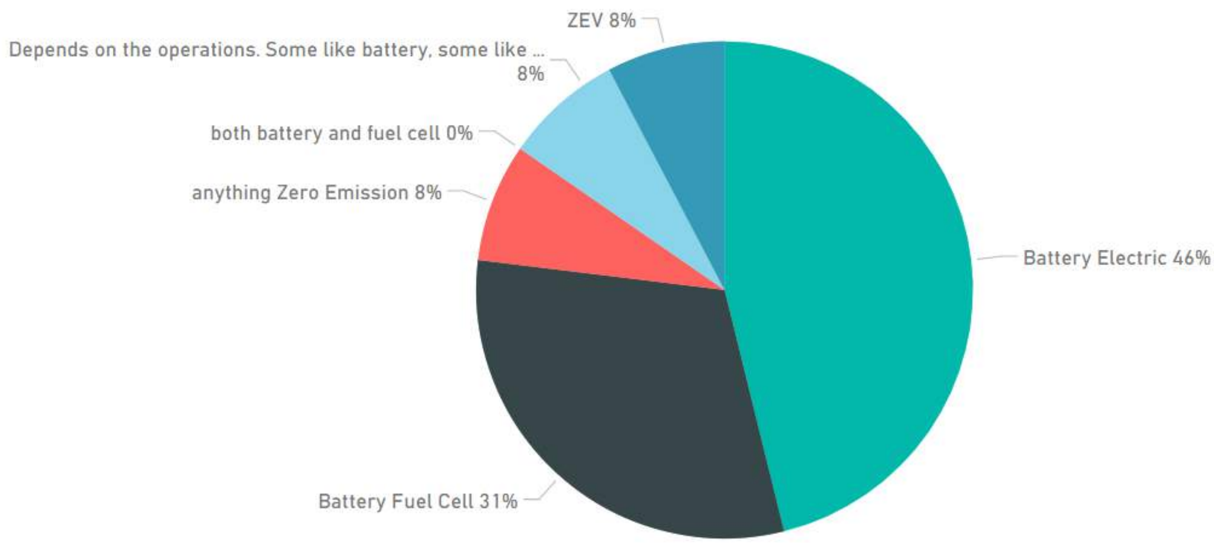


Figure 71: Topic 4, Prompt 5 – Responses from All Stakeholders except Technology Developers/OEMs



Technology developers/OEM responses were removed from this data set because the respondents were heavily weighted towards battery-electric technology developers. With this set removed, the respondents were evenly split between battery electric and battery fuel cell technologies. There was a write-in option for this prompt, allowing a number of similar entries, such as "ZEV," "both battery and fuel cell," and "anything Zero Emission."

3.3.5.4 Topic 4, Prompt 6

Figure 72: Topic 4, Prompt 6

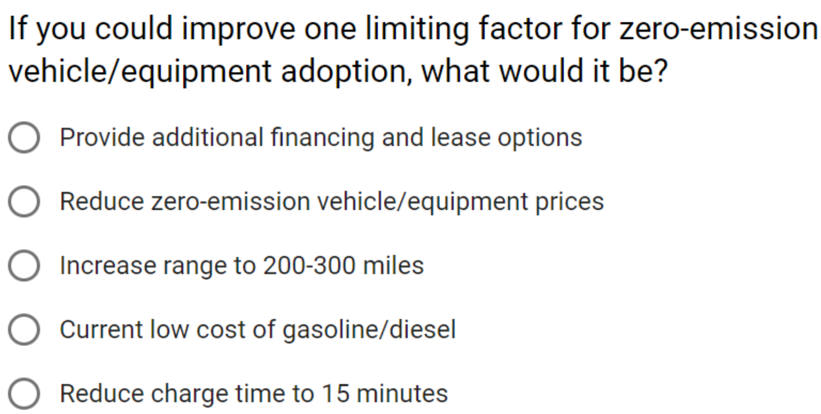


Figure 73: Topic 4, Prompt 6 – Responses from Technology Vendors/OEMs, Terminal Operators, Trucking Companies, and Regulatory Agencies/Financing

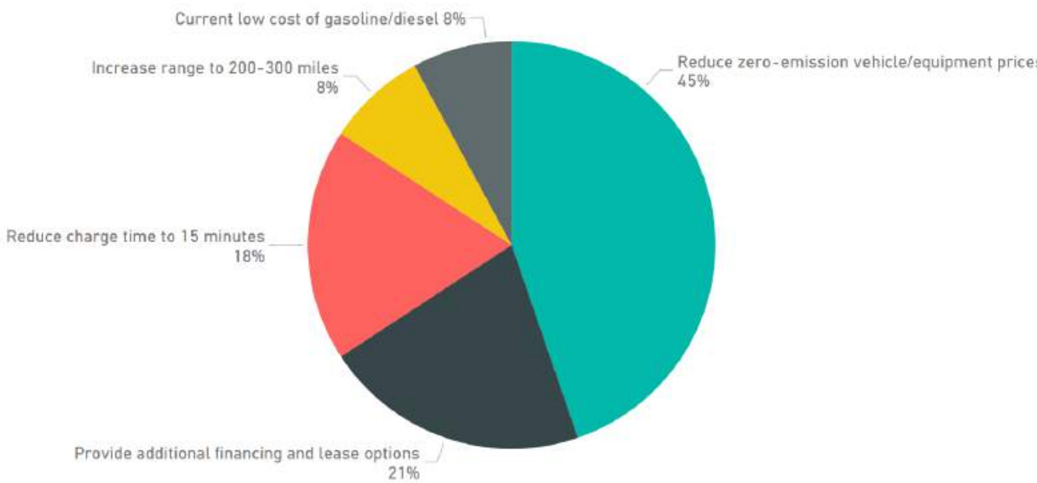
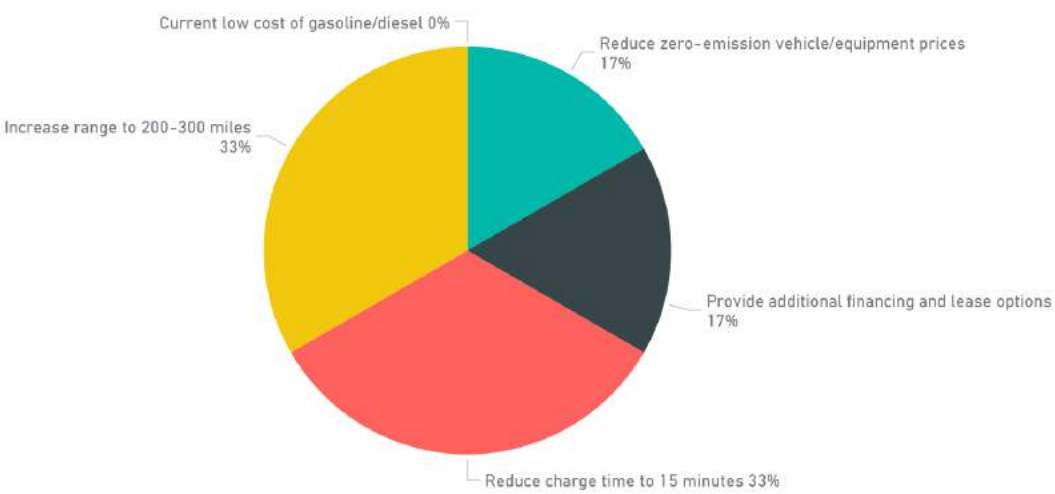


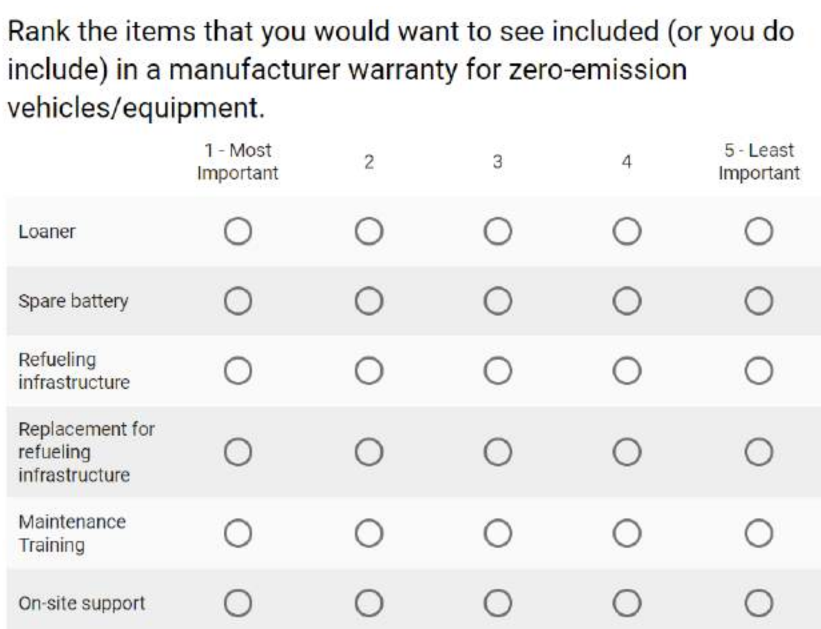
Figure 74: Topic 4, Prompt 6 – Response from All Other Stakeholders



There were two main perspectives presented through the responses to this prompt. The first was shared by the technology vendors/OEMs, terminal operators, trucking companies, and regulatory agencies/financing, with a heavy emphasis on methods to reduce the capital cost of the equipment (66% of responses). These companies represent the direct buyers and sellers of zero-emission equipment. The other stakeholders—those that are not directly buying or selling equipment—were more focused on operations parameters (only 34% selected options related to reduced capital cost). There are many potential reasons for these responses, specifically how each responding entity makes assumptions about battery or fuel cell technology advancements.

3.3.5.5 Topic 4, Prompt 7

Figure 75: Topic 4, Prompt 7



Rank the items that you would want to see included (or you do include) in a manufacturer warranty for zero-emission vehicles/equipment.

	1 - Most Important	2	3	4	5 - Least Important
Loaner	○	○	○	○	○
Spare battery	○	○	○	○	○
Refueling infrastructure	○	○	○	○	○
Replacement for refueling infrastructure	○	○	○	○	○
Maintenance Training	○	○	○	○	○
On-site support	○	○	○	○	○

Figure 76: Topic 4, Prompt 7 – Response from All Stakeholders

The majority of respondents provided consistent answers, with the responses leaning towards on-site support and refueling infrastructure as the two greatest concerns.

3.3.6 Topic 5: Limitations and Barriers to Infrastructure

3.3.6.1 Topic 5, Prompt 1

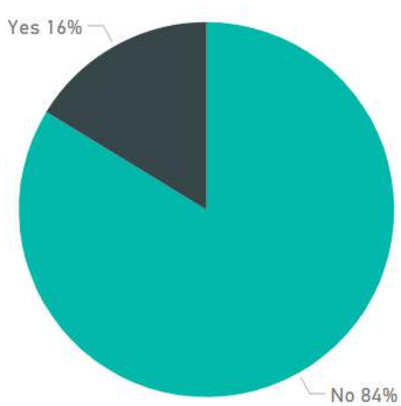
Figure 77: Topic 5, Prompt 1

Do fleet operators generally know how much spare electrical capacity currently exists at the site of their terminal operations?

◯ Yes

◯ No

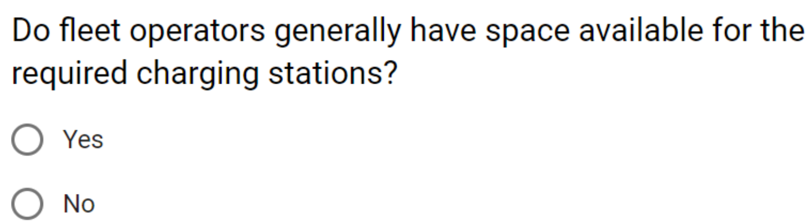
Figure 78: Topic 5, Prompt 1 – Responses from All Stakeholders



Responses to this prompt were consistent across stakeholders groups with a general consensus that fleet operators do not know how much spare electrical capacity exists at the site of their terminal operations. The Port has conducted several studies to begin to acquire this information. Further study and knowledge transfer may be necessary.

3.3.6.2 Topic 5, Prompt 2

Figure 79: Topic 5, Prompt 2


Do fleet operators generally have space available for the required charging stations?

- Yes
- No

Figure 80: Topic 5, Prompt 2 – Responses from Terminal Operators and Trucking Companies

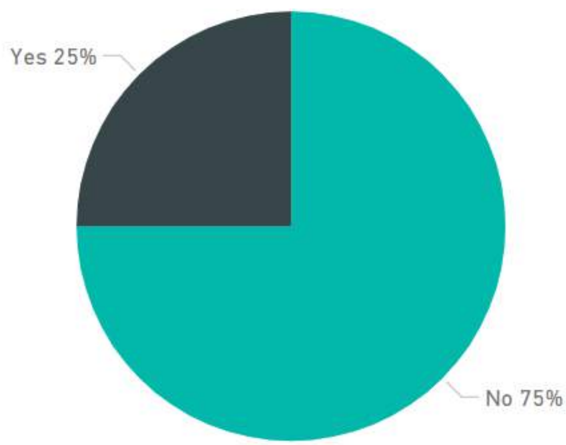
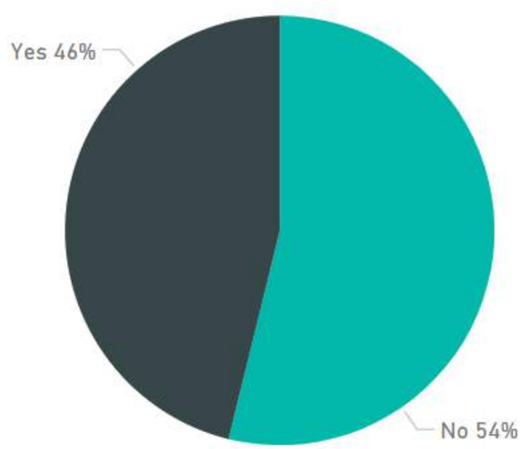


Figure 81: Topic 5, Prompt 2 – Responses from All Other Stakeholders



The results show that there is a perception by other stakeholders that fleet operators know more about space availability than they actually know. There are many contributing factors to knowing if space is available within a terminal operation and there may be benefits to open dialogue among stakeholders so everyone can understand nuisances of charging or refueling installations on terminals in which space is already constrained and expensive.

3.3.6.3 Topic 5, Prompt 3

Figure 82: Topic 5, Prompt 3

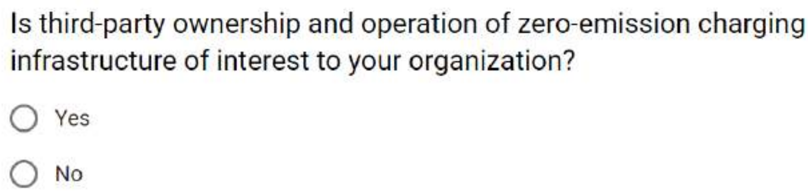
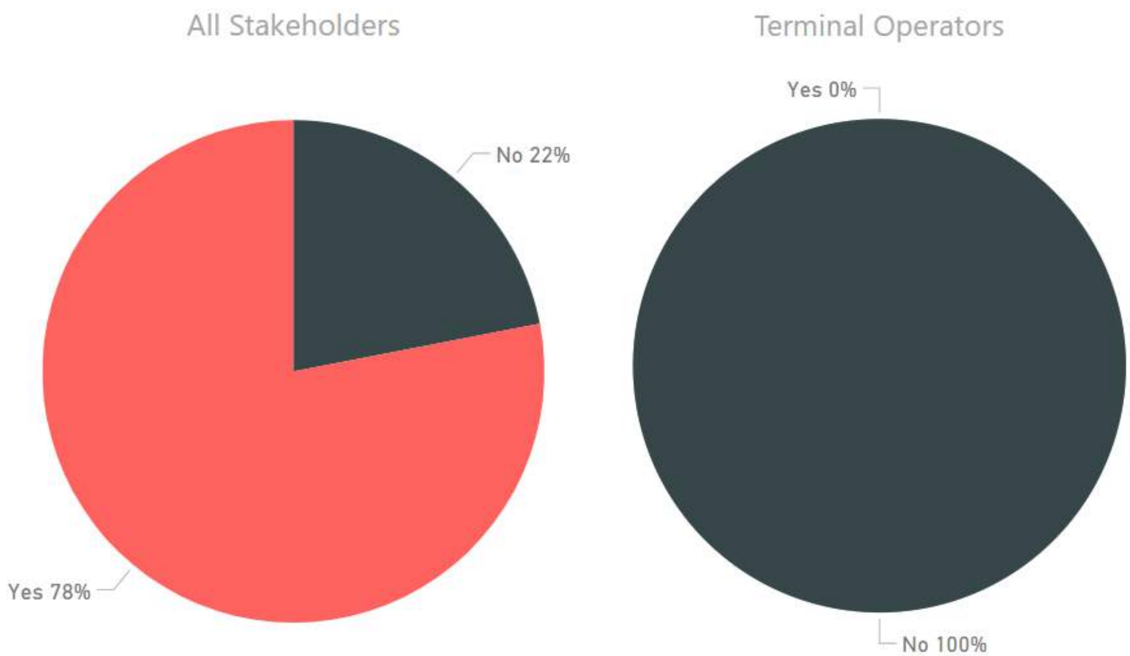


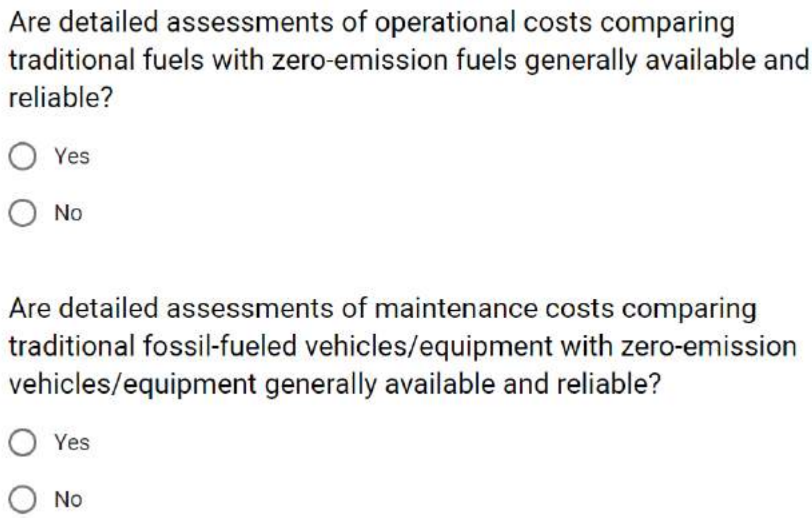
Figure 83: Topic 5, Prompt 3 – Responses from All Stakeholders (left) and Terminal Operators (right)



The majority of respondents indicated that third-party ownership was of interested. However, 100% of the terminal operators indicated that they *were not interested* in third-party ownership (trucking company operators were interested in third-party ownership). This response is important as it relates to a variety of financing opportunities that have been utilized in the on-road sector. Notably, terminal operators did not identify substantial awareness of third-party ownership options in Topic 3 Prompt 8.

3.3.6.4 Topic 5, Prompt 4 and Prompt 5

Figure 84: Topic 5, Prompt 4 and Prompt 5


Are detailed assessments of operational costs comparing traditional fuels with zero-emission fuels generally available and reliable?

Yes

No

Are detailed assessments of maintenance costs comparing traditional fossil-fueled vehicles/equipment with zero-emission vehicles/equipment generally available and reliable?

Yes

No

Figure 85: Topic 5, Prompt 4 and Prompt 5 – Responses from Technology Developers/OEMs and Regulatory Agencies/Financing

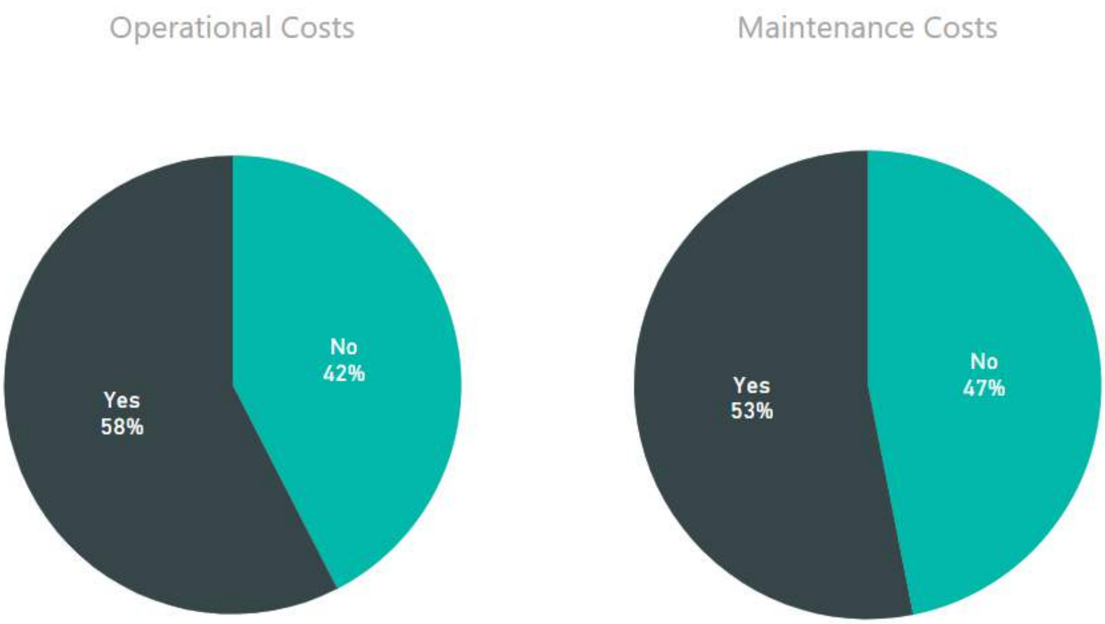
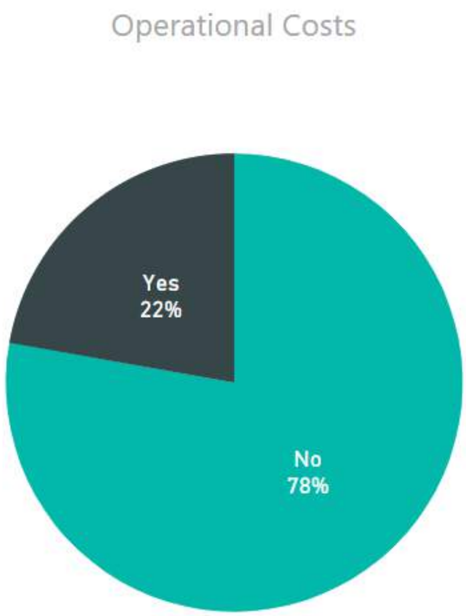
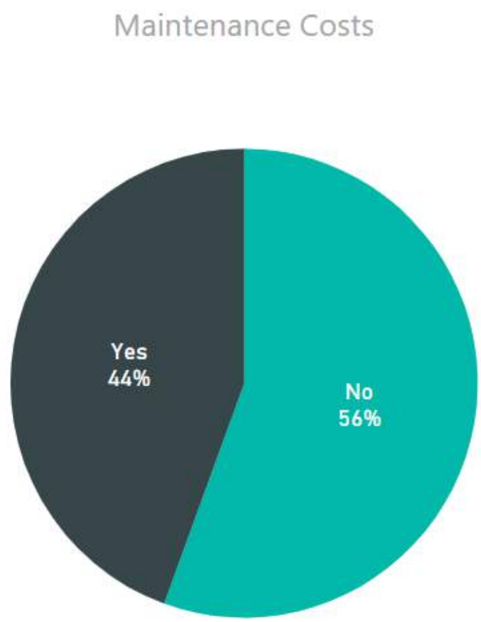


Figure 86: Topic 5, Prompt 4 and Prompt 5 – Responses from All Other Stakeholders

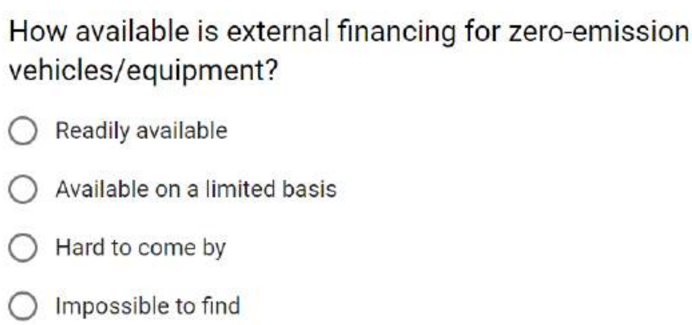




The results from this prompt indicate that technology vendors/OEMs and regulatory agencies/financing groups believe that more data (average 55% availability) about zero-emission technologies are available than other stakeholders (average 33% availability). Even with an average of 55% of technology vendor/OEM and regulatory agency/financing group stakeholder, there appears to be an overall understanding that there are limits to available data. These data are important to identifying and solidifying the business case for zero-emission technologies. The data suggest that continued data collection and analysis along with enhanced knowledge transfer between stakeholders is needed to facilitate accelerated adoption of zero-emissions technologies.

3.3.6.5 Topic 5, Prompt 6 and Prompt 7

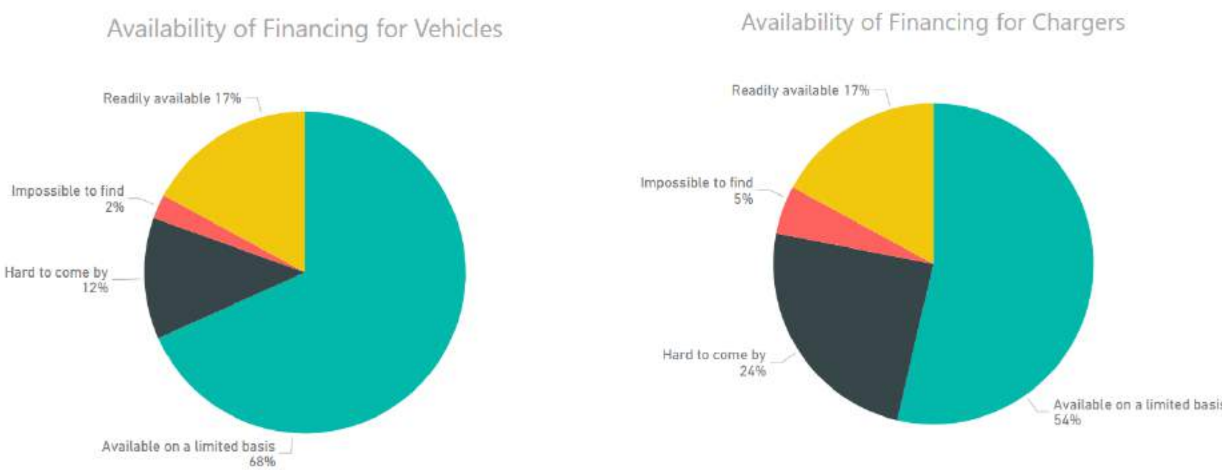
Figure 87: Topic 5, Prompt 6 and Prompt 7



How available is external financing for charging and refueling infrastructure?

- ◯ Readily available
- ◯ Available on a limited basis
- ◯ Hard to come by
- ◯ Impossible to find

Figure 88: Topic 5, Prompt 6 and Prompt 7 – Responses from All Stakeholders



Overall, the stakeholders provided consistent responses to this prompt. The “impossible to find” subsection was exclusively technology vendors/OEMs and the “readily available” was exclusively utilities, regulatory agencies/financing groups, and technology developers/OEMs.

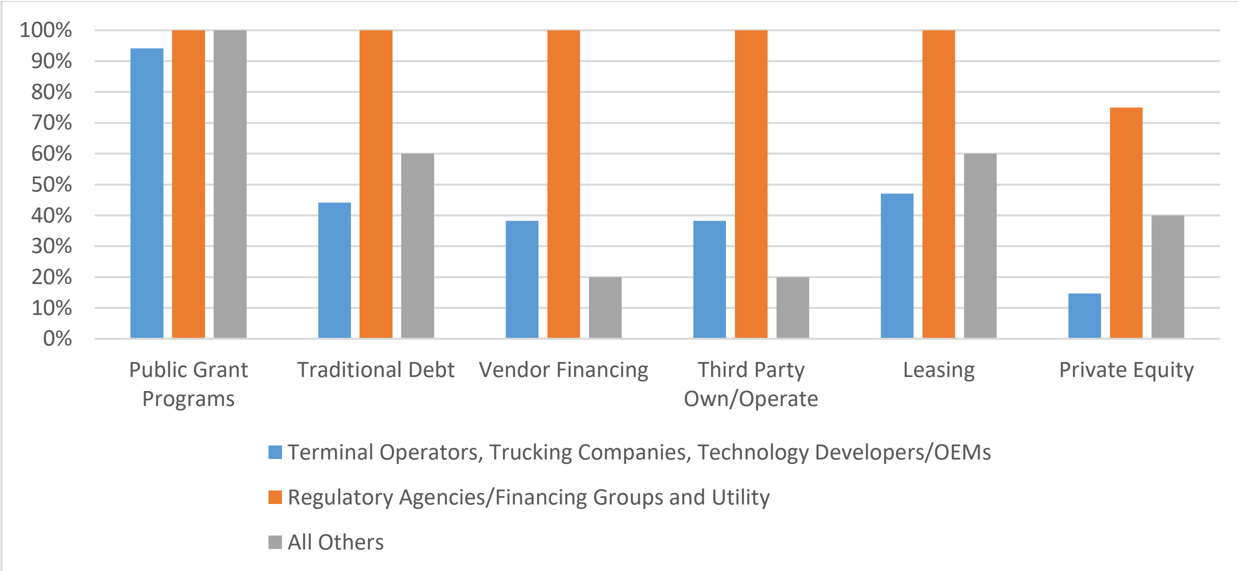
3.3.6.6 Topic 5, Prompt 8

Figure 89: Topic 5, Prompt 8

What types of financing mechanisms does your organization know about addressing zero-emission vehicles/equipment and/or infrastructure?

- ☐ Public grant programs
- ☐ Traditional debt
- ☐ Vendor financing
- ☐ Third party own/operate
- ☐ Leasing
- ☐ Private equity

Figure 90: Topic 5, Prompt 8 – Responses from All Stakeholders

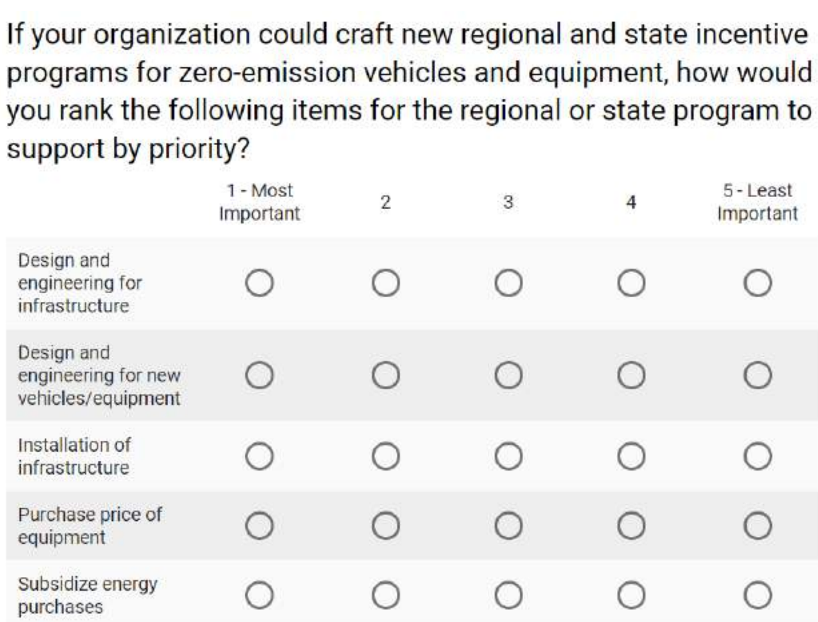


The responses were divided into three categories: 1) organizations directly buying and selling zero-emission equipment (terminal operators, trucking companies, and technology developers/OEMs), 2) organizations offering funding for zero-emission technologies (regulatory agencies/financing groups and utilities), and 3) indirect stakeholders (labor and CBO/EJ groups).

3.3.7 Topic 6: Recommendations

3.3.7.1 Topic 6, Prompt 1

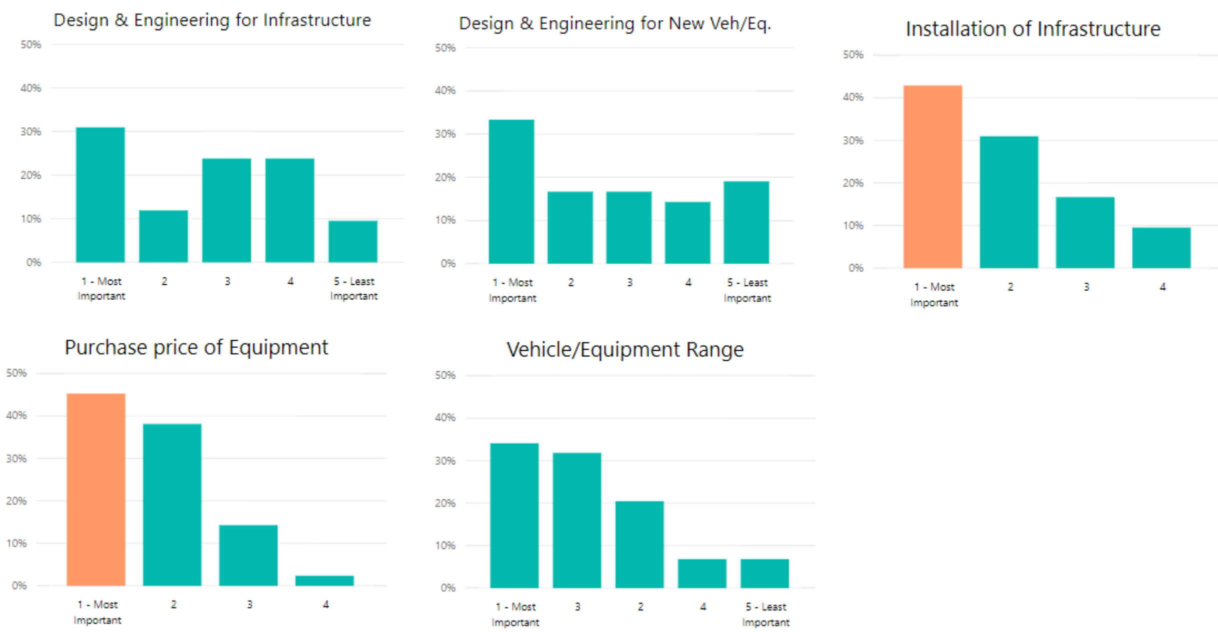
Figure 91: Topic 6, Prompt 1



If your organization could craft new regional and state incentive programs for zero-emission vehicles and equipment, how would you rank the following items for the regional or state program to support by priority?

	1 - Most Important	2	3	4	5 - Least Important
Design and engineering for infrastructure	○	○	○	○	○
Design and engineering for new vehicles/equipment	○	○	○	○	○
Installation of infrastructure	○	○	○	○	○
Purchase price of equipment	○	○	○	○	○
Subsidize energy purchases	○	○	○	○	○

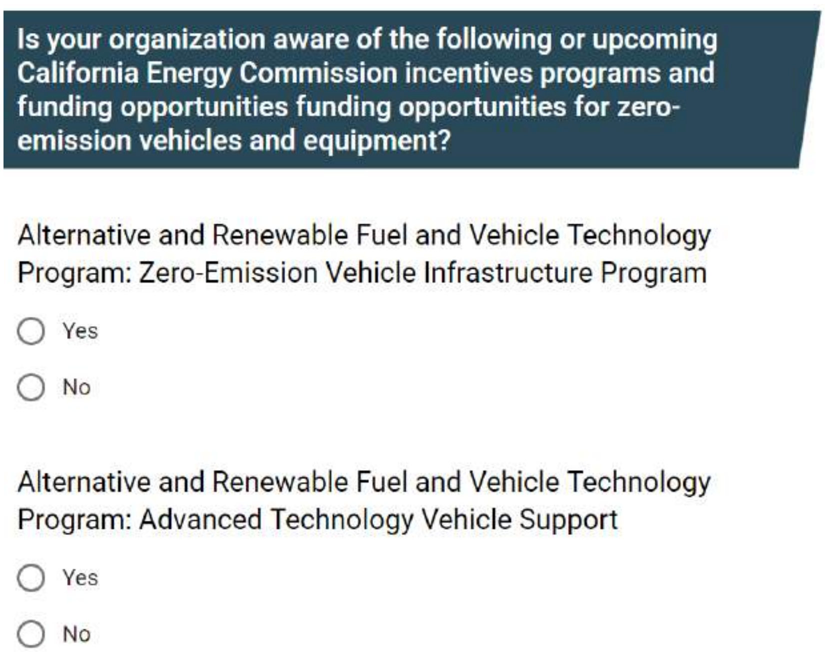
Figure 92: Topic 6, Prompt 1 – Responses from All Stakeholder Groups



The responses to the prompts were consistent across all stakeholder groups. A slight preference to funding associated with installation of infrastructure and equipment purchase is visible in the results.

3.3.7.2 Topic 6, Prompt 2 and Prompt 3

Figure 93: Topic 6, Prompt 2 and Prompt 3



Is your organization aware of the following or upcoming California Energy Commission incentives programs and funding opportunities funding opportunities for zero-emission vehicles and equipment?

Alternative and Renewable Fuel and Vehicle Technology Program: Zero-Emission Vehicle Infrastructure Program

○ Yes

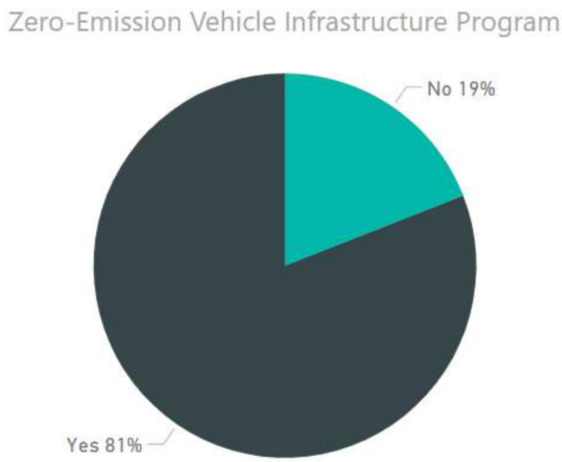
○ No

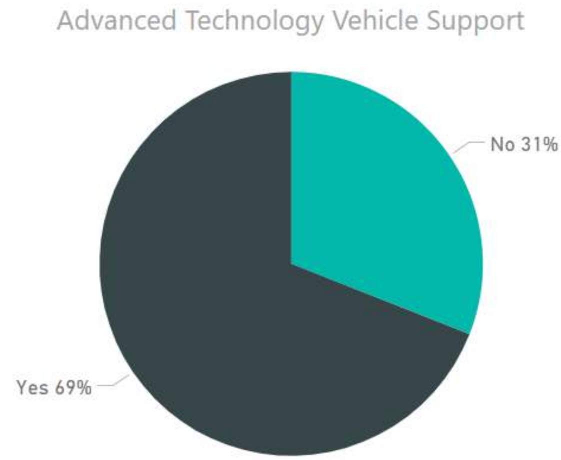
Alternative and Renewable Fuel and Vehicle Technology Program: Advanced Technology Vehicle Support

○ Yes

○ No

Figure 94: Topic 6, Prompt 2 and Prompt 3 – Responses from All Stakeholders

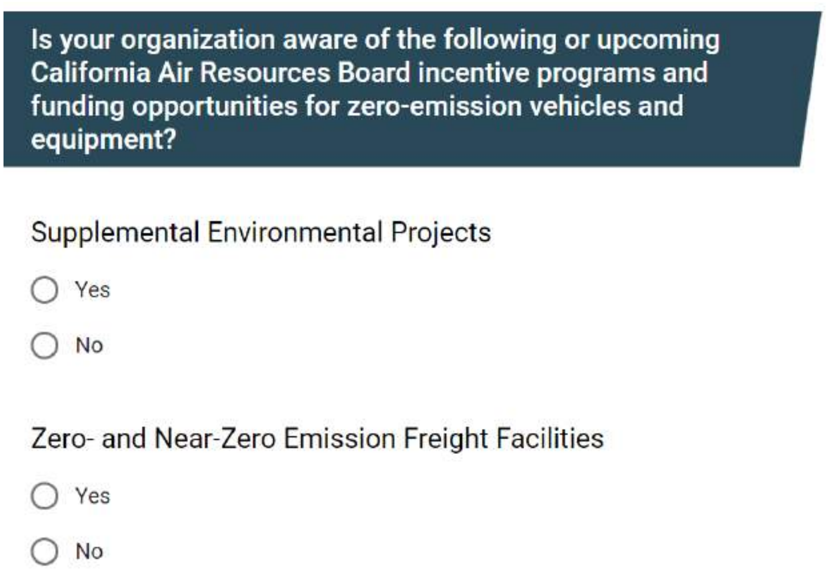




The majority of stakeholders are aware of the California Energy Commission's principal funding programs for zero-emission vehicles, equipment, and infrastructure. However, a substantial portion of these stakeholders are not aware of the potential impacts to the port community. The Port can continue to work closely with the California Energy Commission to provide regular updates on funding opportunities that can help support the zero-emission transition and one of the state's largest freight and good movement facilities.

3.3.7.3 Topic 6, Prompt 4, Prompt 5, Prompt 6, Prompt 7, Prompt 8

Figure 95: Topic 6, Prompt 4, Prompt 5, Prompt 6, Prompt 7, Prompt 8



Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) and Low NOx Engine Incentives

○ Yes

○ No

Volkswagen Settlement Agreement

○ Yes

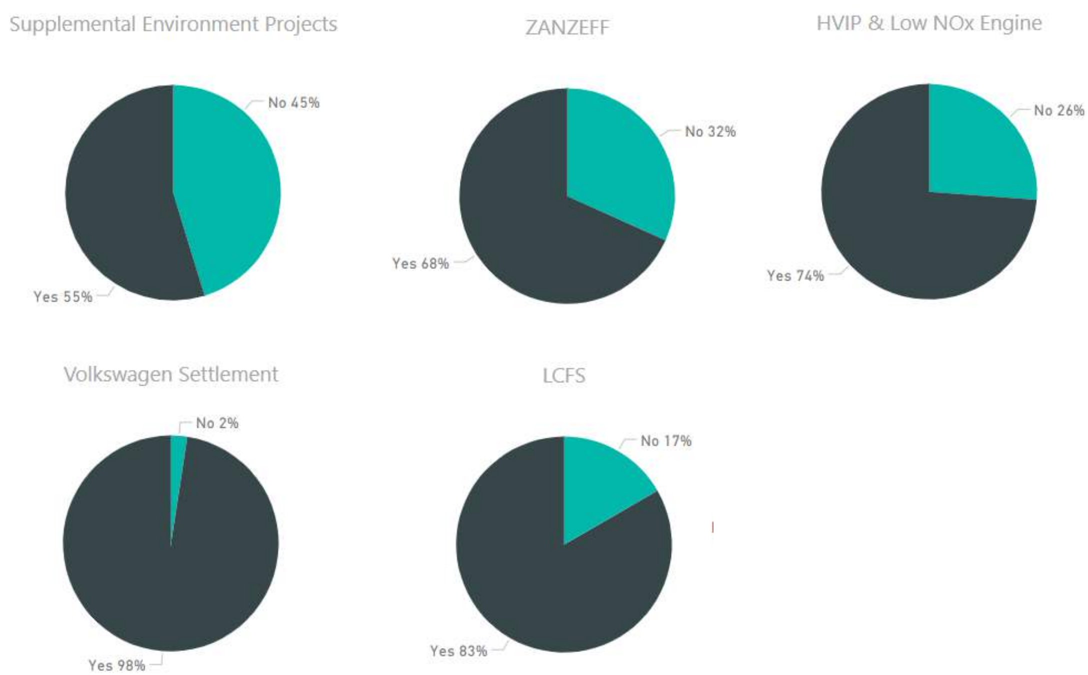
○ No

Low Carbon Fuel Standard

○ Yes

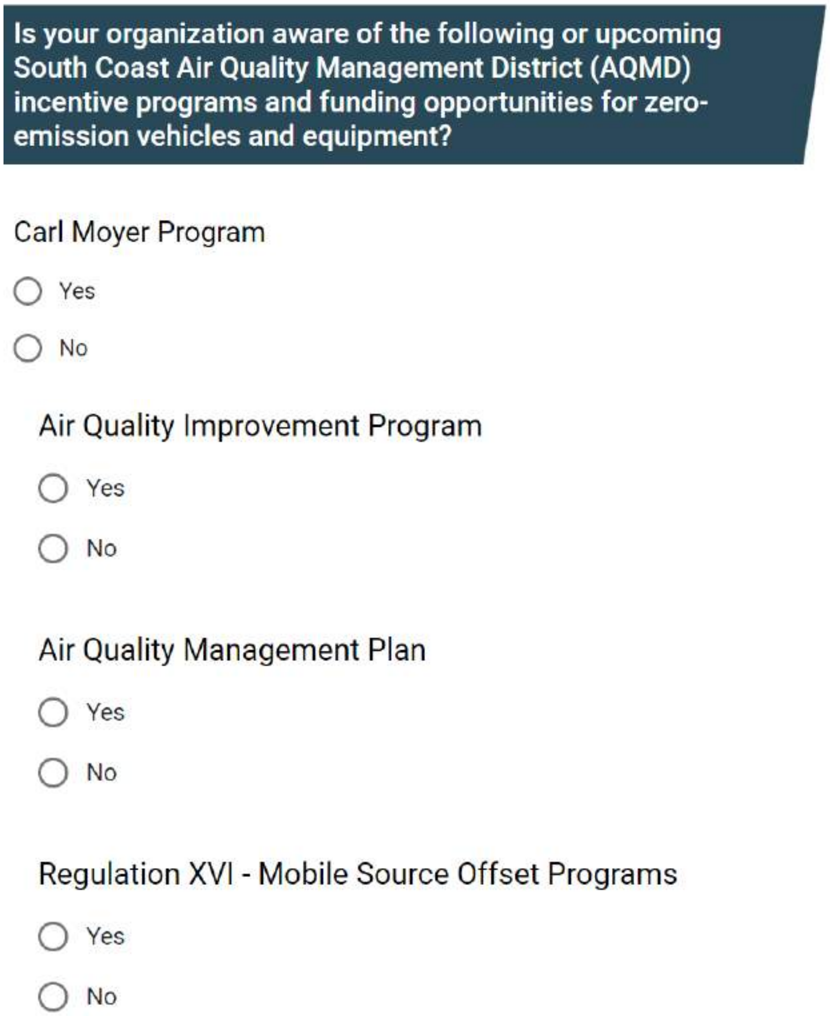
○ No

Figure 96: Topic 6, Prompt 4, Prompt 5, Prompt 6, Prompt 7, Prompt 8 – Responses from All Stakeholders



3.3.7.4 Topic 6, Prompt 9, Prompt 10, Prompt 11, and Prompt 12

Figure 97: Topic 6, Prompt 9, Prompt 10, Prompt 11, and Prompt 12


Is your organization aware of the following or upcoming South Coast Air Quality Management District (AQMD) incentive programs and funding opportunities for zero-emission vehicles and equipment?

Carl Moyer Program

- Yes
- No

Air Quality Improvement Program

- Yes
- No

Air Quality Management Plan

- Yes
- No

Regulation XVI - Mobile Source Offset Programs

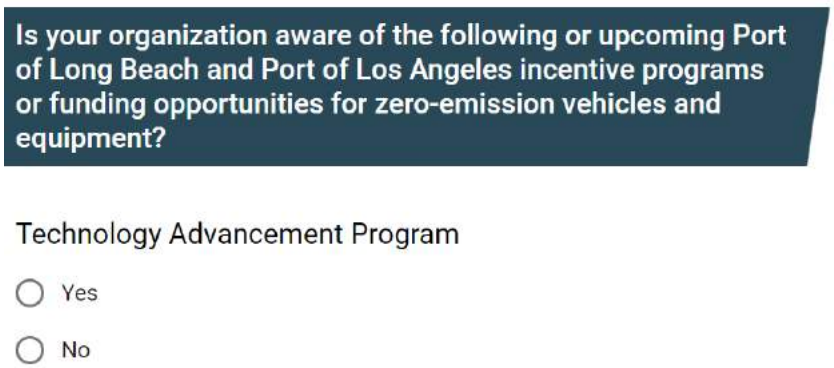
- Yes
- No

Figure 98: Topic 6, Prompt 9, Prompt 10, Prompt 11, and Prompt 12 – Responses from All Stakeholders

Similarly to the responses from the prompt about the California Energy Commission funding, there is incomplete awareness of California Air Resources Board (CARB) funding programs. The Port should continue to work closely with the CARB to facilitate regular dialogue with the port community.

3.3.7.5 Topic 6, Prompt 13

Figure 99: Topic 6, Prompt 13

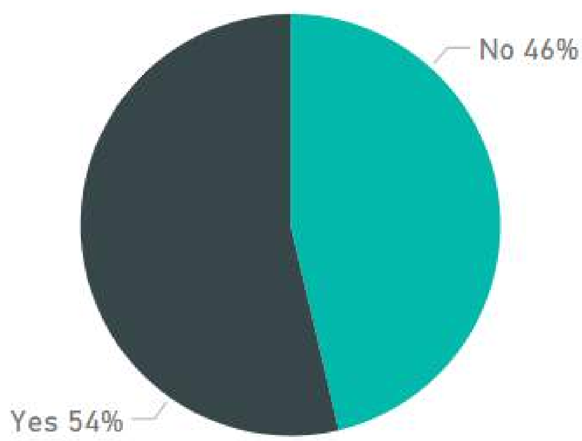

Is your organization aware of the following or upcoming Port of Long Beach and Port of Los Angeles incentive programs or funding opportunities for zero-emission vehicles and equipment?

Technology Advancement Program

Yes

No

Figure 100: Topic 6, Prompt 13 – Responses from All Stakeholders



The TAP program is a stable of the CAAP and is an important way for the POLB and POLA to fund innovations directly impacting the goals of the CAAP. Helping a broad stakeholder group understand the potential within the program will help foster dialogue and collaboration between Port community stakeholders.

4 Findings and Conclusions

The PCEVB Questionnaire provided valuable responses that helped the Project Team better understand the Port Community's understanding of the zero-emission transition ecosystem. Importantly, the results do not represent statistically-significant results, nor was the PCEVB Questionnaire designed with deep scientific rigor. While these caveats limit the ability to make detailed conclusions, the PCEVB was effective in identifying and highlighting discrepancies in perception and opinion among stakeholders. These discrepancies can serve as focal points for further detailed evaluation and review in the development of the Blueprint.

Overall, the Project Team identified two primary themes that stemmed from the analysis of the results: 1) Establishing better baseline information and 2) Facilitating communication channels among stakeholders.

4.1 Establishing Better Baseline Information

The PCEVB Questionnaire results clearly indicated that the information currently available to stakeholders is limited with respect to comprehensive evaluations of zero-emission technologies and impacts. This information bottleneck is not surprising since the Port is at the forefront of the zero-emission technological revolution. Specific areas of focus include:

- **Operational Impacts**: Developing a comprehensive and detailed understanding about the operational parameters that will be impacted by the zero-emission transition will help create an actionable pathway to addressing the barriers identified by various stakeholder groups. This information will be valuable to the development of master plans around the zero-emission transition.
- **Workforce Impacts**: Developing a comprehensive and detailed understanding of the workforce needs will solidify an understanding of the need for additional resources and help create an actionable pathway to addressing these needs.
- **Duty and Drive Cycle Information**: Technology is designed and developed around specific operations and performance goals and objectives. Working with a variety of stakeholders and facilitating real-time data collection on existing equipment to identify the information that needs to be gathered and aggregated to ensure that technology is designed specifically for the Port Community will be important to creating measurable technology targets.
- **Leverage Existing Demonstration Projects**: With new technology, it is expected that there will be limited data available on long-term operations and maintenance of new technology and equipment. Across the state, nation, and world, numerous zero-emission demonstration projects are being conducted to help develop the necessary information to expand the knowledge and scientific frontier. These data are dispersed and are not necessarily accessible to all stakeholders. Working to create an accessible library of information relevant to the Port Community will reduce the "costs" associated with information sharing. The Port is already working with a number of entities to help gather this information. The PCEVB can serve as an aggregating hub of information for stakeholders.

4.2 Facilitating Communication Channels

Open dialogue and communication among stakeholders will be one of the most powerful and important tools to advance zero-emission transition efforts at the Port. The results of the PCEVB Questionnaire suggest the need for the continued development of information and knowledge exchange channels among stakeholders. A selection of communications that could be further developed includes:

- **Technology Developers—Regulatory Agencies/Financing Groups**: Differing perceptions of "commercially-available" technology create an environment where expectations differ between funders and sellers of technology. These different expectations can lead to frustrations that hinder technology progression and evolution. Right-sizing expectations is important to successful collaboration. Developing a common understanding of the steps between technology ideation and commercialization specific to Port equipment will help facilitate information sharing and protect against miscommunication.
- **Technology Providers (Equipment, Vehicles, Charging, and Refueling)—Terminal Operators and Trucking Companies**: Particularly in California, the zero-emission technology ecosystem is constantly changing, with new participants, technologies, and strategies. The Port can serve as a convener of these stakeholders, connecting buyers to sellers on a regular basis that allows the terminal operators and trucking companies to easily keep up-to-date with the latest and greatest technologies and companies.
- **Financing Groups—Terminal Operators and Trucking Companies**: The PCEVB Questionnaire results indicated an interest in new and novel financing opportunities to help with the transition to zero-emission technologies. Third-party groups can play an important role by assuming risk that may be too significant for a terminal operator, trucking company, or the Port to underwrite, as it is not the core competency of these Port organizations. Convening these stakeholder entities will be valuable in developing business models that will work for the Port Community participants.
- **Communication to Community-Based Organizations and Environmental Justice Groups**: The zero-emission transition is broadly in alignment with many CBOs and EJ organizations. However, close engagement with these organizations will help secure local support for Blueprint activities and ensure that the benefits from the zero-emission transition are realized locally. Additionally, many of these groups engage with other port communities around the country. To the extent CBOs and EJ groups can help leverage the PCEVB findings in other communities, it could increase the deployment of zero-emissions equipment nationwide, the minimizing real or perceived adverse impacts on POLB operators. Additionally, a larger zero-emission equipment market should lead to better prices and a more sustainable business model.
- **Broad Stakeholder Participation**: On top of specific communication channels, regular communication among broad audiences is valuable in ensuring that all voices are heard and assist with regular vetting of overall progress. The Port has done an excellent job with this type of engagement through the CAAP. Outreach models developed through the CAAP process may be appropriate for adoptions or integration into the PCEVB effort.

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Appendix C: Port Community Uncertainty Assessment Report

PCEVB Uncertainty Assessment Report

1 Introduction

The Port of Long Beach is initiating the Port Community Electric Vehicle Blueprint (PCEVB) to establish a comprehensive strategy to assist in the identification of the most cost-effective technologies, financial incentives, and infrastructure upgrades for creating the model sustainable, zero-emission port ecosystem of the 21st century. The PCEVB is designed to accelerate the deployment of electrified transportation at local and regional levels with a holistic and futuristic view of regional transportation planning. The PCEVB uncertainty assessment activities, as summarized in this Report, are designed to solicit input from relevant stakeholders to understand policy-level uncertainty based on the traditional risk assessment methodology. The PCEVB Uncertainty Assessment Report builds upon foundational information aggregated and presented in the PCEVB Research Report, PCEVB Engagement Report and the 2014 Risk Assessment Manual.

2 Methodology for Assessing Uncertainty

To understand the challenges and opportunities ahead, the Port conducted a qualitative and quantitative assessment modeled after traditional risk assessment. Risk assessment is the systematic process of planning for, identifying, analyzing, responding to, mitigating, and monitoring project risks. Risk assessments are most effective when performed early in the life of the project and throughout the project's life cycle.

The Port uses a holistic approach assess risk for major construction and development projects in order to identify potential positive and negative impacts on budget, schedule, scope, and stakeholder acceptance as described in the Port's Risk Assessment Manual (2014).[1] The Port's risk assessment approach, which is well integrated into our design and construction process, will be used for specific zero-emission-related infrastructure projects when the time comes. But this process can also be useful

[1] Available for download at: http://www.polb.com/civica/filebank/blobdload.asp?BlobID=14377

for identifying the high-level programmatic challenges and opportunities associated with zero emissions. To that end, the Port adapted and adopted the engineering risk assessment framework to evaluate the challenges and opportunities inherent in the zero-emissions transition, allowing the Port to predict and manage uncertainty.

The uncertainty is categorized upon a scale of likelihood (Table 1) and impact (Table 2). Likelihood measures the chance of event occurrence. Impact measures the gravity of the impact across six categories: Safety and Health, Environment, Financial, Schedule, Reputation, and Operational/Business Impact.

Table 1: Uncertainty Assessment Likelihood Table

Likelihood Category				
A	**B**	**C**	**D**	**E**
The event is very likely to occur (95% chance of occurring)	The event is likely to occur (80% chance of occurring)	The event has occurred on a similar project (50% chance of occurring)	Given current practices and procedures, this even is unlikely to occur (20% chance of occurring)	Highly unlikely to occur (5% chance of occurring)

Table 2: Uncertainty Assessment Category Table

Impact				
1 – Insignificant	**2 – Minor**	**3 – Moderate**	**4 – Major**	**5 – Highly Significant**
No impact or minimal impact	Localized, short term, impact duration in the scale of months	Localized, long-term impacts, lasting a year	Localized, long-term impacts, lastly multiple years or long-term regional impact lasting a year	Long term regional impact, lastly multiple years

The complete sequence of risk management protocols includes a four-step process, which is described in the Port Risk Assessment Manual and modified for the Blueprint in order to gauge uncertainty and to assess challenges and opportunities ahead:

1. **Uncertainty Identification**: This step includes the identification of uncertainty through a collaborative stakeholder process, description of the uncertainty, and evaluation of potential consequences.

2. **Rating the Uncertainty**: This step evaluates and ranks the uncertainty based on the consequence and likelihood for the uncertainty.

3. **Response**: Develop an action plan. For ***barriers or challenges***, action strategies include:
    a. Avoid/Eliminate: Change something to avoid or eliminate the barrier, such as by clarifying requirements, obtaining information, improving communication or acquiring expertise.
    b. Transfer/Share: This requires assigning the solution to the appropriate party, that is, the party with the greatest ability to mitigate the negative impacts.

c. Reduce the Likelihood (Mitigate): Reduce the likelihood of a barrier to an acceptable threshold. Taking early action to mitigate the event is better than trying to repair or deal with the element after the fact.
d. Reduce the Consequence (Mitigate): Reduce the consequence of a barrier to an acceptable threshold.
e. Reduce the Likelihood and Consequence (Mitigate): Reduce the likelihood and consequence of a barrier to an acceptable threshold.
f. Accept: There are barriers and challenges that may occur, regardless of what is done to avoid or mitigate them.

For ***opportunities***, action strategies include:

a. Accept: This is for opportunities where the Port may be the primary beneficiary.
b. Share: Sharing means apportioning the opportunity between the Port and another party who is best able to capture the benefit, for example, by the Port forming partnerships or securing incentive funds on behalf of its terminal operators.
c. Enhance: This strategy modifies the impact of an opportunity by increasing the probability and/or positive impacts and identifying and maximizing key drivers. This might include seeking to facilitate or strengthen the cause to increase the probability that the opportunity will occur.

4. **Uncertainty Plan**: A plan to address the challenges and opportunities will be developed and a point person identified to monitoring progress.

3 Uncertainty Assessment

3.1 PCEVB Uncertainty Questionnaire

The PCEVB Uncertainty Questionnaire was developed to attempt to understand many factors impacting the transition to zero-emission operations. Using results of an activity from the October stakeholder workshop, the Port identified the most significant areas of concern for the zero-emissions transition. From this list, a selection of prompts was assembled and participants were asked to rate the likelihood and impact of each statement based on the following scales:

Likelihood:

A – The event is very likely to occur (95% chance of occurring)
B – The event is likely to occur (80% chance of occurring)
C – The event has occurred on a similar project (50% chance of occurring)
D – Given current practices and procedures, this even is unlikely to occur (20% chance of occurring)
E – Highly unlikely to occur (5% chance of occurring)

Impact:

1 – Insignificant: No impact or minimal impact
2 – Minor: Localized, short term, impact duration in the scale of months
3 – Moderate: Localized, long-term impacts, lasting a year

4 – Major: Localized, long-term impacts, lastly multiple years or long-term regional impact lasting a year
5 – Highly Significant: Long-term regional impact, lastly multiple years

The prompts were:

1. Warranties for zero-emission equipment adequately protect the purchaser/lessor.
2. The adoption of zero-emission equipment results in increased insurance costs due to the higher cost of electric equipment, limited qualified maintenance facilities, and general unfamiliarity by insurance providers.
3. The upfront cost of purchasing/leasing zero-emission equipment is significantly more than traditional equipment.
4. Long-term operational costs of zero-emission vehicles are uncertain, including charging/refueling infrastructure and maintenance.
5. Non-traditional financing (e.g., third party investors, energy-as-a-service) of zero-emission equipment assigns rights to financing parties other than the owner/operator.
6. Purchasers find that their revenue increases after adoption of zero-emission equipment.
7. Purchasers find that their costs increase after adoption of zero-emission equipment.
8. Terminal operators must engage in/adapt to significant operational changes to achieve zero-emission cargo handling equipment goals (e.g., yard reconfiguration, moving piers).
9. 100% zero-emission cargo handling equipment is deployed successfully by 2030.
10. 100% zero-emission cargo handling equipment cannot be deployed successfully by 2030.
11. Adoption of zero-emission cargo handling equipment reduces the flexibility of your operation to make changes.
12. Existing infrastructure does not support zero-emission vehicles.
13. Adoption of zero-emission cargo handling equipment and infrastructure across terminals is inconsistent.
14. The lack of noise produced by electric equipment leads to an increased likelihood of collisions/accidents.
15. Adoption of zero-emission technology improves air quality and public health.
16. Adoption of zero-emission technology creates increased job opportunities in the local area to service the new technology.
17. There are enough qualified personnel for the operation and maintenance of zero-emission equipment.
18. Adoption of zero-emission cargo handling equipment requires education and retraining of current employees.
19. Zero-emissions equipment is unlikely to cause operational disruption.
20. Zero-emissions equipment is vulnerable to cyber-attack.

Participants were given the option to provide written commentary as well, supporting their selection.

3.2 Target Stakeholders

A target list of stakeholders was developed to span a variety of industries and jurisdictions associated with the transition to zero-emission technologies:

Technology Developers

- BYD
- Cavotec
- Conductix Wampfler
- Dannar
- EDI (Now Cummins)
- GE Transportation
- Lightning Systems
- Nikola
- Plug Power
- Siemens
- Thermo King
- Thor
- TransPower
- Unique Electric Solutions
- US Hybrid

Original Equipment Manufacturers (OEMs)

- Capacity
- Hyster
- Kalmar
- Kenworth
- Nordco
- Peterbilt
- Taylor Machine Works
- Tesla
- Toyota
- Volvo
- Wiggins
- ZPMC

Utilities

- Southern California Edison

Marine Terminal Operators and Tenants

- International Transportation Services (ITS)
- Long Beach Container Terminal (LBCT)
- Pacific Merchant Shipping Association (PMSA)
- SSA Marine
- Total Terminals International (TTI)

Trucking and Warehouse Associations and Owners

- Harbor Trucking Association/Pear Strategies
- Additional stakeholder information will be utilized from a survey conducted in September 2018 by Tetra Tech, Port of Long Beach, and Port of Los Angeles, which was sent to the entire Port Drayage Truck group.

EV Charging Station Manufacturers, Distributers, and Operators

- ABB
- BTCPower
- ChargePoint
- CharIN
- Clipper Creek
- EVgo
- Efacec
- eMotorWerks
- Freewire
- Greenlots
- innogy
- Schneider Electric
- Siemens
- Tritium
- Wave IPT

Hydrogen Fueling Station Manufacturers and Distributors

- Air Liquide
- Air Products
- California Fuel Cell Partnership
- Linde
- NEL Hydrogen
- ITM Power
- Shell
- Stratos Fuel

Labor and Workforce Development

- International Brotherhood of Electrical Workers (IBEW)
- International Longshore Workers Union (ILWU)
- Pacific Maritime Association (PMA)
- Center for International Trade and Transportation

Community-Based Organizations and Environmental Justice Organizations

- East Yard Communities for Environmental Justice
- Earthjustice
- Natural Resources Defense Council
- Coalition for Clean Air

Regulatory Agencies

- South Coast Air Quality Management District
- California Air Resources Board
- California Energy Commission
- California Public Utilities Commission
- US Environmental Protection Agency

Public and Private Funding Authorities

- Amply
- California Pollution Control Financing Authority
- California State Treasurer's Office
- CALSTART
- Crossroads Financial
- Generate Capital
- Hydrogen Partners

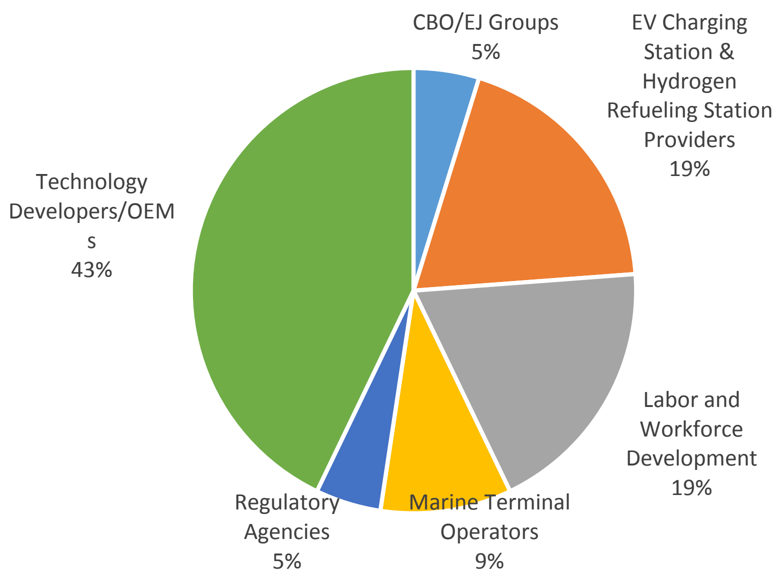
3.3 PCEVB Uncertainty Questionnaire Results

3.3.1 Participants

20 unique responses were collected from six different organization types, including:

- Technology Developers/OEMs
- Marine Terminal Operators
- EV Charging Station & Hydrogen Refueling Station Providers
- Regulatory Agencies
- Labor and Workforce Development
- Community-Based Organizations (CBO)/Environmental Justice (EJ) Groups

Figure 1: Questionnaire Stakeholder Representation

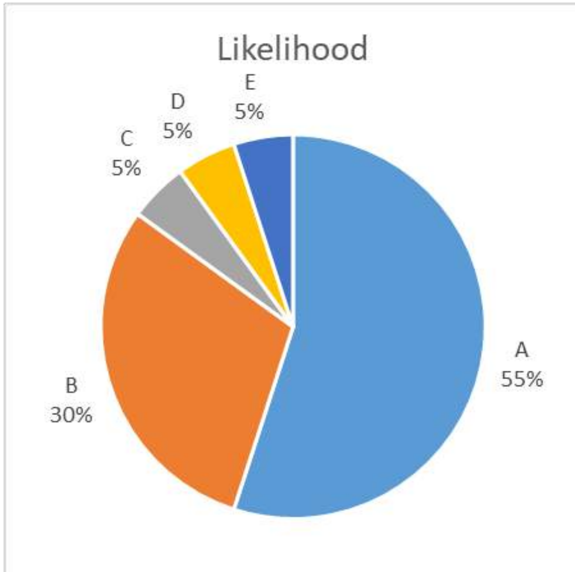


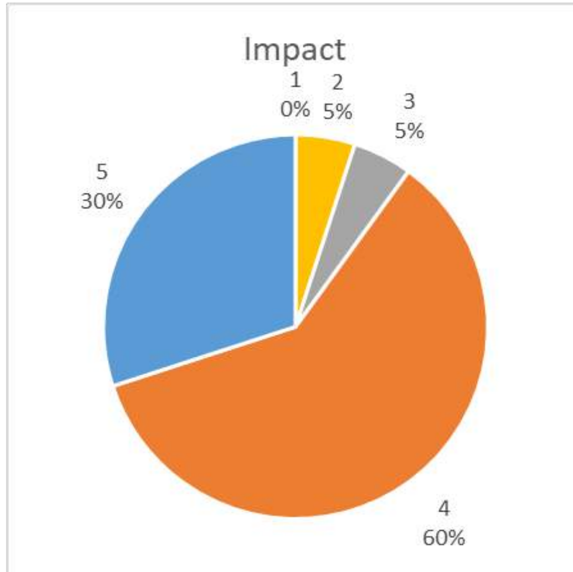
With so few participants, the data gathered offer limited insights that do not meet the bar of statistical significance. These findings were used to focus discussion at subsequent stakeholder meetings.

3.3.2 Question 1

Prompt: Warranties for zero-emission equipment adequately protect the purchaser/lessor.

Results:





Comments:

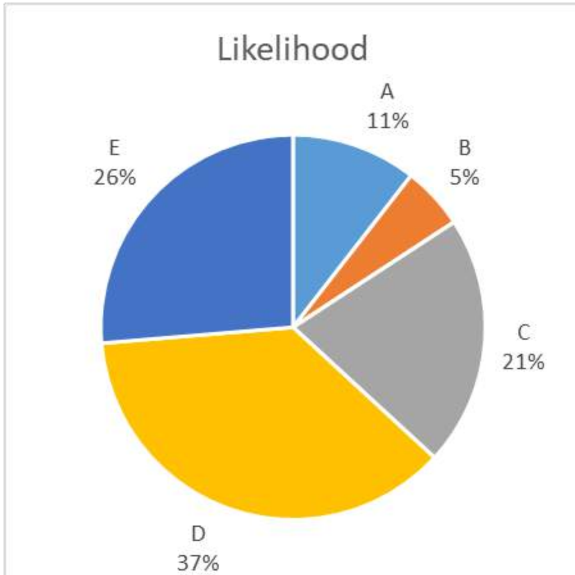
- Very little operating data on hardware Performance & Reliability
- The warranties are no stronger than the company providing. It is important to see company financials, years in business, etc.
- Warranty work for up to three years is an exception to Longshore jurisdiction
- This item is critically dependent on warranty terms.
- A lack of confidence in electric products will slow the acceptance of the product. Strong warranties by prominent OEMs will speed up the adoption. But the OEMs must prove out the equipment to the duty cycles before risking high numbers of units that might not work to the end user expectation. Expectations must be managed initially.
- Currently uncertainty about batteries lifetime need to be solved, currently lack of historic data of lifetime etc.
- Once such products are sold in production quantities, the market will expect warranty coverage on BEVs and FCEVs similar to today's diesel trucks.
- We have a standard 2 year/4,000-hour full machine coverage warranty on all our equipment, including the EV offering.
- A similar topic is being discussed at CARB and is also part of incentive programs such as HVIP.
- Warranties exist for eight years on battery packs where degradation has been limited with level II charging. The exposure is low for end-users as technology and costs continue to move rapidly in a positive direction.

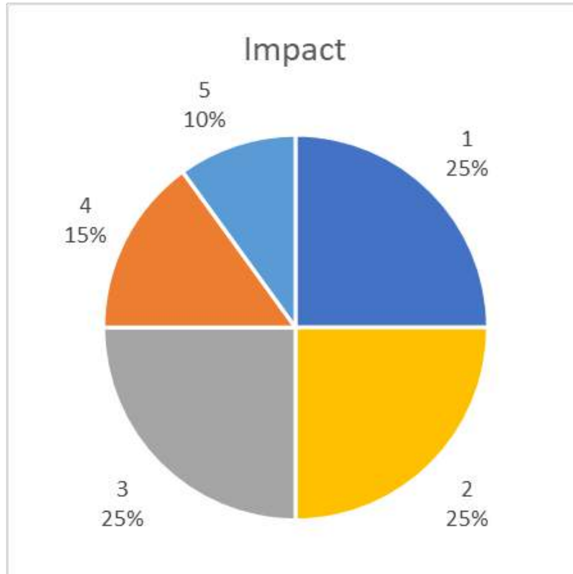
Takeaways: 85% of participants indicated that they believe that warranties will adequately protect the purchaser/lessor of zero-emission equipment and that this would be highly impactful. These results suggest that port stakeholders are not particularly concerned about equipment warranties.

3.3.3 Question 2

Prompt: The adoption of zero-emission equipment results in increased insurance costs due to the higher cost of electric equipment, limited qualified maintenance facilities, and general unfamiliarity by insurance providers.

Results:





Comments:

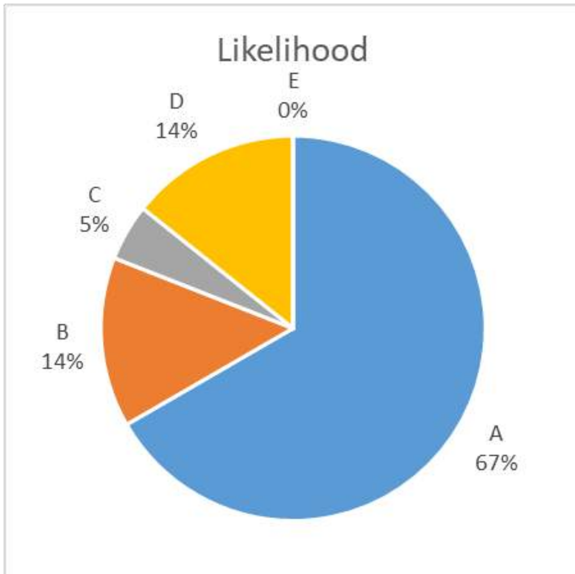
- These technologies are growing rapidly. The support infrastructure is growing as well.
- As costs drop, insurance costs may also drop. In addition, insurance is dependent on a multitude of factors including end user, location, vehicle type, fleets insurance policies.
- I don't see why insurance rates need to increase.
- A timing issue waiting for more statistics from operations to validate risks
- BEV and FCEV trucks will be considerably more costly to purchase than diesel for approx. 10 years. This will drive up insurance costs during that period.
- Insurance costs have not risen much for fleets already deploying such equipment. The cost curve is dropping over time.
- Electric forklifts need less maintenance than diesel forklifts.

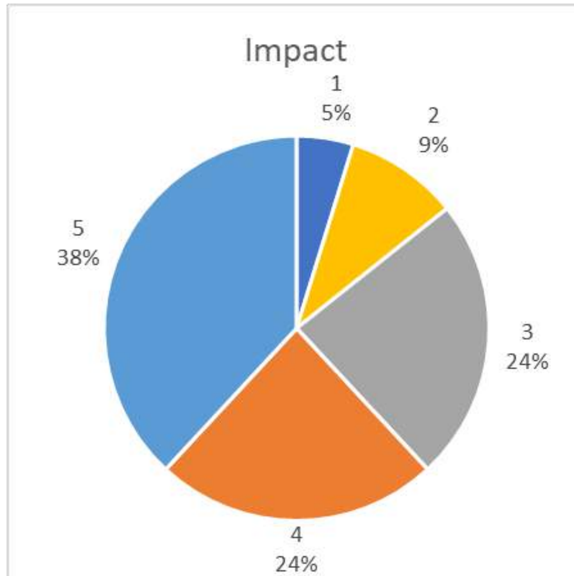
Takeaways: The majority of the respondents (63%) believe there is less than a 20% chance of increased insurance costs with 50% of respondents identifying these costs as insignificant or minor impacts.

3.3.4 Question 3

Prompt: The upfront cost of purchasing/leasing zero-emission equipment is significantly more than traditional equipment.

Results:

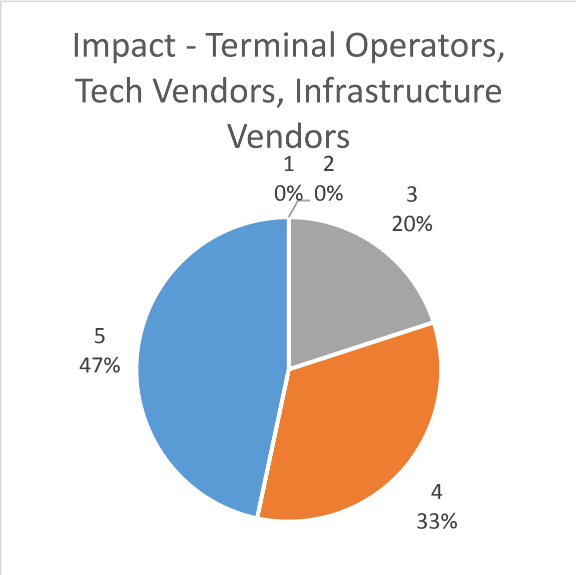


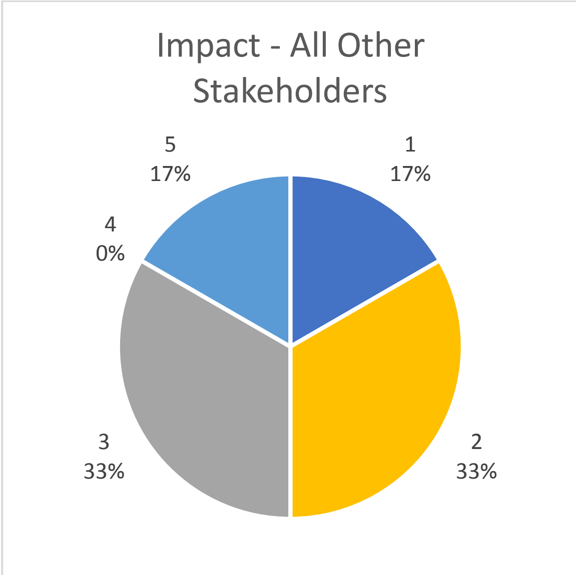


Comments:

- Higher upfront cost but much lower ongoing costs
- Over the lifespan these technologies are often cheaper
- Although costs are higher, operating costs are expected to be lower, pricing is expected to come down as battery prices come down, and some to most of cost difference can be mitigated by incentives/subsidies.
- Mandates (pushing diesel out of the ports) will force the conversion. Until battery prices drop significantly, infrastructure challenges are met and run-time issues well understood, conversion to electric will require incentives for most customers.
- Operational costs lower than conventional driveline. This may move to more of leasing or other business models. Total costs of ownership for many applications may be lower for zero-emission
- I do not expect BEV or FCEV trucks without subsidies to show positive ROI for the end-user for approx. 10 years.
- Lessor's residual position is less than traditional diesel-powered equipment.
- Current incentive programs help alleviate initial costs. Should be evaluated based on Total Cost of Ownership (fueling, maintenance etc.) which is reduced electric setting
- As the technology yields more operational data, the ROI on BEV is only improving. The savings on maintenance, fuel, OSHA requirements, environmental impacts are showing positive results. The predictability of operating costs is much better with BEV.
- Yes. This statement is true now, but with technology advancement. This will not be the case in 5 to 10 years.

Takeaways: The majority of stakeholders (81%) identified the an 80%+ likelihood that upfront costs will be greater than traditional equipment. The response regarding the impacts was more varied among respondents with 62% of respondents identifying the top to most impactful categories. A dichotomy arose between terminal operators, technology developers and charging station manufacturers and all other groups. The first group identified the impact of the upfront costs to have long-term multi-year impacts while the remaining stakeholders (CBO/EJ, Labor, Regulatory Agencies) selected the greatest two impact categories 17% of the time.



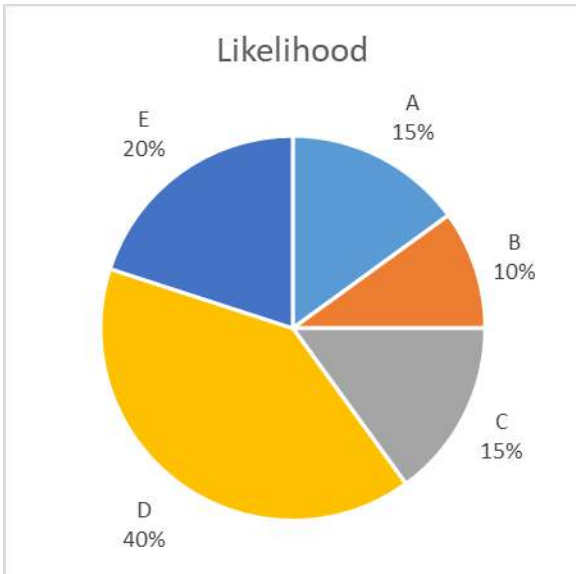


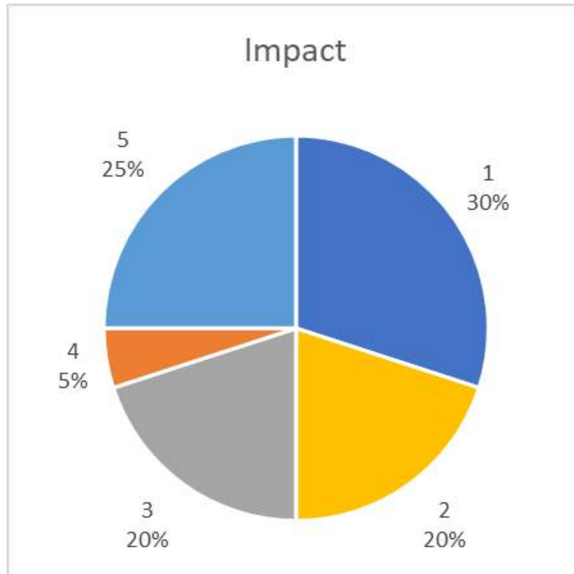
This response may suggest a discrepancy between stakeholders with respect to commercialization timelines and the ability for costs to come down to meet those of traditional technologies. This observation is generally supported by the comments which vary significantly, from expectations that existing technology with existing incentives is commercially competitive now to expectations that zero-emission technologies will not be cost competitive with traditional equipment for 10 years.

3.3.5 Question 4

Prompt: Long-term operational costs of zero-emission vehicles are uncertain, including charging/refueling infrastructure and maintenance.

Results:





Comments:

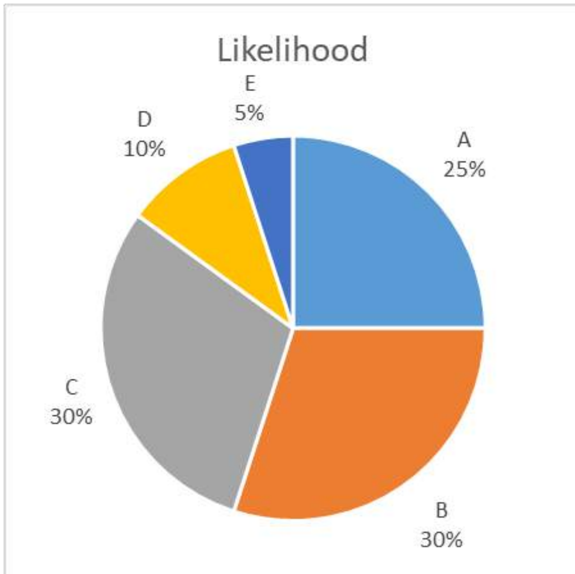
- Uncertain yes, but ultimately lower cost
- maintenance costs will decrease significantly
- EV Charging is becoming ubiquitous. The Maintenance people are in place.
- Grant tests and demonstrations are key to overcoming this concern.
- With IOUs focusing on fleet electrification, new TOU rates are being calibrated to reduce fueling costs and charging infrastructure installation funding and support is also being provided over the next 3-5 years.
- Life of batteries, and replacement costs, could be significant factors. If overall product life is driven by the battery life, then there will be problems.
- In general, lower but there might be a learning curve for both operations and for new type of equipment. Technical maturity of the new solutions is high as most functionality is based on known technology in new applications
- Absolutely the costs are uncertain at this point, since there is no widespread infrastructure for these vehicles. But we need to find a way to build that infrastructure in order for these vehicles to be broadly accepted by the end users, and costs will become better known as the infrastructure develops.
- Over the life of the product the operating costs and maintenance costs are expected to be lower than traditional diesel-powered equipment.
- Maintenance will likely be lower based on current ZEV experience with LD EVs; Charging will depend on use case and can often happen on-site
- Zero emission operational costs are very easy to calculate. It’s not uncertain.

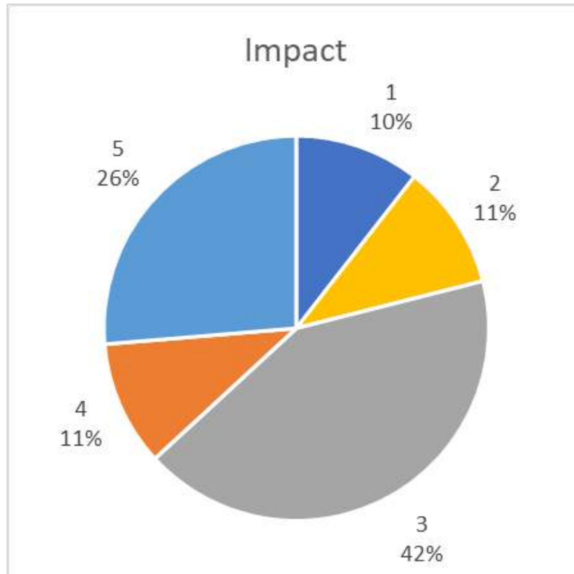
Takeaways: Overall, stakeholders were not concerned about long-term uncertainty of operating costs. Notably, the stakeholder group is predominantly technology vendors of equipment and infrastructure, suggesting greater certainty within this stakeholder population. Terminal operators were more likely to see uncertainty in operational costs and a greater likelihood and impact. More data sharing and collaboration about operational costs and expectations could advance the industry, particularly if structures could be arranged to provide certainty to the terminal operators who see greater risk than the technology providers.

3.3.6 Question 5

Prompt: Non-traditional financing (e.g., third party investors, energy-as-a-service) of zero-emission equipment assigns rights to financing parties other than the owner/operator.

Results:





Comments:

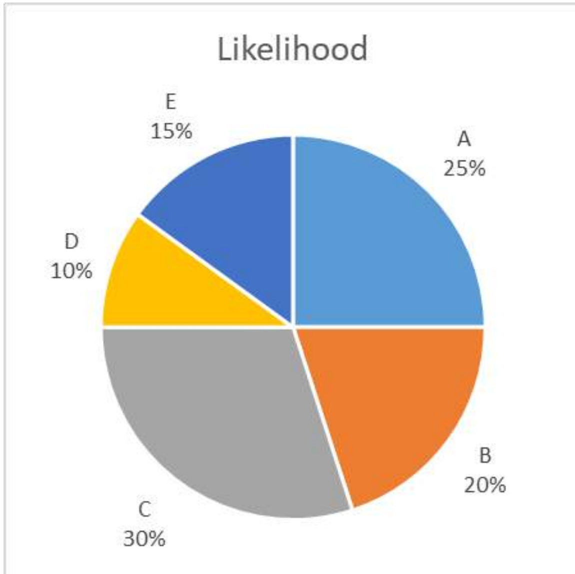
- Only way to scale up the industry
- This model will drive adoption more quickly
- This could be a positive that provides certainty to operators while not necessarily requiring them to be responsible for upfront costs and related requirements for new infrastructure.
- The secondary market for these vehicles is unknown today, and since resale value is a significant portion of Total Cost of Ownership, some of this risk will need to be borne by others invested in the zero-emission goals, at least for some time.
- BEV buyers are already using finance partners and new opportunities are opening up with utilities and second-life batteries industries that are designing lease agreements for batteries removing risk from fleet operators.
- that's not true.

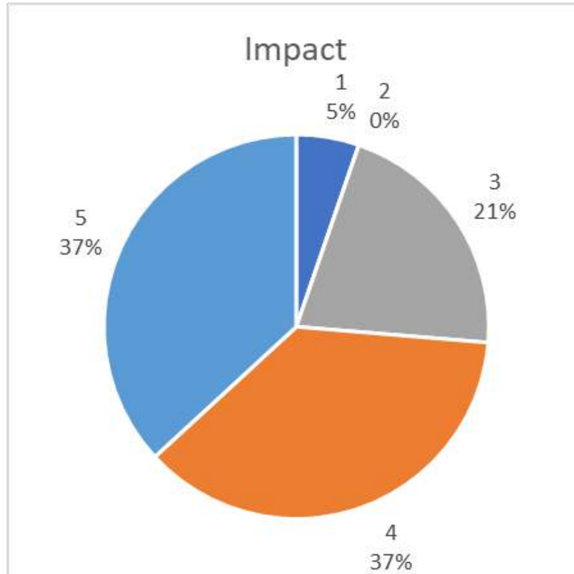
Takeaways: Few participants (15%) identified non-traditional financing as unlikely. Typically, non-traditional financing is used for early-adoption of (relatively) high risk technologies where the non-traditional financing company has an expertise in a sector that helps lower risk. For zero-emission vehicles and near-zero emission vehicles, this business model has developed around credit monetization and energy procurement expertise. One participant’s comment summarizes the potential value of non-traditional financing: “This could be a positive that provides certainty to operators while not necessarily requiring them to be responsible for upfront costs and related requirements for new infrastructure.” One of the challenges with non-traditional financing is that is has not been widely deployed in port setting. Building relationships between non-traditional finance companies and terminal operators, the Port, and trucking companies will be important to identifying if there is a market fit.

3.3.7 Question 6

Prompt: Purchasers find that their revenue increases after adoption of zero-emission equipment.

Results:





Comments:

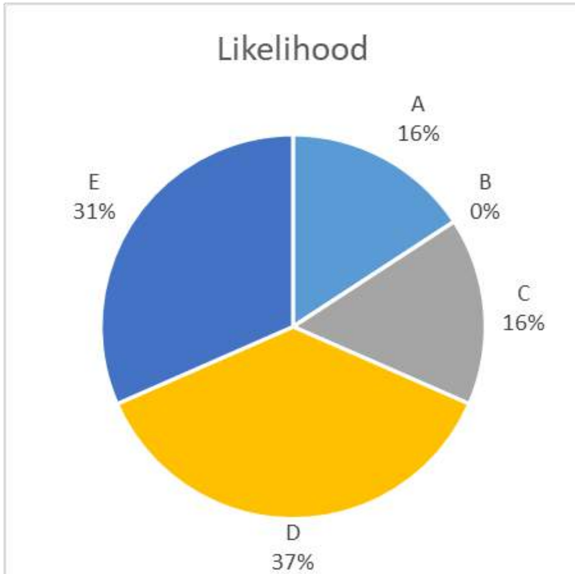
- This information is not generally available
- If reason for selecting zero-emission is regulations some competitions may be excluded
- The phrase above sounds like a carrot, versus the stick of not being able to use traditional diesel by 2030. Revenue may not increase, but if non-zero-emission fees are put in place, then the cost of operating a diesel will go up.
- BEV fleets can operate extended service times because they are quiet. Trash trucks and service vehicles can operate in non-traditional times increasing use and billable time.
- very easy to calculate your ROI

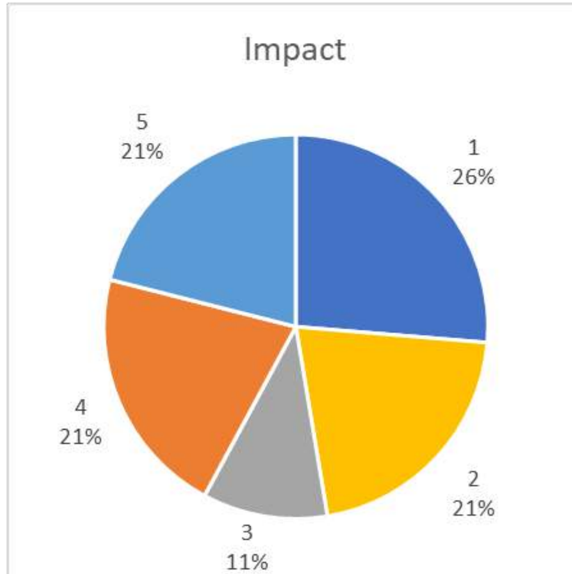
Takeaways: Nearly 40% of respondents indicated significant likelihood that revenues would increase after adoption of zero-emission technologies, however, nearly all respondents (74%) did not believe the impacts would be significant. One comment was particularly notable: “BEV fleets can operate extended service times because they are quiet. Trash trucks and service vehicles can operate in non-traditional times increasing use and billable time.” This lesson learned from outside the Port Community unfortunately may not be applicable to the Port Community where there are no time-of-day restrictions on terminal equipment and trucking companies have time-of-day restrictions based on traffic, not noise. As already identified in the Blueprint, additional revenues from the Low Carbon Fuel Standard may be realized, but these additional revenues are anticipated to be relatively small. The respondents generally supported the notion that increase revenues are expected to be insignificant and comments provided focused on cost impacts (continued in Question 7).

3.3.8 Question 7

Prompt: Purchasers find that their costs increase after adoption of zero-emission equipment.

Results:





Comments:

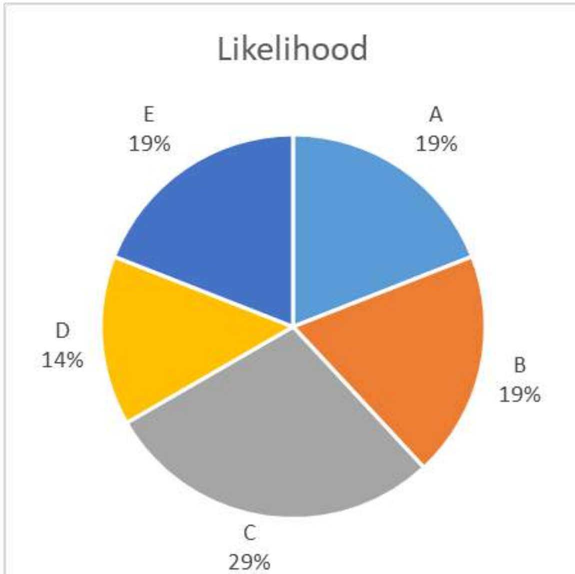
- Will be lower cost TCO
- This information is not generally available.
- At this moment grants in combination with regulations is important. On long term the cost will develop in a positive way. Life cycle cost will be lower when infrastructure is in place and solutions matured.
- We expect that the operation & maintenance costs of BEV and FCEV trucks will be lower than today's (and tomorrow's) diesel trucks with aftertreatment - perhaps not in the infant stages, but rather in the long term.
- Current data is showing dramatic decreases in operating costs. Also, capital requirements are reducing as the components of BEV last longer with much less maintenance.

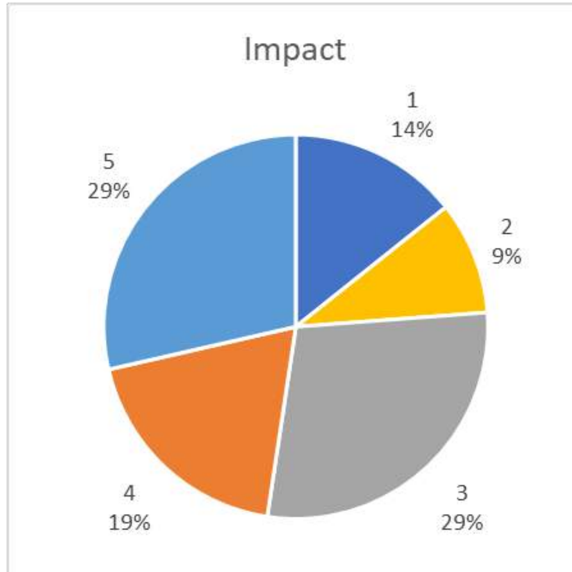
Takeaways: The majority of respondents (68%) believe that the likelihood of cost increases is low (less than 20%). The comments submitted support the idea that costs are expected to decrease relative to traditional equipment. Importantly, terminal operators responded disproportionately with a high likelihood, diverging from the general stakeholder perception. Combining this information with the capital cost information in Question 6, there is a need to further develop information around the financial impacts of zero-emission equipment.

3.3.9 Question 8

Prompt: Terminal operators must engage in/adapt to significant operational changes to achieve zero-emission cargo handling equipment goals (e.g., yard reconfiguration, moving piers).

Results:





Comments:

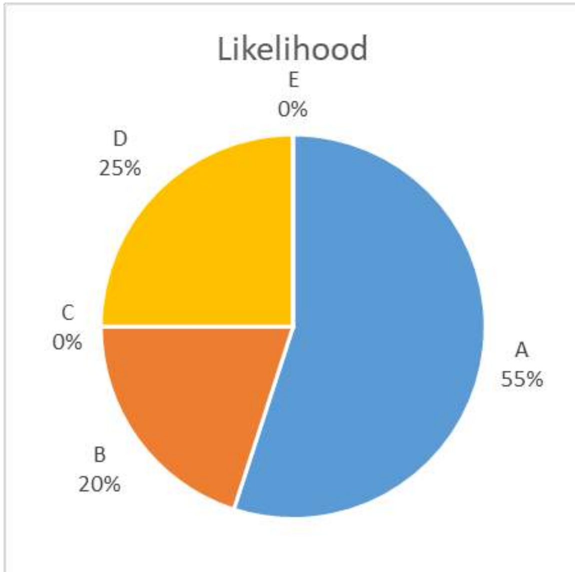
- Automation will lower cost for everyone
- I don't think operators will be required to move equipment, but will rather use this as an opportunity to optimize placement
- EV footprint for charging is massive
- Costs plus the downtime for construction
- Some adaptation could be necessary based on charging layout/space needs.
- We expect that BEV and FCEV trucks should operate virtually identically to today's diesel trucks (except that they will be quieter & cleaner). Note: This response is from the drayage truck perspective, not in-port container handling equipment, with which I have little experience.
- The need for operational re-configuration will likely be localized and not all facilities would require a change of procedure.
- Depends on the type of cargo equipment and what's needed to support it (trucks vs. forklifts vs other items; power capacity available for charging and location etc.)
- BEV vehicles look and largely operate the same as existing fossil fuel vehicles. As range increases, much of the charging scheduling will become a non-issue moving forward.
- The equipment controls do not change, just the power source.

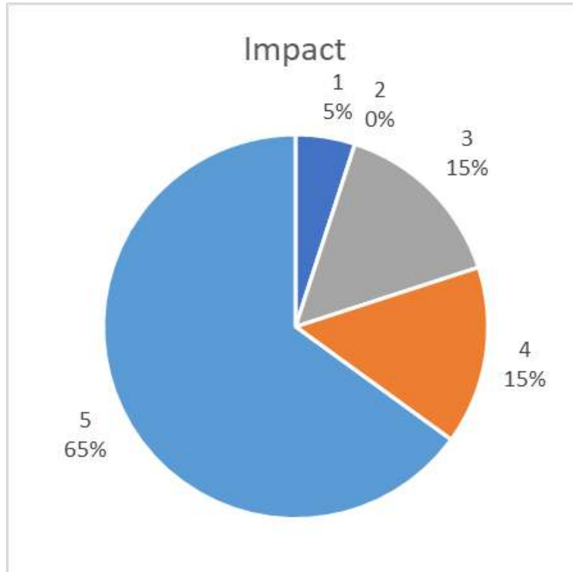
Takeaways: There was a significant diversity of opinions regarding the likelihood of significant operational changes. This confirms and supports data collected in the PCEVB Engagement Report. The respondents identified that if significant operational changes were required that the impacts would be moderate to highly significant (77%). Terminal operators and regulatory agencies were more likely to identify a high likelihood of significant operational changes while technology vendors and other stakeholders were more likely to select low likelihood of changes. This finding highlights the need for further information sharing about the impacts of zero-emission technology adoption so that stakeholder more uniformly agree on the likelihood of significant operation changes. Comments reflect the diversity of thought among stakeholders.

3.3.10 Question 9

Prompt: 100% zero-emission cargo handling equipment is deployed successfully by 2030.

Results:





Comments:

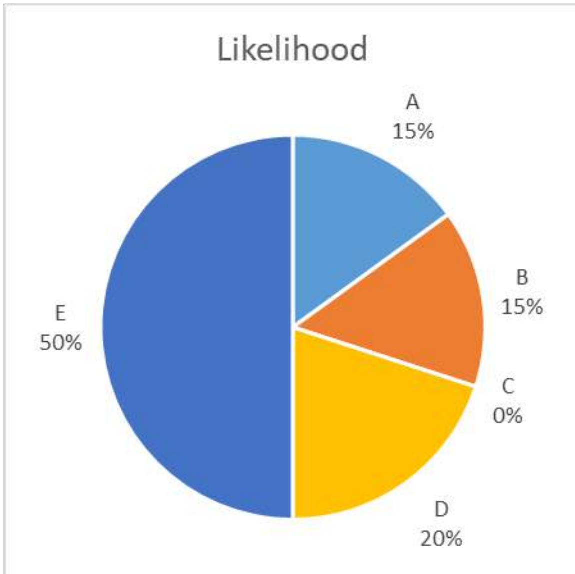
- Let's get it done!
- Very expensive start-up costs, labor resistance and unproven technology
- Reduce costs of equipment and charger, increase battery life, find a cheap above ground automated battery charging system that can charge various vehicle types
- It might happen this soon in California, but unlikely to happen this soon in the rest of US.
- Solutions are available earlier, but we expect a significant cost decrease of equipment when volumes increase. Also replacing or rebuilding current fleets may take time
- With proper incentives through the first 10 years, this can be accomplished.
- BEV is not experimental or in need of a pilot program. It is fully implemented and ready for deployment. Lion Electric has launched a class8 truck that would be ideal for cargo handling and distribution. 200-mile single charge range... (15 minutes) swappable batteries to accommodate longer range.
- The state needs to do more to subsidies the high cost of the zero emissions equipment.

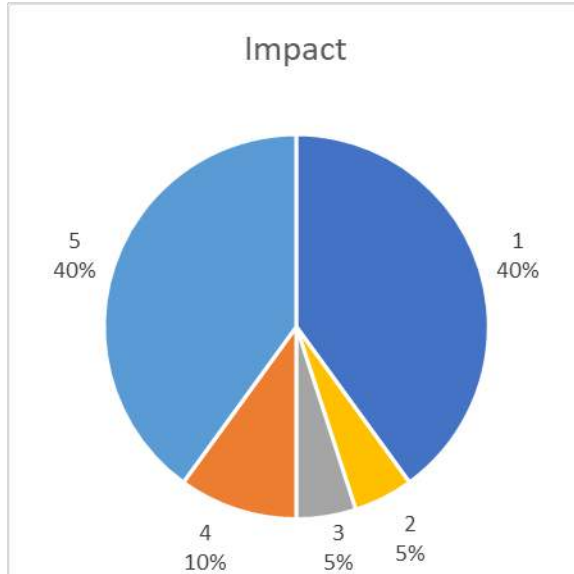
Takeaways: The majority (75%) of respondents believe that the Port can meet its 2030 goals for 100% zero-emission terminal equipment deployment by 2030 and that the impacts will be significant (positively based on the comments).

3.3.11 Question 10

Prompt: 100% zero-emission cargo handling equipment cannot be deployed successfully by 2030.

Results:





Comments:

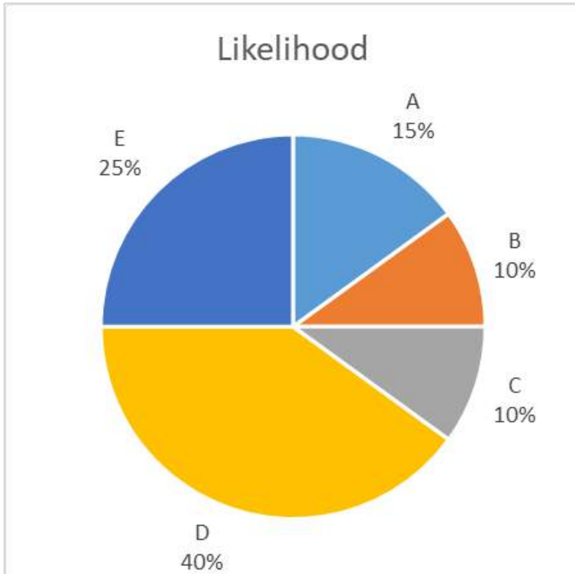
- Not the outcome we want
- With exception of the largest mobile equipment we already offer zero emission on the entire portfolio
- Again, appropriate subsidies for a period of time will be necessary to reach the goal.
- It can be deployed sooner than that with current grants provided by CARB and DERA.

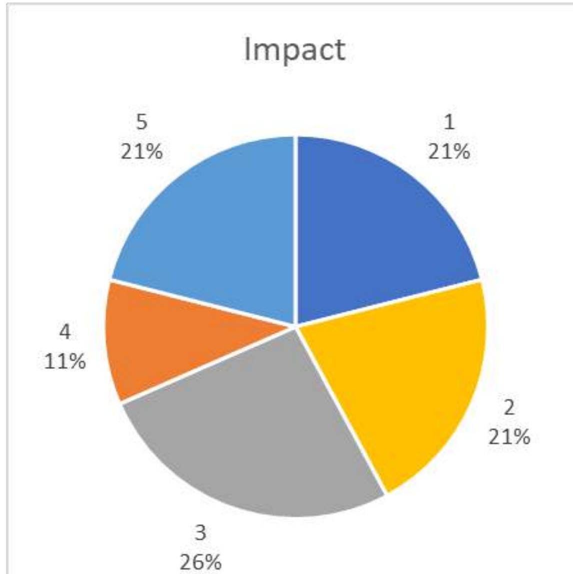
Takeaways: Question 10 is a converse prompt of Question 9. Respondents had similar reactions with the majority of respondents (70%) indicating a low likelihood of missing the 2030 goals. There was a much larger divergence of opinion about the impact of missing the goal.

3.3.12 Question 11

Prompt: Adoption of zero-emission cargo handling equipment reduces the flexibility of your operation to make changes.

Results:





Comments:

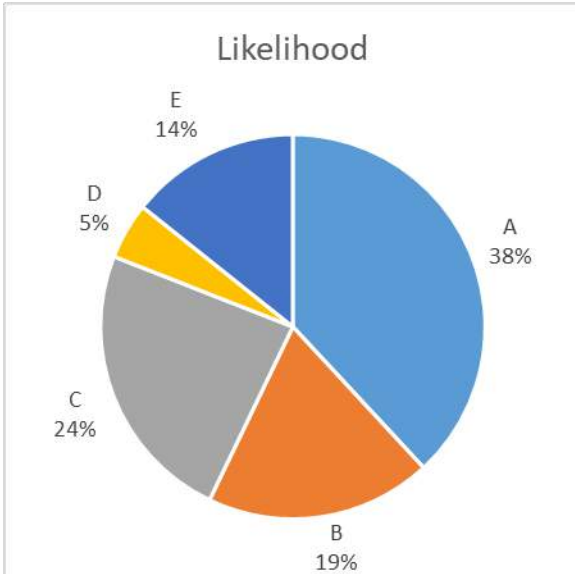
- will add flexibility / efficiency
- Near Zero Emission is not a "gap strategy". It delays the build out of necessary infrastructure. Many of these technologies are not as clean as purported to be and release harmful methane.
- No reduction in flexibility but optimal operation patterns might be different and some time needed for learning and optimization needed
- We will build trucks that meet emission requirements, whatever those requirements are. The open question is the cost of such trucks.

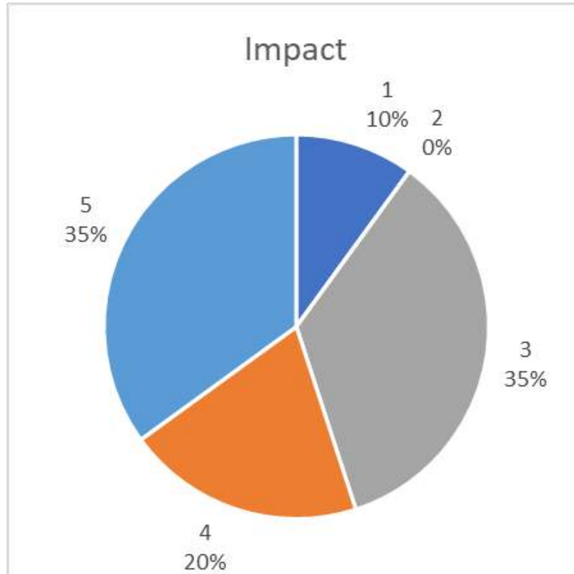
Takeaways: The majority of respondents (65%) do not believe there is a high likelihood of reduced operational flexibility. The responses to this prompt highlights discrepancies between terminal operators and labor versus other stakeholders. Terminal operators and labor identified proportionally higher likelihoods of reduced operational flexibility. It is hard to directly measure the impact of both real or perceived reduced flexibility and this divergent opinion may be a significant barrier to the adoption of zero-emission technologies.

3.3.13 Question 12

Prompt: Existing infrastructure does not support zero-emission vehicles.

Results:





Comments:

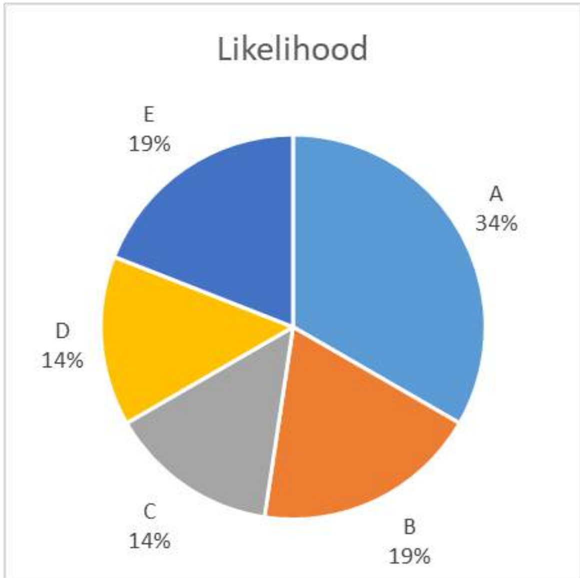
- The issue is related to grid capacity, not the availability of charging equipment
- I believe there will need to be infrastructure improvements. This will have a short-term cost and long-term benefit
- Infrastructure varies between electric plug in vs hydrogen fuel cell vs????
- This question is highly dependent on the specific circumstances at each site.
- Electrical infrastructure could take a long time to upgrade. Hydrogen fuel cells could mitigate this, but adds to up-front and operating cost.
- Rather different at different locations. If investments needed in grid system this will take time and need authority's attention
- Ubiquitous charging and H2 fueling infrastructure are imperative if ZEVs are to become the norm.
- Majority of existing facilities have the availability of electrical needs in their facilities, however most would need to have electrical drops and charging solutions installed in appropriate locations to support their EV needs.
- Very site dependent. Programs starting to focus on this and efforts to deploy infrastructure moving forward so this can change rapidly but does continue to remain as a barrier to ZEV adoption generally
- Infrastructure is necessary. There are costs involved, but will be offset by the decrease in need for fossil fueling infrastructure and the environmental requirements (and exposure) that accompanies combustion engine operation.

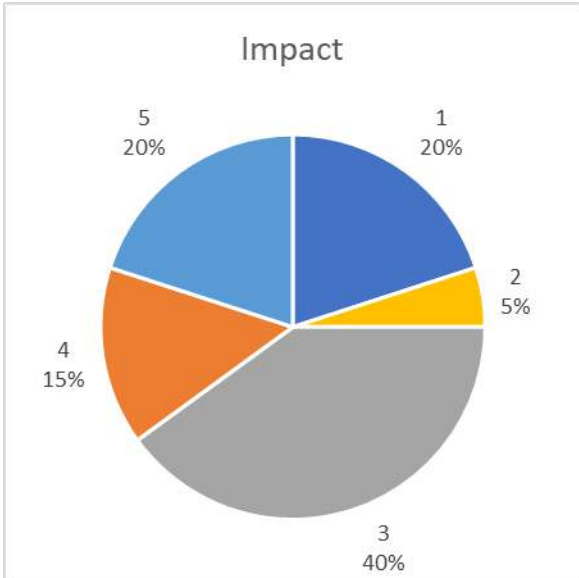
Takeaways: The majority of respondents identified high likelihood (57%) and high impact (55%) associated with insufficient existing infrastructure. As one of the more universally agreed upon concerns, the Blueprint must seek actions to meaningfully address infrastructure.

3.3.14 Question 13

Prompt: Adoption of zero-emission cargo handling equipment and infrastructure across terminals is inconsistent.

Results:





Comments:

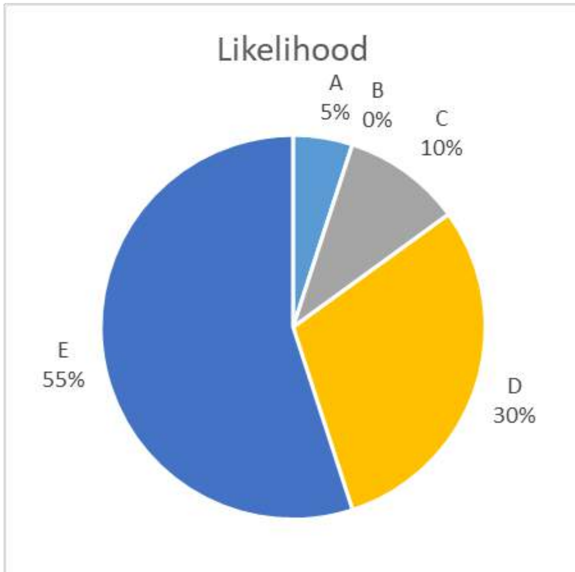
- We control this. It doesn't have to be.
- some terminals have power and some don't, some will use electric and some will use hydrogen fuel cell and others will use?????
- It is still too early to answer this question definitively.
- Investments is large so it might take some time but, in the end, this will be the standard solution
- POLB and POLA certainly appear to moving in this direction. Other ports on the west coast have not made similar announcements, nor have regional transshipment locations.
- The equipment largely looks and acts the same as existing platforms. Having BEV in one location doesn't affect other locations with less adoption

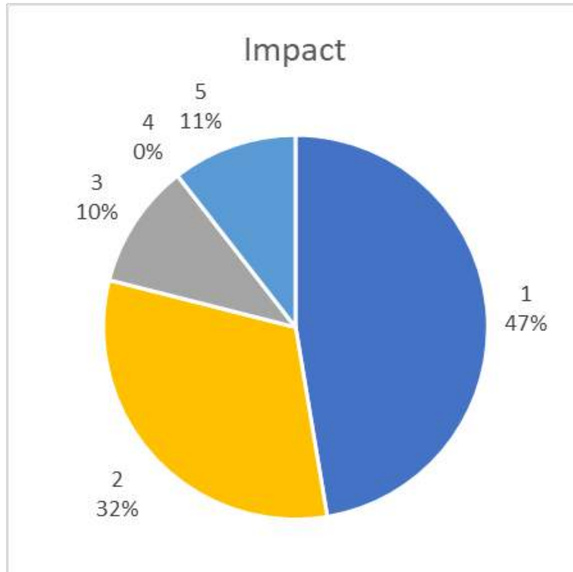
Takeaways: The majority (53%) of respondents identified a high likelihood that adoption of zero-emission technologies would be inconsistent across the Port with fewer respondents (35%) identifying this prompt as having significant impacts. The prompt has significantly more broad implications than infrastructure standards and the Port may need to further investigate the impacts associated with inconsistent adoption across stakeholders.

3.3.15 Question 14

Prompt: The lack of noise produced by electric equipment leads to an increased likelihood of collisions/accidents.

Results:





Comments:

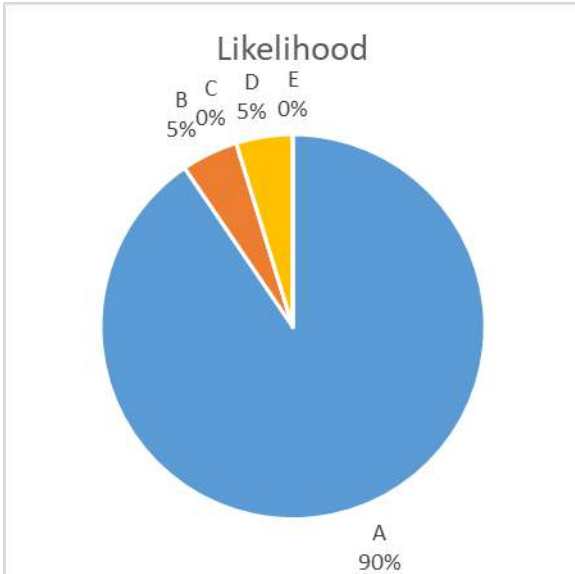
- Can easily add artificial noise
- Additional warning measures can be implemented.
- Can be easily addressed by simple sound generation or a more sophisticated anti-collision warning system, along with AGVs
- The pollutants being breathed daily are a much greater risk to health.
- Unknown.
- Electric trucks will need to have other warning devices. Safety is number 1, so all entities will ensure that there is no increased risk.
- If needed can be solved with various warning systems
- Ref FMVSS 141
- Other safety standards put in place to protect against this and does not seem a significant barrier that can't be overcome.
- There are training issues with safety and power utilization (as there are with any platform). Back up beepers and forward-facing audible devices already exist in the heavy-duty BEV world.
- Technology today on zero or near zero emission vehicles limit the chances of accidents from occurring.

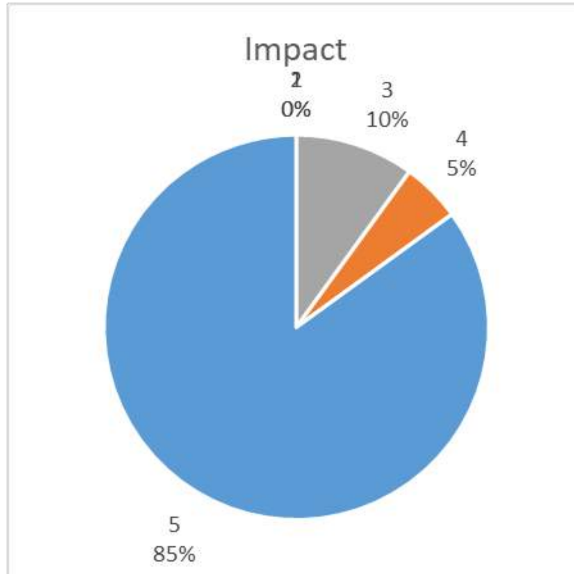
Takeaways: The respondents overwhelming believed that the likelihood of increased collisions/accidents by quieter zero-emission equipment was low (85%) with minimal impact (79%). Comments provided identified readily-available technical solutions to this potential risk.

3.3.16 Question 15

Prompt: Adoption of zero-emission technology improves air quality and public health.

Results:





Comments:

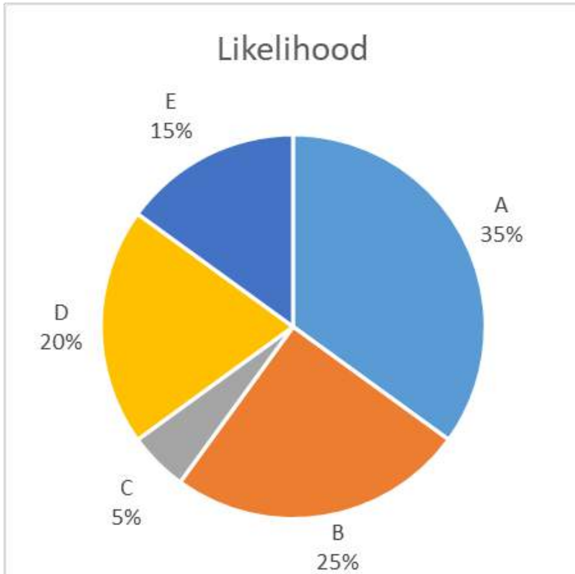
- HUGE reduction in pollution
- The impacts (illness, asthma, children missing school, and worse) of the dirty air along the 710 corridor are well documented
- Especially for the local communities already overburdened by air pollution.
- New engine technologies also bring benefits, so the comparison of ZEV should be made to Tier 4. Electric is not pollution-free. The emissions still occur, but somewhere else.
- Given the air quality targets that still haven't been attained, it is critical to work on zero emission technology today. Beneficial from a local and regional perspective.
- Air quality continues to be a problem in California and the heavy equipment workplace. Diesel is a known carcinogen. Fossil fuel emissions affect lost time at work and workers comp exposure

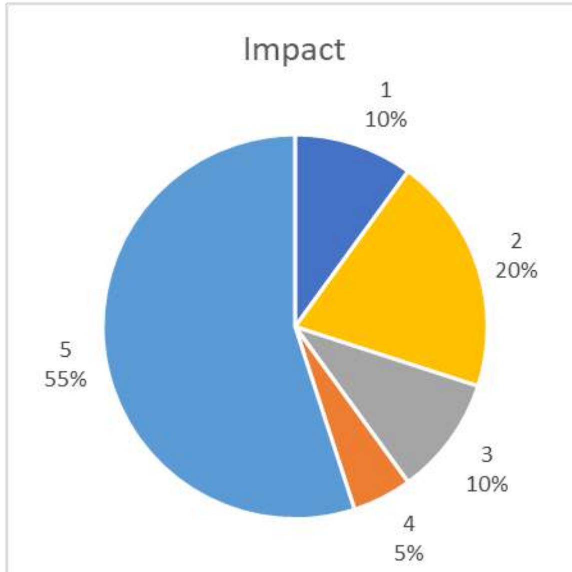
Takeaways: Stakeholders almost universally agree that the adoption of zero-emission technologies are likely to result in significant air quality and health improvement (95%) and that the impact of improved air quality and public health would be significant (90%).

3.3.17 Question 16

Prompt: Adoption of zero-emission technology creates increased job opportunities in the local area to service the new technology.

Results:





Comments:

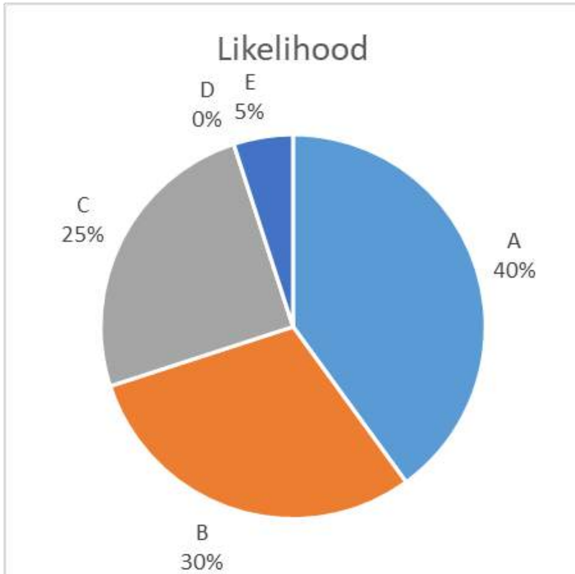
- HUGE job creation opportunity
- Will require specific training, but jobs will not be lost
- This creates jobs with family sustaining wages and benefits and lifelong careers.
- Mechanics will need to be trained to do M and R on new equipment
- The rollout of new technologies can lead to increased employment in the region.
- Probably a zero-sum game. Diesel mechanics will be less, replaced by electric mechanics.
- Need of operator is not changed by zero-emission versus current. In service and maintenance, the major impact is there will be need of new and different competences and less of current
- Unless the total number of trucks goes up, the number of technicians should stay about the same (or perhaps fewer, if such vehicles require less maintenance). The skill set will be different, however.
- Zero emission vehicles are coming and significant adopters like the State of California will see more economic growth as OEM and supply chain business pursue favorable markets. Job training is already a reality for the heavy duty EV industry.

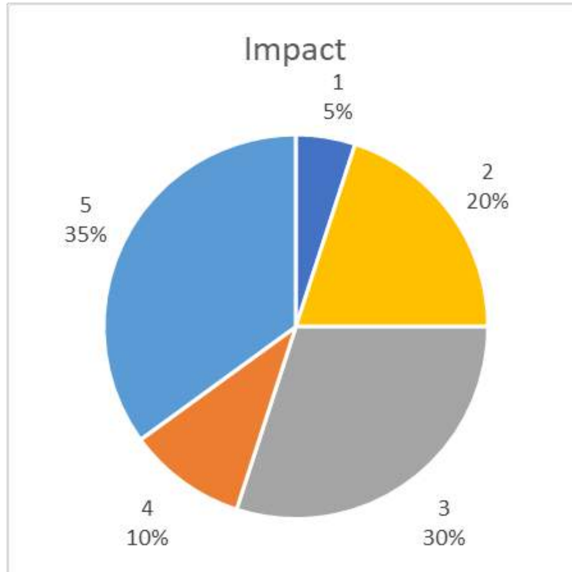
Takeaways: The majority of respondents (60%) generally believe there will be a high likelihood of increased job opportunities associated with the transition to zero-emission technologies and that the impact will be significant (60%). Importantly, comments reflect additional nuance that the majority of the impacts are likely to be focused on mechanics and not operators. At least one of the respondents captured a larger regional expectation of additional economic growth along the supply chain in California, supporting the investment of public funds into these new technologies.

3.3.18 Question 17

Prompt: There are enough qualified personnel for the operation and maintenance of zero-emission equipment.

Results:





Comments:

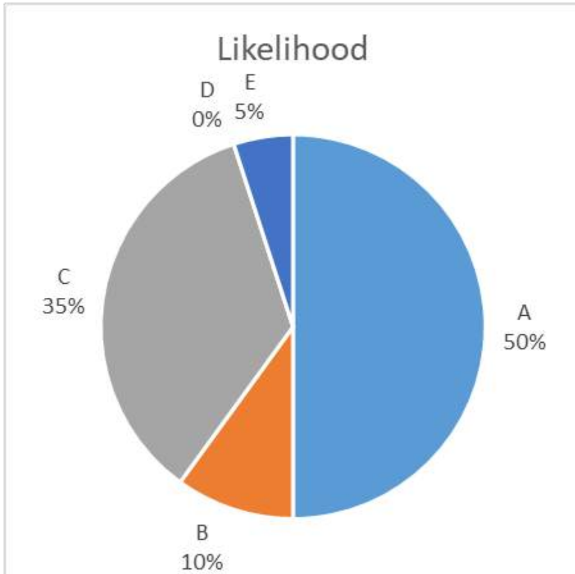
- Need more labor force trained on this
- Define qualified?
- Unknown but rollout is expected to be accompanied by qualified personnel.
- Not enough right now, but the free market will work to get the required skillset. There aren't enough diesel mechanics today either.
- Some change in competences needed require training or new hiring
- Training will be required, but there is time to conduct this training as the quantity of ZEVs increases over time.
- Majority of current service technicians are versed in diesel or other IC engine applications and would require additional training and familiarity with EV technology to be able to support that equipment. The number of technicians is likely appropriate today, but the knowledge base related to EV machines is not.
- Job training programs at the high school and college level already exist through CARB grants. Operational training will have little impact, but technicians will need to adjust somewhat.

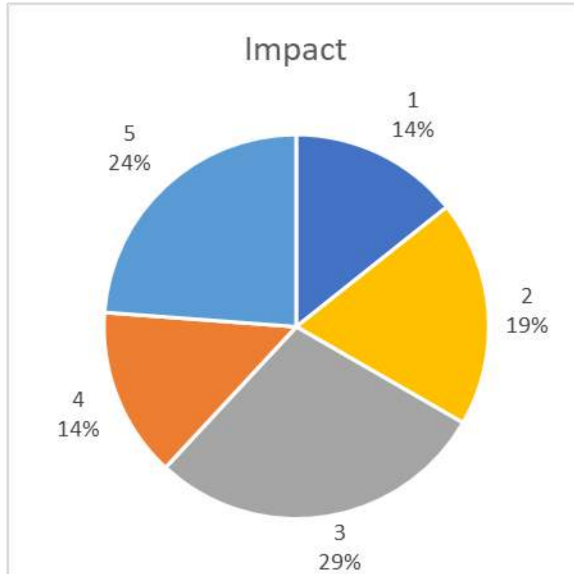
Takeaways: The majority of respondents (70%) were optimistic that there would be sufficient qualified personnel. The comments again reflected the impacts are largely expected to be in the field of maintenance instead of operations.

3.3.19 Question 18

Prompt: Adoption of zero-emission cargo handling equipment requires education and retraining of current employees.

Results:





Comments:

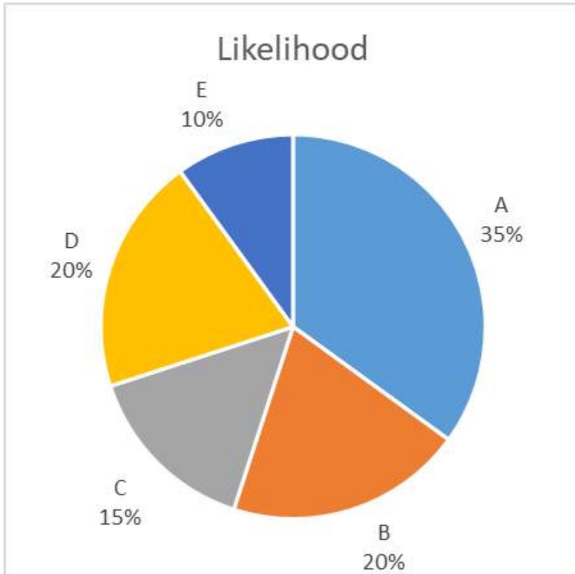
- Operators that we have spoken to actually prefer the ZE equipment
- Operation optimization will look different. Drive patterns, charging instead of fueling etc. have an impact. Changes will include both operators and service and maintenance as well as planning and operation management
- Yes, there will be a requirement for operator training, but this training will be brief and simple.

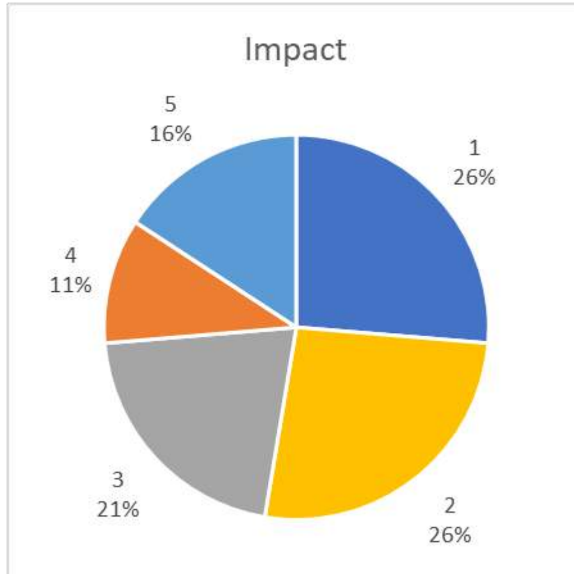
Takeaways: The majority of respondents (60%) identified a high likelihood of the requirement of education and training of current employees. The impacts of this education and training varied and may reflect the different needs for operators vs. maintenance labor (extrapolating from Question 16 and Question 17).

3.3.20 Question 19

Prompt: Zero-emissions equipment is unlikely to cause operational disruption.

Results:





Comments:

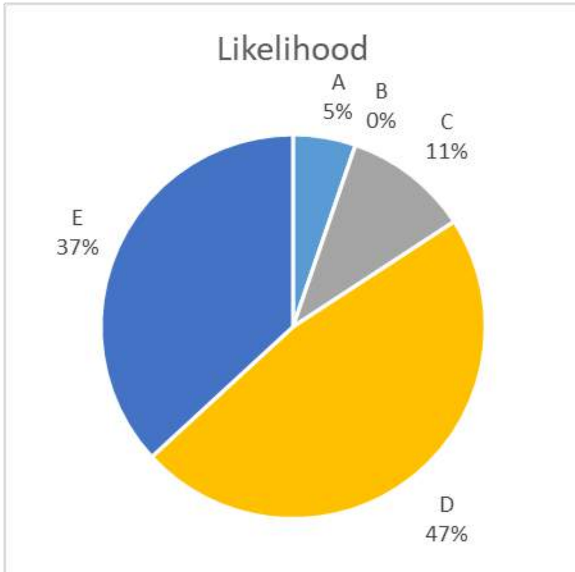
- Will make things more efficient
- I expect a lot of changes required due to battery charging frequency and time, equipment up-time, lower shift life, etc.
- Introduction of the technology needs partly new operational models. With right operation model the loss of productivity due to breakdown, maintenance etc. will be lower than current.
- Once these vehicles are fully developed, they should work as reliably (or more reliably) than today's diesel trucks. Once recharging/refueling infrastructure is fully developed, recharge/refuel time should be close to diesel refuel time.
- Initially there will likely be operational disruption with the introduction of EV machines, but the impact will level out once the learning curve is accomplished.
- If implemented to meet operators' needs, then likely to have minimal impact. But depends on use case and operator needs and how plan to utilize equipment. Need to create a positive customer experience.
- The reduced maintenance will keep fleets operating longer with little down time. If anything, productivity will increase.

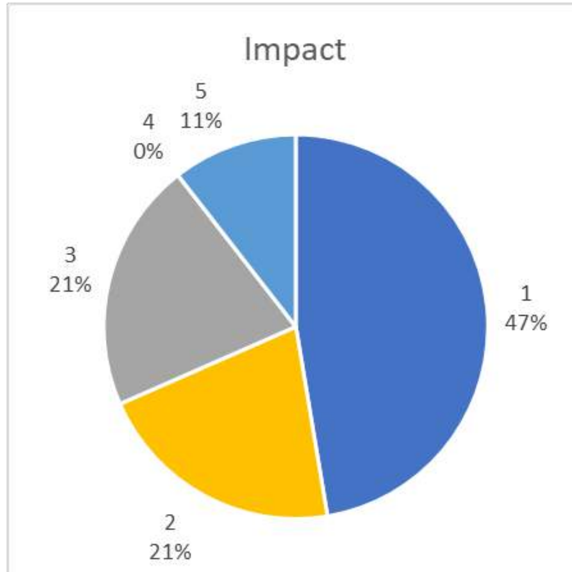
Takeaways: The majority of respondents (55%) agreed that there is a high likelihood of operational disruption with the majority (52%) also identifying that the impacts would be minimal. Comments provide additional insights that respondents generally see the impacts to be greatest during the transition and not lasting long after conversion.

3.3.21 Question 20

Prompt: Zero-emissions equipment is vulnerable to cyber-attack.

Results:





Comments:

- Not qualified to answer
- High level of electronics on "old" equipment too, is equally vulnerable.
- Main risk is for operational control systems, infrastructure control etc. Zero-emissions solutions as such is not increasing the risk versus a diesel powertrain.
- As with diesel trucks, OEMs need to safeguard against hacking. Any vehicle can be hacked if given access, time and equipment, but OEMs must make this very unlikely, even though this is not a trivial task.
- ZEV can be protected similarly to any other technology.

Takeaways: The majority of respondents (74%) identified low likelihood of cyber-attack and in comments noted that existing diesel trucks are also vulnerable. Most respondents did not see cyber security as a new concern associated with zero-emission technology adoption.

4 Assessment

The information collected in the survey can be used to identify where there was agreement and disagreement. While it is acknowledged that the population size is insufficient to make statistically-significant conclusions, basic statistical analysis was used to identify anomalies. Question 15 was removed from the data set because its result was an outlier compared to the rest of the data (overwhelming agreement by all parties).

4.1 Likelihood

Consistency among responses, measured as the greatest percentage of respondents selecting on of the five options (Eq 1), was calculated for each response.

$$Consistency = \frac{Largest\ Number\ of\ Response\ in\ a\ Given\ Category}{Total\ Number\ of\ Responses} \text{ (Eq 1)}$$

The average consistency of responses was 42.2% with a standard deviation of 10.5%. Prompts with high levels of consistency (greater than one standard deviation above the average) included:

- Q1: Warranties for zero-emission equipment adequately protect the purchaser
- Q3: Upfront cost of purchasing/leasing zero-emission equipment is significantly more than traditional equipment
- Q9: 100% zero-emission cargo handling equipment is deployed successfully by 2030
- Q14: The lack of noise will not lead to an increase likelihood of collisions/accidents
  * Note that Q15 (improved air quality and public health) was removed from the dataset and showed significant consistency.

Prompts with high levels of inconsistency (greater than one standard deviation below the average) included:

- Q5: Non-traditional financing of zero-emission equipment assigns rights to financing parties other than the owner/operator.
- Q6: Purchasers find that their revenue increases after adoption of zero-emission equipment
- Q8: Terminal operators must engage in/adapt to significant operational changes to achieve zero-emission cargo handling equipment goals (e.g. yard reconfiguration, moving piers).

Complete scores are provided in Attachment A.

4.2 Impact

Consistency among responses was measured the same as it was for likelihood (Eq 1). The average consistency of responses was 38.6% with a standard deviation of 11.9%. Prompts with high levels of consistency (greater than one standard deviation above the average) included:

- Q1: Warranties for zero-emission equipment adequately protect the purchaser
- Q9: 100% zero-emission cargo handling equipment is deployed successfully by 2030
- Q16: Adoption of zero-emission technology creates increased job opportunities in the local area to service the new technology
  * Note that Q15 (improved air quality and public health) was removed from the dataset and showed significant consistency.

Prompts with high levels of inconsistency (greater than one standard deviation below the average) included:

- Q2: The adoption of zero-emission equipment results in increased insurance costs due to the higher cost of electric equipment, limited qualified maintenance facilities, and general unfamiliarity by insurance providers.
- Q7: Purchasers find that their costs increase after adoption of zero-emission equipment.
- Q11: Adoption of zero-emission cargo handling equipment reduces the flexibility of your operation to make changes.
- Q19: Zero-emissions equipment is unlikely to cause operational disruption.

Complete scores are provided in Attachment A.

4.3 Importance

Using the responses and assigning a weighted score to the responses can help identify where stakeholders showed higher levels of agreement and disagreement on the issues. The following scores were given to each of the responses:

Likelihood	Score	Impact	Score
A	100%	1	20%
B	80%	2	40%
C	60%	3	60%
D	40%	4	80%
E	20%	5	100%

Multiplying scores together gives insight into the overall importance of a topic. Using this methodology, scores vary from 0.04 to 1. Examples are shown below.

Likelihood	Score	Impact	Score	Importance Score
A	100%	5	100%	1.00
A	100%	1	20%	0.20
C	60%	3	60%	0.36
D	40%	2	80%	0.32
E	20%	1	20%	0.04

The highest-ranking items by this measure of importance were:

- Q15: Adoption of zero-emission technology improves air quality and public health.
- Q1: Warranties for zero-emission equipment adequately protect the purchaser/lessor.
- Q9: 100% zero-emission cargo handling equipment is deployed successfully by 2030.
- Q3: The upfront cost of purchasing/leasing zero-emission equipment is significantly more than traditional equipment.
- Q17: There are enough qualified personnel for the operation and maintenance of zero-emission equipment.

The lowest-ranking items by this measure of importance were:

- Q14: The lack of noise produced by electric equipment leads to an increased likelihood of collisions/accidents.
- Q20: Zero-emissions equipment is vulnerable to cyber-attack.
- Q2: The adoption of zero-emission equipment results in increased insurance costs due to the higher cost of electric equipment, limited qualified maintenance facilities, and general unfamiliarity by insurance providers.
- Q7: Purchasers find that their costs increase after adoption of zero-emission equipment.
- Q10: 100% zero-emission cargo handling equipment cannot be deployed successfully by 2030.

Complete scores are provided in Attachment A.

4.4 Observations

Overall, there was consistency among respondents regarding the uncertainties deemed most important. The areas of interest are where there were inconsistencies among respondents. As identified in the previous sections, these were for Q2, Q5, Q6, Q7, Q8, Q11, and Q19. Q2 was removed from further analysis because it was notably identified as un-important (scored in below one standard deviation of the average). The remaining uncertainties with inconsistent responses fall into two principal categories:

<u>Economics</u>

- Q5: Non-traditional financing of zero-emission equipment assigns rights to financing parties other than the owner/operator.
- Q6: Purchasers find that their revenue increases after adoption of zero-emission equipment
- Q7: Purchasers find that their costs increase after adoption of zero-emission equipment.

<u>Operational Impacts</u>

- Q8: Terminal operators must engage in/adapt to significant operational changes to achieve zero-emission cargo handling equipment goals (e.g. yard reconfiguration, moving piers).
- Q11: Adoption of zero-emission cargo handling equipment reduces the flexibility of your operation to make changes.
- Q19: Zero-emissions equipment is unlikely to cause operational disruption.

Assuming divergent responses are indicative of the need for additional information, education, data, and stakeholder engagement, the Uncertainty Analysis has identified inputs to the financial model and impacts on terminal operations as areas with the least consistent Port Community understanding.

5 Discussion

The Uncertainty Assessment identified six areas of focus, defined as areas where respondents had significantly divergent opinions for substantive issues (defined as within one standard deviation of average importance or above). These issues fell into two main categories: financial and operational.

Financial uncertainties revolved around the impacts of the zero-emission transition on revenue and cost in addition to the engagement of non-traditional finance. Typically, non-traditional finance mechanisms are created in sectors that are underserved by traditional finance markets because of layered risk that exposes the financing organization to increased risk relative to traditional financing.[2] A scenario with uncertainty around revenue and costs models is often appropriate for third party finance. However, as discussed in the PCEVB Research Report, third-parties interested in higher risk investments generally seek higher rates of return in order to assume the risk. The Blueprint will have to evaluate how to balance these options:

1. Develop more certainty around revenue and cost models to reduce risk – With new technologies, this approach generally takes time and is not well suited for early adopters. Waiting for technologies to become fully commercially-proven and de-risked will require the Port Community to deviate from the CAAP goals that have clearly put the Port in the driver's seat as an early-adopter and market-driver.

2. Identify parties with higher risk appetite and models for risk mitigation – If the Port Community seeks to continue its leadership as an early-adopter and market-setter, it will be important for the Port Community to attract organizations that have expertise in the zero-emission sector and have developed innovative risk mitigation strategies. Traditionally, the Port Community operates in a high-reliability, low-margin, and high-volume business—one that is not typically associated with high risk investment behavior. Because the Port is accustomed to traditional, low-risk financing models (e.g. leases with established companies, bonds), it does not have extensive experience with non-traditional financing partners (e.g. third-party investors, energy-as-a-service). Developing these partnerships or identifying ways that the Port itself will accept early-adopter risks will be critical to the successful deployment.

Operational uncertainties revolve around the impacts that the zero-emission transition will have on existing operations, including yard reconfigurations, reduced operational flexibility, and business disruption. These operational uncertainties are linked to considerable short-term costs associated with the transition. Discrepancies among stakeholders about the operational impacts of the zero-emission transition are likely to create tension with different stakeholders developing unrealistic expectations. The Blueprint will have to identify ways to create greater common understanding to avoid negative outcomes, principally:

1. Underestimating operational disruption can stifle the successful transition – For example, underestimating operational disruption could result in incentive funding that is insufficient to spark industry to become early-adopters. Alternatively, underestimating operational disruption could result in untimely regulation that is overly burdensome and drives out business with

[2] Consistent with FDIC descriptions of nontraditional mortgages https://www.fdic.gov/regulations/laws/rules/5000-5150.html

significant unintended consequences (e.g. ambitious regulation around air quality results in the loss of an industry that employs a significant portion of the region).

2. Overestimating operational disruption can cause unnecessary delays in implementation – For example, if operational disruption is overestimated, the Port Community could find that it is not moving quickly enough to sustainably adopt zero-emission technologies and could prolong negative air quality and public health impacts.

Creating certainty around operational disruption is challenging as an early-adopter of technology because there is limited information available from which to base key decisions. Lack of information often results in conservative estimates that try to account for real and perceived risk.

Interestingly, the Uncertainty Assessment did not identify uncertainty around equipment as an area of significant divergent opinions. This finding may suggest that there is a general understanding that technological improvements will ultimately create products that can serve the industry, with the existing timing as the greatest unknown (see Q3 discussion). The prompt assessing if the Port would achieve its CAAP goals (Q9 and conversely in Q10) received highly consistent responses across the stakeholders, potentially indicating confidence that the technology will sufficiently advance over the next decade to meet the performance needs—leaving many questions about how to adopt the future technology as the key points of uncertainty.

Attachment A – Complete Scores

Ranked by Likelihood

	Likelihood		Impact		Importance	
	Consistency Score	Rank	Consistency Score	Rank	Score	Rank
Q15	90.5%	1	85.0%	1	91.4%	1
Q3	66.7%	2	38.1%	10	66.0%	4
Q9	55.0%	3	65.0%	2	70.5%	3
Q1	55.0%	3	60.0%	3	70.6%	2
Q14	55.0%	3	47.4%	5	13.2%	20
Q10	50.0%	6	40.0%	8	27.5%	16
Q18	50.0%	6	28.6%	15	50.3%	9
Q20	47.4%	8	47.4%	5	15.6%	19
Q17	40.0%	9	35.0%	12	56.0%	5
Q4	40.0%	9	30.0%	14	28.6%	15
Q11	40.0%	9	26.3%	17	28.9%	14
Q12	38.1%	12	35.0%	12	53.6%	6
Q7	36.8%	13	26.3%	17	26.8%	17
Q2	36.8%	13	25.0%	20	24.6%	18
Q16	35.0%	15	55.0%	4	51.8%	8
Q19	35.0%	15	26.3%	17	36.8%	13
Q13	33.3%	17	40.0%	8	41.3%	11
Q5	30.0%	18	42.1%	7	47.7%	10
Q6	30.0%	18	36.8%	11	52.8%	7
Q8	28.6%	20	28.6%	15	41.2%	12

Green = Above one standard deviation for its category
Orange = Below one standard deviation for its category
No Shade= Within one standard deviation for its category
*Q15 excluded as an outlier

Ranked by Impact

	Likelihood		Impact		Importance	
	Consistency Score	Rank	Consistency Score	Rank	Score	Rank
Q15	90.5%	1	85.0%	1	91.4%	1
Q9	55.0%	3	65.0%	2	70.5%	3
Q1	55.0%	3	60.0%	3	70.6%	2
Q16	35.0%	15	55.0%	4	51.8%	8
Q14	55.0%	3	47.4%	5	13.2%	20
Q20	47.4%	8	47.4%	5	15.6%	19
Q5	30.0%	18	42.1%	7	47.7%	10
Q10	50.0%	6	40.0%	8	27.5%	16
Q13	33.3%	17	40.0%	8	41.3%	11
Q3	66.7%	2	38.1%	10	66.0%	4
Q6	30.0%	18	36.8%	11	52.8%	7
Q17	40.0%	9	35.0%	12	56.0%	5
Q12	38.1%	12	35.0%	12	53.6%	6
Q4	40.0%	9	30.0%	14	28.6%	15
Q18	50.0%	6	28.6%	15	50.3%	9
Q8	28.6%	20	28.6%	15	41.2%	12
Q11	40.0%	9	26.3%	17	28.9%	14
Q7	36.8%	13	26.3%	17	26.8%	17
Q19	35.0%	15	26.3%	17	36.8%	13
Q2	36.8%	13	25.0%	20	24.6%	18

Green = Above one standard deviation for its category
Orange = Below one standard deviation for its category
No Shade= Within one standard deviation for its category
*Q15 excluded as an outlier

Ranked by Importance

	Likelihood		Impact		Importance	
	Consistency Score	Rank	Consistency Score	Rank	Score	Rank
Q15	90.5%	1	85.0%	1	91.4%	1
Q1	55.0%	3	60.0%	3	70.6%	2
Q9	55.0%	3	65.0%	2	70.5%	3
Q3	66.7%	2	38.1%	10	66.0%	4
Q17	40.0%	9	35.0%	12	56.0%	5
Q12	38.1%	12	35.0%	12	53.6%	6
Q6	30.0%	18	36.8%	11	52.8%	7
Q16	35.0%	15	55.0%	4	51.8%	8
Q18	50.0%	6	28.6%	15	50.3%	9
Q5	30.0%	18	42.1%	7	47.7%	10
Q13	33.3%	17	40.0%	8	41.3%	11
Q8	28.6%	20	28.6%	15	41.2%	12
Q19	35.0%	15	26.3%	17	36.8%	13
Q11	40.0%	9	26.3%	17	28.9%	14
Q4	40.0%	9	30.0%	14	28.6%	15
Q10	50.0%	6	40.0%	8	27.5%	16
Q7	36.8%	13	26.3%	17	26.8%	17
Q2	36.8%	13	25.0%	20	24.6%	18
Q20	47.4%	8	47.4%	5	15.6%	19
Q14	55.0%	3	47.4%	5	13.2%	20

Green = Above one standard deviation for its category
Orange = Below one standard deviation for its category
No Shade= Within one standard deviation for its category
*Q15 excluded as an outlier

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Appendix D: Engineering Analysis for Electrification of Port Equipment

PORT OF LONG BEACH

TERMINAL EQUIPMENT ELECTRIFICATION

Final Engineering Study
For
Electrification of Terminal Equipment

July 2017

Prepared by

P. (Ben) Chavdarian, P.E.

Prepared Under the Direction of John Chun, P.E.

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FIGURES

ATTACHMENTS

1.0. General

1.1. General Background

This Final Engineering Study (Study), for Electrification of Terminal Equipment, is intended to provide an overview of the adequacy of the existing Port of Long Beach (POLB) electrical infrastructure to support a Terminal Equipment Electrification project, which would involve the conversion of existing terminal equipment to operate on electricity.

This Study also assesses the existing electrical infrastructure capacity on a terminal, as well as current (short-term) and future (long-term) demands, in order to identify the necessary improvements to facilitate these demands, and provides a high-level cost estimate of such an Electrification project. This Study assumes that a Terminal Electrification program could be done in two phases. The first phase would include a number of equipment electrification projects within POLB major terminals, to demonstrate the feasibility of electrification of equipment. The number of pieces of equipment was based on funding applications submitted by terminal operators in 2016 for Zero Emissions cargo-handling equipment under the Proposition 1B program.[1]

It should be noted that not all terminal operators received funding, nor is it clear whether the successful operators intend to move forward on purchasing the equipment. Assuming a first phase demonstrates that this equipment can meet the performance requirements of the existing equipment, the second phase could require electrification of all equipment within the Harbor District.

To help envision the scope of work involved for a Terminal Electrification project, an overview of the electrical power distribution system for a typical POLB terminal is provided. For a typical major terminal, Southern California Edison (SCE) would extend their power lines to the terminal, and at an appropriate location, place a main electrical meter. Beginning at the meter, the electrical system becomes the Port's and/or tenant's responsibility. From the meter, electrical lines run to various locations on the terminal where electrical power is needed for the various pieces of equipment.

[1] For a list of these applications, please see the South Coast Air Quality Management District's Governing Board agenda of July 8, 2016 for the Proposition 1B awards. http://www.aqmd.gov/docs/default-source/Agendas/Governing-Board/2016/2016-jul8-004.pdf?sfvrsn=4

When electrical equipment is concentrated in one area of the terminal, such as reefer containers, it is usually necessary to provide a transformer to allow the high voltage feeders transmitting power from the SCE meter to change to the required voltage that the equipment needs for operation. From the transformer, branch circuits are extended to the individual equipment and the wiring connection is completed. The transformer and branch circuit equipment, or the circuit breakers, are assembled together and referred to as an electrical substation.

A major component of this Study will be to identify the existing electrical facilities within the typical major terminal and to determine if those facilities are adequate. This Study will also determine if the existing main electrical substations can be utilized to provide electrical service to the equipment identified.

If it is determined that the main substations are of adequate capacity, the terminal will still need electrical installations, such as switchgears and conduit/wiring, to deliver the power needed for the Zero Emissions cargo-handling equipment. If the main electrical substation at the terminals is inadequate to serve the additional Zero Emissions cargo-handling equipment, it would be necessary to arrange for a new electrical service from SCE.

It will also be necessary to determine if SCE has adequate transmission/distribution lines serving the terminal to provide power to the Zero Emissions cargo-handling equipment. If the existing SCE transmission/distribution lines are inadequate, SCE would need to increase their transmission/distribution lines to the terminal.

The designed electrical capacity for Pier E, Middle Harbor, is expected to serve all current and future loads that are planned for this terminal. Some equipment at Pier E is already electrified and their loads are included in the existing available service. As terminal construction continues, future operations will include equipment that will be electrified and therefore, Pier E is not included in this study.

1.2. Clean Air Action Plan (CAAP)

The CAAP program has a number of strategies for reducing emissions within POLB. In this Study, strategies that will impact Terminal Electrification will be considered, while those that don’t will not be. For short-term impacts on terminal electrification, the Port will consider only the Zero Emissions cargo-handling equipment for which the terminal operators applied under the Proposition 1B Funding Program, and the equipment in the 2015 POLB Air Emissions Inventory.

This report and the inventory of equipment can be found at POLB.com/environment/air/ 2015POLB Air Emission Inventory. Summaries of equipment for terminals covered in this Study are shown in Attachments 4 and 5. It should be noted that it is difficult to make cost estimates due to the many variables being introduced.

However, it should be noted that to accomplish the goal of this Study, certain assumptions were made as needed to make conclusive remarks and estimates. This Study makes no attempt to identify any other CAAP program that may have an impact on implementing Zero Emissions cargo-handling equipment, until a clearly defined program is approved by the Board of Harbor Commissioners (Board). Doing so would only lead to confusion and restrict the ability to clearly define the impact of the short-term electrification requirements.

It could also potentially delay the implementation of existing programs, such as those being implemented by POLB's Environmental Planning Division (EP), Air Quality Management District (AQMD), California Air Resources Board (CARB), POLB's tenants, and SCE.

1.3. Conceptual Budget Estimate

The intent of this Study is to quantify an approximate magnitude of cost for a Terminal Electrification project and help better understand some of the major requirements for implementation.

2.0. Short-Term Demand and Capacity Study – Typical Terminal

In the short term (next 3 to 5 years), POLB terminals have received funding from Proposition 1B to purchase the following pieces of Zero Emissions cargo-handling equipment:

- At Middle Harbor, 12 automated guided vehicles (AGVs), 7 Automated Stacking Cranes (ASCs), 1 Intermodal Yard Crane (IYC)
- Total Terminals International, 3 yard hostlers
- International Transportation Service, 68 yard hostlers, 3 forklifts

Additionally, the following POLB terminals have received funding from the California Energy Commission for Zero Emissions cargo-handling equipment:

- At Middle Harbor, 5 yard hostlers
- At ITS, 7 yard hostlers
- At SSA, repower of 9 rubber-tired gantry cranes

This section of the Study shows the short-term impact of terminal electrification for those terminals participating in the demonstration projects.

2.1. Short-Term Electrical Demand per Terminal

The electrical demand at each major terminal is obtained from various sources and summarized herein, as a guide to determine the past history of power usage. For additional information on how to use this demand, please refer to Section 2.3.

2.1.1. Pier A, SSA Terminal

Pier A has one main substation that is served by SCE. The electrical demand at Pier A is 9,073 kVA as shown in Figure 1.

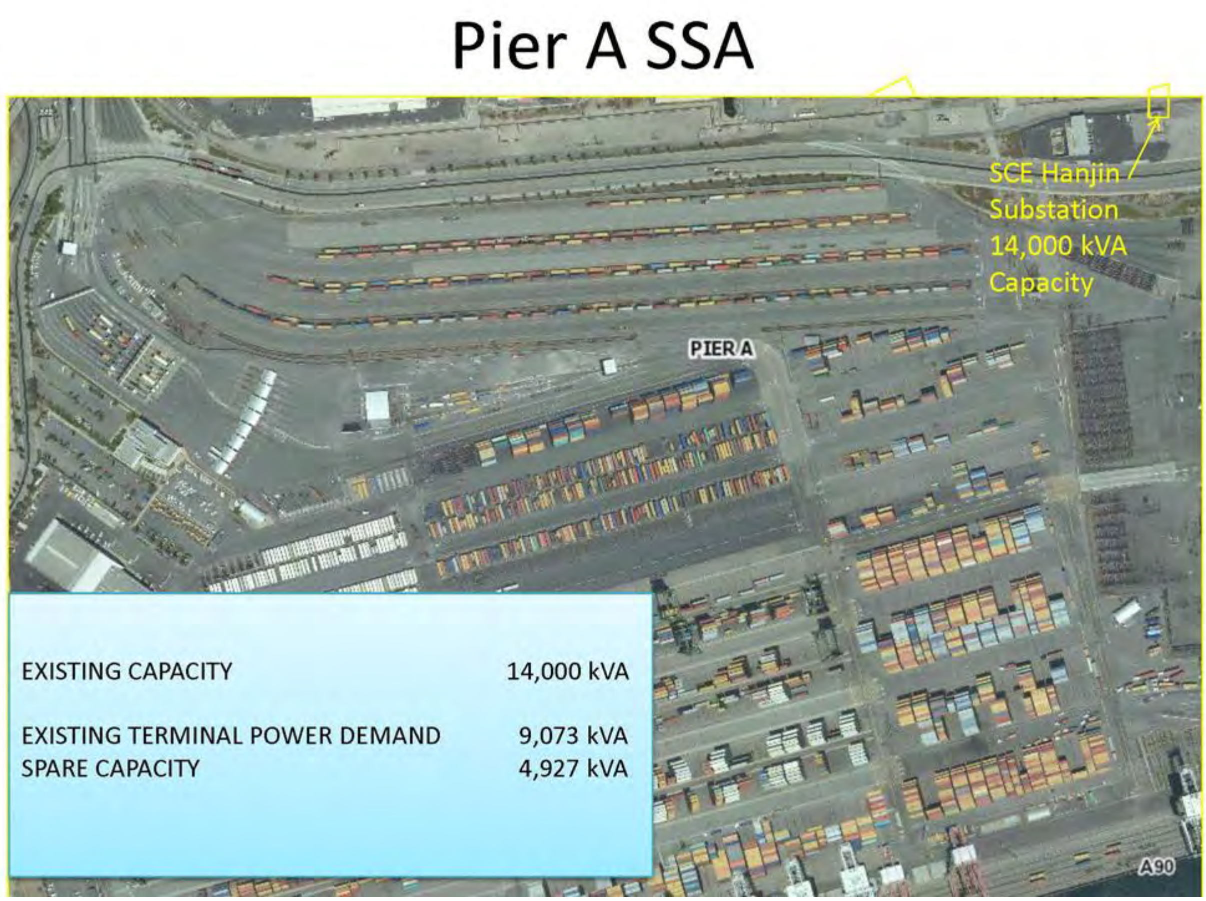

Figure 1: Pier A SSA– Electrical Capacity and Demand

2.1.2. Pier C, SSA Terminal

Pier C has one main substation served by SCE, which has two services. One is for the general terminal electrification and the other is for the "cold ironing" operation. The electrical demand at Pier C is 4,959 kVA as shown in Figure 2.

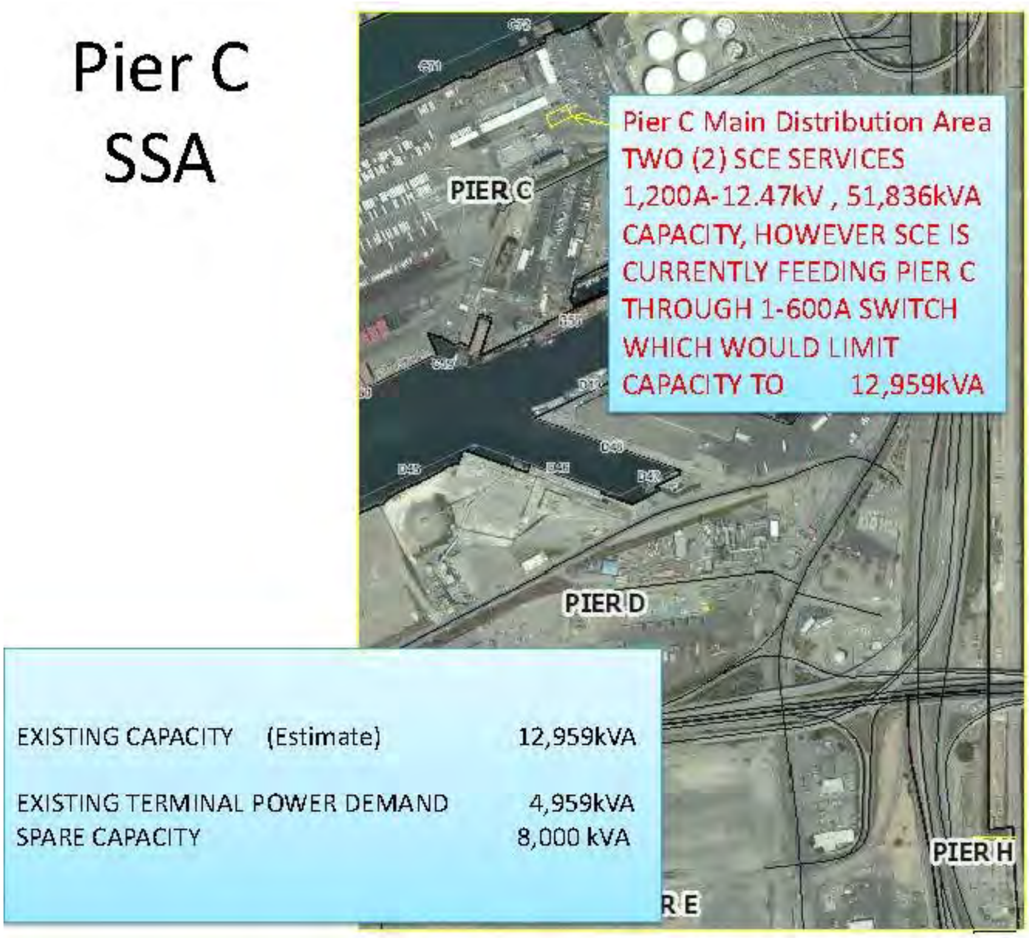

Figure 2: Pier C SSA – Electrical Capacity and Demand

2.1.3. Pier G, ITS Terminal

Pier G has two main substations served by SCE. Pier G has additional SCE services but will not be considered in this Study. Per an agreement between SCE and POLB, any future electrical loads will be transferred to the two main substations. The electrical capacity and demand at Pier G West is 5,300 kVA and the electrical demand at Pier G East is 3,726 kVA, as shown in figures 3 and 4.

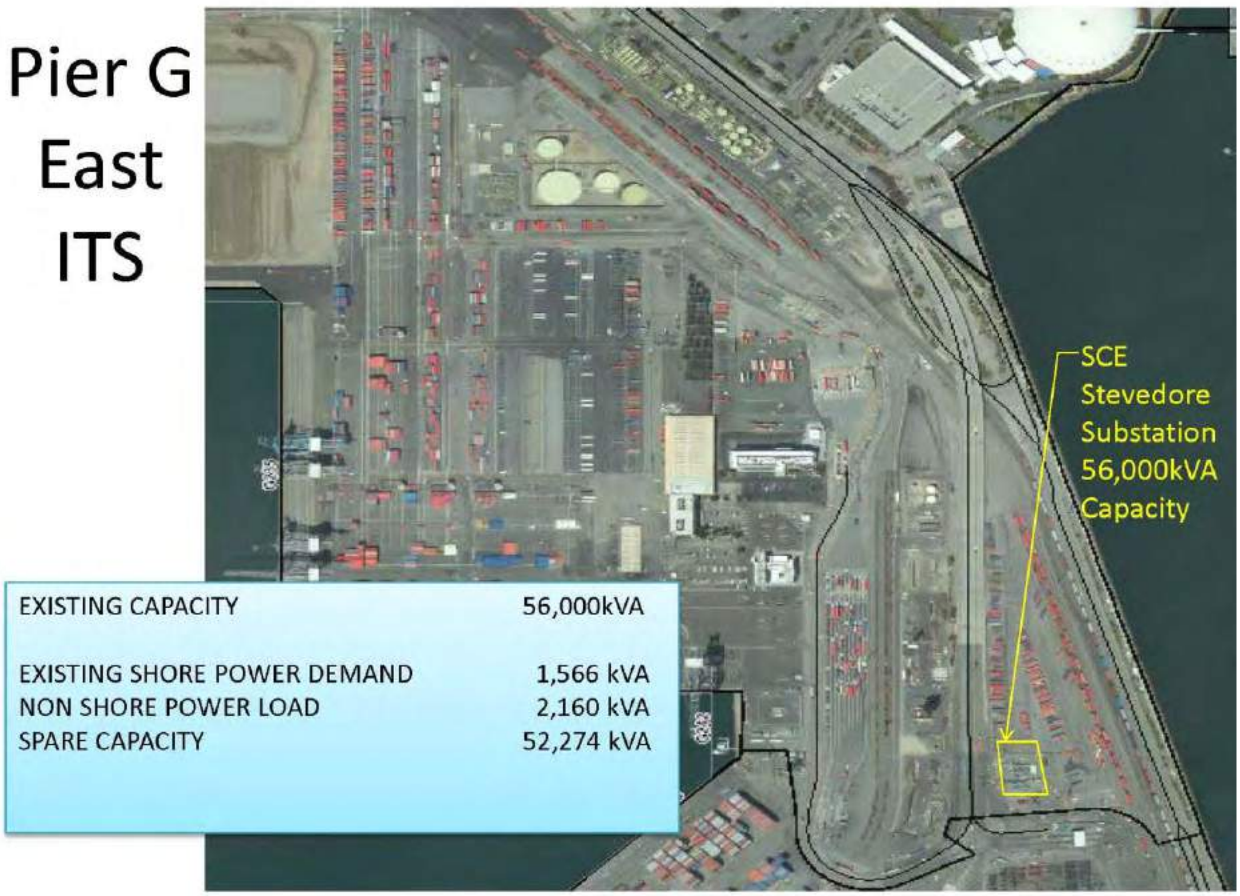

Figure 3: Pier G East ITS– Electrical Capacity and Demand

Figure 4: Pier G West ITS– Electrical Capacity and Demand

2.1.4. Pier J, PCT Terminal

Pier J has one main substation served by SCE. Pier J also has additional SCE services but will not be considered in this Study. Per an agreement between SCE and POLB, any future electrical loads will be transferred to the main substation. The electrical demand at Pier J is 3,996 kVA, as shown in Figure 5.

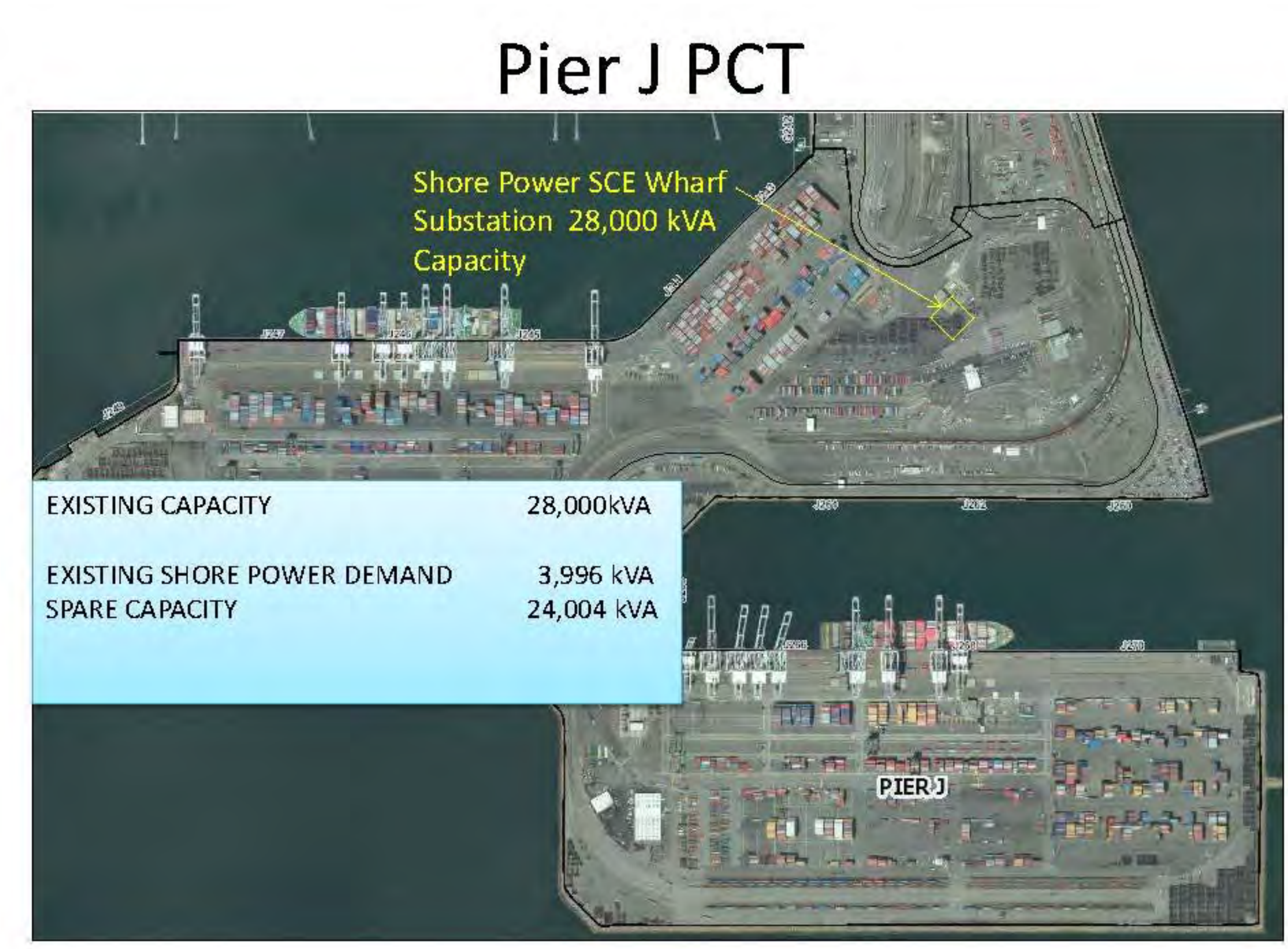

Figure 5: Pier J PCT – Electrical Capacity and Demand

2.1.5. Pier T, TTI Terminal

Pier T has one main substation served by SCE. The electrical demand at Pier T is 10,890 kVA, as shown in Figure 6.

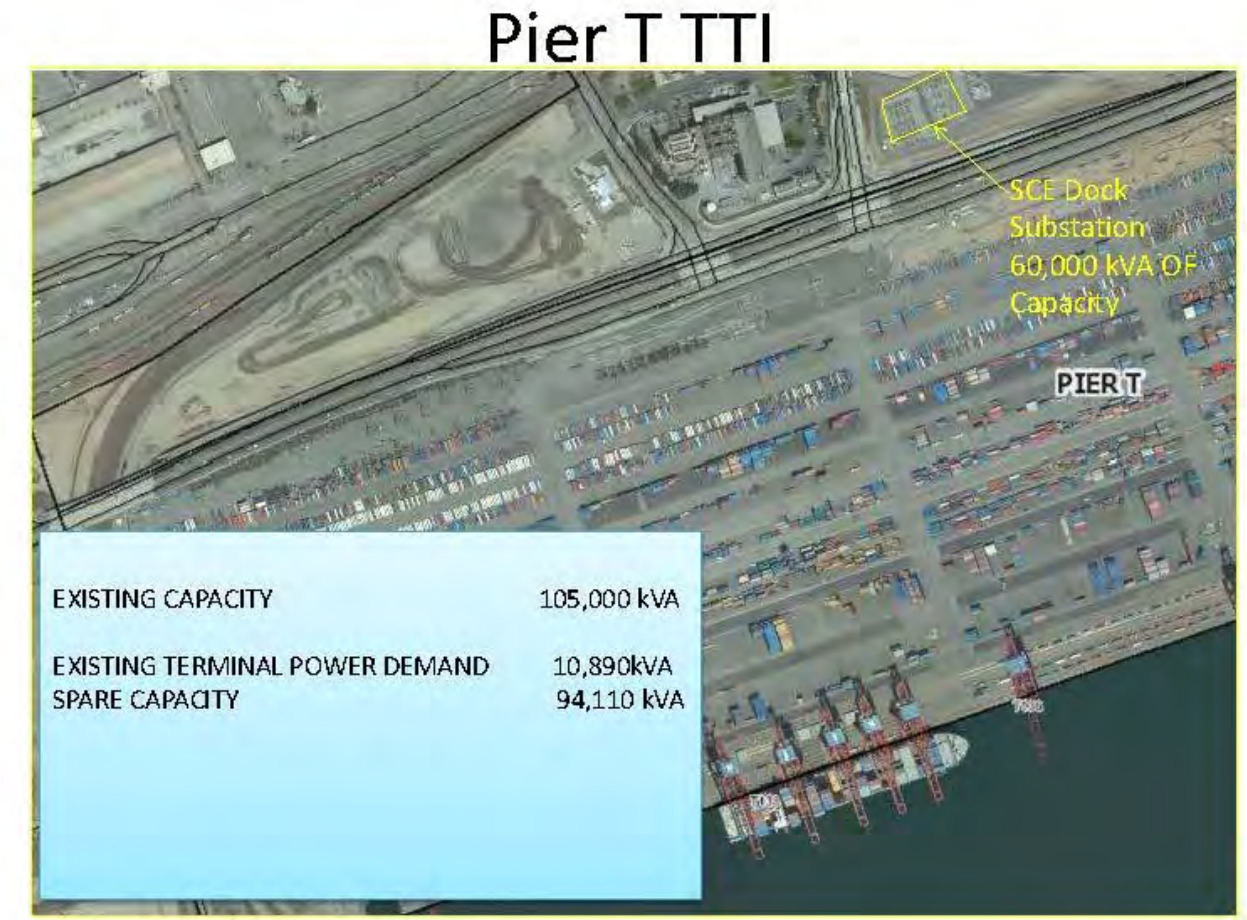

Figure 6: Pier T TTI– Electrical Capacity and Demand

2.2. Short-Term Electrical Capacity per Terminal

The electrical capacity at each major terminal is obtained from As Built information and summarized below, as a guide in determining the existing electrical system capabilities of servicing the terminals.

2.2.1. Pier A, SSA Terminal

Pier A has one main substation served by SCE and the electrical capacity at Pier A is 14,000 kVA. (See Fig. 1.)

2.2.2. Pier C, SSA Terminal

Pier C has one main substation served by SCE, which has two services. One service is for general terminal electrification and the other is for "cold ironing". The electrical capacity at Pier C is 12,959 kVA. (See Fig. 2.)

2.2.3. Pier G, ITS Terminal

Pier G has two main substations served by SCE. The electrical capacity at Pier G West is 28,000 kVA, and the electrical capacity at Pier G East is 56,000 kVA. (See Fig. 3 and 4.)

2.2.4. Pier J, PCT Terminal

Pier J has one main substation served by SCE. The electrical capacity at Pier J is 28,000 kVA. (See Fig. 5.)

2.2.5. Pier T, TTI Terminal

Pier T has one main substation served by SCE. The electrical capacity at Pier T is 105,000 kVA. (See Fig. 6.)

2.3. Short-Term Tenant Improvements per Terminal.

For short-term impact of the terminal electrification, the equipment considered was noted above. With the anticipated relatively large electrical loads to be added at a terminal for Zero Emissions cargo-handling equipment, a review of the main electrical substation(s) was done in order to make a determination if adequate capacity exists.

In the future, if a Terminal Electrification project is identified, in addition to the main substation(s) it will be necessary to review all existing terminal electrical installations to determine if the additional electrical requirements, such as new switchgears and conduit/wiring, will overtax the existing main substation(s) capacity.

If it is determined that the main electrical substation at a terminal is inadequate to serve the additional Zero Emissions cargo-handling equipment, it will be necessary to arrange for a new electrical service from SCE.

If required, it will also be necessary to determine if SCE can provide the additional power demand from their existing system(s). In some instances, a terminal may have adequate capacity at its main substation; however, SCE transmission/ distribution systems may be inadequate to supply the necessary power for the Zero Emissions cargo-handling equipment. In such a case, SCE would need to increase power through their existing transmission/distribution lines.

If additional power from SCE is required, SCE, as in the past, would request compensation for increasing their services and this can vary greatly. The estimates included in this Study for such a service are based on similar past installations at POLB.

This Study will also determine whether additional electrical loads can be added to an existing substation, versus the capacity of the substation, versus the demand at that substation. Many other factors to consider are:

- Are there cranes connected to that substation either directly or indirectly through SCE transmission lines?
- Are there other big electrical loads connected to the substation indirectly through the SCE transmission lines, such as the Cruise ships?
- How stiff (electrically speaking) is the SCE transmission line feeding the subject substation?
- How stiff (electrically speaking) is the transformer located to the substation?
- What is the Power Factor at the substation and what is the Power Factor of the loads being added?
- What is the cumulative harmonics generated by the hostlers’ charging system?
- What is the spare capacity desired on the substation for either future loads or for emergency capabilities, such as business continuity program?

These are some of the common considerations in determining whether or not an electrical load may be added to a substation, but are not included in this Study in an attempt to keep it brief and to the point. However, this Study does make some conclusive remarks based on past experience and does determine the likelihood of adding electrical loads successfully and safely. Detailed analysis for such consideration is left for future determination when the actual requirements are clear and the scope of the project is better defined.

For the purpose of this Study, the demand for the new load will be taken at 100% of the calculated connected load. During the actual design, it would be necessary to study this to determine the most appropriate factor. This could help reduce initial installation costs, as well as operational costs.

Depending on the exact conditions and desired outcome, the electrical work involved for this type of a project could generally include, but not be limited to, adding a new substation, modifying an existing substation, trenching, conduit/wiring, and outlet installations for the equipment installed. It would also require an environmental permit, coordination with a tenant, and coordination with utility companies, vendors, consultants, and others as required.

In addition to the electrical work, it will be necessary to perform certain civil site work, such as grading, paving, striping, fencing, and installation of bollards. For the purpose of this Study, such work is lumped together as an estimated value.

2.3.1. Pier A, SSA Terminal

At this time, there are no short-term electrification tenant improvements planned for Pier A that would impact the electrical demand or capacity.

2.3.2. Pier C, SSA Terminal

At this time, there are no short-term electrification tenant improvements planned for Pier C that would impact the electrical demand or capacity.

2.3.3. Pier G, ITS Terminal

It is estimated there may be seven (7) hostlers requiring electrification at this terminal that would affect the capacity. Each hostler is estimated to require approximately 208 kVA per load, for a total of 1,456 kVA. The existing main substations at Pier G West and Pier G East are adequate to provide the required power to the proposed Zero Emissions cargo-handling equipment (Fig. 3 and 4).

Currently, SCE is providing adequate power for the additional equipment demands, but will need to be notified of the additional electrical load. New electrical design and installation will be required in order to extend the power to required additional outlets to serve the Zero Emissions cargo-handling equipment.

In addition, a Harbor Development Permit (HDP) will be required if the Zero Emissions cargo-handling equipment is planned to be serviced from the existing SCE system. Also, an application from the PUC was submitted in August 2017 for the Pier G Short-term Electrification project. Based on early assumptions, approval from PUC, approval of a HDP, and final design, the construction of the required facilities is expected to be complete sometime in early 2019.

2.3.4. Pier J, PCT Terminal

The equipment identified for this terminal includes nine (9) future RTGs that need to be electrified, for which funding was received.

SCE will provide the cost of installation of the needed infrastructure. Each RTG will require approximately 1,000 kVA load, for a total of 9,000 kVA. The existing main substation at Pier J is adequate to provide this additional load.

Although SCE is completing the necessary infrastructure to support the electrification of the vehicles at their cost, the project will require a HDP.

2.3.5. Pier T, TTI Terminal

It is estimated that there may be three (3) hostlers to be electrified at this terminal. Each hostler requires approximately 208 kVA per load, for a total of 624 kVA. The main substation at this terminal is adequate to provide the additional power required for the Zero Emissions cargo-handling equipment proposed.

Although there is adequate power being provided by SCE, they will need notification of the proposed electrical load being added to their system. As before, a new design and installation of the additional improvements is needed to serve the vehicles. The cost of these improvements will be borne by others.

2.3.6. Non-Container Terminals

The CAAP program has a number of strategies for reducing emissions within POLB. This Study looks at the equipment that will impact Terminal Electrification, such as trucks and other terminal vehicles. Equipment that will have no impact on terminal electrification are not considered.

A summary of the list of equipment for terminals covered in this Study is shown in Attachment 4, Container Terminal – Equipment Inventory, and Attachment 5, Non-Container Terminal – Equipment Inventory. No other equipment is considered in this Study.

2.4. Short-Term POLB Improvements per Terminal

The electrical improvements needed in the short-term, to satisfy the goals for the application of Zero Emissions cargo-handling equipment, include a Study of the main substations within each terminal, to determine what equipment exists, and what equipment will be needed. In addition to any requirement to the main substations, additional electrical installations such as switchgears and conduit/wiring may be required in order to deliver the power needed for the Zero Emissions cargo-handling equipment.

If it is determined that SCE is involved in such a project, the costs associated with their work would require SCE to conduct its own study. For SCE to conduct such a study requires POLB to provide a clear definition of the scope of the project, and would be required to fund such a study.

In such a study, the demand for the new load would be taken at 100% of the calculated connecting load. However, if an actual project is identified, it would be necessary to perform a study to determine an appropriate factor. This could reduce the initial installation costs, as well as the operational cost. For this Study, the factor used was 100% of the calculated connecting load.

Depending on the exact conditions and desired outcome, the electrical work involved for this type of project would include, but not be limited to, adding a new substation or modification of an existing substation, trenching, conduit/wiring, outlet installations for the equipment, and underground (flush-mounted) troughs where RTGs are involved.

As with any project in the Port, a HDP would be required along with coordination with tenants, utility companies, vendors, consultants, and others.

It will also require site civil work, such as striping, fencing, and possibly re-grading of certain areas, to accommodate the desired electrical work. For the purpose of this Study, such work and is lumped together as an estimated value.

2.5. Short-Term SCE Improvements per Terminal

The electrical improvements needed to satisfy the short-term goals for a Zero Emissions cargo-handling equipment project will need to include a study to determine if SCE has adequate transmission/distribution lines at the main substation of the terminal. If SCE does not have adequate transmission/distribution lines to the main substation, SCE would need to increase the power supply to the substation. As in the past, it can be anticipated that POLB would compensate SCE for increasing these services.

2.5.1. Pier A, SSA Terminal

Since there are no short-term tenant requirements planned regarding terminal electrification, there will be no SCE impact and therefore no additional work by SCE is required.

2.5.2. Pier C, SSA Terminal

Since there are no short-term tenant requirements planned regarding terminal electrification, there will be no SCE impact and therefore no additional work by SCE is required.

2.5.3. Pier G, ITS Terminal

SCE has already provided adequate load capacity for this terminal. Once electrification is implemented, SCE will need to be notified of the additional electrical load being added to their existing service.

2.5.4. Pier J, SSA Terminal

SCE has already provided adequate load capacity for this terminal. Once electrification is implemented, SCE will need to be notified of the additional electrical load being added to their existing service.

2.5.5. Pier T, TTI Terminal

SCE has already provided adequate power to the main substation at this terminal. Once electrification is implemented, SCE will need to be notified of the additional electrical load being added to their existing service.

2.6. Short-Term Electrification Cost Estimates per Terminal

For the electrical improvements needed to satisfy the short-term goals of Zero Emissions cargo-handling equipment, a study will be required of the main substations within each terminal to determine what equipment is available and what additional equipment will be required. In addition to the main substations, it will be necessary to understand the terminal's overall electrical distribution system for all existing and planned future installations, for the purpose of adding additional electrical installations to deliver the power needed for Zero Emissions cargo-handling equipment. In addition, it will be necessary to understand the location of equipment to receive the electrical power, in order to understand the amount of new infrastructure required.

2.6.1. Pier A, SSA Terminal

Since there are no short-term electrification improvements planned for this terminal, there are no costs considered in this Study.

2.6.2. Pier C, SSA Terminal

Since there are no short-term electrification improvements planned for this terminal, there are no costs considered in this Study.

2.6.3. Pier G, ITS Terminal

Currently, this terminal is planning for the electrification of seven (7) hostlers in the short-term. To estimate the approximate cost of the required improvements, this Study prorated the costs based on a study by POLB and POLA performed for approximately 200 hostlers.

The estimated cost from the POLB/POLA study was $67.8 Million or approximately $339,000 per hostler. (See Attachment 3, E-Truck Cost Estimate, for a more detailed breakdown.)

The estimated cost for the POLB/POLA study includes, but is not limited to, utility work, switchgears, transformer(s), trenching, conduit/wiring, project contingency, engineering, construction management, and miscellaneous civil-related site work.

Based on the POLB/POLA study, it would be appropriate to prorate the cost of the short-term Pier G project based on the unit cost of the hostler. Utilizing this prorated cost per unit, the approximate cost for the short-term electrification of Pier G would be $2.373 Million.

2.6.4. Pier J, PCT Terminal

Currently, this terminal is planning for the electrification of nine (9) RTGs for which grant funding has already been received. In addition to the already received grant funding, SCE has agreed to provide the cost of installation of the required infrastructure. To estimate the approximate cost of the 9 RTGs, this Study will prorate it based on a study involving 20 RTGs, done by others. The estimated cost in that study for 20 RTGs was $27.2 Million or approximately $1.3 million per RTG. (See Attachment 1, RTG Cost Estimate, for a more detailed breakdown.)

The prorated cost includes, but is not limited to, utility work, switchgears, transformer(s), trenching, conduit/wiring, underground (flush-mounted) troughs, contingency, engineering, construction management, and miscellaneous civil-related site work. The work will actually be done by SCE; however, the tenant, POLB, and others will incur expenses, such as the cost of a HDP, construction inspections, and assisting SCE's contractor and the tenant with technical support.

2.6.5. Pier T, TTI Terminal

Based on input from the terminal operator, it is estimated that there may be three (3) hostlers requiring electrification at this terminal. The cost to modify the terminal for this application will be borne by SCE. The estimated prorated cost for this application is based on a unit cost of $339,000 per hostler, for a total estimated cost of $1.017 million. This cost includes utility work, switchgears, transformer(s), trenching, conduit/wiring, contingency, engineering, construction management, and miscellaneous civil-related site work.

The work will be done by SCE and the tenant; however, POLB and others will incur expenses such as the cost of a HDP, construction inspections, and assisting SCE's contractor and the tenant with technical support.

2.7. Summary – Short-Term Costs

The short-term costs anticipated for POLB, as shown in Table 2.7, is based on an estimated cost for engineering support, which is anticipated to be funded by the various grants awarded to these projects.

Table 2.7

Short-Term Electrification			
Terminal	POLB Cost	Tenant Cost	SCE Cost
Pier A	$0	$0	$0
Pier C	$0	$0	$0
Pier E	$0	$0	$0
Pier G	$100,000	$560,000	$ 1,713,000
Pier J	$100,000	$720,000	$11,420,000
Pier T	$100,000	$240,000	$ 677,000
Total	**$300,000.00**	**$1,520,000.00**	**$13,810,000.00**

3.0. Port wide Terminal Electrification Study- Long-Term Demand and Capacity Study – Typical Terminal

For the long-term impact of terminal electrification, the equipment listed in the POLB 2015 Air Emission Inventory report is included in the analysis for this Study. A summary of the equipment covered is shown in Attachment 4, Container Terminal – Equipment Inventory, and Attachment 5, Non-Container Terminal – Equipment Inventory.

This Study has identified some of the equipment listed as major equipment and some as miscellaneous equipment. The major and miscellaneous references are in relation to the electrical power required. Equipment, per terminal, exceeding 4000 kVA electrical power is referenced as major equipment, and equipment, per terminal, requiring less than 4000 kVA electrical power is referenced as miscellaneous equipment.

Major equipment is considered to be hostlers, RTGs and top picks. Estimates for the electrical power needs of this equipment in kVA are based on their present Horsepower ratings. Miscellaneous equipment as listed in Attachment 4 are assumed to be a certain percentage as calculated in Attachment 4 of the major equipment.

The details for the calculations as to how this percentage is derived are shown in Attachments 4 and 5.

The miscellaneous equipment, sometimes referred to as terminal ancillary equipment, may include, but is not limited to, buses, vans, trucks, pickups, maintenance trucks, sweepers, gardening equipment, air blowers, rail pushers, forklifts, service trucks, flatbed trucks, fuel trucks, etc. Using these estimates, this section of this Study shows the long-term impact of terminal electrification.

As stated in the beginning, the intent of this Study is to outline the financial magnitude of the electrification requirements for the terminals. When additional data are determined, such as the quantity and type of equipment involved for an electrification program on a terminal, it will be necessary to revise the conclusions derived in this Study for a more accurate calculation of costs.

Similar to the process involved for the short-term electrical improvements, the determination of long-term electrical improvements include a study of the main substations within each terminal in order to determine what equipment is available and what additional equipment could be required.

In addition to any upgrades or other improvements to the main substations, additional electrical installations such as switchgears, conduit/wiring, and other infrastructure improvements to assure delivery of the necessary power for the Zero Emissions cargo-handling equipment, may be required. If the main electrical substation is inadequate to serve the additional Zero Emissions cargo-handling equipment, it may also be necessary to arrange for a new electrical service from SCE.

Another consideration for providing power to the Zero Emissions cargo-handling equipment is to determine if SCE has adequate transmission/distribution lines serving the terminals. In some instances, a terminal may have adequate capacity at its main substation; however, the SCE transmission/distribution lines serving the main substation may be inadequate to supply power to the additional Zero Emissions cargo-handling equipment. In such a case, SCE would need to increase their transmission/distribution line services.

In the past, such additional SCE services when requested by POLB have been paid for by POLB. The estimates included in this Study for these costs are based on similar past installations.

For this Study, the demand for the new load will be taken at 100% of the calculated connected load. In the future, when an electrification project is defined, additional study of this factor is recommended in order to better determine the appropriate factor, which would reduce initial installation costs, as well as operational costs.

Depending on the exact conditions and desired outcome, electrical work for this type of project could generally include adding a new substation, modification of existing substation, trenching, conduit/wiring, and outlet installations for the equipment. Such a project would require a HDP along with associated coordination with tenants, utility companies, vendors, consultants, etc.

In addition to the electrical work, there could be the need to perform some site civil work, such as striping, fencing and possible re-grading of certain areas, to accommodate the desired electrical work. For the purpose of this Study, such work is lumped together as an estimated value.

3.1. Existing Terminal Equipment

Some terminals already include some major equipment that is operating on electricity such as gantry wharf cranes and reefer installations. Middle Harbor Terminal (Pier E) already has AGVs and RTGs operating on electricity.

This Study assumes that this equipment will remain in operation and the impact of the electrification of future equipment will be analyzed as part of the program for future terminal electrification.

3.2. Long-Term Electrification of Terminal Equipment

The long-term impact of the POLB 2015 Air Emission Inventory report data was used in this Study for Terminal Electrification. The estimate of the power needs for all equipment is made in kVA in order to determine the future power needs of the terminal. The estimate of kVA power needed for the equipment includes such variables as the speed of operation and the load involved. For this Study, the assumed kVA load used is based on what has been observed to date in order to better quantify the results of this Study.

For miscellaneous equipment, a percentage was calculated based on equipment in the POLB 2015 Air Emission Inventory report. A summary of the miscellaneous equipment for the terminals covered in this Study is shown in Attachment 4.

3.2.1. Hostlers

For the purpose of this Study, when hostlers are electrified, they were rated at 208 kVA each. Based on the POLB 2015 Air Emission Inventory report, it is assumed that if terminal electrification is implemented the quantity of hostlers expected in the future are as follows:

For Pier A: 99
Pier C: 34
Pier E: Not considered in this Study
Pier G 118
Pier J: 138
Pier T: 173

When these estimates are more accurately quantified, it will be a simple process to recalculate the results. This will need to be monitored more closely as terminal electrification proceeds.

3.2.2. Rubber Tired Gantry Cranes (RTGs)

For the purpose of this Study, when RTGs are electrified, they were rated at 1,000 kVA each. Based on the POLB 2015 Air Emission Inventory report, it is assumed that if terminal electrification is implemented, the quantities of RTGs expected in the future are as follows:

For Pier A: 6
Pier C: 0
Pier E: Not considered in this Study
Pier G 13
Pier J: 9
Pier T: 24

When these estimates are more accurately quantified, it will be a simple process to recalculate the results. This will need to be monitored more closely as the terminal electrification process proceeds.

3.2.3. Top Picks (Also referred to as the Front End Loader)

For the purpose of this Study, when top picks are electrified, they were rated at 1,200 kVA each. It should be noted that there are no known electrical prototypes of top picks at this time. For the purpose of this Study, it is assumed that for a top pick, when compared to RTGs, the electrical load requirements would be similar but slightly higher. Based on the POLB 2015 Air Emission Inventory report, this Study assumes that if terminal electrification is implemented, the quantities of top picks in the future are as follows:

Pier A: 26
Pier C: 11
Pier E: Not considered in this Study, since all top picks are electrified.
Pier G 27
Pier J: 36
Pier T: 54

When these estimates are more accurately quantified, it will be a simple process to recalculate the results. This will need to be monitored more closely as the terminal electrification process proceeds.

3.2.4. Miscellaneous Equipment

For this Study, miscellaneous equipment load estimation is based on a calculated percentage in order to increase the total major loads in order to arrive at the total electrical loads at the terminal.

The calculations of the percentages calculated are shown below:
Pier A: 5.3%
Pier C: 3.2%
Pier E: Not considered in this Study.
Pier G 11.6%
Pier J: 6.1%
Pier T: 2.4%

When these estimates are more accurately quantified, it will be a simple process to recalculate the results. This will need to be monitored more closely as the terminal electrification process proceeds.

3.3. Long-Term Electrical Demand per Terminal

Present electrical demands per terminal have already been specified in Section 2.1. It was discussed that future electrification of equipment will be considered based on their electrical ratings and not on calculated or assumed demand. It was also recommended that a study be done by terminal would benefit future development of the terminal.

Until such a study by terminal can be performed, the analysis used in this Study, for determining the electrical demand, used equipment electrical ratings and an assumed quantity of electrical equipment per terminal, which provided the required information for a preliminary estimate of costs.

3.4. Long-Term Electrical Capacity per Terminal

Existing electrical capacities per terminal have already been specified in Section 2.2. For the purpose of this Study, long-term goals for terminal electrification of existing capacities will remain the same. When terminal electrification implementation is considered, a review of the existing capacity will be required.

3.5. Tenant Improvements Needed

For long-term impact of terminal electrification, the equipment considered is identified in Section 3.2. When the expected relatively large electrical loads are to be added to a terminal for electrification of Zero Emissions cargo-handling equipment, a review of the main electrical substation(s) will need to be analyzed to determine if adequate capacity exists.

In the future, if a Terminal Electrification project is identified, in addition to the main substation(s) it will be necessary to review all existing terminal electrical installations to determine if the additional electrical installations required, such as new switchgears and conduit/wiring, will overtax the existing main substation(s).

Part of the analysis will be to determine where such equipment will be located. If the substation at a terminal is inadequate to serve the Zero Emissions cargo-handling equipment, or if the main substation is inadequate, it will be necessary to arrange for new and/or additional electrical services from SCE.

Another consideration for providing power to the Zero Emissions cargo-handling equipment is to determine if SCE has adequate transmission/distribution lines service the terminal. A terminal may have adequate capacity at its main substation; however, SCE transmission/distribution lines may be inadequate to supply the required additional power. In such a case, SCE would need to increase their transmission/distribution lines. The estimates in this Study include additional costs associated with SCE upgrades and are based on similar past installations at POLB.

The decision as to whether additional electrical loads can be added to an existing substation is not just a comparison between the capacity of the substation and the demand at that particular substation. Many other factors to consider are:

- Are the various cranes connected to the substation being studied either directly or indirectly through SCE transmission lines?
- Are there other large electrical loads connected to the same substation indirectly through the SCE transmission lines?
- How stiff (electrically speaking) is the SCE transmission line feeding the substation?
- How stiff (electrically speaking) is the transformer located at the substation?
- What is the Power Factor at the substation and what is the Power Factor of the loads being added?
- What is the cumulative harmonics generated by the hostlers' charging system?
- What is the spare capacity of the substation for future loads or emergency capabilities, such as the Port's business continuity program?

These are just some of the common considerations in determining whether an electrical load may be added to a substation or not, but are not considered in this Study. This Study makes some conclusive remarks based on past experience to determine the likelihood of adding electrical loads successfully and safely. Detailed analysis for such additional loads would need to be considered when the requirements are clear and the scope of the project is better defined.

Depending on the exact conditions and desired outcome, the electrical work involved for this type of a project includes, but is not limited to, adding a new substation or modification of an existing substation, trenching, conduit/wiring, and outlet installations for the equipment installed. In addition, a HDP will be required along with coordination with tenants, utility companies, vendors, consultants, and others will also be required.

In addition to the electrical work, some site civil work will be required, such as striping, fencing, and re-grading of certain areas, to accommodate the desired electrical work. For the purpose of this Study, such work is lumped together as an estimated value.

3.6. POLB Improvements

3.6.1. Pier A, SSA Terminal

For the long-term application and based on the estimated equipment as outlined in Section 3.2, the total additional load to be added is calculated at 61,000 kVA. The existing main substation is not adequate to provide the required power for the proposed Zero Emissions Equipment, thus a new electrical service from SCE will be required. This work will require a new electrical terminal design and installation plan to extend power to the Zero Emissions cargo-handling equipment and provide the necessary outlets.

3.6.2. Pier C, SSA Terminal

For the long-term application, based on the estimated equipment as outlined in Section 3.2, the total additional load to be added is calculated at 21,000 kVA. The existing main substation at Pier C terminal is not adequate to provide the additional power for the Zero Emissions cargo-handling equipment, thus a new SCE service will be required. This work will require a new electrical terminal design and installation plan to extend the power to the Zero Emissions cargo-handling equipment and provide the necessary outlets.

3.6.3. Pier G, ITS Terminal

For the long-term application and based on the estimated equipment as outlined in Section 3.2, the total additional load to be added is calculated at 78,000 kVA. The existing main substation at Pier G terminal is not adequate to provide the additional power for the Zero Emissions cargo-handling equipment, thus a new SCE service will be required. This work will require a new electrical terminal design and installation plan to extend the power to the Zero Emissions cargo-handling equipment and provide the necessary outlets.

3.6.4. Pier J, PCT Terminal

For the long-term application and based on the estimated equipment in as outlined in Section 3.2, the total additional load to be added is calculated at 86,000 kVA. The existing main substation at Pier J terminal is not adequate to provide the additional power necessary for the Zero Emissions cargo-handling equipment, thus a new SCE service will be required. This work will require a new electrical terminal design and installation plan to extend the power to the Zero Emissions cargo-handling equipment and provide the necessary outlets.

3.6.5. Pier T, TTI Terminal

For the long-term application and based on the estimated equipment as outlined in Section 3.2, the total additional load to be added is calculated at 128,000 kVA. The existing main substation at Pier T terminal is not adequate to provide the required power for the proposed Zero Emissions cargo-handling equipment, thus a new SCE service will be required. This work will require a new electrical terminal design and installation plan to extend the power to the Zero Emissions cargo-handling equipment and provide the necessary outlets.

3.7. SCE Improvements

3.7.1. Pier A, SSA Terminal

For SCE to provide the required 61,000 kVA as outlined, SCE will need to extend a new transmission line from one of their existing main substations. This would most likely come from their existing substation located on Pier T. SCE would also have to extend a transmission line from one of their other main substation, which most likely would be the (former) Hanjin Substation, in order to meet this demand.

3.7.2. Pier C, SSA Terminal

In order for SCE to provide the additional 21,000 kVA as outlined, SCE would need to extend a new transmission line from one of their existing main substations. This would most likely come from their existing Pico Avenue substation.

3.7.3. Pier G, ITS Terminal

In order for SCE to provide the additional 78,000 kVA as outlined, SCE would need to extend a new transmission line from one of their existing main substations. This would most likely come from their existing Pico Avenue substation.

3.7.4. Pier J, SSA Terminal

In order for SCE to provide the additional 86,000 kVA as outlined, SCE would need to extend a new transmission line from one of their existing main substations. This would most likely come from their existing Pico Avenue substation.

3.7.5. Pier T, TTI Terminal

In order for SCE to provide the additional 86,000 kVA as outlined, SCE would need to extend a new transmission line from one of their existing main substations. This would most likely come from their existing Pier J substation.

3.8. Long-Term Electrification Cost Estimates per Terminal

The following cost estimate per piece of equipment is used for this Study. These costs are based on a study done by POLB/POLA, as discussed above. A breakdown of the costs per unit can be found in Attachments 1, 2 and 3.

a. Hostler Cost: $339,000
b. RTG Cost: $1.36 million
c. Top Pick Cost: $1.424 million
d. SCE Transmission Cost Per extension: $40 million

All costs include, but may not be limited to, switchgear(s), transformer(s), trenching, conduit/wiring, engineering, construction management, miscellaneous civil site work, and a 30% contingency.

3.8.1. Pier A, SSA Terminal

For this terminal, it was assumed that 99 hostlers, 6 RTGs, 26 top picks, and an additional miscellaneous load of 5.3% would be required. The estimated total electrification cost would be $83.1 million, and the SCE line extension would be an additional $40 million.

3.8.2. Pier C, SSA Terminal

For this terminal, it was assumed that 34 hostlers, 0 RTGs, 11 top picks, and additional miscellaneous load of 3.2% would be required. The estimated total electrification cost would be $28.1 million, and the SCE line extension would be an additional $40 million.

3.8.3. Pier G, ITS Terminal

For this terminal, it was assumed that 118 hostlers, 13 RTGs and 27 top picks, and an additional miscellaneous load of 11.6% would be required. The estimated total electrification cost would be $107.4 million, and the SCE line extension would be an additional $40 million.

3.8.4. Pier J, PCT Terminal

For this terminal, it was assumed that 138 hostlers, 9 RTGs and 36 top picks, and additional miscellaneous load of 6.1% would be required. The total estimated electrification cost would be $117 million, and the SCE line extension would be an additional $40 million.

3.8.5. Pier T, TTI Terminal

For this terminal, it is assumed that 173 hostlers, 24 RTGs and 54 top picks, and additional miscellaneous load of 2.4% would be required. The total cost would be $172.2 million, and the SCE line extension would be an additional $40 million.

3.8.6. Non-Container Terminal

For a non-container terminal, such as Morton Salt on Pier F, based on the equipment list found in the POLB 2015 Air Emission Inventory report, the additional power required is approximately 1.4 MVA. Based on existing electrical facilities at the Morton Salt terminal, a new SCE service and power distribution system within the terminal would be required. The approximate estimated cost for this terminal would be $10 million for a complete installation.

3.9. Summary – Long-Term Electrification Costs

Long-term electrification costs by terminal are listed in Table 3.9. In accordance with past experience, it can be assumed the SCE costs shown would most likely fall to POLB. However, as in the past, the actual SCE work would be done by SCE.

Table 3.9 also shows what was assumed for the combined Terminal and POLB Improvement costs. For the purpose of this Study, it was assumed that the actual cost of the equipment would be the responsibility of the terminal and the actual construction costs for the infrastructure serving the equipment would be POLB's.

Table 3.9

Terminal	Terminal/POLB Improvements	SCE Improvements
Pier A	$83.1 Million	$40 Million
Pier C	$28.1 Million	$40 Million
Pier G	$107.4 Million	$40 Million
Pier J	$117 Million	$40 Million
Pier T	$172.2 Million	$40 Million
Non-Container Terminal	$ 9 Million	$ 1 Million
TOTAL	**$516 Million**	**$201 Million**

4.0. Electrification of Automated Terminal – Middle Harbor Terminal

Middle Harbor Terminal, also known as Pier E terminal, has already been designed for all electric applications (except for the land-side traffic and other miscellaneous operations) now and in the future, and therefore no additional impact on the existing electrical service is anticipated and is not included in this Study.

5.0. Future Terminal Improvements

For the purpose of this Study, it was assumed that, for terminal electrification only, major equipment such as hostlers, RTGs and top picks, plus a small added percentage of loads for miscellaneous equipment, was considered. It was also assumed that all existing electrically operating equipment will remain in place in the future.

Specific equipment is not considered in this Study and will have no major impact. Such specific equipment is included under miscellaneous equipment and includes, but is not limited to, buses, vans, all trucks, sweepers, gardening equipment, air blowers, rail pushers and forklifts.

6.0. Conclusion

6.1. Costs Per Acre

Table 6.1 summarizes the area/terminal involved along with the long-term estimated cost and the estimated cost per acre.

Table 6.1

Cost Per Acre			
Terminal	Acreage	Total Cost	Cost Per Acre
Pier A	193	$123.1 Million	$0.64 Million
Pier C	68	$68.1 Million	$1.00 Million
Pier G	258	$147.4 Million	$0.57 Million
Pier J	256	$157.0 Million	$0.61 Million
Pier T	381	$212.2 Million	$0.56 Million
Average			$0.68 Million

6.2. Summary

The information provided in this Study is for general knowledge and guidelines in an attempt to better understand general requirements for terminal electrification for certain equipment. If the scope of the electrification is changed in regards to the number or type of equipment involved, or the size in kVA ratings of the equipment is changed, a review of the related facts as outlined herein will be necessary to determine the impact of the change.

It is also important that when implementation of any electrification at a given terminal is considered, and the existing electrical services as stated in this Study have changed due to other activities that were not been considered, additional analysis will be required for the additional load(s). Such other activities may include, but not be limited to, equipment added or deleted, services taken out of use, services combined with other services, and/or similar modifications.

Attachment 1: RTG Cost Estimate

Cost Estimate

Project: Rubber Tired Gantry (RTG) Charging Infrastructure (For One Terminal)

Assumptions:

1. 20 RTG (For one terminal).
2. Assumed 1000 kVA each RTG, 12kV System.
3. RTGs will be permanently connected into the electrical outlets.
4. There will be a designated area in the terminal, for the electrical outlets.
5. Power factor of 90% is assumed for each RTG.
6. Cost of electricity: $0.15/KWH

System Description:

It is envisioned that the terminal operator will utilize maximum of 50% of the RTG fleet at any one time.

Load Calculations:

The following are the calculations showing the electrical load and its distribution requirements:

For 20 RTG, with 50% of the fleet connected at any time, the load is:

(20 RTG x 50% x 1000 kVA) = 10,000 kVA = 10 MVA

To normally operate 20 RTGs connected to the system will require 10 MVA power. This will require one additional electrical service from SCE rated for 10 MVA, 12 kVA, 3-phase. This service will feed through a 12 kVA rated meter/main and distribution switchgear.

10 MVA power at 12 kVA, 3-phase translates to 482 Amperes. Typical maximum sized 12 kVA switchgear will be rated at 1200 Amperes. This will then require the installation of one 12 kVA switchgear lineup, rated at 1200 Amperes. The 12 kVA switchgear will feed 20 RTG charging outlets.

System Installation Cost:

	System Description	Unit Cost (M $) *	Units Required	Total Cost (M$) *
1	SCE Electrical Service Entrance, 10 MVA, 12 kV, 3-phase **	1.0	1	1.0
2	12 kV Electrical Main and Meter Switchgear Line up	0.5	1	0.5
3	12 kV Electrical Switchboard and 20 draw out vacuum circuit breakers, with power logic and all necessary relay, control power, and communication equipment.	3.5	1	3.5
4	Trenching, conduit and wires	LOT		8
5	Other equipment & materials	LOT		3
	Subtotal:			16.0
6	Contingency (30%)			4.8
7	Engineering and Construction Mgmt. (40%)			6.4
	Total Cost:			27.2
	* Indicates installed cost			
	** Includes SCE charges			

Prepared by:
P. (Ben) Chavdarian
Date: March 16, 2017

Attachment 2: Top Pick Cost Estimate

Cost Estimate

Project: Top Pick Charging Infrastructure (For One Terminal)

March 28, 2017

Assumptions:

1. 25 Top Picks (For one terminal).
2. Assumed 1200 kVA each, at 12 kV System.
3. Required maximum charging time of 4 hours (from zero to full charge).
4. Top Picks will be automatically plugged into the charging system.
5. There will be a designated charging area in the terminal.
6. Charging power factor of 90% is assumed for each Top Pick.
7. Cost of electricity: $0.15/KWH

System Description:

It is envisioned that the terminal operator will be able to operate the top picks for two 8-hour shifts without recharging.

Load Calculations:

The following are the calculations showing the electrical load and its distribution requirements:

For 25 Top Picks, with 50% of the fleet connected at any time, the load is:

(25 Top Picks x 50% x 1200 kVA) = 15,000 kVA = 15 MVA

To normally operate 25 Top Picks connected to the system will require 15 MVA power. This will require one additional electrical service from SCE rated for 10 MVA, 12 kV, 3-phase. This service will feed through a 12 kV rated meter/main and distribution switchgear.

15 MVA power at 12 kV, 3-phase translates to 723 Amperes. Typical maximum sized 12 kV switchgear will be rated at 1200 Amperes. This will then require the installation of one 12 kV switchgear lineup, rated at 1200 Amperes. The 12 kV switchgear will feed 25 Top Pick charging outlets.

System Installation Cost:

	System Description	Unit Cost (M $) *	Units Required	Total Cost (M$) *
1	SCE Electrical Service Entrance, 15 MVA, 12 kV, 3-phase **	1.0	1	1.0
2	12 kV Electrical Main and Meter Switchgear Line up	0.5	1	0.5
3	12 kV Electrical Switchboard and 25 draw out vacuum circuit breakers, with power logic and all necessary relay, control power, and communication equipment.	4.4	1	4.4
4	Trenching, conduit and wires	LOT		8
5	Other equipment & materials	LOT		3
6	Auto-charging system			4
	Subtotal:			20.9
7	Contingency (30%)			6.3
8	Engineering and Construction Mgmt. (40%)			8.4
	Total Cost:			35.6
	* Indicates installed cost			
	** Includes SCE charges			

Prepared by:
P. (Ben) Chavdarian
Date: March 16, 2017

Attachment 3: E-Truck Cost Estimate

Cost Estimate
Project: E-Truck Charging Infrastructure (For One Terminal)
March 30, 2017

Assumptions:

1. 100 E-trucks (For one terminal).
2. 250 A, 480V, 3-phase outlet per truck (Standard outlet as agreed between POLA and POLB and major E-truck manufacturers.
3. Required maximum charging time 1 hour (from zero to full charge).
4. Fully charged E-truck can operate one 8-hour shift and will need to be charged to full charge again during 1 hour lunch break.
5. E-trucks will be automatically plugged into the charging system.
6. There will be a designated charging area in the terminal.
7. Charging power factor of 90%
8. Average 8 hours of active charging per one 24 hour day
9. Cost of electricity: $0.15/KWH

System Description:
It is envisioned that trucks will be utilized within the terminal and will operate for eight hours (a full shift) without re-charging. During the hour lunch break, the trucks will be returned to the charging area and will be connected to the charging stations.

Load Calculations:
The following are the electrical calculations showing the electrical load and its distribution requirements: For 200 trucks, with 50% of the fleet connected at any time, the load is: (200 trucks x 50% x 480V x 1.732 x 250 Amperes)/ (1000 x 0.9 Power Factor) = 23,093 kVA = 23 MVA

To simultaneously charge all 100 trucks connected to the system will require 23 MVA power. For redundancy and system resiliency purposes, it will be required to split the load into two incoming utility circuits. Therefore, this means that it will be necessary to obtain two (2) services from LADWP, each rated for 12 MVA, 34.5 kV, 3-phase. Each of these circuits will feed through a 34.5 kV rated meter/main and distribution switchgears.

23 MVA power at 480 volts 3-phase translates to 27,666 Amperes. The typical maximum sized 480 Volt switchgear is rated at 4000 Amperes. Including only 12% spare capacity, this means that we need to install eight (8) 3.5 MVA transformers to transform the power from 34.5 kV level to 480 Volt level, and correspondingly install a total of eight (8) 480 Volt switchgear lineups, each rated at 4000 Amperes.

System Installation Cost:

	System Description	Unit Cost (M $) *	Units Required	Total Cost (M$) *
1	LADWP Electrical Service Entrance, 15 MVA, 34.5 kV, 3-phase **	1.5	2	3
2	34.5 kV Electrical Main and Meter Switchgear Line up	1	2	2
3	34.5 kV Electrical Switchboard and (6) draw out vacuum circuit breakers, with power logic and all necessary relay, control power, and communication equipment.	1.5	2	3
4	Transformer, 34.5 kV Prim. -480V Second, 3-phase	0.6	8	4.8
5	4000 A, 480V, 3-phase Distribution switchgear, with (20) 300A rated, ground fault electronic trip circuit breakers.	1	8	8
6	Trenching, conduit and wires	LOT		8
7	Other equipment & materials	LOT		3
8	Auto-Charging System			8
	Subtotal:			39.8
9	Contingency (30%)			12.0
10	Engineering and Construction Mgmt. (40%)			16.0
	Total Cost:			67.8
	* Indicates installed cost			
	** Includes SCE charges			

Prepared by:
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Date: April 19, 2016

Attachment 4: Container Terminal – Equipment Inventory

PORT of LONG BEACH Container Terminal – Equipment. Ref: POLB 2015 Air Emissions Inventory		**Equipment Population**	**Non Electric Equipment** **Energy Consumption HP (Per Equipment)**	**Total Energy** **1HP= 1kVA All Equipment operating**
	Intl. Trans. Service (ITS) - Pier G			
MAJOR EQUIP.	Rubber tired gantry crane	13	1,043	13,559
	Top handler	27	375	10,125
	Yard tractor	118	243	28,674
	MAJOR EQUIPMENT -- TOTAL kVA			**52,358**
MISC. EQUIPMENT	Forklift	17	134	2,278
	Man Lift	2	68	136
	Miscellaneous	2	949	1,897
	Rail Pusher	2	260	520
	Sweeper	1	191	191
	Truck	2	525	1,050
	MISCELANEOUS EQUIPMENT - TOTAL kVA			**6,072**
	RATIO = (MISCELANEOUS kVA)/(MAJOR kVA)			**10.4%**
	Pacific Container Terminal - Pier J			
MAJOR EQUIP.	Rubber tired gantry crane	9	1,043	9,387
	Top handler	36	375	13,500
	Yard tractor	138	243	33,534
	MAJOR EQUIPMENT - TOTAL kVA			**56,421**
MISC. EQUIP.	Forklift	15	134	2,010
	Side pick	6	240	1,440
	MISCELANEOUS EQUIPMENT - TOTAL kVA			**3,450**
	RATIO = (MISCELANEOUS kVA)/(MAJOR kVA)			**5.8%**
	SSA-Matson - Pier C			
MAJOR EQUIP.	Top handler	11	375	4,125
	Yard tractor	34	243	8,262
	MAJOR EQUIPMENT - TOTAL kVA			**12,387**

MISC. EQUIP.	Forklift	3	134	402
	MISCELANEOUS EQUIPMENT - TOTAL kVA			**402**
	RATIO = (MISCELANEOUS kVA)/(MAJOR kVA)			**3.1%**
	SSAT - Pier A			
MAJOR EQUIP.	Rubber tired gantry crane	6	1,043	6,258
	Top handler	26	375	9,750
	Yard tractor	99	243	24,057
	MAJOR EQUIPMENT - TOTAL kVA			**40,065**
MISC. EQUIP.	Forklift	9	134	1,206
	Side pick	3	240	720
	Sweeper	1	191	191
	MISCELANEOUS EQUIPMENT - TOTAL kVA			**2,117**
	RATIO = (MISCELANEOUS kVA)/(MAJOR kVA)			**5.0%**
	Total Terminals International (TTI) - Pier T			
MAJOR EQUIP.	Rubber tired gantry crane	24	1,043	25,032
	Top handler	54	375	20,250
	Yard tractor	173	243	42,039
	MAJOR EQUIPMENT - TOTAL kVA			**87,321**
MISC. EQUIP.	Forklift	14	134	1,876
	Sweeper	1	191	191
	MISCELANEOUS EQUIPMENT - TOTAL kVA			**2,067**
	RATIO = (MISCELANEOUS kVA)/(MAJOR kVA)			**2.3%**

Attachment 5: Non-Container Terminal – Equipment Inventory

PORT of LONG BEACH Non - Container Terminal – Equipment. Ref: POLB 2015 Air Emissions Inventory		Equipment Population	Non Electric Equipment Energy Consumption HP (Per Equipment)	Total Energy 1HP= 1kVA All Equipment operating
	Morton Salt			
ALL EQUIP.	Bulldozer	1	146	146
	Forklift	3	134	402
	Loader	1	402	402
	Sweeper	1	191	191
	ALL EQUIPMENT - TOTAL kVA			**1,141**

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Appendix E: Pier C – Yard Tractor Electrification Study

Port of Long Beach Pier C –
Phase 1 Yard Tractor Electrification Study

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List of Acronyms

BEYT	Battery Electric Yard Tractor
BLAST	Battery Lifetime Analysis and Simulation Tool
CAN	Controller Area Network
CO_2	Carbon Dioxide
EV	Electric Vehicle
GPS	Global Positioning System
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
kW	Kilowatt
kWh	Kilowatt-Hour
MPG	Miles Per Gallon
MPH	Miles Per Hour
NO_X	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
PCEVB	Port Community Electric Vehicle Blueprint
POLB	Port of Long Beach
RPM	Rotations Per Minute
SOC	State of Charge
SO_X	Sulfur Oxides

Executive Summary

The objective of this effort is to provide the Port of Long Beach (POLB) with technical assistance in evaluating the potential for vehicle electrification and providing input data and analysis to inform the Port Community Electric Vehicle Blueprint (PCEVB). Yard tractors make up 58% of landside port CO_2 emissions meaning improvements in efficiency and electrification of yard tractors may have a significant impact. The National Renewable Energy Laboratory (NREL) conducted this yard tractor electrification study using real-world diesel performance data along with modeling and analysis of battery electric yard tractors (BEYTs) to compare to conventional vehicles operating in the POLB's pier C which is a terminal operated by SSA Marine. This report summarizes the initial data collection and electrification evaluation of SSA Marine's yard tractors that occurred in August and September of 2018. Results from this project will provide detailed operational data and performance requirements of BEYT operated within the context of Pier C. The project will also provide a methodology to evaluate opportunities, strategies, and challenges associated with future expansion of BEYTs in meeting PCEVB goals. NREL collected data on 14 of 34 yard tractors totaling 12,286 miles of operation in August and September of 2018 providing enough information to assess the vehicle operation for electrification potential.

Over the collection period the yard tractors had an average daily distance of 37 miles and an average speed around 4 MPH. Further, the maximum daily brake energy or usable energy produced by the engine was 270 kWh with up to 33% of the daily energy spent at idle making these vehicles candidates for electrification. A simplified vehicle model was developed to further identify the opportunity for yard tractor electrification and examine the full duty cycles including both use patterns and charging availability. Outputs of this model indicate 11 out of 14 yard tractors or approximately 80% of the vehicles studied could be electrified using vehicles currently on the market that have a battery size of 220kWh and can charge at 60kW. However, operational changes, more vehicles or smart scheduling may be needed to electrify all vehicles using current technology. Adoption of BEYTs could reduce CO_2 emissions by roughly 80% eliminating approximately 3 million pounds of CO_2 each year.

Charging infrastructure is another large consideration when adopting electric vehicles. Net monthly energy for Pier C was estimated using the vehicle model by extrapolating the 14 vehicles monitored in this study to the 34 yard tractors in the terminal inventory. While the total energy use increased 25-30%, the scenario showed that peak power demand could more than double resulting in a possible increase in utility bill of nearly 60%. However, this scenario assumes all the vehicles are charging at once and coincides with the current peak energy demand at the terminal, and does not include offsets from reduction in fuel costs due to conversion. The less aggressive mid-peak charging scenario only showed a 17% increase in electric bill due to BEYT adoption.

The detailed duty cycle data and preliminary results described above lay the ground work for more detailed follow-on analysis in close collaboration with the POLB, terminal operators, Southern California Edison, and the vehicle manufacturers. Future work will include examining charge mitigation strategies and managed charging opportunities where the charging power is tapered so the overall peak power draw from the grid is reduced. The brief example shown in this

study estimated overall peak demand from the BEYT could be reduced by 75% in an ideal scenario. Actual implementation would likely be less-effective due to practical port operational constraints that may affect charging and scheduling scenarios. Additionally, validation of the model with actual in-use testing of a BEYT will help verify and refine drivetrain efficiencies. This modeling effort took a very conservative approach, so it is possible that actual BEYTs would perform better due to the addition of regenerative braking and a more efficient drivetrain.

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1 Introduction

Yard tractors are the largest source of landside port CO_2 emissions making up nearly 58% of emissions in the Port of Los Angeles as of 2014 [1] with most of these vehicles being powered using internal combustions engines such as Diesel or Natural Gas [1], [2]. Plug-in hybrid electric yard tractors have been shown to save up to 60% in fuel along with associated reductions in tailpipe emissions due to electric operation when compared to conventional diesel vehicles. However, these vehicles are more complex thus having more systems to maintain [3]. Recent advances in electric vehicle technology have enabled companies including TransPower and Kalmar to develop and demonstrate full battery electric yard tractors with available battery sizes up to 220 kWh.

The objective of this effort is to provide the Port of Long Beach (POLB) with technical assistance in evaluating the potential for vehicle electrification and providing input data and analysis to inform the Port Community Electric Vehicle Blueprint (PCEVB). Using a suite of data acquisition, analysis and visualization tools, the National Renewable Energy Laboratory (NREL) conducted real-world performance evaluations of battery electric yard tractors (BEYTs) compared to conventional vehicles operating in the POLB's pier C which is a terminal operated by SSA Marine. This report summarizes the initial data collection and electrification evaluation of SSA Marine's yard tractors that occurred in August and September of 2018. Results from this project will provide detailed operational data and performance requirements of BEYT operated within the context of Pier C. The project will also provide a methodology to evaluate opportunities, strategies, and challenges associated with future expansion of BEYT s in meeting PCEVB goals.

1.1 Data Collection

Engineers from NREL instrumented sixteen diesel yard tractors (shown in Figure 1.1) at Pier-C, with Isaac Instruments DRU900/908 J1939 controller area network (CAN) and global positioning system (GPS) data loggers. Data was collected continuously over a 5-week period in August and September of 2018. Vehicle performance data including detailed engine CAN and GPS position information were monitored at 1Hz generating nearly 10 million data points and over 12 thousand miles of data. High level metrics of the data collection are shown in Table 1.1.

Figure 1.1 Picture of Pier-C yard tractors in POLB (left) and data logger (right)

Table 1.1 Data collection statistics

Yard Tractor Stats	
Miles of Data	12,286 miles
Gallons Used	3,825 gallons
Hours of Operation	2,742 hours
Vehicle Days	345 days

A map of the vehicle GPS data is shown in Figure 1.2 showing the location from each second of operation of each instrumented vehicle and highlighting the coverage and frequent locations of operation.

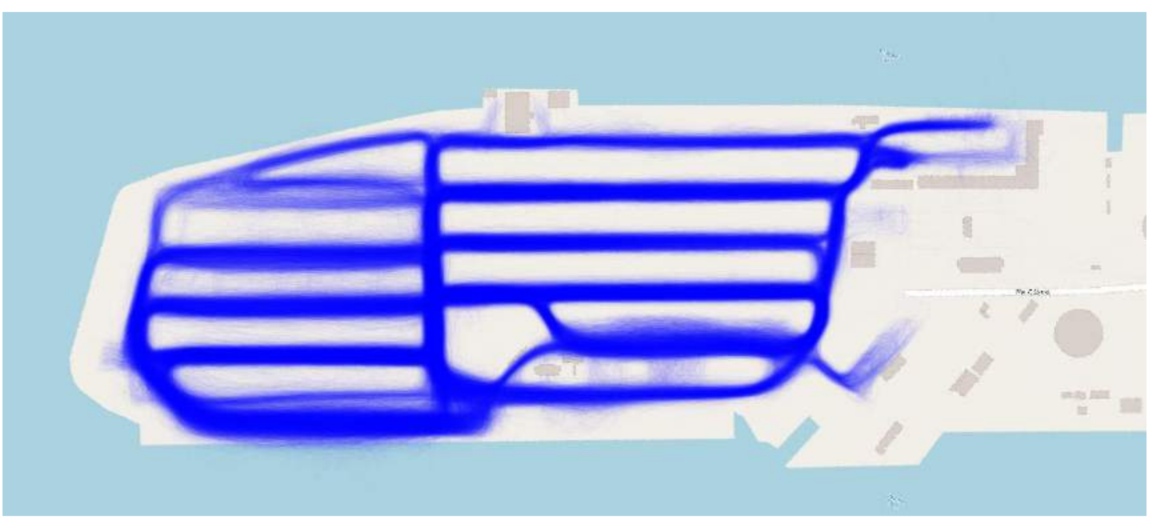

Figure 1.2 GPS trace of all driven routes

2 Analysis

NREL's experience in evaluating, measuring, and verifying fleet deployments of advanced medium and heavy-vehicle technologies has illustrated the relationship between vocational duty cycle, energy efficiency, and emissions, as well as the potential impacts on life cycle costs, barriers to implementation, and commercial viability. This work has shown that knowledge of real-world port-vehicle applications and yard tractor operation is critical in selecting the right technology for the given application and maximizing potential energy efficiency as wells as economic and performance impacts.

2.1 Duty Cycle

Understanding duty cycle is critically important when evaluating a vehicle fleet for electrification. Attributes such as average speed and daily distance are a first step in evaluating whether a duty cycle has characteristics conducive to electrification. Vehicles with frequent speeds above 40 MPH expend significant energy to overcome aerodynamic drag which is energy that cannot be recovered through regenerative braking unlike the kinetic energy. Distributions of daily average speed and distance are shown in Figure 2.1. While the average daily distance of the yard tractors was around 37 miles per day, there were some vehicles that traveled up to 75 miles per day. If BEYTs are expected to provide a one-to-one replacement for conventional vehicles they will need to accommodate the longest daily distance. The average daily speed was around 4 MPH suggesting that the vehicles operate at low speeds and do not expend much energy overcoming aerodynamic drag. Confirming with the fleet operator, these vehicles are limited to 25 MPH.

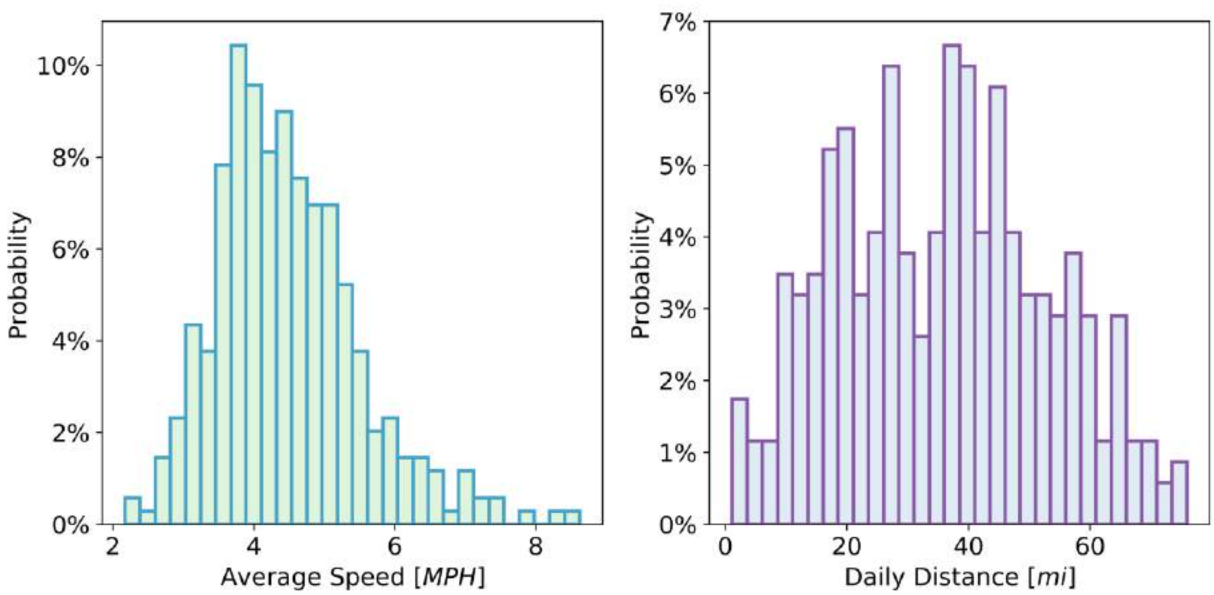

Figure 2.1 Daily average yard tractor speed and distance

The average daily fuel economy as measured from the CAN-reported fuel consumption was 3.2 MPG for the data collection period, which equates to 11 gallons of fuel per day at an average rate of 1.4 gal/hr. Distributions of both daily fuel economy and fuel consumption rate are provided in Figure 2.2 which includes data from all 14 vehicles over the full data collection period.

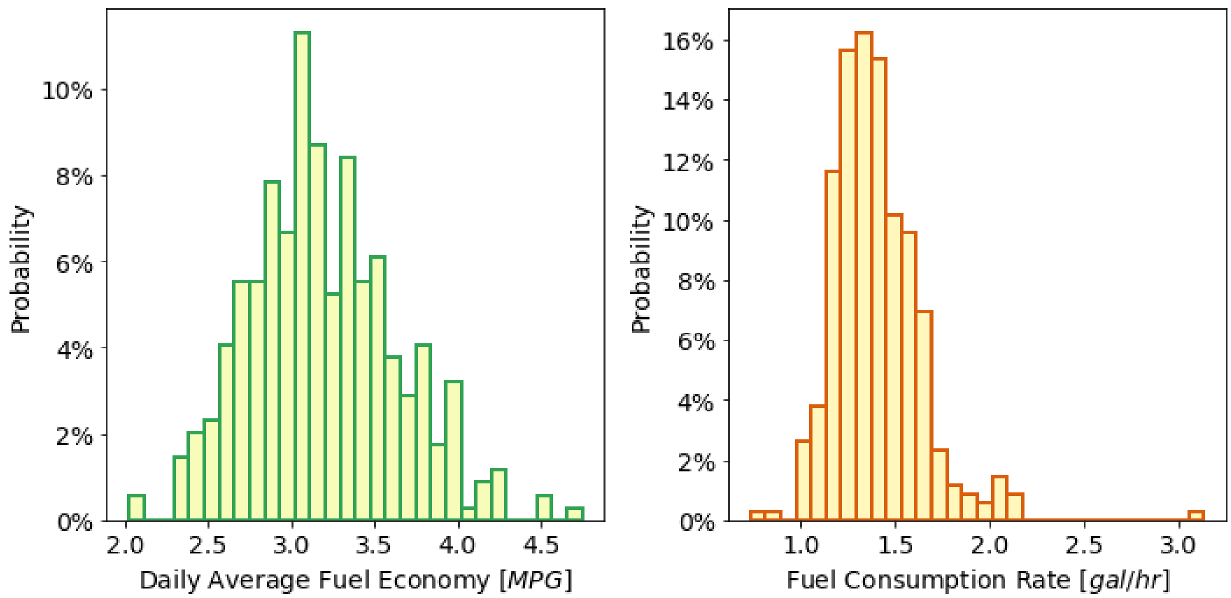

Figure 2.2 Daily average yard tractor fuel economy and fuel consumption rate

One benefit to vehicle electrification is that the vehicles use very little, if any, energy when they are stopped. Conventional internal combustion engine vehicles may use a significant amount of fuel and emission while the engine is idling when the vehicle is stopped. This can provide a substantial reduction in energy use depending on vehicle drive cycle and requirement for operating accessories like air conditioning. Figure 2.3 shows the distributions of daily engine run time and the daily idle time. Engine run time is a key component in identifying the ability for a vehicle to be electrified as this relates to the vehicle's utilization. A vehicle with high engine run-time and low idle time can be difficult to electrify since it will be consistently using energy while moving and have limited stopped time to charge. Yard tractors in this study had an average engine run time of about 8 hours with a maximum daily run time of 16 hours. Further, the average idle time per day was 3.2 hours with a maximum of 8 hours. This may provide a benefit for BEYTs, as they consume little or no energy during idle times – depending on the number of electric accessories. A deeper understanding of vehicle accessory loads is required to fully understand this potential benefit.

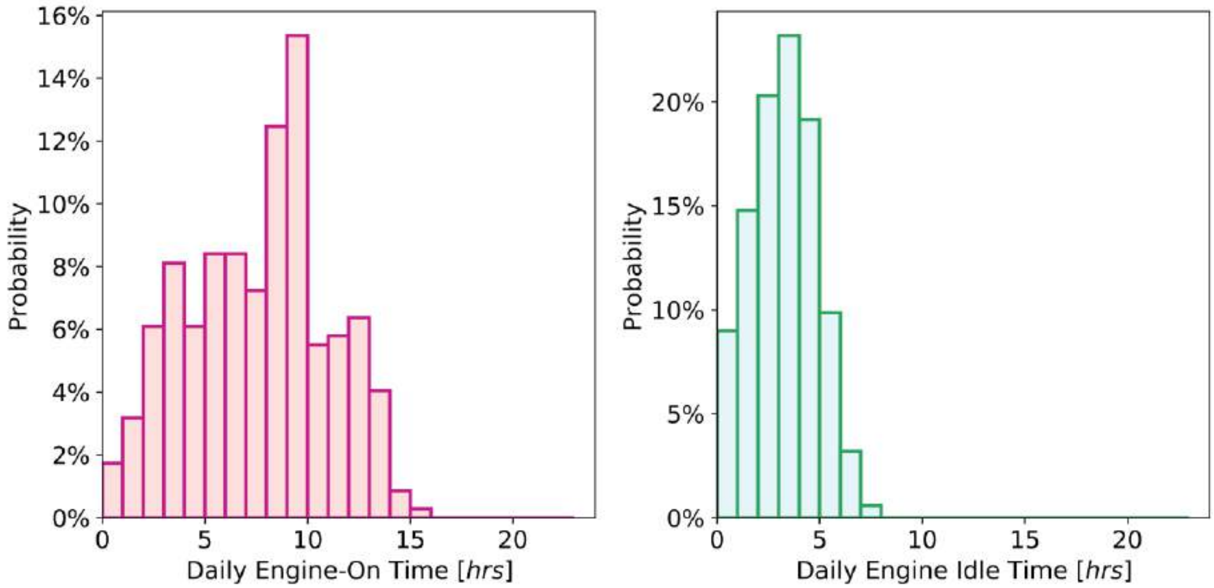

Figure 2.3 Daily average yard tractor engine-on hours and engine idle hours

As of this writing, the largest commercially available yard tractor battery is 220 kWh (included on the Kalmar Ottawa 2TE). Therefore, a candidate yard tractor duty cycle would have to use less energy than 220 kWh per day. While energy use is highly dependent on the drive train, examining an existing vehicle's daily brake energy, or usable energy produced by the engine, is a good approximation of the energy requirement of an electric vehicle. Daily engine brake energy and percent of daily energy used at idle are shown in Figure 2.4. Most vehicles' use less than the 220kWh per day, which is the energy of the largest available yard tractor battery. Further, up to 33 % of the day's energy is expended at idle with the idle energy being 7% of total energy consumed. This implies up to 33% of the daily energy which is used at idle would not be needed in an electric vehicle application thus enabling more vehicle days to be electrified. However, it is important to examine the full vehicle duty cycle to identify the opportunity for charging.

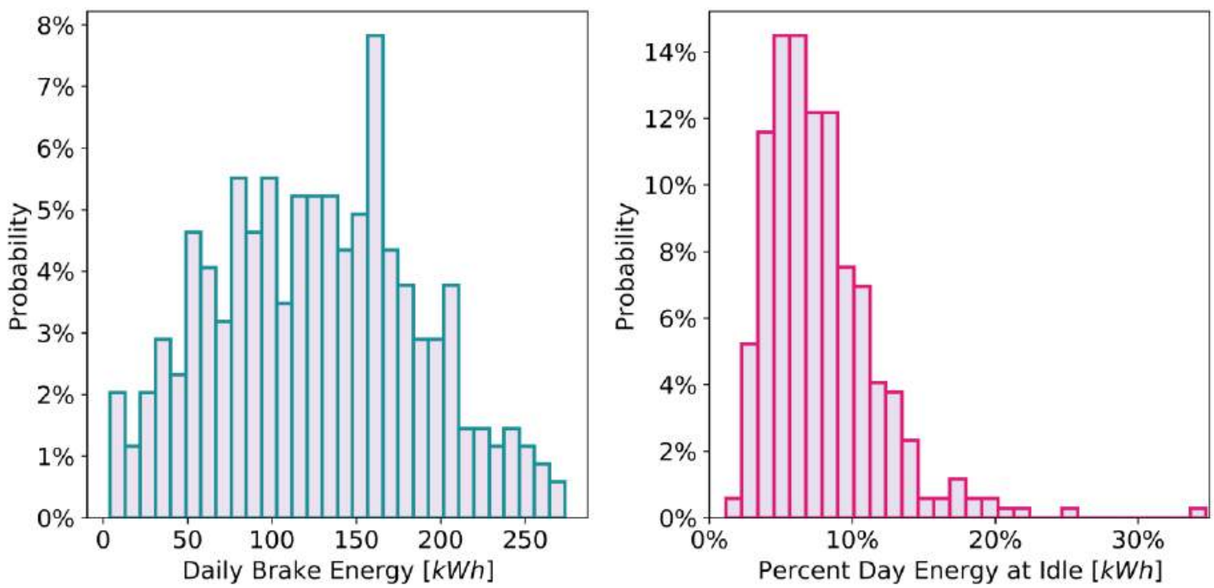

Figure 2.4 Daily average engine brake energy and percent of energy used at idle

2.2 Vehicle Model

Taking a vehicle system level approach, we examined the vehicle operation using the engine RPM as an indicator for indicating when the vehicle is active – i.e. engine is on. Each vehicle's activity was then plotted with Figure 2.5, where each color represents an active vehicle. Figure 2.5 providing a real example of low vehicle utilization where only 10 of the 14 vehicles were used at one time. If these vehicles were electric, this scenario would allow for vehicles that are not in use to be swapped out when a vehicle's battery gets low on charge.

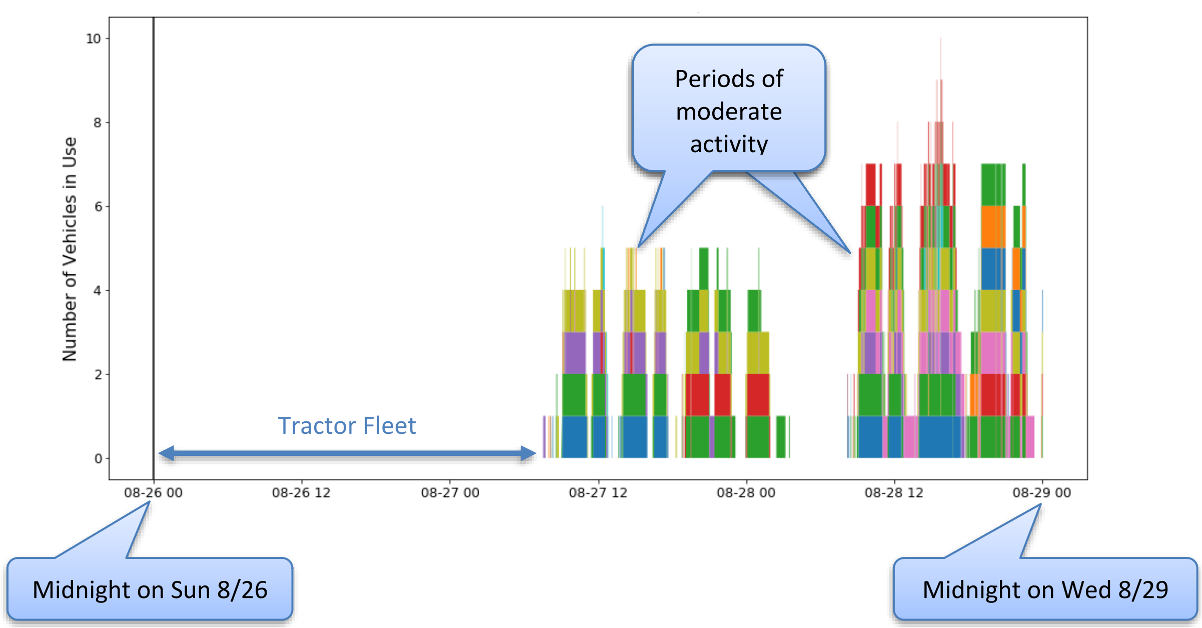

Figure 2.5 Low-use example with individual colors showing vehicle in-use

Alternatively, Figure 2.6 shows a high-use example with all 14 vehicles in operation at once and limited down time making it challenging to charge the battery. Further, this operation lasted from 8AM Friday to 4PM Saturday, with only 5 hours of down time prior, meaning an electric vehicle would need to have a battery large enough for this sustained operation. Such periods of prolonged operation are what drive the battery capacity requirements.

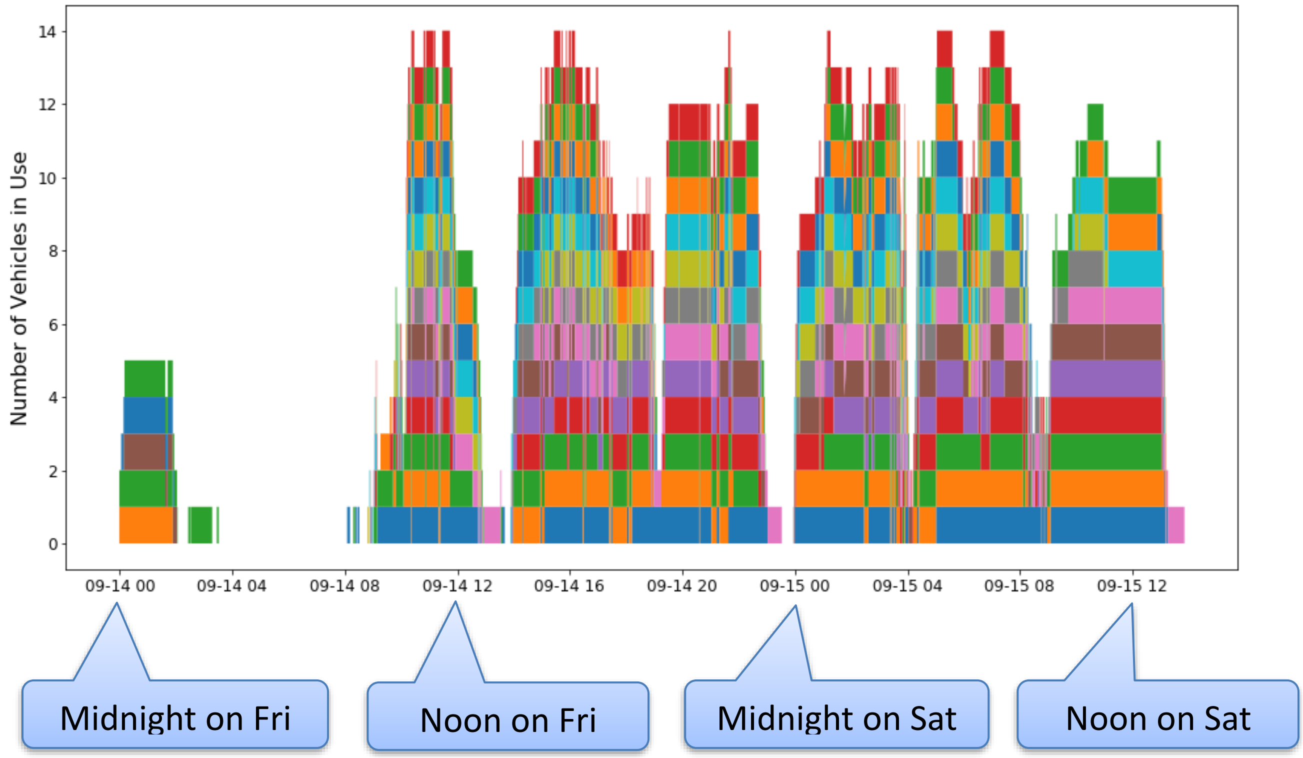

Figure 2.6 High-use example with individual colors showing vehicle in-use

A simplified vehicle model shown in Figure 2.7 was developed to further understand how the vehicle's full operation impacts the battery size requirement. The conventional yard tractors have a Tank (energy storage), Engine (energy converter), transmission and wheels. The data collected has estimated useful power or brake energy output at the flywheel of the engine which is shown as the point between the engine and transmission. Assuming this energy demand is the same that would be required for an electric vehicle, we swap the Tank and Engine for a Battery and Motor and calculate the battery size to meet the demand of the given drive cycle. To make this model more realistic it was assumed that the motor had a 90% efficiency meaning 90% of the energy from the battery makes it to the transmission. Energy use at idle was removed, since most electric vehicle drive trains do not use much if any energy at idle. The model does not include energy savings from regenerative braking, which would decrease overall energy use – i.e. the model is conservative.

Once established this model can provide estimates of battery power and state of charge over the entire drive cycle. For instance, Figure 2.8 shows the maximum battery energy usage predicted by simulating a rolling 24-hour window of real-world operation (i.e. actual drive cycle). The bars in red are the tractors being examined in the study, however one fork lift and two power shop towing vehicles called RoRos were also simulated. Interestingly, tractor H087 shows values over 300 kWh at the highest simulated usage, which is approximately 12% higher than the maximum of 270 kWh measured from the conventional vehicle data loggers.

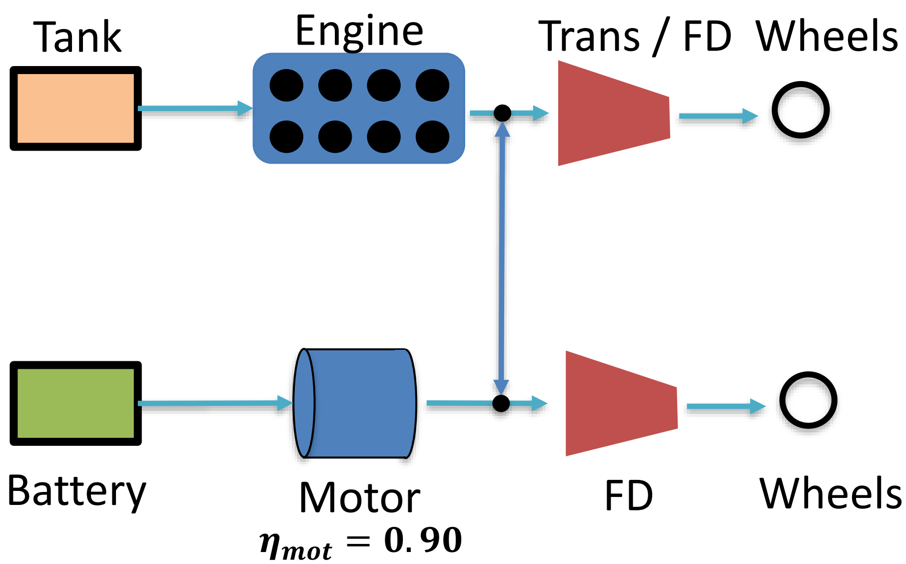

Figure 2.7 Vehicle model diagram for electric charging simulation

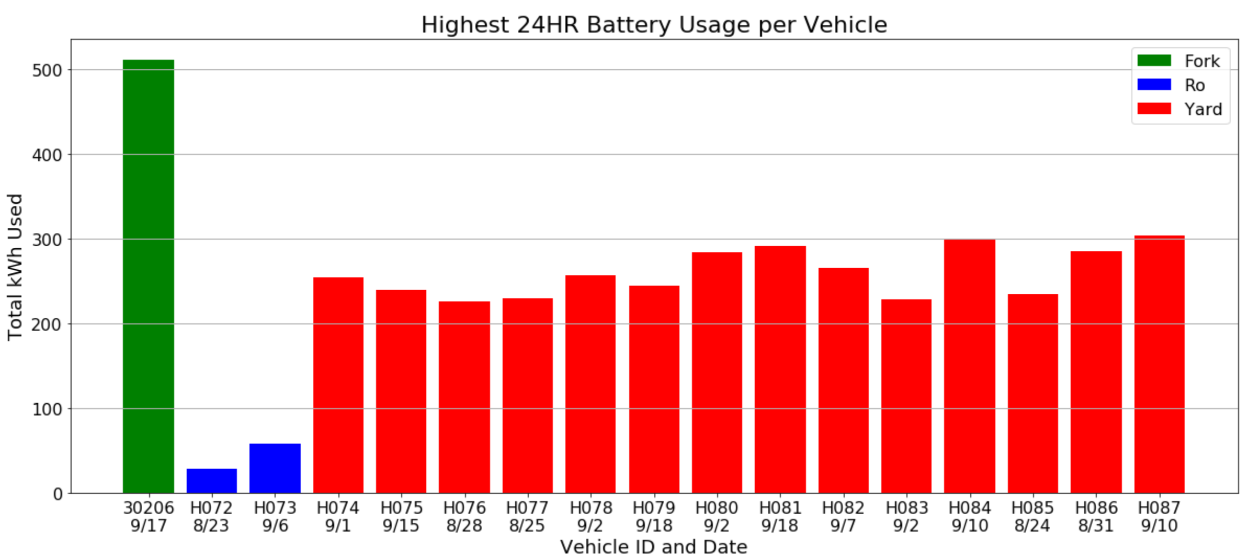

Figure 2.8 Maximum daily fly wheel energy production by vehicle

2.3 Charge Modeling

In addition to the vehicle model, NREL's battery lifetime analysis and simulation tool (BLAST) was used to identify optimal charging locations based on how long vehicles stopped at a given locations. Figure 2.9 shows the candidate location with valid locations shown in yellow and invalid location shown in green. A valid location was a location where the vehicle stopped for greater than 50 minutes and was collocated next to nightly parking. The zoomed-in photo in the top right of the figure shows the layout of parking for theses vehicles highlighting an optimal location to setup charging stations. While this was highlighted as the best location for overnight charging, there may also be some ability to take advantage of opportunity charging during lunch/coffee breaks or while waiting for containers. Figure 2.10 provides a distribution of stop duration for all yard tractors over the data collection period. Purple and pink bars represent stop durations greater than one hour highlighting the availability for slower Level-2 (60 kW for these vehicles and delayed charging which may occur over a weekend. However, a large portion of stops fall in the 5-minute to 1-hour category represented by the green bars suggesting potential for opportunity charging should the duty cycle require more energy than the battery capacity.

Figure 2.9 Analysis of charging location. Valid locations are those collocated by nightly parking.

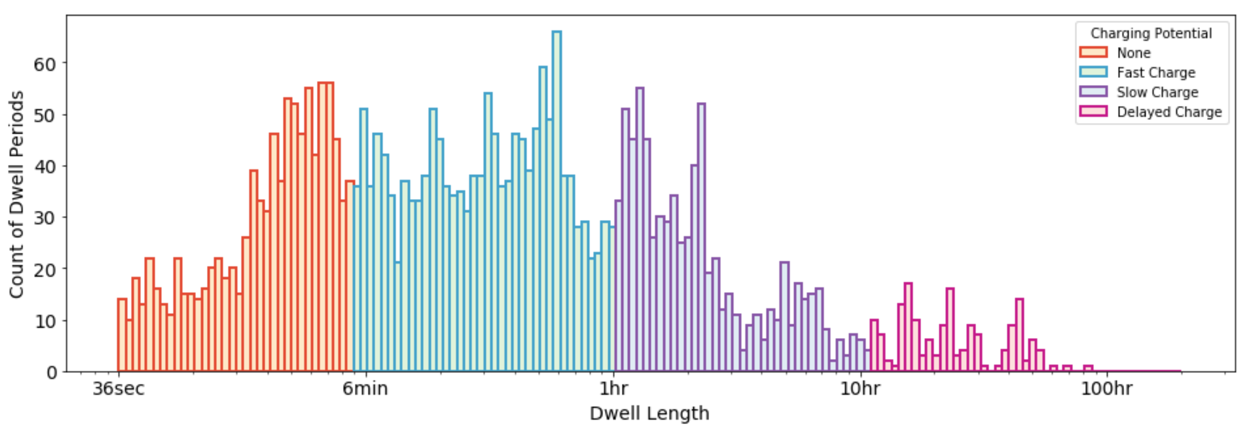

Figure 2.10 Logarithmic distribution of stop duration

3 Results and Discussion

3.1 Component Sizing

Each vehicle day was run through the model developed in section 2 to identify battery sizes and charge rates that accommodate each yard tractors duty cycle. Figure 3.1 provides an example of the full state of charge (SOC) profile where the modeled vehicle accomplishes the whole duty without any SOC violations. The assumed battery capacity was 200kWh and 60kW charge power which is like available technologies today. Reductions in SOC are associated with the modeled electric tractor performing tasks in the port consistent with real world operation, and increases in SOC are from the opportunity charging, occurring during park events within the geofenced location. The yellow line represents a state of charge of zero meaning the battery is empty. In this instance the plotted SOC represents vehicle activity for which an electric vehicle may be a suitable candidate since it does not fall below the zero line.

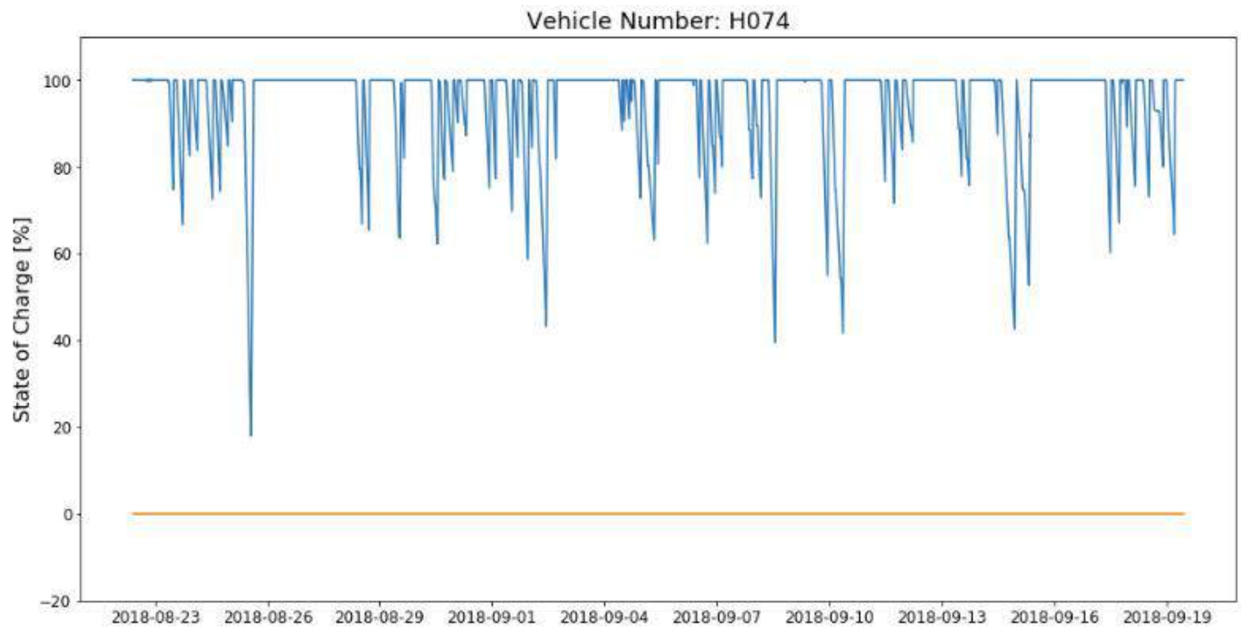

Figure 3.1 BEYT model showing 200 kWh and 60kW charging where vehicle successfully completes daily operation

While the vehicle in Figure 3.1 passed without going below 20% SOC, not all vehicles passed with a 200kWh battery and 60kW charging. Figure 3.2 provides an example of a vehicle duty cycle with an SOC violation meaning the vehicle needed more energy than could be provided with the modeled battery size and charging rate. This is due to more aggressive use and prolonged periods of activity with minimal opportunities to charge. The vehicle shown is an example of a yard tractor which is not ready to be fully electric with current technology. However, the SOC violation may be addressed in several ways, including larger battery sizing, increased charge power, or intelligent pairing between electric tractors and use-cases requiring limited activity.

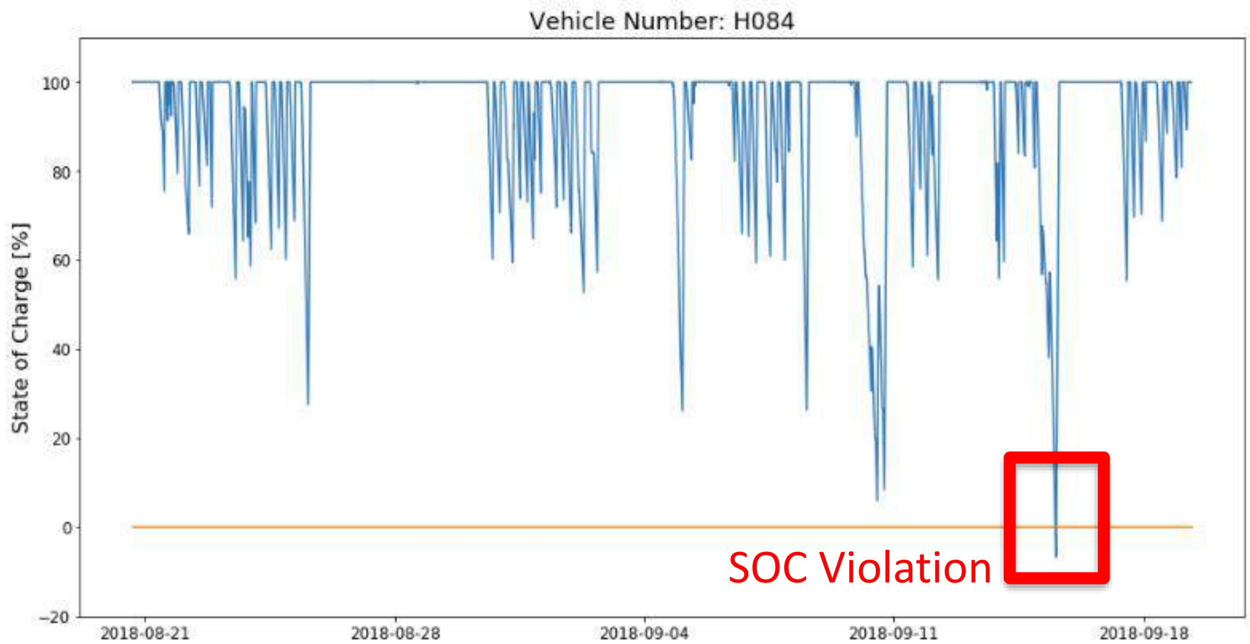

Figure 3.2 BEYT model showing 200 kWh and 60kW charging where vehicle has SOC violation during daily operation

Using this vehicle modeling framework, we explore the range of tractor parameters to identify battery size and charge rates that can meet the full duty cycle for all vehicles and better understand the relationship between tractor performance and component specifications. Figure 3.3 shows the number of SOC violations or failures in response to a sweep of input parameter. Battery size is shown to be the strongest predictor of successful tractor electrification. Increased charge power is associated with greater fleet performance, but only within intermediate battery sizes of 125 and 225 kWh. This simplified vehicle model shows that nearly 80% or 11 out of 14 yard tractors were able to be electrified using current technology with a 220 kWh battery that can charge at 60 kW meaning electrification is an option, though changes to operation may be needed to electrify all vehicles using current technology.

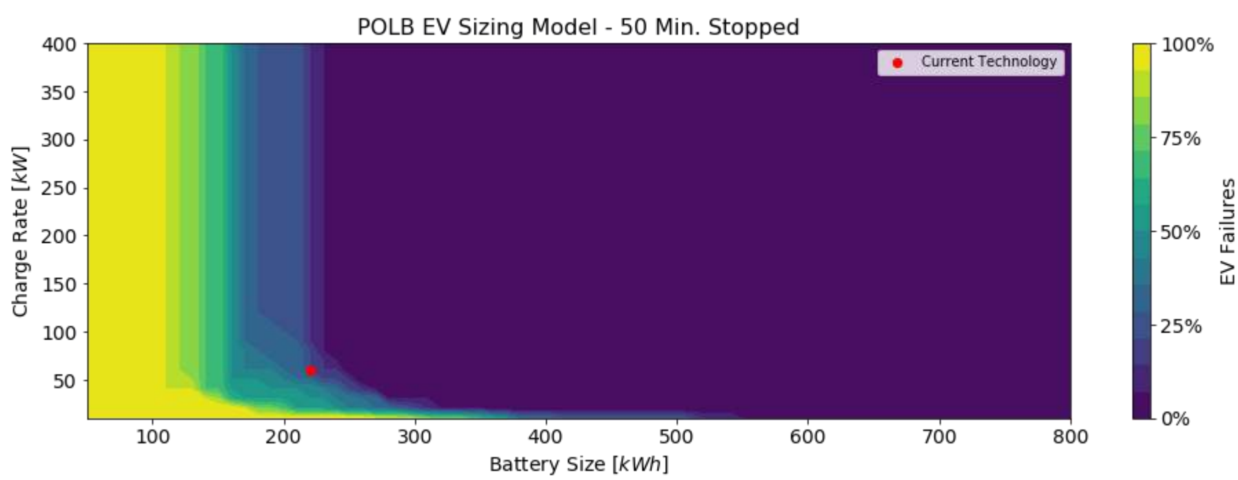

Figure 3.3 Full sweep of battery size and charge rate with BEYT model

Aside from battery size and charge rate, this framework also generates charging profiles that can highlight when vehicles are charging throughout the day, and the magnitude of the power dispensed from the grid. Figure 3.4 shows an example energy profile for the testing period based on 14 vehicles charging at 60kW. Unlike fuel-powered vehicles, electric vehicles require support from the electric grid making charging demand a key consideration when implementing electric vehicles. Aggregating the power delivered to each tractor produces a load profile incurred by the local distribution feeder. Analysis of the load profile is critical, as it may inform necessary feeder upgrades and implications on the port's utility bill.

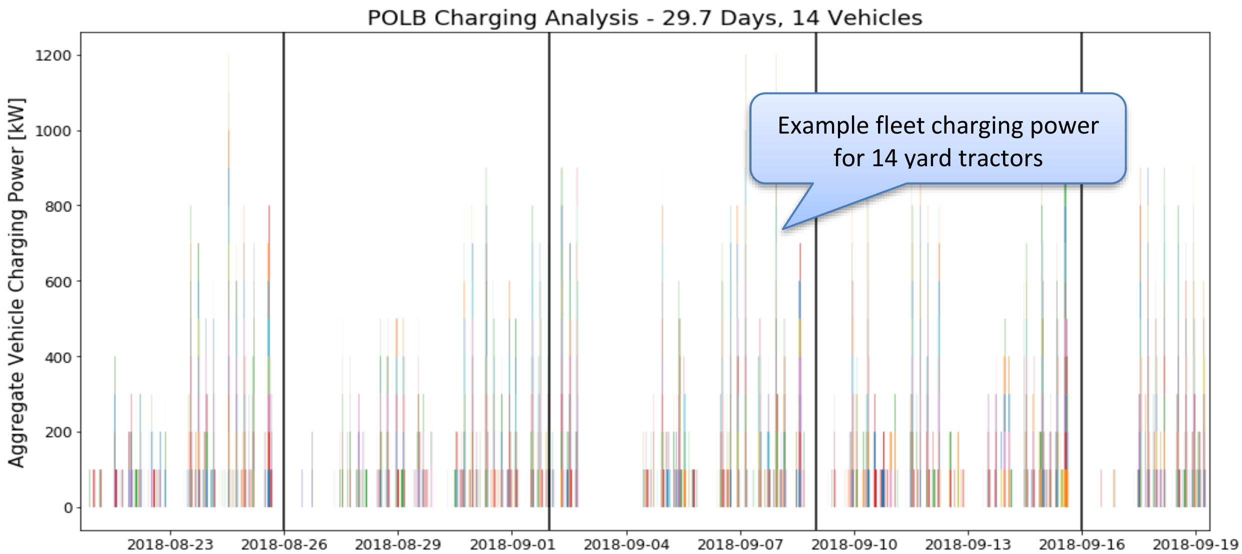

Figure 3.4 Example of fleet charging power versus time

Maximum power demanded from the grid is a key parameter for financial calculations since this dictates the rate structure for the port often called the demand charge which is a charge associated with delivering peak power draw. Like the EV sizing model sweep in Figure 3.3, aggregate max charging power was plotted against charge rate and battery size in Figure 3.5 to understand the relationship between vehicle component sizing and the maximum demand power. While battery energy was shown to be the predominate variable of interest in Figure 3.3, charge power is shown to influence the peak demand power in Figure 3.5 and is not dependent on battery size.

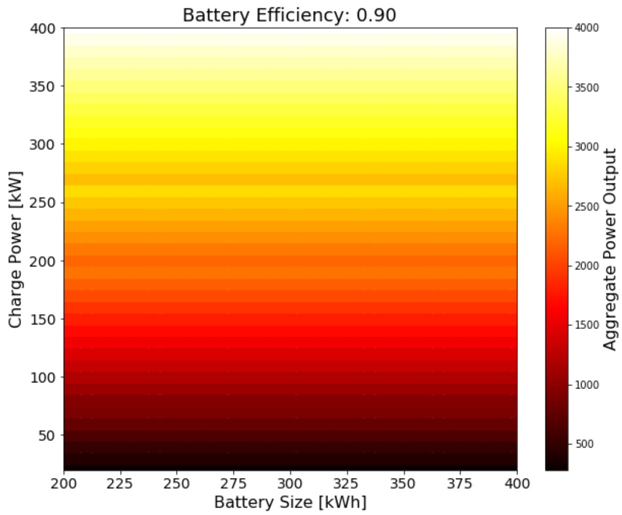

Figure 3.5 Dependence of aggregate charge power on battery size and charge rate

3.2 Emissions

Reductions in emissions are a large benefit from adopting electric vehicles, though many figures only examine tailpipe emissions and neglect emissions from producing both fuel and electricity. Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model examines this by incorporating national inventories and examining the full process for fuel and energy production [4]. Using outputs of the GREET model in conjunction with data collected from the yard tractors, energy estimates from the model developed in Section 2.2, and emission information from the U.S. Energy Information Administration [5], Figure 3.6 provides a comparison of CO_2, oxides of nitrogen (NO_X) and sulfur oxides (SO_X) emissions between diesel and electric yard tractors. The left plot shows the emissions broken out by tailpipe and production where tailpipe emissions are emissions generated by the vehicle, and production emissions are from producing fuel or electricity depending on the drivetrain technology. The electric vehicle has zero tailpipe emissions compared to the diesel vehicles which is a large benefit to local air quality and operator exposure to these emissions. CO_2 emissions from producing the energy sources are roughly the same for both diesel and electric powertrains with a slight increase in NO_X from electricity production, but near zero SO_X emissions as compared to diesel production.

The plot on the right of Figure 3.6 shows the combined tailpipe and production emissions highlighting the overall benefit from electric yard tractor adoption on Pier C with an 80% reduction in CO_2, 75% reduction in NO_X and a near elimination of SO_X. Extrapolated to the entire fleet of 34 yard tractors, adopting electric vehicles would eliminate approximately 3 million pounds of CO_2 each year. Likely this number will increase as the electric grid switches to renewable energy.

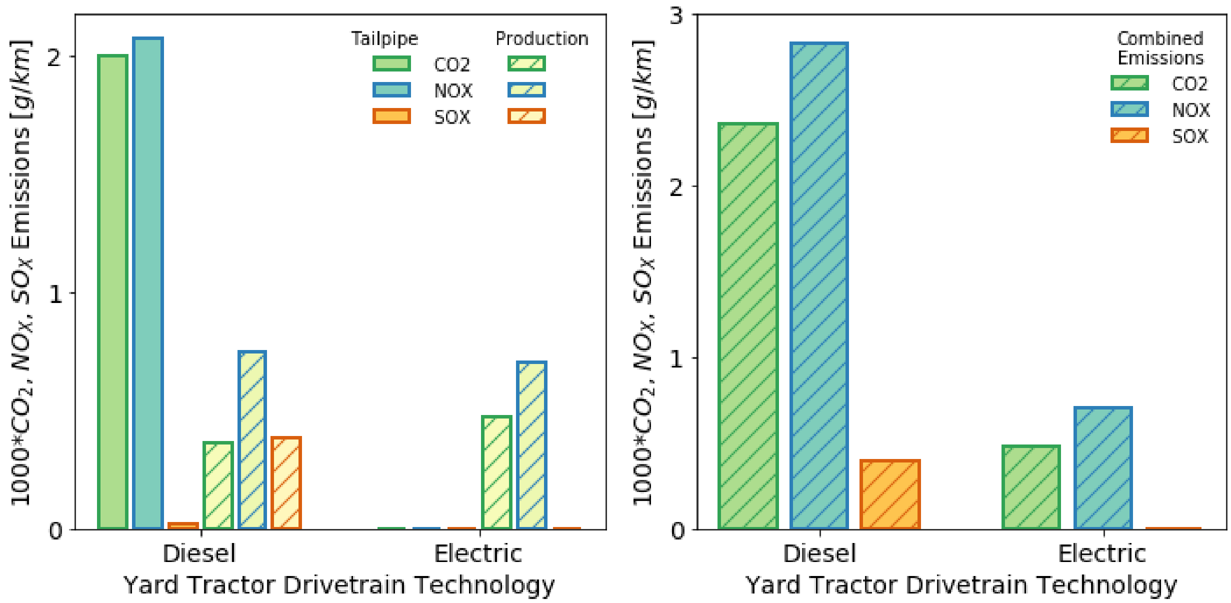

Figure 3.6 Emissions comparison between diesel and electric yard tractors

3.3 Utility Impacts

Supporting a fleet of electric tractors is certain to raise utility bills as a result of increases in energy use and peak energy demand when replacing non grid-supported vehicles including the diesel yard tractors examined in this study. To identify the magnitude of this increase fleet operation was scaled to a month-long period and total energy dispensed to vehicles was calculated. Figure 3.7 compares the calculated increase to the existing monthly port electrical energy use and shows an increase in total energy use from the current state between 25% and 30%.

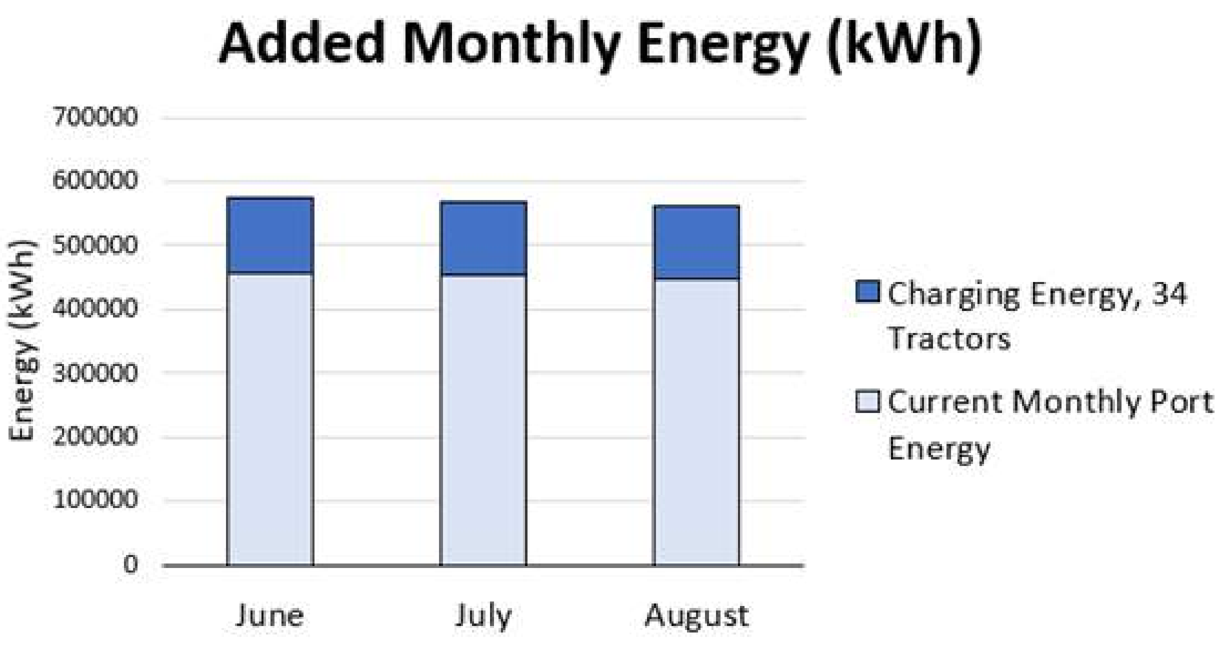

Figure 3.7 Month energy use comparison

Additionally, the utility bill incurred is influenced by the maximum power draw during the billing period. To quantify the influence of increased peak demand, the monthly electric vehicle demand from Figure 3.5 was added to the existing peak demand and compared in Figure 3.8 to highlight a worst-case scenario or situation in which the maximum charging power delivered to the vehicles occurs simultaneously with the existing maximum demand. While possible, this case is unlikely as all vehicles are not likely to be plugged in at once during peak demand, however it represents a conservative estimate for the increase in peak demand. If the peak charging demand occurs during times of low power demand throughout the rest of the port, the monthly peak demand will be significantly less.

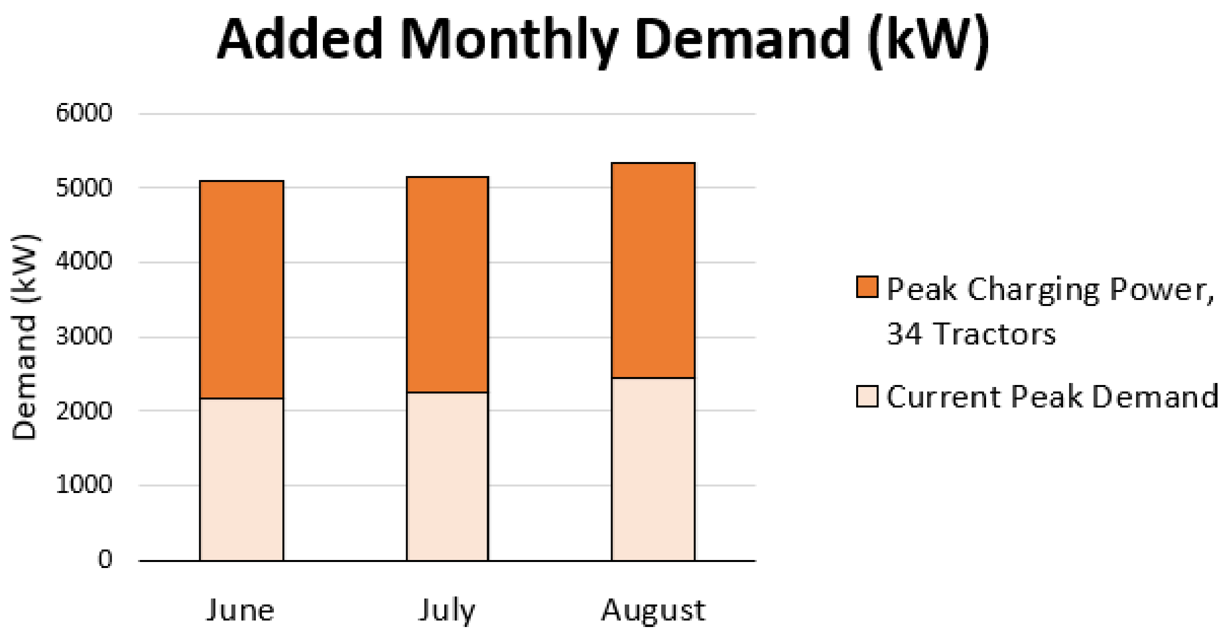

Figure 3.8 Month peak energy demand comparison

Rates currently paid for energy and demand charges by the port were used to translate the increased monthly energy consumed and peak power demanded from the grid into utility bill increases which are shown in Figure 3.9. Three charging scenarios are shown along with the associated utility bill increase depending on what time during the day charging occurs. Demand charge is the predominate driver of increased costs especially for the on-peak charging scenario suggesting the need for coordinated charging or charge mitigation strategies to a avoid having all vehicles charging at once.

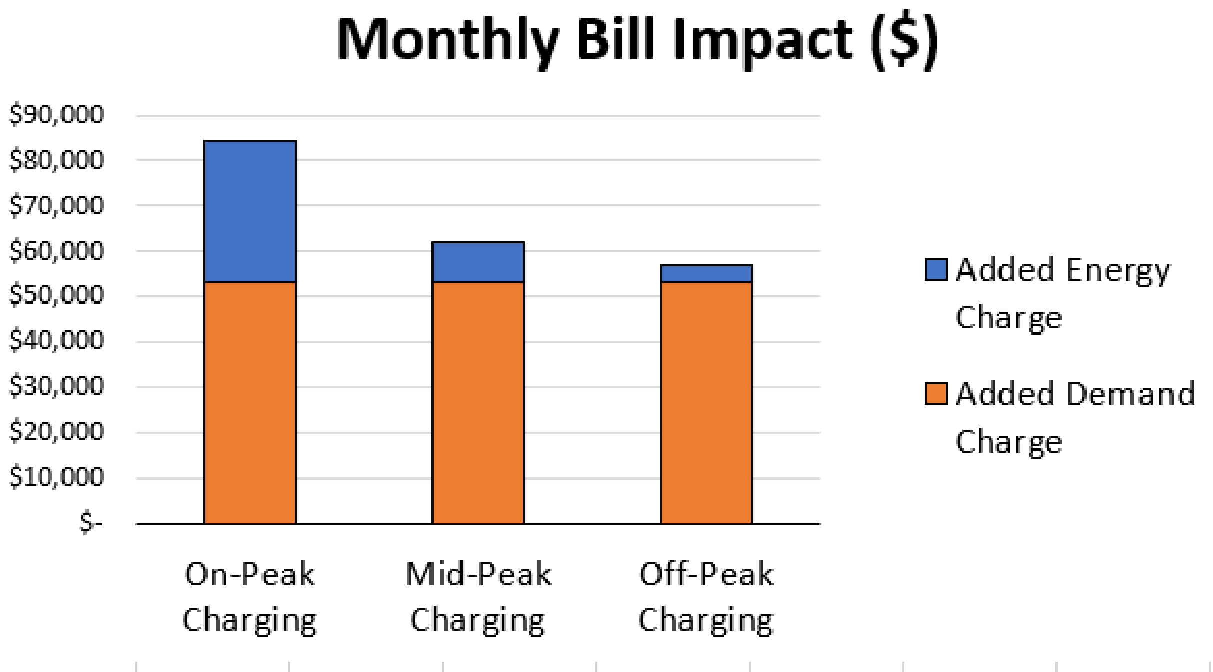

Figure 3.9 Monthly bill impacts of electrification for three charging scenarios

Managed opportunity charging was explored by reducing the charge power during longer dwell periods such the same energy was delivered but at a lower power and longer duration to reduce the overall power demand. An example trace of charge managed fleet operation is shown in Figure 3.10 with the blue curve modeling no charge management and the yellow assumes all vehicles are minimizing their charging load when permitted. This modeled charge demand strategy has effectively reduced the peak demand of the fleet from 800kW in the scenario with no charge management to just over 200kW when charge management is enforced. While charge management showed a nearly 75% reduction in peak demand, the modeling assumes omniscience such that the vehicle operator would have full awareness when plugging in as to when the vehicle will be used again which may be inconsistent with real world operation.

Further, the scenario shown in Figure 3.10 is an optimal use case, but these vehicles may have short, desperate stops where no opportunity exists for charge optimization. Figure 3.11 shows the same comparison, but over a period of high fleet utilization. For most of the time period, the traces of managed and non-managed charging are identical suggesting that there was minimal opportunity to reduce charge power of the vehicles. The peak demand of 1200kW was not reduced, making high demand charges inevitable without changes to fleet operations. Such changes may include adding more tractors and swapping them out as they deplete or keeping a mix of fuel-powered vehicles and electric vehicles.

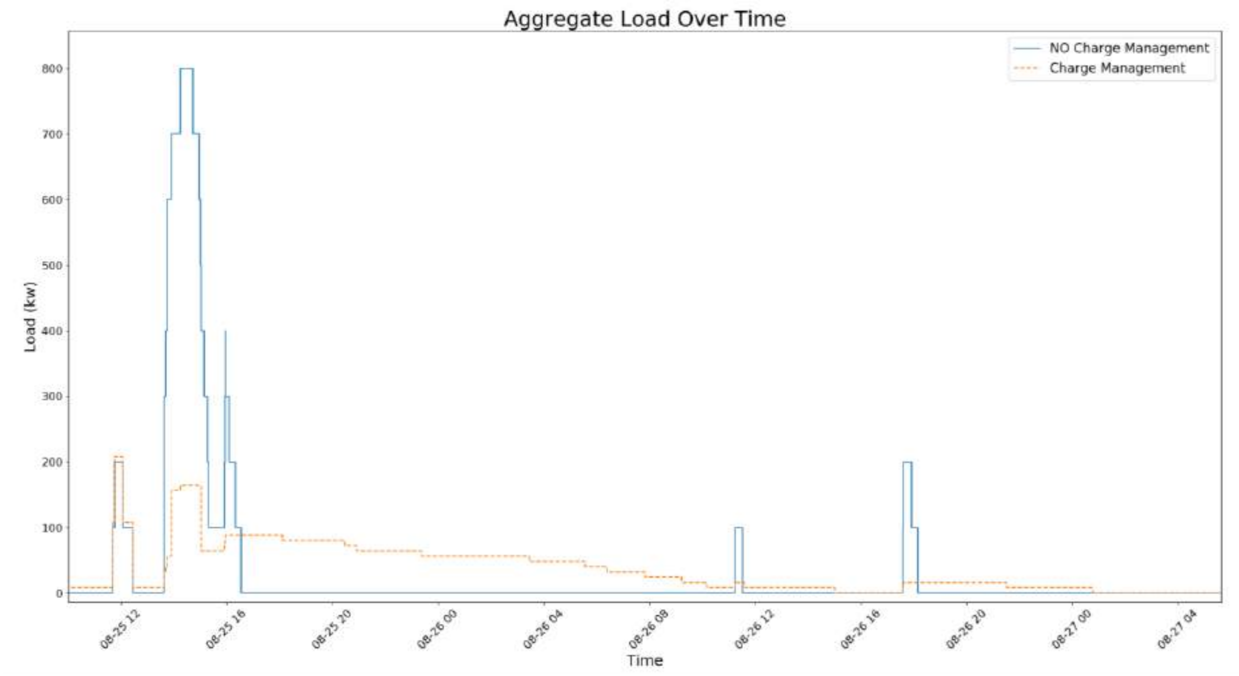

Figure 3.10 Example of charge management opportunity

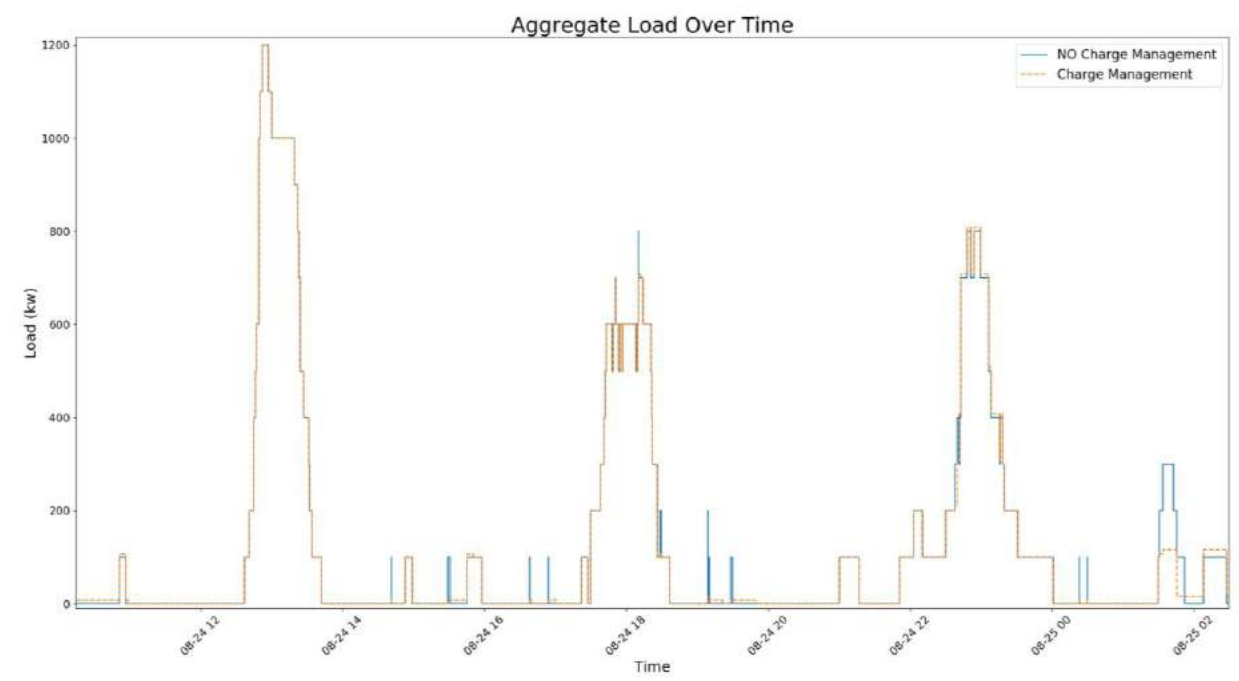

Figure 3.11 example of poor charge management opportunity

4 Summary and Recommendations

Yard tractors make up 58% of landside port CO_2 emissions meaning improvements in efficiency and electrification will have a significant impact. This research examined yard tractor operations at POLB Pier-C to evaluate the potential for yard tractor electrification and provide input data and analysis to inform the Port Community Electric Vehicle Blueprint (PCEVB). NREL collected data on 14 of 34 yard tractors totaling 12,286 miles of operation in August and September of 2018 providing enough information to assess the vehicle operation for electrification potential.

Over the collection period the yard tractors had an average daily distance of 37 miles and an average speed around 4 MPH. Further, the max daily brake energy or usable energy produced by the engine was 270 kWh with up to 33% of the daily energy spent at idle make these vehicles candidates for electrification. A simplified vehicle model was developed to further identify the opportunity for yard tractor electrification and examine the full duty cycles including both use patterns and charging availability. Outputs of this model indicate 11 out of 14 yard tractors or approximately 80% of the vehicles studied could be electrified using vehicle currently on the market that have a battery size of 220kWh and can charge at 60kW, however, operational changes, more vehicles or smart scheduling may be needed to electrify all vehicles using current technology. Adoption of BEYTs would reduce CO_2 emissions by roughly 80% eliminating approximately 3 million pounds of CO_2 each year.

Charging infrastructure is another large consideration when adopting electric vehicles. Net monthly energy for Pier C was estimated using the vehicle model by extrapolating the 14 vehicles monitored in this study to the 34 yard tractors in the terminal. While the total energy use increased 25-30%, the worst-case scenario showed that peak power demand could more than double resulting in a possible increase in utility bill of nearly 60%. However, this scenario assumes all the vehicles are charging at once and coincides with the current peak energy demand at the terminal and does not include offsets from reduction in fuel costs due to conversion. The less aggressive mid-peak charging scenario only showed a 17% increase in electric bill due to BEYT adoption.

Future work will include examining charge mitigation strategies and managed charging opportunities where the charging power is tapered so the overall peak power draw from the grid is reduced. The brief example shown in this study estimated overall peak demand from the BEYT could be reduced by 75% in an ideal scenario. Actual implementation would likely be less-effective due to unforeseen charging and scheduling scenarios. Additionally, actual in-use testing of a BEYT is prudent to verify drivetrain efficiencies. This modeling effort took a very conservative approach, so it is possible that actual BEYTs would perform better due to the addition of regenerative braking and a more efficient drivetrain.

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Appendix F: Charging Standards White Paper

Status of Electric Vehicle Charging Standards for Port Applications

Introduction

Currently, there are several standards in the United States for electric vehicle supply equipment (EVSE), nearly all of which can be used for heavy-duty vehicles at the Port of Long Beach (POLB). There have been two standards developed by the Society of Automotive Engineers (SAE) for alternating current (AC) manual conductive connectors (SAE J1772 and J3068), both of which can be equipped with additional direct current (DC) pins to charge vehicles more quickly. There is also a separate DC charging standard used by Japanese automakers (CHAdeMO) and an automatic connection standard under development that uses a pantograph or similar connection (SAE J3105). SAE has published a standard on wireless charging for light-duty vehicles (SAE J2954) and is developing one with faster charging times more appropriate for heavy-duty vehicles. These standards are summarized in Table 1, and the three basic types of connections are shown schematically in Figure 1. In addition, there are proprietary standards for single manufacturers (e.g. Tesla uses a proprietary standard for its sedans and SUVs and may introduce another standard for its tractor trailer), and U.S. Department of Energy's National Laboratories are conducting research and development on a megawatt-scale charger. Many of the standards below are undergoing revisions to increase maximum power among other improvements.

Table 1. EVSE Standards in the United States

EVSE Standard	Connection Type	Current Type	Preferred Communication Type	Maximum Current Rating (A)	Maximum Voltage Rating (V)	Maximum Power (kW)
J1772 Level 1	Handheld Conductive	Single-Phase AC	PWM	16	120	1.92
J1772 Level 2	Handheld Conductive	Single-Phase AC	PWM	80	240	19.2
J1772 CCS	Handheld Conductive	DC	PLC	400	1000	400
J3068	Handheld Conductive	Single or Three-Phase AC	LIN	160	600	166
J3068 CCS	Handheld Conductive	DC	LIN	400	1000	400
CHAdeMO	Handheld Conductive	DC	CAN	400	1000	400
J3105 Level 1	Automatic Conductive	DC	Unpublished	600	1000	350
J3105 Level 2	Automatic Conductive	DC	Unpublished	1200	1000	1200
J2954	Automatic Wireless	AC	Wireless	Unknown	Unknown	22

J2954/2 (Pre-Draft)	Automatic Wireless	AC	Wireless	Unknown	Unknown	200

(a) (b) (c)

Figure 1. EVSE Connection Type
(a) Handheld Conductive (b) Automatic Conductive (c) Automatic Wireless

Most of the cargo handling equipment (CHE) that POLB terminal operators intend to electrify as well as the thousands of drayage trucks that visit the port are classified as heavy-duty vehicles, which consume large amounts of energy (e.g. 1-2 kWh/mile). Therefore, they will require large batteries (i.e. hundreds of kWh) and, in some cases, high-power charging throughout 10 piers and 80 berths. As of 2015, the equipment based at POLB used the energy equivalent of 162 GWh of electricity per year or approximately 444 MWh per day (Figure 2), although electrified replacements are typically 2-4 times more efficient than diesel equipment. A list of current POLB CHE by manufacturer and type can be found in Appendix A. Additionally, Moultak et. al (2017) have identified several companies that have deployed various types of medium and heavy-duty electric trucks.

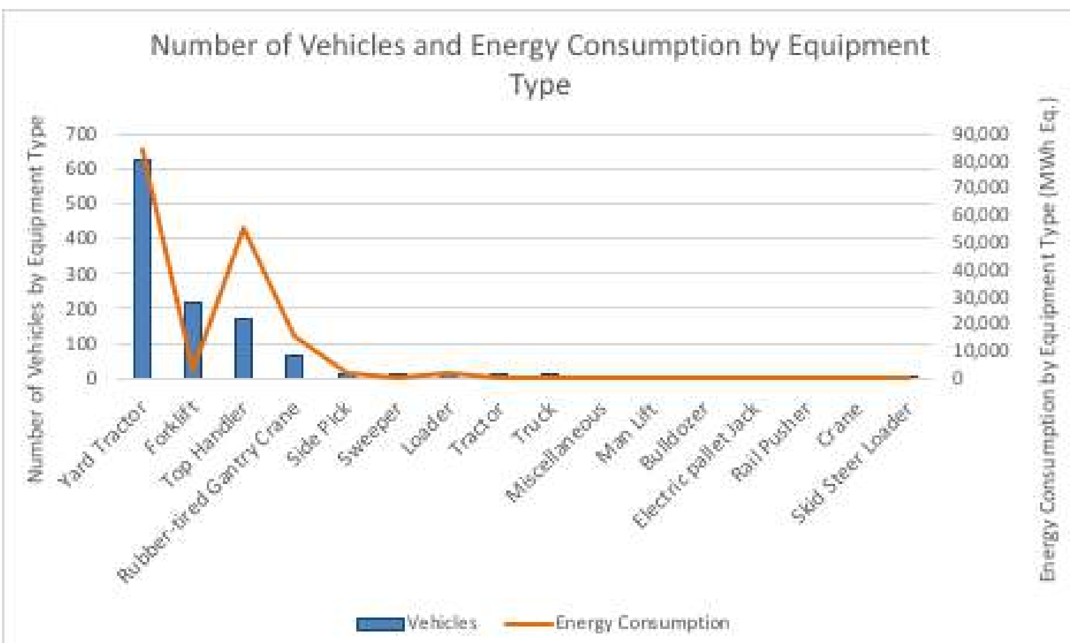

Figure 2. Port of Long Beach Fleet

Based on this profile, the key characteristics that POLB should consider in selecting EVSE units are charging speed, ability to manage load to reduce peak demand charges, cost of equipment and infrastructure upgrades, and compatibility with multiple manufacturers. This report reviews existing and forthcoming US standards, focusing on HD considerations applicable to POLB.

EVSE Fundamentals

The majority of EVSE in production are manually connected conductive couplers. These units are designed with safety in mind: standardized units include a protective plastic sleeve so that people cannot put their fingers between the EVSE and the vehicle; they have a first-make, last-break protective earth (ground pin) to carry power in the case of a malfunction; and they use some variation of control and proximity pins to send the correct amount of power to a properly connected vehicle. To ensure the device always operates in a safe manner, energy will only flow when a proper connection is made, and a ground connection is always present to carry fault current in the event of a failure.

Electric vehicle (EV) batteries store energy in the form of direct current (DC) power; however, U.S. utilities and many EVSE units provide energy in the form of alternating current (AC) power. In order to provide a conversion between these two different forms of energy, EVs typically have on-board rectifiers to convert AC power from the EVSE to DC power in the batteries. These rectifiers are normally limited to relatively low power conversion. They range in power level, but 6.6 kilowatts (kW) is common in light-duty passenger vehicles. In order to transmit higher levels of power to the battery, a larger rectifier on or off the vehicle is necessary. For this reason, DC fast chargers (DCFC) are a popular option for public charging and heavy-duty applications. This method of charging incorporates a rectifier within the EVSE and bypasses the onboard charger, as shown in Figure 3, in order to provide a higher level of power directly to the batteries. As an example, Tesla's "Supercharger" network of DCFCs supplies power at 90-120 kW. Theoretically, 120 kW of continuous power would charge a Tesla Model 3 60 kWh battery pack in half an hour for an additional driving range of 230 miles. Although this faster charging method typically has a higher installation cost, it has become increasingly popular to help facilitate long distance travel.

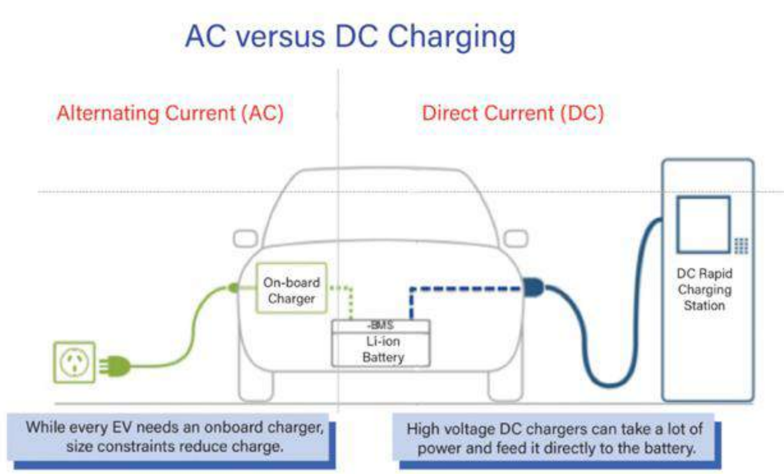

Figure 3: AC vs. DC Charging (Source: Tilsey 2017)

The two remaining types of standardized EVSE are automatic couplers and wireless inductive pads. Automatic couplers may attach via an overhead pantograph or side arm. Wireless pads are typically embedded in a street or parking lot. Both are good options for fast charging, with the wireless pads and pantographs projected to offer 200 kW and 1200 kW respectively. The J3105 pantograph system will specify DC power under two potential power levels, one capped at 350 kW and the second up to 1200 kW. Proterra currently uses a prototype for the J3105 pantograph that provides up to 500 kW to their buses. (Proterra 2019). To generate higher power levels for heavy duty vehicles, the J2954 wireless power transfer standard refers to multiple coil configurations transferring multi-phase AC power to the receiving equipment onboard the vehicle.

Overview of Charging Standard-Related Organizations

This report focuses on SAE standards along with the CHAdeMO standard because they are the most commonly used in the United States. SAE International is an association of motor vehicle and aerospace engineers that develops standards and technical reports for both industries. They are based in the United States but address an international audience.

However, there are many different organizations that develop standards independently. For example, Europe's Type 2 connector, while similar to the J3068 EVSE, follows the International Electrotechnical Commission (IEC) standard 62196. China developed a slightly different standard through the Guobiao association for their internal market with a male EVSE connector and female inlet on the vehicle in contrast to all of the other standards discussed in this report. In addition, CHAdeMO has been published as an IEC standard and an Institute of Electrical and Electronics Engineers (IEEE) standard. International Organization of Standards (ISO) is also relevant. ISO has published key EVSE communication standards as part of its operations across several technology sectors.

Several other organizations play major roles in standard development and promotion. This memorandum references CharIN and the CHAdeMO Association, but other trade organizations such as the Open Charge Alliance and research institutions such as the Electric Power Research Institute are key participants as well.

SAE Standard Approval Process

SAE publishes a wide variety of automotive standards and technical reports following a prescribed process.[1, 2] SAE has three overarching committees, each of which may create committees or task forces to investigate or develop new standards. The overarching committees focus on aerospace, automotive, and commercial vehicles. The latter is focused on trucks and buses and may be more applicable to heavy-duty vehicles, although charging standard committees may arise from either the automotive or commercial vehicle technical committees. SAE also has steering committees for topic areas, including the EV / Hybrid Vehicle Steering Committee (Wilson 2016).

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[1] https://www.sae.org/standardsdev/devprocess.htm

[2] https://www.sae.org/standardsdev/participationReq/

SAE creates technical committees that are responsible for developing reports and standards. These committees are led by a sponsor who drafts the standard or report. Then the committee members provide feedback and eventually vote on a completed version. The sponsor is responsible for attempting to resolve committee comments. Then the developed document is reviewed and voted on by the overseeing committee before being published. Anyone may request that SAE develop or formalize a standard by submitting a form online, or they may get involved through SAE's calls for experts. (SAE 2018b).

Anyone may volunteer to participate in a standard committee or request that SAE develop or formalize a standard. SAE has over 600 motor vehicle technical committees with nearly 10,000 members, many of whom work for technology companies (Wilson 2016). For example, WAVE (a company which developed wireless power transfer (WPT) technology) participates in the J2954 committee for WPT.

SAE J1772 AC

The most commonly used EVSE in the United States is the J1772 Type 1 connector. It was designed for light-duty vehicles, although it can charge heavy-duty vehicles. J1772 AC charging speed is limited to 19.2 kW. By comparison, BYD class 8 tractors are sold with a 435 kWh battery, meaning it would take at least 23 hours to charge the entire battery using the fastest J1772 connection available. A primary limitation of J1772 is that it only accepts single-phase power, whereas industrial facilities like ports often have three-phase power readily available.

There are five pins in a J1772 AC port. While the inlet, which is mounted on the vehicle, appears to be the female connection at first glance, the pins are actually located in the inlet (shown at right in Figure 4):

- two lines to carry power (one of which serves as a neutral on 120V connections),
- ground
- proximity detection
- control pilot

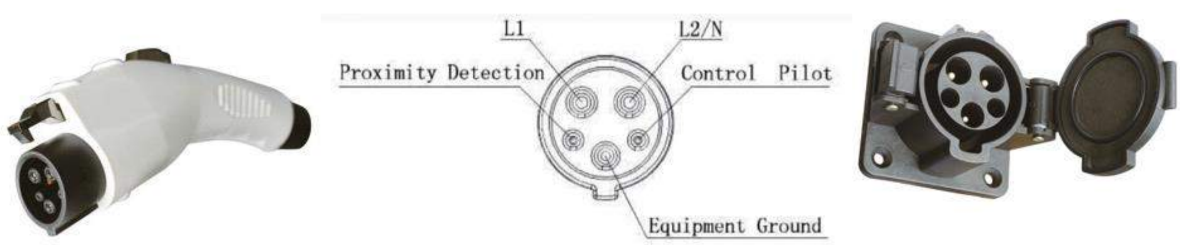

Figure 4: J1772 Coupler, Schematic, and Inlet (Sources: KLS Electronic, Electric Car Parts Company)

The J1772 EVSE uses the proximity detection pin to signal that the vehicle is connected, to immobilize the vehicle, and identify if someone has pressed the release button. It uses the control pilot pin to send additional messages using pulse width modulation (PWM). These messages include initiating charging, determining appropriate current level, and recognizing errors such as overheating. Through PWM, the EV applies resistance to drop the 12V signal sent by the EVSE to a specified level for sending messages. Detailed specifications can be found in the SAE standard (SAE 2017).

SAE J1772 DC (CCS)

In 2012, SAE introduced DCFC to the J1772 standard with the placement of two additional pins to carry DC power. The new standard, commonly referenced as the combined charging system (CCS), builds off of the J1772 platform with the same top five pins. However, the two DC pins shown in Figure 5 can provide much more charging power than the AC version. DC Level 1 power is limited to 600 V and 80 A (theoretical maximum of 48 kW although the SAE standard refers to a 40 kW limit) on 3.6 mm pins, and DC Level 2 power can provide up to 1000 V and 400 A (for a theoretical maximum of 400 kW) on 8 mm pins. These high power levels typically require cooled cables and connectors as well as the larger pins. When the DC pins are energized, the AC pins are not.

Figure 5. CCS Inlet, Coupler, and Schematic (Sources: Bloomfield 2012, SAE 2017)

In 2015, an industry alliance, known as CharIN, formed to promote the CCS standard. They are currently discussing an updated, faster standard specific to heavy-duty trucks. At least one alliance member expressed interest in a unified standard across vehicle classes or at least a backwards compatible standard for different power requirements (Hurt 2018).

CCS uses PWM communication along the control pilot pin for basic communication, as described under J1772 AC. For high-level communication, CCS uses power line communication (PLC). PLC is the most common communication method used by automatic metering infrastructure, providing vehicles the ability to integrate CCS with smart grid communication systems. The CCS PLC protocol is HomePlug Green PHY as described in the ISO 15118 standard. This standard allows communication between the vehicle and the EVSE, a necessary precursor for exporting power. (See Digikey 2018 for more information.) HomePlug offers a series of interoperable standards to integrate with smart appliances and meters. Other standards such as Open Automated Demand Response (OpenADR) integrate demand response capabilities with utilities through the power grid.

CHAdeMO

Charge de Move (CHAdeMO) was the first standardized DCFC connection deployed in the United States. A Japanese-led consortium began developing the standard in 2005 and continues to support it. There was some controversy surrounding SAE's decision to develop the CCS standard in lieu of CHAdeMO (Herron 2012). The protocol currently allows vehicles to charge up to 200kW, with an enhanced version in development that would allow up to 350-400 kW. There are ten pins in a CHAdeMO connector (Figure 6):

- two lines to transmit power
- charge sequence control signals for each line
- ground
- proximity detection
- vehicle charge permission
- two CAN signals
- one remains unassigned

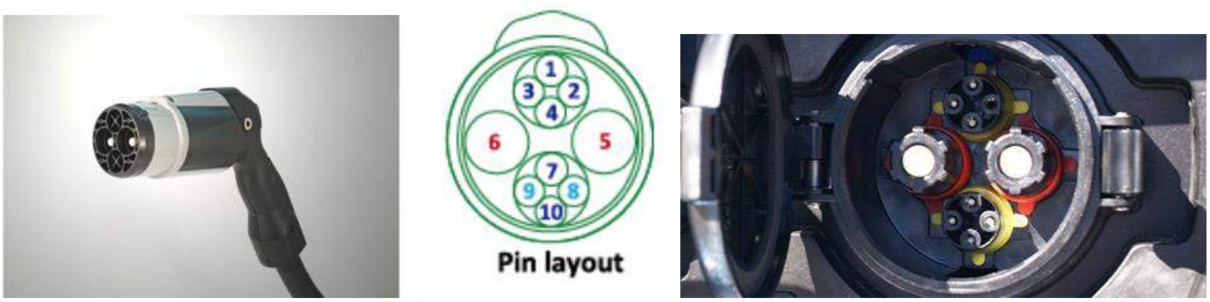

Figure 6: CHAdeMO Coupler, Schematic, and Inlet (Source: CHAdeMO)

CHAdeMO uses the same controller area network (CAN) bus communication protocol that vehicles do. This communication protocol allows vehicle to export power to the grid (V2G). Companies like Nuvve have developed a business model participating in utility power markets using CHAdeMO, making more than $1,000 annually per vehicle (Travers 2018). This presents an interesting opportunity for POLB to earn revenue. They may be able to earn more money by providing frequency regulation than storing energy for operating reserves. "Prices for regulation services often include a capacity component, which pays providers for guaranteeing that the resource will be available when needed, and an energy component that compensates the provider for the energy actually exchanged." (Steward 2017).

CHAdeMO features several safety checks, including charging cessation if the pilot signal or CAN communication is broken, a pre-charge automatic safety check, and a mechanical latch protected by an electronic latch.

SAE J3068

The newest SAE mechanical coupler standard is J3068, released in 2018. The key distinction between J1772 is that J3068 can provide three-phase power to EVs, although it can operate on single-phase power as well. The three-phase power system is intended to better serve industrial power supplies and heavy-duty trucks, suggesting that it may be preferable for POLB equipment.

Although new to the US market, J3068 uses the same physical connection as the IEC 62196 Type 2 “Mennekes” standard used in Europe and other parts of the world (SAE 2018a).

J3068 charges vehicles at rates up to 166 kW on 600 VAC three-phase power and 133 kW on 480 VAC at 160 A. 160-A connections require advanced contacts. Standard contacts only permit up 63 A on three-phase voltage and 70 A on single-phase voltage. The standard only allows the EVSE to transmit symmetric three-phase loads. If one phase provides higher current than the others (e.g. high-leg delta), the EVSE will draw the lowest value of all phases.
J3068 EVSE may be configured to accommodate DCFC using the same pins specified in the J1772 standard. There are seven pins for the AC configuration and nine for DC (Figure 7):

- three lines to carry AC power
- neutral
- ground
- control pilot
- proximity pin
- two lines to carry DC power

Figure 7. J3068 Inlet Configuration with and without DC Pins (Source: SAE 2018a)

The J3068 communication protocol defaults to a digital local interconnect network (LIN) datalink, but it can use analog PWM controls below 250 VAC and 63 A. In order to take full advantage of high-speed three-phase charging, J3068-compatible vehicles should use LIN communication. LIN is a master-slave protocol: the EVSE as master sends messages to the EV which can only send specified responses. An EV that requires battery ventilation during charging to avoid overheating requires PWM because the ventilation command cannot be sent through LIN.

BYD uses a variation on the J3068 standard with a higher power connection. Rather than adhering to the maximum current of 160 A and 166 kW in the standard, BYD offers up to 240 A for a total power rating of 200 kW. (Symington 2019).

SAE J3105

SAE J3105 (Electric Vehicle Power Transfer System Using a Mechanized Coupler) standard for overhead conductive automatic charging is in the final stage of completion. The recommended practices was scheduled to be published in the first quarter of 2019. In general, this standard will be focused towards buses and heavy duty vehicles.

The recommended practice will consist of one main document followed by four sub-documents. The main document will include the electrical interface, power flow (voltage and currents), communications, safety and systems. The four sub-documents will detail the different connections and the unique parts, including connection locations and alignment. All connections will use the common requirements established in the overall document J3105 (SAE Standards News 2018).

Two power levels are under consideration: Level 1 would permit up to 350 kW, and Level 2 would allow up to 1200 kW. The images below illustrate the various connection points, all of which were found in a presentation by the SAE Committee Chairperson at the June 2018 Electric Power Research Institute meeting (Figure 8, 9, 10, and 11). As shown in the figures, connection can be made via a stationary pantograph, stationary blade, a pantograph on the bus, or a pin and socket automatically installed into the side of the bus.

All connections are made using wireless communication. Once connected, the EVSE and vehicle can communicate along the control pilot similarly to the other conductive chargers described above.

Figure 8. Infrastructure-mounted Cross Rail Connection (Source: Kosowski 2018)

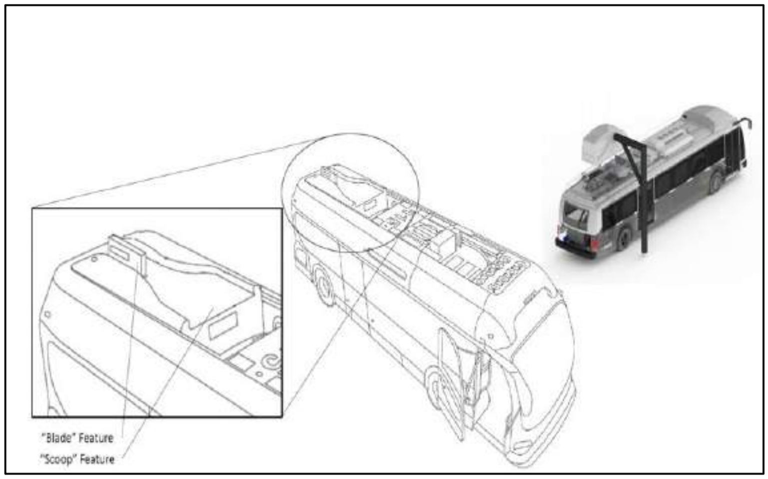

Figure 9. Infrastructure-mounted Blade Connection (Source: Kosowski 2018)

Figure 10. Vehicle-mounted Pantograph Connection (Source: Kosowski 2018)

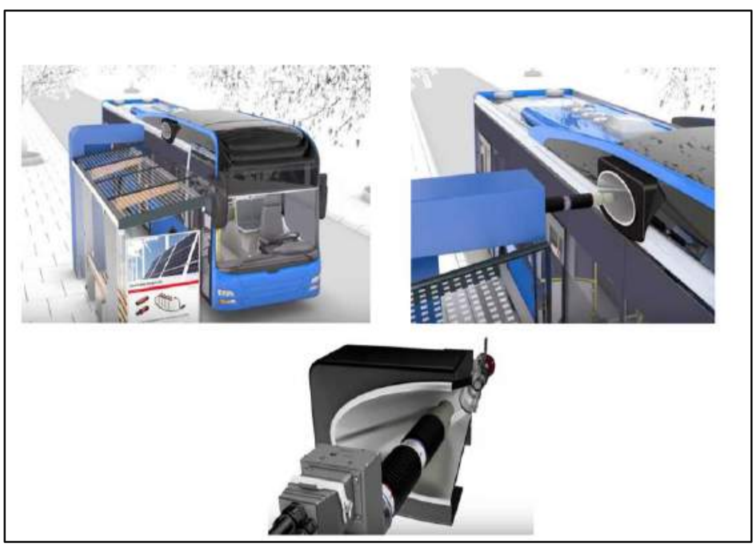

Figure 11. Enclosed Pin and Socket Connection (Kosowski 2018)

SAE J2954 and J2954/2

In wireless charging applications, electromagnetic coils buried in the ground generate magnetic energy which is transferred through a controlled air gap to receiving coils in the vehicle as AC power. Then the vehicle uses on-board equipment, including a rectifier, to convert the energy into DC power and charge its battery. SAE standard J2954 describes the process for light-duty vehicles, which allows for power transfer up to 11 kW. Efficiency is an area of concern for wireless charging; the J2954 standard requires that wireless applications achieve efficiency levels exceeding 85% when the ground and vehicle coils are aligned.

Standard J2954/2 will address wireless charging for heavy-duty vehicles. It is under development, and it is not scheduled for publication until 2020. J2954/2 plans to provide power from 22 to 200 kW. The existing standard discusses the likelihood that the new standard will include multiple power transfer coils with multi-phase arrangements to increase power and redundancy.

A unified wireless communication system is necessary for the vehicle and EVSE to function as discussed in SAE J2847-6 and J2931-6. Additional communication requirements include assisting the vehicle through manual or automated positioning above the power transfer coil, allowing the vehicle to control charging power, and identifying charging errors. The minimum alignment standard is known as low power excitation for the ground assembly to signal to the vehicle, although vehicles may incorporate other methods to park above the coils. Figure 12 showcases several applications in the pilot stage.

Figure 12. Wireless Power Transfer Pilot Projects (Source: Published in Green Car Congress, originally Condutix Wämpfler, Scania, and WAVE Technologies)

Networks

The majority of communication between EVSE units and external users takes place through EVSE networks. EVSE may be equipped with controls to manage time of charging, identify users, accept payment, and transmit data. These are generally referenced as "smart chargers." There are two distinct applications of smart chargers that POLB and terminal operators may elect to use: CHE parked at individual terminals and payment collection for external users. Terminals may choose to utilize networked solutions for their own CHE as it would likely be easier to manage charging times, minimize peak demands and electrical equipment upgrades, and collect data on energy consumption. If POLB or the terminals elect to install EVSE for external users, collecting payments may be another motivation for networking those stations.

Managing charging times can significantly reduce electricity costs and improve lifecycle economics for EVs. This is primarily accomplished by charging vehicles at times that do not coincide with peak demands to the extent possible. With maximum demand charges exceeding $30/kW in the majority of California (McLaren 2017), charging 1,000 vehicles simultaneously at 166 kW could yield approximately $5,000,000 monthly in demand charges. This is completely unnecessary. Most battery packs for heavy duty vehicles are in the 100-500 kWh range, and most vehicles do not consume all of the energy in their battery packs on a given day. Assuming that the average vehicle only consumes 100 kWh per day and rest for 12 hours, they could be charged much more slowly (e.g., at 8.3 kW) or charging could be staggered for 1/20 of the demand charge (e.g. $250,000 at $30/kW). These tactics can be used in conjunction with smaller electrical equipment (e.g. transformers, conductors, and service panels) to reduce the cost of electrical upgrades. Not all networks can manage charging or power.

Many EVSE networks can collect payment from external users. Most commonly to date, this has been enabled by manual input from the driver to the EVSE unit outside of the vehicle. For example, users may need to join a network and then identify themselves via an RFID token, cell phone application, or key code. In other cases, they may be able to simply pay by credit card. However, ISO 15118.1-standardized wireless communication allows for communication directly from the vehicle to EVSE. Hubject has used this standard to develop an autonomous communication system called Plug&Charge that removes the manual input steps (Hubject). There are several EVSE networks participating actively in the light-duty market, and some such as ChargePoint are making overtures to enter the heavy-duty market as well. Below is a list of several of the most popular public networks in the US and Canada (Table 2). Terminals or outside entities may elect to partner with a public network provider to install EVSE, provide power, and collect payment.

Table 2. EVSE Networks (Source: ChargeHub) (Modified by Authors)

Network/Operator	
ChargePoint	
Blink	blink
Sema Connect /Sema Charge	
NRG eVgo	nrg EVgo
Aerovironment	
Greenlots	
FLO	flo
OP Connect	
Circuit Électrique	
myEVroute	myEVroute
Tesla	TESLA
Sun Country Highway	
Volta	VOLTA
Doc Borné	Doc BORNE
Astria	ASTRIA

Electric HD Drayage Truck and CHE Market

Several vehicle original equipment manufacturers (OEMs) have announced heavy duty battery-electric drayage trucks and CHE that may be good candidates for port operations. These include yard tractors, tractor-trailers, box trucks, fork lifts, and top picks. However, only a few of these models are currently available commercially. Most are in the demonstration or pilot phase prior to commercial deployment. Some OEMs produce electric vehicle components such as motors, batteries, or chassis (e.g. Transpower, Kalmar, and Motiv), suggesting a degree of configurable optionality. Many have not announced publicly what type of EVSE they plan to use, although many have announced or suggested a charging rate. While photographs from public demonstrations may show a particular EVSE port, the power level of that port does not necessarily match the power level announced by the OEM. For example, Cummins stated their Aeos truck would be able to charge at 140 kW, but the photo at the unveiling clearly shows a J1772 Level 2 port which is limited to 19.2 kW (Marsh 2017). All of this suggests that the heavy-duty OEM decisions on which EVSE to incorporate is still evolving. See Table 3 for a partial listing of heavy-duty EVs that may be appropriate for port operations along with battery capacity, estimated range, EVSE type, and maximum charging rate to the extent these attributes could be identified.

Table 3. Heavy-Duty Electric Trucks and Equipment, EVSE Type, and Maximum Charging Rate

Vehicle Manufacturer	Vehicle Type	Vehicle Model	Battery Capacity (kWh)	OEM Estimate Range	EVSE Type	Maximum Charging Rate (kW)
BYD	Box Truck	6F			BYD Proprietary/ J1772 CCS	40 AC / 120 DC
BYD	Yard Tractor	8Y	217			
BYD	Road Tractor	8TT				
Capacity of Texas	Yard Tractor	PHETT				
Caterpillar	Material Handler	2EP 1100				
Cummins	Class 7 Truck	Aeos				140
First Priority Group 1	Box Truck	EVI-MD Class 6			J1772	16.5
Freightliner	Road Tractor	eCascadia				293
Frieghtliner	Box Truck	eM2				260
Fuso	Box Truck	eCanter				
Gottwald	AGV				Battery Swap	
Hyster	Forklift	Several				
JLG	Miscellaneous					
Kalmar	Forklift	ECG90-180				
Kalmar Ottawa	Terminal Tractor	T2E	132	8-20 hours	J1772, CHAdeMO , J3068	70
Kalmar Ottawa	Terminal Tractor	T2E	176			
Kalmar Ottawa	Terminal Tractor	T2E	220			
Lion Electric	Road Tractor	eLion8			J1772	19.2 AC / 150 DC
Motiv	Chassiss	Various			J1772 Level 2	55
Orange EV	Terminal Tractor	T-Series	80	50 miles	J1772, J1772 CCS	10
Orange EV	Terminal Tractor	T-Series	160	100 miles		80
Raymond	Forklift		Lead acid			
Taylor-Dunn	Utlity Truck	Bigfoot	1.3	40 miles	120 V cord	1
Tennant	Sweeper	6100	7.9	4.5 hours		
Terberg Tractors Americas	Yard Tractor	YT202-EV	113	5-8.5 hours	Siemens- Not compatible with North America	80
Terberg Tractors Americas	Yard Tractor	YT202-EV	170	7.5 -13 hours		
Taylor Machine Works	Forklift					
Taylor Machine Works	Top Pick	ZLC976	200			
Tesla	Road Tractor	Semi				1 MW+
Thor	Road Tractor	ET One			J1772 CCS	350
Thor	Delivery Truck					200
Toyota	Forklift	THDE	2 x 40.5	5 hours		
Transpower / Kalmar	Yard Tractor	T2E			Non Standard 208 VAC, 200A	70
US Hybrid	Road Tractor	eTruck			60 kW or J1772 CCS	60 AC / 150 DC

Wiggins	Forklift	eBull			J1772 CCS	20 AC/ 100 DC

Conclusions

There are several EVSE standards currently published or in process that can serve the heavy-duty electric drayage truck and CHE market, and the most appropriate technology may vary according to the application in question. CHE owned by terminal operators involves different concerns and requirements than drayage trucks owned by visiting drivers. Slower charging may be sufficient for equipment housed at terminals that remains stationary for significant periods of time or that are not often used. However, fast and opportunity charging may be required for in-use CHE and visiting drayage trucks. In addition, EVSE power management may be helpful to minimize peak demand charges and electrical equipment upgrades at terminals, but visiting trucks might not have the same flexibility. Operators should attempt to minimize onsite EVSE costs to the extent possible while providing sufficient controls and capabilities to operate their fleet. This includes considering the type of power available to minimize the cost of electrical upgrades. It also includes identifying how much power individual pieces of equipment need overnight by charging location.

There are additional considerations for drayage trucks: due to the steady stream of traffic queuing, fast charging (whether conductive or wireless) may service them best without accruing unnecessary demand charges. Automated charging and communication could eliminate congestion at charging stations and may improve the flow of traffic as well. If installing EVSE for visitor use on port property, POLB may want to initiate a method of collecting payment from drivers.

Although a single approach to heavy-duty charging at POLB may not address all instances, standardization will be important to aid in the rapid transition to zero-emissions equipment and drayage operations. While POLB should not bear the responsibility of developing technical EVSE standards, the port may be able to influence OEM decisions regarding EVSE type as a major early adopter of heavy-duty electric drayage trucks and CHE. This could potentially involve specification on EVSE types that are permitted within the port or prescribing voltage and amperage levels. Otherwise, OEMs might specify proprietary standards which may not be compatible with other vehicles.

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Appendix G: Public Funding Report

2019 CALIFORNIA PUBLIC FUNDING

Opportunities for Public Funding to Support Port-Related Zero Emission Projects

Submitted to:

Port of LONG BEACH
The Green Port

Submitted by:

GRANT FARM
WHERE GREAT IDEAS COME TO GROW

February 2019

Contents

1 Public Incentives Options

To advance its many environmental and clean energy policies, California has developed a well-established ecosystem of incentive opportunities, funding programs, and financing mechanisms to offset the capital and operational expenses associated with the deployment of advanced energy and zero-emission transportation technologies. California's cleantech funding ecosystem is rather unique in that it extends beyond state-level incentives to include many opportunities at the local and regional levels. The Port of Long Beach has been a critical partner in the State of California's goals of developing and deploying zero-emission transportation technologies. To date, the Port has engaged in six early-stage technology demonstrations for advanced energy and zero- and near-zero-emission vehicles and cargo handling equipment. As these technologies continue to develop and mature, the Port should seek to continue diversifying the technology types and vendors to be demonstrated at the Port in an effort to expand the state of the technology and generate increased competition that will drive further innovation and future cost savings.

The following sections provide an overview of the public funding programs, incentive opportunities, and financing mechanisms within California that will continue to support the development and deployment of advanced zero- and near-zero-emission technologies in furtherance of the state's goals as well as those contained with the San Pedro Bay Ports Clean Air Action Plan.

1.1 California Air Resources Board

The California Air Resources Board (CARB) administers a variety of funding programs that could support the Port of Long Beach's sustainability and zero-emission transportation goals and those of its port tenants. Relevant programs overseen by CARB include the Low Carbon Clean Transportation Incentives Program, the Carl Moyer Program, the VW Mitigation Trust, Supplemental Environmental Projects, and the Low Carbon Fuel Standard (LCFS).

1.1.1 Low Carbon Transportation and Air Quality Improvement Program

The Clean Transportation Incentives Program includes the Low Carbon Transportation Program, Air Quality Improvement Program (AQIP), and the Zero-Emission Warehouse Program (one-time funding). In fiscal year 2018-19, the Low Carbon Transportation incentives program allocations include:

- Low Carbon Transportation Investments (LCT): $455 million
- Air Quality Improvement Program (AQIP): $28.6 million

In 2018, the funding between these two programs was divided among a number of focus areas across the light-, medium-, and heavy-duty transportation sectors (Table 1).

Table 1: 2018-2019 Clean Transportation Incentive Program Investment Plan

Project Category	Allocation* (millions)
LIGHT-DUTY VEHICLE AND TRANSPORTATION EQUITY INVESTMENTS	
CVRP (including increased Rebates for Lower Income Applicants)	$200
Transportation Equity Projects	$75
Light-Duty Vehicle and Transportation Equity Investment Total	**$275**
HEAVY-DUTY VEHICLE AND OFF-ROAD EQUIPMENT INVESTMENTS	
Clean Truck and Bus Vouchers (HVIP + Low NOx Engine Incentives)	$125
Freight Equipment Advanced Demonstration and Pilot Commercial Deployment Project	$55
AQIP-FUNDED HEAVY-DUTY INVESTMENTS	
Truck Loan Assistance Program	$25.6
Diesel Particulate Filter Retrofit Replacements	$3
Heavy-Duty Vehicle and Off-Road Equipment Investment Total	**$208.6**
TOTAL	**$483.6**

Relevant incentive programs within the light-duty transportation sector include:

- Clean Vehicle Rebate Program (CVRP): The Clean Vehicle Rebate Project (CVRP) promotes clean vehicle adoption by offering rebates of up to $7,000 for the purchase or lease of new, eligible zero-emission vehicles, including electric, plug-in hybrid electric and fuel cell vehicles. The CVRP will receive $200 million in funding under the FY 2018-19 Investment Plan Update. The CVRP provides first-come, first-served vouchers of up to $7,000 for the purchase or lease of qualified zero-emission vehicles and motorcycles. Voucher amounts vary by technology type with hydrogen fuel cell vehicles receiving $5,000 vouchers, battery electric vehicles receiving $2,500 vouchers, plug-in hybrid vehicles receiving $1,500 vouchers, and electric motorcycles receiving $900 vouchers. The CVRP is currently administered by the Center for Sustainable Energy. The Port of Long Beach and its tenants have a substantial fleet of light-duty on-road vehicles that are, or will soon be, primed for replacement with zero-emission technologies. The CVRP will provide an easy-to-navigate incentive to offset the cost of transitioning these fleets to zero-emission technologies. Accordingly, the Port of Long Beach should work with its fleet procurement division, terminal operators, and tenants to encourage their adoption of zero-emission vehicles utilizing the CVRP incentive.

Relevant incentive programs within the medium- and heavy-duty transportation sector include:

- Clean Off-Road Equipment Voucher Incentive Project (CORE): This program is intended to be a new program analogous to the existing Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) for off-road freight equipment. The program's $40,000,000 allocation is targeted toward commercialized products and is designed to accelerate deployment of cleaner technologies by providing a streamlined way for fleets ready to purchase specific zero-emission equipment to receive funding to offset the higher cost of such technologies. Similar to the Clean Mobility Options program, an administrator will be selected for the CORE program. The Port of Long Beach and its terminal operator tenants have been heavily engaged in numerous demonstration projects for many of the equipment types that will soon be eligible under the CORE program. The terminal operators' unique experience with these technologies could increase their interest and willingness to pursue further deployments of zero-emission off-road vehicle and cargo handling equipment technologies. Accordingly, the Port of Long Beach should work with its terminal operators to support their utilization of the CORE vouchers as they continue acquiring or replacing equipment.

- Clean Truck and Bus Vouchers (HVIP and Low NO_x Engine Incentives): HVIP and Low NO_x Engine Incentives are intended to encourage and accelerate the deployment of on-road zero-emission trucks and buses, vehicles using engines that meet the optional low-NO_x standard, and hybrid trucks and buses in California. HVIP will receive $125 million in funding under the FY 2018-19 Investment Plan Update plus an additional $80 million that will be carried over from FY 2017-18. HVIP provides first-come, first-served vouchers of up to $300,000 for the purchase or lease of zero-emission trucks and buses, up to $30,000 for eligible hybrid trucks and buses, and up to $40,000 for low-$NO_x$ engines. HVIP is currently administered by CALSTART. The Port of Long Beach has a limited jurisdiction that includes recreational and visitor serving areas that would be well-served by zero-emission transit routes. Additionally, there are many vehicles within the Port's fleet, the fleets of its terminal operators, and the drayage fleets visiting the port that could utilize the HVIP program to offset the capital expense of deploying zero-emission transportation technologies. Accordingly, the Port of Long Beach should work with the City of Long Beach, the Port's terminal operators, and the visiting drayage fleets to support their utilization of the HVIP vouchers as they continue acquiring or replacing equipment.

- Truck Loan Assistance Program: Launched in 2009, the Truck Loan Assistance Program is designed to help small business fleet owners affected by CARB's In-Use Truck and Bus Regulation to secure financing for upgrading their fleets with newer trucks or diesel exhaust retrofits. The program is implemented in partnership with the State Treasurer's Office's California Pollution Control Financing Authority (CPCFA) through its California Capital Access Program (CalCAP) and leverages public funding with private funding from participating lending institutions. This financing program may be an asset for the Port of Long Beach, its terminal operators and their drayage partners to secure low-interest financing to provide low-cost capital that will form the basis of the vehicle's purchase.

In addition to the above LCT-AQIP funding opportunities, CARB plans to develop new programs in 2019 that could begin providing further incentives in support of the Port's sustainability and electrification goals, with funding becoming available as early as 2020. These potential programs, which will be developed throughout 2019 via stakeholder engagement and public workshops, include:

- Zero-Emission Drayage Pilot: Zero-emission drayage trucks, while relatively new, have been advancing quickly. CARB anticipates that, by next year, zero-emission drayage trucks will be ready for larger pilot-scale deployments to maintain momentum and continue to pushing the technology toward commercialization.

- Small Ports Pilot: California's emission reduction goals at ports and upcoming regulations for ships at berth necessitate continued investment, especially at California's small ports. The pressing need at small ports and their more limited resources in applying for funding highlights the need for a streamlined project providing funding focused on small ports. In 2019, CARB will explore options for funding holistic projects at small ports that include shore power or bonnet systems in addition to zero- and near- zero-emission port equipment.

- Zero-Emission Facilities: As numerous technologies and applications advance into pilot and commercial stages, it is becoming increasingly important to facilitate the broader transition of large facilities to zero-emission. CARB plans to review lessons learned from previous and ongoing pilot- and commercial-sized zero-emission vehicle and equipment deployment projects. The information gathered will be incorporated into an upcoming program that will seek to rapidly fund larger-scale deployments of pre-commercial and/or commercial zero-emission vehicles and equipment at freight facilities across California.

1.1.2 Volkswagen 2.0- and 3.0-Liter Settlement – Environmental Mitigation Trust Fund

The California Air Resources Board also manages California's $423-million Volkswagen Environmental Mitigation Trust Fund which was established to mitigate the excess NO_X emissions caused by VW's use of illegal defeat devices in certain diesel vehicles. The VW Settlement will fund a range of medium- and heavy-duty projects with a focus on "scrap and replace" projects, which include commercial marine vessels, CHE, and heavy-duty on- and off-road vehicles and equipment. The State of California's Proposed Beneficiary Mitigation Plan (April 20, 2018) recommended the following allocations:

- $130 million for zero-emission transit, school, and shuttle buses and specifically identified funding allocations up to $100,000 for battery-electric shuttle buses.
- $90 million for class 8 zero-emission freight and port drayage trucks and specifically identified funding allocations up to $200,000 for class 8 trucks, targeting 2009 or older model year replacements.
- $70 million for zero-emission forklifts, port CHE, airport ground service units, and shore power and specifically identified funding allocations up to $175,000 for forklifts and port CHE and up to $2.5 million for shore power.
- $60 million for combustion freight/marine projects and specifically identified funding allocations up to $1 million in funding per Ferry, Tug, and Tow Tier 4 or Hybrid Repower, up to $60,000 for low NOx class 7-8 truck repowers or replacements, and up to $1.35 million for switcher locomotive Tier 4 repowers or replacements.
- $10 million for light-duty ZEV infrastructure funding up to 100 percent of public charging at government property, up to 80 percent of public charging on private property, and up to 33 percent of hydrogen fueling infrastructure.

The VW Environmental Mitigation Trust Fund is expected to be fully funded by November 2018 and to begin issuing the first Requests for Proposals (RFP) in early 2019. The Port of Long Beach and the members of the Port Community have a diverse population of on- and off-road vehicles, locomotives, vessels, and equipment that could qualify for the Volkswagen funding to upgrade or replace their engines with higher tier or zero-emission offerings. Accordingly, the Port should work closely in the coming months and years with its tenants, the City of Long Beach, and CARB to encourage the deployment of Volkswagen funding to reduce emissions from a broad range of transportation modes operating within the Port Community.

1.1.3 Supplemental Environmental Projects

The Supplemental Environmental Projects (SEP) Policy permits community-based projects to be funded from penalties received during ARB's settlement of enforcement actions. The ARB is instructed to solicit, compile, and maintain a library of eligible projects that violators may choose from during the settlement process. The SEP Policy permits CARB to allocate up to 50% of penalties obtained from violators towards eligible SEPs that have some nexus to the violation, either by location or type of pollutant to be addressed. Funds may cover all phases of the selected SEP, including capital, operational, and administrative costs. Examples of potential projects include air monitoring studies, vehicle and equipment upgrades, workforce training and awareness campaigns, projects reducing exposure to air pollutants, and projects achieving direct and indirect emissions reductions beyond regulatory requirements. This funding mechanism is intended for projects that do not have an alternative avenue for funding. A pre-application process is used to evaluate CARB's level of interest in each proposed project. The Port of Long Beach should work with the members of the Port Community to identify projects that may fit within the structure of the SEP Policy. Additionally, the Port should educate its tenants that, in the event of an air quality violation, they may elect to allocate a portion of their penalty to support projects that reduce emissions within the Port Community.

1.1.4 Low Carbon Fuel Standard

The Low Carbon Fuel Standard (LCFS) was developed to address long-term operational challenges associated with alternative fuel adoption through incentives for actual alternative fuel utilization and disincentives for the production and use of dirtier fossil fuels. The LCFS program is well-established and was recently (2015) readopted in the California legislature, overcoming significant opposition from regulated industries (e.g. oil and gas). Additionally, the LCFS program recently (2018) underwent amendments and updates that will expand the program and authorize its continued operations through 2030. The LCFS program awards credits for emissions reductions achieved by producing and providing lower carbon intensity transportation fuels in California, allowing participants to gain value for these emission reductions in the LCFS credit marketplace where regulated entities can purchase credits to offset the higher carbon intensity of their fuels. Currently, LCFS credits are being valued in the open market in the range of $170-$195 per credit, providing a reimbursement on electricity used for transportation fuels in excess of $0.10/kWh for the majority of vehicle and off-road equipment types.

There are two major components to the LCFS program: 1) the fuel pathway carbon intensity (CI) and 2) the energy economy ratio (EER). The CIs for diesel fuel and California grid electricity are well established in the program; the operator of an electric fleet could be eligible to use the existing pathway for electricity or elect to incorporate renewable energy through co-generation or the purchase of renewable energy certificates (RECs). The EER ratio establishes the relative efficiency of an alternative fuel engine compared to the diesel or gasoline baseline.

The LCFS program recently underwent an amendment and rulemaking process that is poised to dramatically increase the potential value of the program to the Port of Long Beach, its terminal operators, and tenants. Relevant changes include:

- Owner of the fuel-supplying equipment (FSE) is first owner of the credits, if they opt in. If the FSE owner does not claim them, then they go to the electrical distribution utility (SCE) by default.
- Owners of the FSE can transfer status to a third-party if agreed by written contract.
- Change to EER values, including shore power to ocean-going vessels (EER of 2.6), yard tractors (EER of 5.0), other mobile equipment (generic EER of 2.7), and electric transport refrigeration units (eTRUs) (EER of 3.4) qualify for crediting.
- FSE owner can apply for an EER specific to particular equipment.
- Third party verifier is required to audit projects annually.
- FSE owners can claim that their charging came from any renewable energy (with a carbon intensity value of 0.0 gCO_2/MJ) put into the California balancing authority that is not used for the state RPS.
- ZEV direct current (DC) fast charging stations can accrue LCFS credits for capacity, instead of delivered energy.

The final rulemaking was adopted by the California Air Resources Board on September 27, 2018 and implementation of the new rules are took effect on January 1, 2019.[1]

To understand the potential impacts of the LCFS program, an excel-based tool was developed to provide ROM estimates for the potential value of the LCFS credits as they related to CHE and shore power. Drayage trucks were not included as the FSE owner is expected to be different than the truck operator for drayage trucks, due to the longer routes which typically require fueling/charging at third-party owned stations. A summary of the findings is presented in Table 2.

Table 2: Summary of Potential LCFS Values

Scenario	Low-Value Estimate	High-Value Estimate
H2 Fuel Cell, Compressed H2 from Natural Gas	$3,628,000	$6,309,000
H2 Fuel Cell, Compressed H2 from Landfill Gas	$4,684,000	$8,146,000
H2 Fuel Cell, Compressed H2 from CA Average Grid Electricity	$911,000	$1,584,000
H2 Fuel Cell, Compressed H2 from Renewable Electricity	$9,851,000	$17,131,000
Battery-Electric, CA Average Grid Electricity	$7,545,000	$13,121,000
Battery-Electric, Renewable Electricity	$10,461,000	$18,193,000

1.1.5 Carl Moyer Memorial Air Quality Standards Attainment Program

The Carl Moyer Program seeks to cost-effectively reduce smog-forming and toxic air contaminant emissions. To achieve these goals, the Carl Moyer Program focuses on vehicle or equipment replacement, repower, or retrofit; vehicle retirement; and, alternative fuel infrastructure. The program is focused on commercially-available (not demonstration) technologies. Carl Moyer funds are organized by CARB and annually CARB will send a solicitation to each air district, which will apply for funding through a competitive solicitation. The funding is intended to support a wide range of mobile equipment, including heavy-duty trucks, drayage trucks, off-road equipment, locomotive equipment, and marine vessels. All project proposals submitted to the Carl Moyer Program are judged competitively on a cost per ton of emissions reduced or avoided. Relevant project categories identified for funding under the Carl Moyer Program in 2019 will likely include:

- On-Road: Eligible project types include vehicle replacement and repower/conversion projects; on-road retrofit projects will be considered on a case-by-case basis. Emergency vehicles, including but not limited to prisoner transport buses and fire apparatus, are exempt from CARB regulations and therefore are eligible for Carl Moyer funding. All on-road projects must generate surplus emission reductions and be fully compliant with all applicable fleet regulations.

- Off-Road: Propulsion engines greater than 25 horsepower on mobile off-road equipment are eligible for Carl Moyer funding. Off-road projects must demonstrate compliance with any applicable CARB regulation at the time of application. Off-road heavy-duty equipment/engines include, but are not limited to, construction equipment, cargo handling equipment, agricultural tractors, marine engines, shore power, and locomotive equipment. Priority investment areas of SCAQMD include cargo handling equipment electrification, shore power, and locomotive projects at seaports or intermodal rail yards along major trade corridors.

[1] Cal. Air Res. Bd., *Notice of Decision, Agenda Item #18-7-4* (Sep. 28, 2018). Available at https://www.arb.ca.gov/regact/2018/lcfs18/nodlcfs.pdf.

- Infrastructure: The 2017 update to the Carl Moyer Program Guidelines allow funding for infrastructure projects that enable the deployment of alternative, advanced, and cleaner technologies to support the State's air quality goals. Specifically, projects that install fueling or energy infrastructure to fuel or power a "covered source" are now eligible for funding consideration. A "covered source" includes heavy-duty on-road vehicles, off-road non-recreational equipment and vehicles, locomotives, marine vessels, agricultural sources of air pollution, and other categories as determined by CARB and SCAQMD that are necessary for the state and air district to meet air quality goals.

In 2019, the allocation of Carl Moyer funding to select local air districts is presented along with the selection of technologies that the districts are expected to fund (Table 3). Additional allocations from AB 134 and AB 617 are anticipated to be provided to the state's air districts in 2019 to supplement the Carl Moyer program.

Table 3: Local Air District Funding Allocations for CARB's Carl Moyer Program

Air District	Total Funding	Equipment Priorities
South Coast AQMD	$30 million	On-Road, Off-Road, Infrastructure
Bay Area AQMD	$11 million	On-Road, Off-Road, Infrastructure
San Joaquin Valley APCD	$8 million	On-Road, Off-Road, Infrastructure
Sacramento Metropolitan AQMD	$4 million	Off-Road, Infrastructure

The Port of Long Beach and its tenants have diverse equipment and vehicle populations that could greatly benefit from the targeted funding made available through the Carl Moyer Program. Perhaps more important in the current funding ecosystem is the ability for Carl Moyer to fund the costs of installing alternative fuel infrastructure. Utilizing Carl Moyer for the installation of electric vehicle charging stations and hydrogen fueling stations would enable the Port to address one of its largest hurdles: the cost of infrastructure necessary to support widespread adoption of zero-emission vehicle and equipment technologies in alignment with the 2030 and 2035 CAAP goals. The Port should work closely with its tenants and South Coast AQMD to identify and fund priority infrastructure deployments.

1.2 California Energy Commission

The California Energy Commission (CEC) is the state's primary energy policy and planning agency, tasked with advancing state energy policy, achieving statewide energy efficiency goals, investing in energy innovation, developing renewable energy technologies, and transforming the transportation sector. The CEC administers a variety of funding programs that could support the Port's sustainability and zero-emission transportation goals and those of its tenants. Relevant programs overseen by the CEC include the Electric Procurement Investment Charge (EPIC) Program and the Alternative and Renewable Fuel and Vehicle Technologies Program (ARFVTP).

1.2.1 Electric Procurement Investment Charge

The EPIC program, funded by fees assessed to all California ratepayers, supports the development of non-commercialized new and emerging clean energy technologies in California and provides assistance to commercially viable projects. Most of the funding procured through this mechanism (80%) is administered by the California Energy Commission as directed through its Triennial Investment Plan.[2] The Triennial Investment Plan consists of eight themes, of which three are considered targets for the

[2] http://docketpublic.energy.ca.gov/PublicDocuments/17-EPIC-01/TN217347_20170428T145448_The_Electric_Program_Investment_Charge_Proposed_20182020_Trienn.pdf

PCEVB (Theme 2, Theme 3, and Theme 5). The remaining themes—Theme 1, Theme 4, Theme 6, Theme 7, and Theme 8—are considered tangential to the long-term zero-emission CHE and trucking goals of the Port. EPIC funding allocations are categorized by investment type:

- Applied Research and Development: $159.8 million;
- Technology Deployment and Demonstration $173.2 million; and,
- Market Facilitation: $66.6 million.

These investment areas could include technologies that increase energy efficiency and renewable energy generation, support distributed energy resources and microgrids, and enable the widespread deployment of zero-emission electric vehicles and equipment. Of significant importance to the Port of Long Beach is the continued push for investments in microgrid technologies and projects that will have a high likelihood of commercialization while advancing microgrid technologies' business cases and their ability to meet the needs of a wide range of end use customers.

Theme 2: Accelerate Widespread Customer Adoption of Distributed Energy Resources

The funding priorities of this theme focus on the transition to a more decentralized and decarbonized electric economy. Specifically, the relevant objective is to identify optimal technology packages for specific uses and applications that can drive down costs for distributed energy resources (DER). Specific initiatives that directly address goals of the PCEVB include:

- **Initiative 2.2.1**: Advance Microgrids to the Tipping Point of Broad Commercial Adoption

Theme 3: Increase Grid System Flexibility and Stability from Low-Carbon Resources

The funding priorities of this theme focus on the enabling system flexibility and stability from low-carbon resources including demand response, energy storage, smart inverters, and balancing supply and demand over larger geographic areas. Specific initiatives that should directly address goals of the PCEVB include:

- **Initiative 3.1.1**: Pilot Test for the Next Generation Demand Response Landscape
- **Initiative 3.1.2**: Assess Performance of Load Control Systems
- **Initiative 3.1.3**: Assess iDERs and Load Management Systems
- **Initiative 3.2.1**: Grid-Friendly PEV Mobility
- **Initiative 3.2.2**: Battery Second Use

Theme 5: Create a Statewide Ecosystem for Incubating New Energy Innovations

The funding priorities of this theme focus on transforming California's electricity sector and reimagining the current model for delivering clean energy technologies to the market. Specifically, the relevant objective is to overcome barriers to broader and more diverse clean energy entrepreneurship Specific initiatives that should directly address goals of the PCEVB include:

- **Initiative 5.1.3**: Cost Share for Private, Non-Profit Foundation, or Federal Clean Energy Funding Opportunities

1.2.2 Alternative and Renewable Fuel and Vehicle Technology Program

The Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) was established by AB 118 (Núñez 2007) to provide funding for projects that will "transform California's fuel and vehicle types to help attain the state's climate change policies." This program targets projects that:

- Reduce criteria and toxic air pollutant emissions from vehicles;
- Reduce the use of 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 available to the public, existing fleets, public transit, and along transportation corridors;
- Improve the efficiency, performance, and market viability of alternative light-, medium-, and heavy-duty vehicle technologies;
- Retrofit medium- and heavy-duty on-road fleet and off-road freight vehicles to alternative technologies or fuel use;
- Offer incentives for the purchase of alternative fuel vehicles;
- Establish workforce training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies;
- Support local and regional planning for zero-emission vehicle and fueling infrastructure deployment.

The program is directed by an annual investment plan that guides the program's investment activities for the year. The 2018/2019 Investment Plan has identified several initiatives relevant to the Port of Long Beach and the Port Community Electric Vehicle Blueprint. In recent years, the ARFVTP has experienced a large transition in its programmatic targets to focus primarily on the development of alternative fuel infrastructure that enables the widespread adoption and deployment of zero-emission vehicles. This is of critical importance to the Port's 2030 and 2035 zero-emission transportation goals in that these infrastructure funding opportunities will expand the network of public and private alternative fueling stations. Currently, the 2018/2019 Investment Plan is being updated and the 2019/20 Investment Plan is likely to be released in late 2018 or early 2019. Specifically, the current funding areas within the ARFVTP include:

<u>Zero-Emission Vehicle Infrastructure</u>

This initiative focuses on the fueling infrastructure necessary to support widespread deployment of zero-emission vehicle technologies. Specific relevant funding allocations are proposed for electric vehicle charging infrastructure ($134.5 million, now proposed $94.2 million), hydrogen refueling infrastructure ($92 million, now proposed $20 million), and manufacturing and workforce training and development ($8.5 million, now proposed $17.5 million).

- <u>Electric Vehicle Charging Infrastructure</u>: This program has been developed in a highly on-road-vehicle-centric manner with direct current fast charging infrastructure and advanced grid integration and management tools. There is a clear opportunity to assert the value of funding off-road charging infrastructure as a specific activity.
- <u>Hydrogen Refueling Infrastructure</u>: This program has been developed to support a network of stations needed to support the initial deployment of hydrogen fuel cell vehicles.
- <u>Manufacturing and Workforce Development</u>: This program had been two separate programs, one for manufacturing and one for workforce development. In the current investment plan,

these topic areas have been combined with a clear indication that ARFVTP's investment in manufacturing will be expected to be in conjunction with workforce development efforts.

Advanced Technology Vehicle Support

This initiative is focused on advanced freight and fleet technologies and has been allocated $17.5 million. There is a single programmatic effort in this year's Investment Plan.

- Advanced Freight and Fleet Technologies: This funding initiative will fund both demonstration and deployment projects. The 2017/2018 investment portfolio included $24 million for advanced vehicles at California seaports. Given the high priority of ports for GHG reductions, additional emphasis should be placed on funding activities at the ports.

1.3 California Office of the State Treasurer

The California Office of the State Treasurer administers a variety of funding and financing mechanisms programs that could support the Port of Long Beach's sustainability and zero-emission transportation goals and those of its port tenants. Potentially relevant programs overseen by the State Treasurer include the forthcoming Green Bonds and the programs of the California Alternative Energy and Advanced Transportation Financing Authority.

1.3.1 Green Bonds

The California State Treasurer, John Chiang, announced the creation of California's Green Bond Market on August 7th, 2018 at the Global Climate Action Week in San Francisco, CA. The Green Bond Pledge, to which California is now a signatory, states that California agrees "all infrastructure and capital projects will need to be climate resilient and, where relevant, support the reduction of greenhouse gas emissions." The forthcoming Green Bonds program aims to support the rapid growth of a green bonds market "that will finance infrastructure and capital projects that meet the challenges of climate change." These bonds will enable California and its local government agencies to efficiently raise billions of dollars in new and affordable capital to build climate-friendly infrastructure. The program remains under development and will soon enable corporations and government organizations to use debt financing to issue green bonds to fund a healthy, prosperous, and enduring future of technologically advanced infrastructure. The Port of Long Beach should work closely with its tenants and the State Treasurer to explore how to harness these green bonds to support the infrastructure deployments necessary to spur adoption of electric vehicles and cargo handling equipment, advance sustainable freight corridors, and achieve the Port's myriad sustainability and environmental goals.

1.3.2 California Alternative Energy and Advanced Transportation Financing Authority

The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) is the division of the California State Treasurer's Office tasked with providing innovative and effective financing solutions for California's industries, assisting in reducing the state's greenhouse gas emissions by increasing the development and deployment of renewable energy sources, energy efficiency, and advanced transportation and manufacturing technologies to reduce air pollution, conserve energy, and promote economic development and jobs. CAEATFA operates a range of programs that could potentially support the Port's adoption of clean technologies including renewable energy platforms and zero-emission technologies. The Port should work with CAEATFA and the State of California to continue exploring opportunities for expanding and utilizing CAEATFA programs to offset the capital costs of deploying renewable energy, advanced energy management, and zero-emission technologies.

1.4 Local Funding Sources

1.4.1 South Coast Air Quality Management District

The South Coast Air Quality Management District ("South Coast AQMD" or "SCAQMD") is the regional governmental organization tasked with safeguarding and improving air quality within its multi-county jurisdiction. In furtherance of its mission, SCAQMD has developed extensive inventories and planning tools for reducing air emissions in non-attainment zones within its district. These plans are regularly updated through amendments and comprehensive new plans. POLB is located in areas targeted for emission reductions. In the SCAQMD Clean Air Plan, a minimum of $448 million is expected to be invested from 2017-2024 from a variety of funding sources. These funding sources include the region's Carl Moyer Memorial Air Quality Standards Attainment Program (discussed above), Rule 2202 On-Road Motor Vehicle Mitigation Options, and a host of other bundled incentive opportunities that can vary annually.

> <u>On-Road Motor Vehicle Mitigation Options</u>: The South Coast AQMD operates multiple emissions reduction programs pursuant to its authority to regulate indirect sources within its jurisdiction. These programs may have strict enforcement requirements and compliance guidelines that should be fully evaluated prior to participation in any Rule 2202 opportunity. Among the Rule 2202 programs that may have relevance to the Port of Long Beach and its tenants are the Air Quality Improvement Program (AQIP) and the Employee Commute Reduction Program (ECRP).

> <u>Air Quality Improvement Program</u>: The AQIP program is funded through annual investments from employer-participants and returns that funding via competitive solicitations for a wide range of projects that reduce emissions and support SCAQMD's efforts to reach attainment with the Clean Air Act's National Ambient Air Quality Standards (NAAQS). Historically, SCAQMD's AQIP has generated more than $6 million in annual project funding.

> <u>Employee Commute Reduction Program</u>: The ECRP is a local program that enables employers to generate credits that can be sold or retired for compliance within SCAQMD's local stationary source cap and trade program.

1.4.2 Port of Long Beach and Port of Los Angeles

The Ports of Long Beach and Los Angeles jointly operate the Technology Advancement Program (TAP) which offers grant and incentive funding to test promising clean air technologies in a real-world port environment. The TAP provides grants of up to $500,000 for research and demonstration projects that reduce emissions of diesel particulate matter (DPM), NO_X, SO_X, or GHG from the ships, trucks, harbor craft, cargo handling equipment, and rail locomotives that service the San Pedro Bay Ports. The TAP solicits applications for projects on an annual basis via a two-phase evaluation process.

1.4.3 Southern California Edison: Charge Ready and Market Education Program

SCE currently implements Charge Ready and Market Education programs to support California's policies to reduce GHGs and air pollutant emissions to help meet the state's zero-emission vehicle goals. The Charge Ready program deploys electric infrastructure to support light-duty EV charging at customer sites throughout SCE's service area. As of April 2018, SCE had deployed infrastructure to support 941 charge ports at 60 customer sites, including 462 charge ports at 36 sites located in disadvantaged communities, exceeding the Charge Ready program goals of 10% disadvantaged community deployments. The Charge Ready Pilot Program was open to non-residential customers in long dwell-time locations, including workplaces, multi-unit dwellings, fleets, and destination centers. This program is well-suited for the customer-centric locations within the Port Communities, including cruise terminals, the Queen Mary, and nearby hotels. Additionally, SCE is developing the Charge Ready Heavy Duty program, taking the lessons learned from the existing light-duty-centric Charge Ready program and adapting it for the heavy-duty sector.

1.4.4 Southern California Edison: SB 350

Southern California Edison is the largest electric utility service provider in Southern California, serving some 14,000,000 residents in and around the Los Angeles area. On May 31, 2018, the California Public Utilities Commission approved $738 million in transportation electrification projects for the state's electric utilities. SCE had $356.3 million approved across two programs:

<u>Medium- and Heavy-Duty Make-Ready Program</u>

- Authorizes $343 million for SCE to support make-ready installations at a minimum of 870 sites to support the electrification of at least 8,490 medium- or heavy-duty fleet vehicles.
- Requires a minimum of 15% of the infrastructure budget to serve transit agencies.
- Requires a maximum of 10% of the infrastructure budget to serve forklifts.
- Requires a minimum of 25% of the infrastructure budget to serve vehicles operating at ports and warehouses.
- Requires SCE to spend a minimum of 40% of its program budget in DACs.
- Requires SCE to offer rebates of up to 50% of the cost of the EVSE for sites in DACs and sites that support electric transit and school buses.

<u>Commercial Rate Proposal</u>

- Authorizes SCE to establish three new, time-of-use rates for commercial customers with electric vehicles under which, for the first five years the rates are available, they would not include a demand charge, and costs would instead be recovered through a volumetric energy charge.
- Allows SCE to update its definition of "electric vehicle" for the purposes of rate eligibility to include all forms of transportation electrification described in SB 350.
- No incremental funding will be incurred associated with this rate.

1.5 Federal Funding Sources

1.5.1 US EPA: Diesel Emissions Reduction Act

The Diesel Emissions Reduction Act (DERA) directs the U.S. Environmental Protection Agency (EPA) to annually distribute competitive grant moneys for the retrofit or replacement of diesel engines to achieve emissions reductions above and beyond regulatory requirements. The EPA Office of Transportation and Air Quality anticipates awarding funds to retrofit or replace older diesel engines in school buses, class 5–8 heavy-duty on-road vehicles, locomotives, marine engines, off-road equipment and vehicles, and diesel generators and pumps.

1.5.2 US EPA: Targeted Air Shed Grant Program

Funded through congressional appropriations, the Targeted Air Shed Grant Program aims to reduce air pollution in nonattainment areas that the Agency determines are ranked as the top five most polluted areas relative to ozone, annual PM2.5, or 24-hour PM2.5 standards. The Los Angeles South Coast Air Basin ranks as the highest ozone nonattainment area and third highest PM2.5 nonattainment area in the county. Funding for this program has been appropriated in 2010, 2015, 2016, and 2017.

1.5.3 US DOT: Better Utilizing Investments to Leverage Development

The Better Utilizing Investments to Leverage Development (BUILD) Transportation Discretionary Grant program, provides a unique opportunity for the Department of Transportation to invest in road, rail, transit, and port projects that promise to achieve national objectives. Previously known as Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grants, Congress has dedicated nearly $5.6 billion for nine rounds of National Infrastructure Investments to fund projects that have a significant local or regional impact. The eligibility requirements of BUILD allow project sponsors at the State and local levels to obtain funding for multi-modal, multi-jurisdictional projects that are more difficult to support through traditional DOT programs. BUILD can fund port and freight rail projects, for example, which play a critical role in our ability to move freight, but have limited sources of Federal and local funds. BUILD can provide capital funding directly to any public entity, including municipalities, counties, port authorities, tribal governments, MPOs, or others in contrast to traditional Federal programs which provide funding to very specific groups of applicants (mostly State DOTs and transit agencies).

1.6 Other Funding Opportunities

1.6.1 Incentives and Credits for Light-Duty Vehicles/Fleets

Several additional rebate programs are currently active in California that provide funding for zero-emission vehicles and fueling/charging infrastructure for which the Port and its tenants could be eligible. These include but are not limited to:

- **Federal Tax Credit:** The federal Internal Revenue Code (Section 30D) provides a credit for qualified Plug-in Electric Drive Vehicles -- including passenger vehicles and light trucks. The credit varies from $2,500 to $7,500 per vehicle depending on battery size. The base credit amount is $2,500 for qualified on-road vehicles, with an additional $417 available for each additional 5-kilowatt hours of capacity, up to a cap of $7,500. The credit begins to phase out for a manufacturer's vehicles when at least 200,000 qualifying vehicles manufactured by that OEM have been sold for use in the United States (determined on a cumulative basis for sales after December 31, 2009). Some Tesla vehicles may be subject to the phase-out beginning in 2019.[3]

- **The CVRP Public Fleet Pilot Project** offers up to $15,000 in rebates per EV for ***public agency*** fleet operators for the purchase of new, eligible zero-emission and plug-in hybrid light-duty vehicles. The Public Fleet Pilot Project is administered by Center for Sustainable Energy for the California Air Resources Board and replaces standard CVRP rebates with increased incentives for public agencies operating in California's most pollution-burdened areas (which includes the Port of Long Beach and surrounding areas).[4]

- **The California Capital Access Program (CalCAP)** Is a loan loss reserve fund that can help finance EVSE procurement by providing direct support to lenders to lower interest rates and enable more liberal credit requirements. The maximum enrolled loan amount is $500,000 per qualified borrower, and can be insured for up to four years (though the actual term of the loan can be

[3] https://www.irs.gov/businesses/irc-30d-new-qualified-plug-in-electric-drive-motor-vehicle-credit
[4] https://www.driveclean.ca.gov/pev/Incentives.php

longer). Lenders set the terms and conditions of the loans and decide which loans to enroll in the EVCS Program. The EVCS Program contributes 20% of the principal balance enrolled to a loss reserve account. CalCAP will contribute an additional 10%, up to a maximum of 30%, if the installation is in a multi-unit dwelling or located in a disadvantaged community as designated by the California EPA via their “CalEnviroScreen” tool (https://oehha.ca.gov/calenviroscreen.) In general, the Port qualifies as a Disadvantaged Community.[5]

[5] https://www.treasurer.ca.gov/cpcfa/calcap/evcs/summary.asp

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Appendix H: Private Funding Report

2019 INNOVATIONS IN PRIVATE FINANCE

Opportunities for Innovative Private Financing Models to Support Zero-Emission Equipment and Infrastructure

Submitted to:

Port of LONG BEACH
The Green Port

Submitted by:

GRANT FARM
WHERE GREAT IDEAS COME TO GROW

February 2019

Contents

1 Introduction

As part of the Clean Air Action Plan (CAAP), the Port of Long Beach has adopted the world's most aggressive strategies to reduce port-related air emissions, chiefly by accelerating the transition to zero emissions. The 2017 Clean Air Action Plan Update, which was jointly adopted by the Boards of Harbor Commissioners for the Port of Long Beach and Port of Los Angeles, formalized the path to zero emissions with two key goals:

- Transition up to 100% of the terminal equipment to zero emissions by 2030
- Transition up to 100% of the drayage trucks to zero emissions by 2035

The transition to zero-emission technologies will require considerable capital investment from the Port and Terminal Operators. As part of the CAAP, the Port of Long Beach and Port of Los Angeles retained EnSafe Inc. to developed preliminary cost estimated for select 2017 CAAP strategies. Importantly, this cost estimates assumed:

- Replacement of existing equipment with zero-emission technologies occurs on a 1:1 basis.
- Zero-emission equipment already deployed at the Port will not be replaced.
- Where commercial pricing is not available for zero-emission equipment, projection factor multipliers of 2.4x and 1.6x the traditional diesel-fueled equivalent are used for electric equipment and fuel-cell equipment respectively.

Costs associated with the transition of all CHE are presented in Table 1 and Table 2.

Table 1: Estimate of Cost of CHE Replacements/Retrofit for the Port of Long Beach

Tier 4 Diesel Equipment Cost		Electric Equipment Fleet Cost		Electric Equipment Incremental Fleet Cost		Fuel Cell Fleet Cost		Fuel Cell Equipment Incremental Fleet Cost	
Low End	High End	Low End	High End	Low End	High End	Low End	High End	Low End	High End
$265,100,000	$283,000,000	$625,500,000	$694,900,000	$360,400,000	$411,900,000	$1,000,200,000	$1,111,400,000	$735,100,000	$828,400,000

Table 2: Estimate of Cost of Heavy-Duty Truck Replacements for that Serve the San Pedro Bay Ports

Diesel (2010) Fleet Cost		Electric Equipment Fleet Cost		Electric Incremental Fleet Cost		Fuel Cell Fleet Cost		Fuel Cell Incremental Fleet Cost	
Low End	High End	Low End	High End	Low End	High End	Low End	High End	Low End	High End
$2,323,800,000	$2,912,100,000	$5,250,600,000	$7,000,800,000	$2,926,800,000	$4,088,700,000	$8,401,100,000	$11,201,300,000	$6,077,300,000	$8,289,200,000

In addition to equipment costs, the EnSafe report include high-level estimates of $40,000,000 of electrical infrastructure upgrades for each of the major container terminals and $1,000,000 of electrical infrastructure upgrades for each bulk terminal. At the time of the report, the costs of hydrogen fueling for fuel cell equipment was deemed too speculative.

These capital costs are additive to numerous existing projects capital improvement projects that are necessary to ensure the safe and reliable utilization of the Port. Unlike traditional capital projects, the zero-emission transition represents greater risk associated with the deployment of new technologies—both equipment and infrastructure. Traditional debt finance used by the Port typically requires projects to demonstrate low risk, resulting in an extended timeline for the deployment of zero-emission technologies. Alternative and innovative private finance models could be used to help mitigate risk to the Port and Terminal Operators while accelerating the deployment of zero-emission equipment and infrastructure.

2 Private Finance Overview

Private financing offers unique opportunities for rapid, large-scale investment in new infrastructure and technologies. Many private-sector investment firms interested in zero-emissions technologies have experience in renewable energy procurement (electricity and renewable natural gas). Through their expertise with these business models, numerous innovative financial strategies, instruments, and structures have been developed to support zero-emission technology deployment. There is no "one size fits all" type of structure, and the particular approach will be highly dependent on the specifics of any given project or deal, in particular the risk profile and the resulting required returns from investors.

Across the industry, there are several types of investment classes, each requiring different returns apportioned to perceived level of risk. Traditional financing at the Port, including municipal bonds, green bonds, corporate bonds, and traditional debt, fall into the investment grade debt category with the lowest risk profile. To accelerate the deployment of the zero-emission transition, it may be beneficial for port stakeholders to work with private sector finance partners that are interested in higher-risk projects, shifting financial and technical risk from the terminal operators and Port to a third party. A summary of equity considerations is presented in Table 3.

> **CASE STUDY**
>
> **Macquarie and Port of Los Angeles**
>
> The Harbor Performance Enhancement Center (HPEC), a unique $130 million-dollar public-private partnership dedicated to facilitating sustainable freight movement and supply chain efficiencies throughout the United States, has completed a strategic transaction with Macquarie Principal Finance, to provide capital for the development of the 5.5 million square foot container staging hub located at Terminal Island in the Port of Los Angeles.

Table 3. Equity Risk-Return Profiles

	Investment Grade Debt	Junior Debt	Core Equity	Core + Equity	Value-Added Equity	Opportunistic Equity
Return Assumptions[1]	3.5-5.5%	5.5-9%	5-9%	8-12%	11-15%	15-17%
Key Risks	Operating Assumptions, Investment Structure	Market Risk, Operating Assumptions, Strategy Implementation	Operating Assumptions, Leverage Levels, Regulatory	Construction	Strategy Implementation	Market Risk, Political Risk and Currency Risk
Revenue Certainty (contracted)	Yes	No	Yes	Yes	No	In Some Cases
Already Revenue Generating?	N/A	N/A	Yes	No	In Some Cases	In Some Cases
Main Return Driver	Income	Income and Appreciation	Income	Income and Appreciation	Appreciation	Appreciation
GDP Sensitivity	Low	High	Low	Low	High	High
Greenfield or Brownfield	Both	Both	Brownfield	"Dark Green"	Both	Both
Development Risk	In Some Cases	In Some Cases	No	No	In Some Cases	In Some Cases
Return Driven by Exit?	No	No	No	No	Yes	Yes
Operating Complexity	Low	Low	Medium	Medium	High	Medium/High

Source: BlackRock, February 2015. 1 These ranges are BlackRock's return assumptions for infrastructure assets. BlackRock has arrived at these long-term, project-level return assumptions by applying the cost of capital and a discounted cash flow methodology, taking into account anticipated revenues and operational factors, to projects currently available in the market. The upper end of each targeted return range assumes the use of leverage and/or manager skill. The estimates are as of March 2015, may change as subsequent conditions vary and are presented for informational purposes only. No guarantee is made regarding the ability of investors to obtain returns within these ranges, either now or in the future.

3 Barriers to Third-Party Investment

Despite the benefits of zero-emission adoption and other asset electrification efforts, several barriers have hindered adoption.

3.1 Multi-Tenant Split Incentives

Multi-tenant property management arrangements can result in split incentives between tenants and owners. In some scenarios, the costs of electrical upgrades may be borne by the owners, while the benefits are enjoyed mainly by the tenants. Conversely, tenants may bear the zero-emission infrastructure upgrade costs, but their tenancy may be too short to reap the full benefits over the lifetime of the equipment. Some tenants with shorter-term leases will have a short-term investment bias that prevents the full lifetime of benefits for an energy-related improvement to pay-back initial retrofit costs. This split incentive is apparent at the Port in the relationship between terminal operators, who lease their space, and the Port as the property owner. Zero-emission solutions must consider the needs, limitations, and benefits of project implementation for both terminal operators and the Port as the property owner.

3.2 Prohibitive Capital Costs

Given current market conditions, the upfront capital costs of adopting zero-emission equipment are higher than that of fossil fuel-based equipment. The 2017 *Preliminary Cost Estimates for Select Clean Air Action Plan Strategies*[1] estimates that upfront zero-emission equipment costs are two to three times higher than equivalent diesel equipment. However, the report does not estimate or compare lifetime operational costs. By contrast, other studies (Hagman, 2016[2], Raustad, 2017[3]), indicate that avoided fueling, maintenance, and operational costs of electric equipment result in a lifetime Total Cost of Ownership (TCO) that is less than fossil fuel-based equipment. Full cost accounting models are better able to capture all aggregate costs–including capital costs of equipment, discount rate, infrastructure retrofit, and variable operations and maintenance costs–to better inform decision making.

3.3 Unaccounted for Externalities within Fossil Fuel Pricing

The negative impacts of fossil fuel combustion on human health and environmental outcomes are currently not internalized into the price of fossil fuels. However, policymakers are likely to increase the effective tax on fossil fuels through California's cap and trade policies and other carbon taxation approaches, which presents an economic risk to the Port's fossil-fueled transportation operators.

3.4 Increased Complexity

Adoption of zero-emission assets presents new complexities to fleet operators and asset owners. Initial procurements will present challenges relative to operational capabilities, installation, interconnection, and the need to navigate new financing structures. Port staff and other informed stakeholders may need to provide enhanced technical assistance to ensure that terminal operators have the information they need to efficiently adopt and integrate zero-emission equipment and related infrastructure, including new standards and best-practices.

[1] https://www.portoflosangeles.org/pola/pdf/caap_2017_costing_report-final.pdf
[2] https://www.sciencedirect.com/science/article/pii/S2210539516000043
[3] http://fsec.ucf.edu/en/publications/pdf/fsec-cr-2053-17.pdf

3.5 Inexperience

Uncertainty driven risk and a lack of deal uniformity for zero-emission fleet projects is a near-term barrier for widespread adoption and for larger (over $100MM) zero-emission equipment and infrastructure deals. Initial projects may be small (less than $15MM) and ad hoc until successful business models, structures, and opportunities can be validated. Utility upgrade timelines and hydrogen availability will be critical risk factors, and significant barrier, to successful the Port's zero-emission transition.

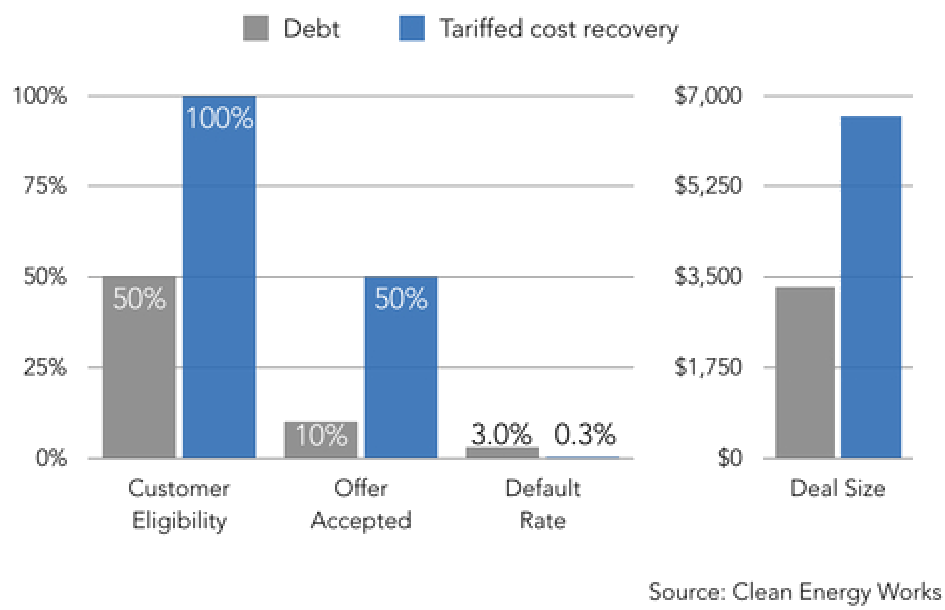
4 Innovative Financing around Zero-Emission Technologies

The transition to zero-emission technologies in the light-duty sector and near-zero-emission technologies in the heavy-duty sector has sparked the development of new and innovative business models. In the light-duty sector, which is dominated by vehicle electrification, business models developed for distributed renewable energy projects have been adapted to support transportation financing. In the heavy-duty sector, which is dominated by compressed natural gas (CNG) and renewable natural gas (RNG), packaged procurement models have been developed to guarantee availability of fuel and manage Renewable Identification Numbers (RIN) and Low Carbon Fuel Standard Credits (LCFS). A selection of potentially relevant models are described in this section.

4.1 Tariffed On-Bill Investment Programs

Tariffed on-bill investment programs—also known as “Pay as You Save” or inclusive financing—provide an alternative to on-bill repayment or on-bill financing models by integrating equipment financing directly into the underlying pricing of the tariff. Voluntary participants in a tariffed repayment program typically carry no debt or lien on the improvement. The capital can be sourced either by the utility or from a third party. According to Clean Energy Works, the creators of the Pay as You Save (PAYS) tariff structure, customer eligibility is broader, and repayment rates on tariffed financing are higher than debt financing and can result in larger deal sizes as shown in Figure 1.

Figure 1: Benefits of Inclusive Financing



Under an inclusive financing models, such as Pay as you Save (PAYS), the utility recovers the costs on utility bills for improvements at the customer location at a rate that is less than the estimated savings the electrification produces. Charges for the asset appear as a line item on the customer’s bill. A majority of savings are distributed to the utility until capital costs are recovered, at which point full savings are retained by the customer. One recent development of PAYS involves financing of electric bus batteries. The goal of PAYS financing for E-Bus batteries is to lower the upfront costs of electric buses via a utility service agreement for the batteries and charging stations. This enables customer ownership of the assets while also enabling increased electricity sales and full cost recovery for the utility.[4]

PAYS Tariff Design Structure: The following schematic demonstrates the transaction flow for PAYS, based on the E-Bus model, which could be applied to other Medium and Heavy-Duty commercial vehicles by agreement with the sponsoring utility.

Figure 2: PAYS Transaction Flow

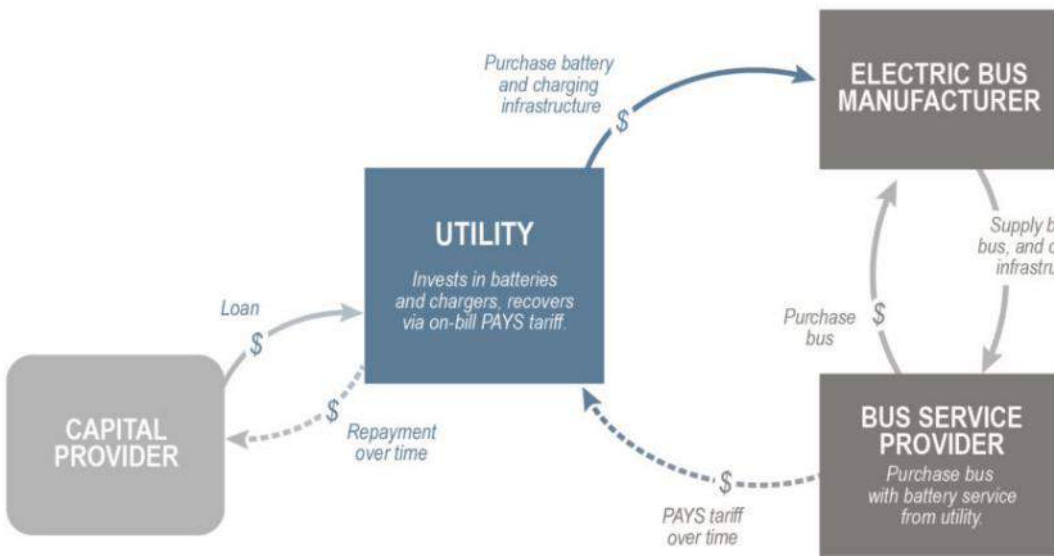


Image from The Climate Finance Lab

In a PAYS transaction, the transit agency buys E-buses from the electric bus manufacturer without batteries or charging infrastructure, typically at or near the same upfront price point as diesel buses. The utility in turn sources the capital to finance the costs of batteries and charging infrastructure. The utility recovers its investments through on-bill repayments from transit agency each month, providing funds to repays the capital provider (which could be a third-party financer or potentially the utility itself.)[5]

PAYS provides benefits to multiple parties including:

- The utility gains new load and revenue resulting from fuel switching. When timed with off-peak charging, the utility also enhances asset utilization efficiency.
- The capital provider is able to finance a clean energy asset through the balance sheet of the utility while being insulated from credit party risk.
- The Port or Port tenant may be able to procure a zero-emission vehicle at cost parity with conventional fossil fuel-based assets on a TCO basis, financed over the life of the asset (e.g. 10 years).
- The OEM EV vendor is likely able to offer an EV at an upfront price point in parity with conventional fossil fuel-based assets.

[4] http://www.cleanenergyworks.org/home/clean-transit/
[5] The Climate Finance Lab: Pay as You Save for Clean Transport. Retrieved from: https://www.climatefinancelab.org/project/pay-save-clean-transport/

The PAYS approach can be expanded to other assets types, such as onsite solar plus storage, forklifts, drayage, or other electrification initiatives. Building on the example of the PAYS E-bus procurement, implementation of an equivalent PAYS program for Port vehicles and infrastructure could follow these steps:

- The utility (SCE in the case of POLB) establishes an elective repayment tariff
- The Port or terminal operator opts into the voluntary tariff
- The utility provides the upfront cost of the asset purchase with funding sourced from a third-party capital provider or internal utility fund and buys the EV battery from the OEM
- POLB or terminal operator purchases the vehicle without a battery from the OEM
- The OEM provides the EV and battery in a single delivery
- The relevant ratepayer (tenant or Port) pays the elective tariff, which includes their price of power plus a fixed rate that includes the cost of the battery plus interest.

Inclusive financing via tariffed repayment successfully navigates the split incentive challenge experienced by the Port and Terminal operators. Table 4 identifies other key challenges and opportunities of the model within the context of the Ports of Long Beach. Adoption of the PAYS approach will require that SCE or other utility sponsors to petition the CPUC to modify a current statute that prohibits linking financing to the electricity meter. Clean Energy Works is currently building a coalition of transit agencies and other interested organizations in California to enable this change. The participation of the Ports in this coalition would likely further strengthen the effort.

Table 4: Opportunities and Challenges of PAYS Financing

Opportunities	Challenges
• Cost recovery is tied to the meter -- enabling repayment to continue with tenant turnover • Simplifies financing so that individual financing deals are not required with every new electrification project at the port • Low default risk as the arrangement provides ongoing positive cash flow for the end user based on efficiency gains • TOU tariffs to promote managed charging can be paired with on-tariff repayment to create mutually beneficial outcomes for the port, its tenants, and the utility • New models of PAYS could incorporate the cost of EV purchase in addition to the battery cost	• Requires utility engagement and a positive CPUC decision -- which may delay implementation • Requires a careful analysis of cash flow and avoided costs of fueling to create financing confidence and ability to attract third-party financing support

4.2 “Charging as a Service” and “Mobility as a Service” Payment Models

New business models and product offerings are rapidly developing in the zero-emission fleet market that are designed to bundle zero-emission vehicles, infrastructure, and charging/fueling into one-stop-shop offerings for fleet operators. “Charging-as-a-Service” or ”E-Mobility-as-a-Service” platforms typically bundle financing for the vehicle, the alternative energy distribution infrastructure, the charging/refueling equipment, and the energy in a 10+ year financing structure with a firm “pay by the unit” or “pay by the mile” fee. In practice, the model requires minimal or no up-front financing, and acts similarly to a Power Purchase Agreement for E-Fueling or E-Mobility. The financing approach is agnostic as to vehicle or charger/refueling types. It also has the potential to provide greater certainty with regarding to fueling, operations, and maintenance costs. Perhaps most importantly, it enables access to capital needed to handle the battery/fuel cell costs and infrastructure upgrades required to make the initial transition to zero-emission transportation, within an operational expense (OpEx) framework that is familiar to operators. Specific features of the charging/mobility as a service model include:

- **Pay-by-the-kWh or mile / all-inclusive financial solution:** Charging/Mobility as a Service model is a pay by the energy unit OR pay by the mile driven approach, and includes a) the charging/refueling equipment, b) infrastructure upgrades; c) a 10-year (typical) charging/refueling as a service PPA like structure; d) Smart charge management (electricity), including telematics for both fleet and charging management, and charging-grid integration (electricity). End-to-end charging/refueling solution management – including labor, operations, and maintenance cost – is available as part of the fixed charge approach.
- **Demand charge management and energy cost certainty:** Contracts typically provide firm energy costs over the contract period. The charging-as-a-service provider typically "owns" the meter (i.e., the service contract with the utility), and is 100% responsible for demand charge & energy cost management. This model is only applicable to battery-electric technologies.
- **100% renewable energy access:** Energy cost certainty can be supported by provision of appropriate stationary energy storage and low-cost solar, either on-site or remotely. For larger users that qualify for direct access (DA) to wholesale energy markets, charging-as-a-service providers may be able to source 100% renewable wind or solar power at significantly lower rates than local utility offerings. (Note that new rules governing direct access in California will open up this option to more customers effective in 2019, per the discussion on DA below).
- **Turn-key service, including labor & smart charge management:** Charging-as-a-service firms will optimize charging regimes based on duty cycle analysis matched to energy and demand cost minimization, taking into account Time of Use (TOU) tariffs and any applicable Demand Charges (which are typically levied based on peak monthly use in a 15 minute billing window). Charging-as-a-service solution providers typically support a variety of EVSE hardware solutions most appropriate for a given fleet mix and duty cycle.

Mobility-as-a-Service models are likely to be attractive to many Port stakeholders. However, contract terms should be developed to insulate the Port and its tenants from technological, business, and counterparty risk. These new business models are widely applicable to battery-electric technologies and have fewer overlaps with hydrogen fuel cell technologies. To lower risks tenants and the Port will likely seek to:

- Review contracting mechanisms to ensure that the terms effectively link payment to performance on energy cost and charger uptime guarantees and (where applicable) to vehicle availability
- Ensure that relevant staff can be trained in internal use of software tools to plan and manage duty cycles and related e-fueling needs
- Fleet data management and access rights and protocols are clear both during and after the contract period.

Large institutional users of electricity may be eligible for direct access to wholesale electric service providers (ESPs), with local distribution provided by SCE. This could result in significant discounts for uses such as EV charging, when compared to regular rates for commercial customers. The direct access market has been capped at a statewide level of 24,000 gigawatt-hours of load, with firms able to access the market off of a waiting list using a lottery system. However, in 2018, new legislation (SB 237) was passed that expands the cap by an additional 4,000 gigawatt-hours to enable additional participation from the waitlist. This move will increase the share of statewide load in the DA market from ~13 percent today to ~15.5 percent. Information on the SCE Direct Access.[6] SB 237 also directs the CPUC to submit a report to the legislature by July 2020 regarding further expansion of the direct access cap and a reopening of the DA program.

4.3 Collaborative Approaches to Purchasing EVs and EVSE

Collaborative procurement programs have long been utilized by government agencies to access discount bulk pricing, gather required capital threshold for improved financing rates, and to create administrative efficiency through reduced procurement barriers and knowledge transfer. For the Ports of Long Beach and Los Angeles, the recently entered agreement between Mayors Garcetti and Garcia represent an opportunity to align energy, electrification, and climate needs and to seek scaled procurement and cost reductions.

- **Climate Mayors' Electric Vehicle Purchasing Collaborative:** Collaborative procurement of EVs and EVSE in the region are currently underway. In January 2017 the city of Los Angeles issued an EV Request for Information (RFI) facilitated with 30 other municipal participants to better understand municipal EV needs. On September 11th, 2018 Los Angeles Mayor Eric Garcetti announced the launch of the *Climate Mayors' Electric Vehicle Purchasing Collaborative.* The collaborative receives technical support from the Electrification Coalition, Sourcewell, The National Auto Fleet Group, and National Cooperative Leasing. The collaborative aims to "combine the buying power of more than 50,000 government, education, and non-profit organizations."[7]

- **California Opportunities for Procurement (Cal-OP) – Accelerating Clean Energy:** The Cal-OP project is a recently funded, CEC-sponsored project to provide procurement assistance and discounts for large institutional procurers of Distributed Energy Resources, likely to include EVSE and energy storage. The Cal-OP project is administrated by Prospect Silicon Valley with support from the ZNE Alliance, Lawrence Berkeley National Labs, Energy Solutions, and others. The goal of the Project is to match institutional buyers with best-in-class technologies, and to establish purchasing collaboratives in key product types. More information will be available at www.prospectsv.org.

Multi-stakeholder procurement processes can result in cost saving opportunities and administrative efficiency, but technical expertise will be needed to ensure effective execution. The Port's central role in the regional and national economy – and its close relationships to other Ports -- can create buying power conducive to lower pricing associated with longer-term and larger scale procurement commitments.

4.4 Vehicle Grid Integration Opportunities

The term vehicle-grid integration or VGI, as defined by California's *Vehicle-Grid Integration Roadmap,* encompasses multiple mechanisms for EVs to provide grid services. These include "smart" or managed

[6] https://www.sce.com/wps/portal/home/partners/partnerships/direct-access
[7] https://driveevfleets.org/commitment-to-electrification/

charging – which reflects the technical capability to modulate charging through timing shifts, charge rate variation, or switching load on or off. This capability is known as “V1G” or one-way charge management. Two-way energy flow is known as V2G, and refers to the two-way charge and discharge of power between the vehicle and the grid. Two-way flow can also occur between vehicles and building or appliance loads. These configurations are referred to as Vehicle-to-Building (V2B) and Vehicle-to-Appliance (V2A) or simply V2X.

VGI is enabled through a variety of technologies to provide additional revenue opportunities for vehicle and EV asset owners, while reducing operational risk and creating cost savings opportunities for grid operators. VGI-relevant tools include smart software controls, smart chargers, V2G enabled chargers, and utility programs and products, such as time of use tariffs or bundled charging packages. Vehicle-Grid-Integration VGI technology is developing progressively, and several medium and heavy-duty vehicle manufacturers have indicated that their equipment will be enabled for two-way Vehicle to Grid (V2G) connectively either at the factory or with minimal upgrades after deployment. However, for vehicles that are not factory-enabled for V2G, there is risk of voiding warranties on vehicle batteries when used in V2G applications. Warranty issues must be resolved at the outset of any program.

While all V2G applications involve some battery degradation when used extensively in stationary applications, degradation rates must be carefully modelled based on actual cycling. Low depth of discharge for such applications as frequency response may have relatively negligible battery impacts, while deeper and more frequently battery cycling results in faster degradation. Utilization of batteries for grid services can potentially provide significant revenue for the asset owner if there is significant and regular downtime for those batteries. Given the round-the-clock operations of the Port, it is not clear whether there will be such opportunities in the future as EV’s begin to be deployed in large numbers. That said, the larger capacity of EV batteries in many Port applications will provide a unique test bed opportunity to determine revenue potential. Recent grant funding opportunities provided by CARB and the CEC have supported VGI pilot testing and deployment. VGI pilot projects at the Port could provide needed data on both battery and revenue impacts and help tailor EV load management to the needs of Port and its tenants and other stakeholders.

5 Interviews with Key Stakeholders

Fourteen (14) companies and organizations were interviewed to better understand the landscape of third-party finance and project development for the proposed electrification of California's ports. Interviewees included capital providers and investment banks, energy and infrastructure consulting firms, equipment and infrastructure providers, utility investment groups, industry organizations and non-profits, and providers of innovation capital. The results of the interviews, as well as key-take-aways from those interviews, are included in the following sub-sections.

5.1 Capital Providers and Investments Banks

Generate Capital: Generate Capital offers multiple types of equity and debt financing facilities of varying durations and structures to deploy infrastructure capital. They emphasize flexibility for their partners, and their goal is to build scalable, repeatable, and standardized offerings in emerging asset classes. Generate Capital is particularly interested in energy infrastructure investments and the Port's zero-emission opportunity is of particularly interest.

Key Take-Aways

- Innovative infrastructure investors are beginning to move into the electric vehicle and infrastructure space. Identifying these players, and engaging them early, will be critical to establishing EV infrastructure as an asset class capable of providing consistent returns.
- Both equity and debt financing will be critical for Port electrification.

Wells Fargo: Wells Fargo has extensive experience providing capital and advisory services to energy related infrastructure and equipment projects, and they have experience working with the California Ports during previous attempts at meeting Port emissions reductions targets. Specifically, in the mid-2000s, Wells Fargo was hired by a client interested in making investments that supported the Ports' effort to transition to alternative fuel fleets. The economic downturn of 2008 stalled this effort prematurely, but not before the Ports were able to make significant progress and successfully deploy alternative fuel vehicles and supporting infrastructure.

Wells Fargo believes the California Ports have a huge opportunity to take a national leadership role, providing some level of risk mitigation that will allow the first investors to step up and go first. The initial private investors, technology providers, utilities, and interested third-parties must learn how to make money together, but these efforts will ultimately open the door for more, larger deals.

Key Take-Aways

- Zero-emission technology has significant opportunity to be a successful investment vehicle across a wide spectrum of deal sizes and stakeholders.
- Private capital providers need a few big initial deals to drive interest in wider scale investment and to begin answering some of the outstanding questions about zero-emission investments.
- The "Ports as a Lab" model can be a game changer for wide-scale adoption of zero-emission fleets and lay the groundwork for business models that provide an appealing return on investment.

Macquarie Capital: Macquarie is a global investment bank, with a global capability in merger and acquisition advisory, debt and equity capital markets, and principal investments. They are one of the largest infrastructure investment groups in the world, and have taken an interest in zero emission equipment and infrastructure. Macquarie recently announced a $130MM investment in the Port of Los Angeles (POLA) to support the POLA Harbor Performance Enhancement Center (HPEC), and they are currently working with POLA on an environmentally friendly cargo valet service, for which they are partnering with a small company developing the technology to be implemented. They believe there will be huge opportunity for zero emission infrastructure and equipment investment, but see several near-term challenges, in particular a lack of uniformity in how to approach these projects. Macquarie has significant experience with solar projects, which is their baseline of experience for investments in the renewable energy and sustainability sector. Macquarie has access to lessons learned from their European office, which has further advanced concepts around investment in zero-emission technologies.

Key Take-Aways

- Deal uncertainty and a lack of deal uniformity for zero-emission fleet projects is a near-term barrier for widespread adoption and larger zero-emission equipment and infrastructure deals.
- Initial deals may remain small and ad hoc until successful business models, structures, and opportunities can be validated.

IronOak Energy Capital: IronOak is an investment firm and strategic advisor, facilitating much larger deals than they might invest in themselves. Their projects are all in clean energy, and they focus on low- to mid-market deals (less than $100M). In their experience, the structure of clean technology investments varies significantly based on the details of the situation, and there is no single one-size fits all approach. IronOak expects that zero-emission equipment and infrastructure development at the Port will require infrastructure-style investors who can make the types of investments not covered by a bond issuance, somewhat riskier deals with higher potential returns than from bonds.

A second type of investor are those willing to get involved in idiosyncratic deals requiring a higher level of complexity built around a stable core of asset finance. These types of projects may involve government agencies, public/private organizations, utilities, or secondary cash flows from the sale of carbon offset credits. Given the ad hoc nature of these types of projects, as well as the higher amount of risk, this type of investor will expect higher returns than green bond investors or pure infrastructure investors. This type of investor constitutes a diverse set of specialty finance groups (e.g. Generate Capital), many of whom are willing to do innovative deal with voucher programs, rebates, etc. They are willing to assess asset financing needs on a deal by deal basis, and do not require a set, standard deal type that conforms to investment norms.

Key Take-Aways

- Optimal deal structure is highly dependent on deal size, the investors and companies involved, and the technology type. The involvement and support (or lack thereof) of local government, semi-government entities, and utilities can have a huge impact on deal structure as well.

Diode Ventures: Diode Ventures is a relatively new part of Black and Veatch (B&V), a global engineering and infrastructure development firm. Diode makes direct investments in infrastructure projects, as well as partners with external capital providers to facilitate larger infrastructure project financings. Because B&V is typically engaged early on infrastructure and engineering projects, Diode joins a project with a great deal of information and understanding of any project complexities, allowing them to move quickly on many of their deals. They are also willing to manage complex deals that may not be of interest to more traditional banks. For example, Diode is willing to help clients manage government voucher programs, rebate programs, and other incentives. Furthermore, they are interested in a diverse set of deal structures, including infrastructure-as-a-service, lease buy-back, debt financing, tax equity, etc.

Diode provided a useful example of an infrastructure purchase and lease-back model: Terminal Operator X wants to purchase several electric gantry cranes from a well-known provider of this equipment. Diodes creates Crane Owner LLC, which purchases the cranes, installs them, manages them, and installs a long-term lease between Crane Owner LLC and Terminal Operator X for use of the cranes. Crane Owner LLC funds the purchase of the cranes via an equity investment by Diode (and any other partners), and debt financing that's typically 60-70% of the total capital requirement. Diode captures the carbon offset credits from the project, providing them with a secondary revenue stream beyond the lease payments from Terminal Operator X. They may also leverage other state incentives. Given their ability to monetize non-lease value, Crane Owner LLC is able to provide Terminal Operator X with a better lease rate than they might otherwise capture from traditional financing structures. This structure may be valuable to terminal operators who are unwilling to take on the technology or infrastructure risk where B&V's experience gives Diode more certainty about specific operational risks.

Ideally, given enough deal volume over the coming 3-5 years, Diode would like to see zero-emission equipment and infrastructure (as well as storage) emerge as its own asset class.

Key Take-Aways

- Long-term design and planning studies will help the investment community begin to plan for future investment models and deal structures.
- EV equipment and infrastructure has the potential to emerge as its own asset class. Outcomes from the next 3-5 years of investment will be critical to normalizing these types of investments.

Bluesource: Bluesource is an environmental commodities firm focused on creating markets for environmental products, advising companies interested in participating in environmental markets, and providing capital to environmental projects. Specifically, Bluesource creates carbon offsets such as LCFS, RINS, and RECs, and manages and transacts them on behalf of clients. Their team consists of engineers, scientists, and bankers with experience in institutional investing. Bluesource prefers deals where they can participate in revenues overs a multi-year program, which incentivizes them to maximize outcomes for the offset sales. They see a huge opportunity for carbon offset programs to create add-on value for port infrastructure deals. Once validated, these revenue streams may be the critical piece that builds momentum for port zero-emission equipment and infrastructure investments.

Key Take-Aways

- Carbon offset programs like LCFS, RINS, and RECs may be a critical factor driving zero-emission equipment and infrastructure investments. A stable state regulatory framework will be necessary for the long-term viability of these environmental investment products.

5.2 Energy and Infrastructure Consulting Firms

Gladstein, Neandross, and Associates (GNA): GNA partners with their clients to develop environmental programs and policies to improve air quality, increase the use of clean fuels and advanced technologies in transportation, and promote the creation of innovative public-private partnerships in a variety of sectors. They have experience working with the ports, port operators, utilities, and port equipment providers. Port projects such as being described in the CAAP will require significant upgrades to existing utilities and surrounding infrastructure, completely separate from the actual purchases of zero-emission vehicles and charging/refueling equipment.

To be successful, the Ports will need to take a leadership position to help private capital become more comfortable with risks like utility upgrade timing. They must also develop relationships with truckers and other stakeholder groups to facilitate the scald of projects required to be successful.

Key Take-Aways

- Utility upgrade timelines will be a critical risk factor, and barrier, to successful port electrification. The Ports can act in a leadership/facilitator role to help mitigate this risk.

Black and Veatch: Black and Veatch (B&V) is an engineering and project development firm with decades of experience in infrastructure and electrification projects, having installed over one thousand EV chargers to date. B&V engages with their clients from planning all the way through commissioning and are involved in all aspects of project development. For example, on behalf of a recent electrification customer, B&V explored the existing utility interconnection to define upgrade requirements and understand potential implications for project financing. They worked with the client and utility to develop a path forward for the necessary upgrades. When it comes to project financing, B&V can work with their internal infrastructure capital group, Diode Ventures, or seek external capital partners to bring in permanent capital once a deal is ready to go.

Key Take-Aways

- Site Planning and Engineering should happen right away to open the door for detailed planning on the part of project developers and project financiers. Third party project developers and financiers will want a lot of information to build internal deal models and to begin understanding the types of projects they may be able to develop. The Ports engaging outside engineering and design firms with experience in large-scale electrification may be critical.

5.3 Equipment and Infrastructure Providers

AMPLY: Amply builds fully automated EV charging systems, targeted at fleet managers and transit agencies. A big challenge for OEMs and end customers is that they are not familiar with electric infrastructure, and they see electric fueling costs as a big bundle of risk. Furthermore, they do not fully understand performance and reliability issues, which presents further risk. Amply's approach is to engage equipment providers and the demonstration partners directly. They are the account holder for the meter (or the submeter for charging) and operationalize the entire process to manage all unknowns and inject certainty and efficiency into projects.

Key Take-Aways

- The success of pilot projects will be critical to opening the flood gates for at-scale fleet electrification.
- Understanding and quantifying risk across the entire supply and value chain should be a goal of early projects.

5.4 Utility Investment Groups

National Grid Ventures: National Grid Ventures is the venture investing arm of the large utility National Grid, based in the UK and U.S. East Coast, and they are very interested in opportunities to invest in areas that complement their future growth or that leverage existing assets. Port electrification projects are an opportunity to find new customers and partners, and utilities can leverage the ports as a vehicle for their portfolio companies. Ports are not typically on National Grid's radar, but may present interesting opportunities to leverage their expertise and to get utilities involved in non-traditional ways.

Key Take-Aways

- Utility investment arms may be a powerful partner in developing port electrification projects. They may have internal leverage that can help prioritize early projects.

Exelon Ventures: Exelon Ventures is the venture investing arm of the large utility Exelon, based in Chicago. Exelon tends to invest in Series B fundraising, providing follow-on funding for energy related startups that have successfully met the milestones of earlier, riskier funding rounds. Exelon is interested in technology that complements their portfolio, which very clearly would include port electrification projects. Exelon Ventures is interested in the Port electrification initiative as a pipeline for their portfolio companies and partners, and they also like the idea of diversifying their portfolio by investing in energy projects in other states beyond their current footprint.

Key Take-Aways

- In-house investment groups from utilities in other states, or from large corporations, may provide an interesting opportunity to de-risk initial port electrification projects. These organizations have large amounts of cash on hand, can finance projects off balance sheet, and are highly experienced with electricity infrastructure and equipment projects.
- In-house investment groups from utilities in other states, or from large corporations, see large initiatives like Port electrification as a potential pipeline for their portfolio companies and partners.

5.5 Industry Organizations and Non-Profits

CALSTART: CALSTART is a national nonprofit focused on accelerating clean transportation within California. In 2012, CALSTART released a study called "Technologies, Challenges, & Opportunities: I-710 Zero-Emission Freight Corridor Vehicle Systems" to examine whether a Class 8 trucks could be developed that would meet the zero-emissions requirements of a transit project looking at freight movements from POLB/POLA to central Los Angeles. Through their experience developing reports and researching the future of zero-emission equipment and infrastructure, CALSTART sees a massive opportunity for the ports to fully electrify. The I-710 report discusses several case studies and integrates feedback and perspective from large equipment companies like Siemens and other design-build partners that own and operate equipment.

At the time, there was a lot of interest in PPA-like agreements with guaranteed contracts for electricity, use of the vehicles themselves, or use of portions of the vehicle (e.g., battery packs). CALSTART is a proponent of disconnecting the ownership from the user for EV fleets; ownership does not need to be a traditional private firm, but could be a non-profit or semi-public organization whose mission is to own and lease electric trucks. LA Metro has done something like this through the LA Metro Public Private Partnership Team. Fixed equipment like a network of charging stations around the port may be better candidates for direct acquisition through financing.

CALSTART sees the ports becoming major electricity consumers. This massive energy requirement may facilitate a need for storage, hydrogen, and renewable energy as well. Battery banks, for example, can sell energy back to the grid at optimal times. In this way, ports become massively important players on the grid, and can provide valuable ancillary services. Ports become a microgrid of microgrids, which should be thought of as a holistic system, not simply a collection of eclectic parts.

Key Take-Aways

- Mobile components of the EV build-out (e.g. trucks) may lend themselves nicely to lease-back structures and PPA-like structures. The complexity around operations and maintenance, coupled with carbon offset revenue streams, makes this valuable as a turn-key solution to end users.
- The Ports will become massive electric demand hubs, making them powerful players on the grid. There may be opportunities for the ports to provide ancillary services at a large enough scale that this can be considered as a secondary source of value.

5.6 Innovation Capital

Los Angeles Cleantech Incubator (LACI): LACI is a cleantech business incubator located in downtown Los Angeles and is managing a regional collaborative that may have value to the Blueprint. LACI is also involved in planning exercises with several other organizations looking broadly at the electrification of transportation. Specifically, LACI is managing its own public/private Transportation Electrification Partnership consisting of utilities, OEMs, LA Metro, public agencies, and they are developing the Zero Emission 2020 Roadmap in support of their role in the Los Angeles County EV Blueprint. Much of their work is in early stage clean energy companies, many of whom will be interested in partnering with larger players to provide solutions for electrification of the CA ports.

Key Take-Aways

- California has many organizations currently working on public/private roadmaps and blueprints exploring the risks associated with electrification. The Port can leverage many of these efforts to enhance and improve their own planning and to attract outside investment.

California Clean Energy Fund (CalCEF): CalCEF is an Oakland based, early stage clean energy technology incubator and ecosystem developer that manages California's cleantech startup fund, CalSEED. The founder of CalCEF was instrumental in developing lease models for solar panel, and sees financial structures for EV electrification maturing in a similar way as more deals get done. The availability of land and space may cause unforeseen issues with adding additional grid capacity and infrastructure, and this should be considered during initial planning. Increasing feeder capacity and installation of new equipment requires land and space, often in already highly developed areas (including ports). Technology to support this issue may need to "miniaturize" in order to fit land and space requirements.

Innovation will continue to play an important role in the evolution and roll-out of EV equipment and infrastructure.

Key Take-Aways

- Land and space will be a key consideration in utility expansion plans in support of port electrification.
- Innovation, both in technology and in business models, will continue to play an important role in the evolution and roll-out of EV equipment and infrastructure.

6 Conclusions

The Port has an estimated $14 billion in total costs associated with the zero-emission transition. The magnitude of investment at the Port alone is attractive to external investors and has the potential for further replication across California Ports and potentially others in the U.S. Through targeted stakeholder outreach, there is general consensus that third-party financing is an option for the Port community and that tailored solutions will need to be developed to address unique demands of individual terminal operators, technologies, infrastructure, and the port environment. To advance the engagement of third-party finance, the Port can serve in a central convening role—bringing together finance groups, the Port, and terminal operators—to allow finance stakeholders to better understand the port and the port community to better understand the financial options, particularly as they may reduce risk associated with terminal operations with zero-emission technologies.

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Appendix I: Zero Emissions Workforce Development Report

PORT OF LONG BEACH
ZERO EMISSIONS WORKFORCE DEVELOPMENT REPORT

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1. Executive Summary

Electric vehicle technology and related zero-emission targets are creating significant workforce development challenges in port terminal environments. As combustion-engine focused port terminal operations are superseded by advances in electrification and fuel cell technology, the required skill sets of the future will be very different from the predominantly diesel-fueled industry of the past. From operations and maintenance to leadership and management roles, new pathways will be required for positions associated with the operation of zero-emissions vehicles (ZEVs) moving freight within and beyond the Port of Long Beach (POLB).

Public transit authorities using electric-battery and fuel-cell drivetrains are overcoming barriers to commercialization as technology has caught up with near-term environmental priorities, and alternative fuel options are becoming more viable. Transit operators in California now have ongoing orders to original equipment manufacturers (OEMs) for more Battery-Electric Buses (BEBs). Similarly, the availability of support infrastructure and applicable electric solutions for cargo handling operations has allowed POLB to begin shifting toward a ZEV fleet for terminal operations.

Zero-emissions electric cargo handling equipment (CHE) and charging station technologies provide port terminal operators with viable alternatives to traditional gas and diesel vehicles if costs of implementation are addressed. Global collaborative efforts in the fields of engineering, information technology, and technical trades have shown how these sectors of the workforce will be necessary for innovating and growing ZEV infrastructure. Although ZEVs have already been deployed throughout POLB, results from an October 24, 2018 POLB stakeholder workshop indicate that the majority of the port equipment workforce is not trained or ready to service the new vehicles and there is a need for data collection regarding operations and maintenance of new ZEVs. Furthermore, peer-exchange webinars with ZEV industry professionals, conducted by CITT, revealed a need for standardized ZEV training, a need for energy efficiency planning, and a current lack of high-voltage knowledge among electro-automotive workers. Additionally, there is concern regarding an aging/retiring workforce as this new generation of technology is ushered in in terms of who really needs to be learning these new skills during the transition.

An in-depth labor market analysis of port-related jobs in sustainability and environmental disciplines (green jobs) spotlights a high demand for candidates across a range of education and work experience prerequisites. These roles predominantly include skills in electrical and automotive trades; however, there is also a requirement for engineering roles and knowledge of utility policies. Most existing jobs will require additional safety awareness and familiarization training or work experience in installing, manufacturing, and maintaining ZEV systems. While some of the emerging ZEV systems at the ports will include autonomous functionality, the majority of the port workforce skills gaps will be driven by electrification rather than automation. Therefore, automated technologies are not expected to reduce the ranks of the supply chain workforce moving goods through the ports.

A case study analysis conducted by the CITT team identified other sustainability leaders in the port operations industry in order to compare ZEV approaches being implemented internationally. Comparative analysis makes it possible to gain insights into what can be learned from related ZEV workforce development efforts. The Port of Rotterdam, for example, offers a useful point of reference for applications of renewable energy infrastructure, hydrogen fuel research, and innovative disposal of industrial waste.

Combined insights from research and industry discussions influenced our workforce development analysis and played a key role in identifying a top-five list of ZEV-critical occupations, as follows:

- Electricians
- Solar Photovoltaic Installers
- Automotive Specialty Technicians
- Electrical Engineers
- Electrical Power-line Installers and Repairers

2. Introduction: Research and Analysis

The ZEV blueprint is a part of POLB's grant application to the California Energy Commission (CEC) to support the adoption of zero-emissions equipment and the goal of transitioning to complete zero-emissions port infrastructure by 2030.

Targets include:

- Improve freight system efficiency by 25% relative to the amount of carbon that it produces by 2030;
- Deploy more than 100,000 freight vehicles and equipment capable of zero-emissions operations and maximize near-zero-emission freight vehicles and equipment powered by renewable energy by 2030; and
- Establish targets for increased state competitiveness in zero-emissions adoption, developed by leaders in industry, government, and research and development.

Although adoption of renewable energy technologies and ZEVs have been increasing for decades, the recent growth in commercialization of battery-powered transit vehicles and CHE is unprecedented. However, the implications for workforce opportunities and development are somewhat unclear as this technology evolves. As the POLB establishes itself as a leader in adopting zero-emission solutions to port terminal management and operations, it is important to understand the shifting trends in job availability and openings as first-generation ports shift into obsolescence and electrification becomes the new developing industry standard.

CITT is assisting this process by analyzing the current labor market and identifying pathways into emerging opportunities resulting from electrification of cargo handling and hauling vehicles/equipment and its associated infrastructure in the supply chain industry.

This research addresses parallels in the increasing electrification of the U.S. bus transit system and the barriers faced in the transition. The research identifies the necessity for additional charging infrastructure. Furthermore, our investigation identifies current solutions to adopting this technology in the port environment, recognizing the current climate of government investment and support from utilities. Understanding financing and the availability of support infrastructure allows for a sense of how large entities such as POLB can introduce the new zero-emissions fleet over the coming years. The vehicles and the facilities needed for their operation opens the potential for entirely new job opportunities at the port in operations, maintenance, and leadership roles. This report outlines those positions, as well as pathways for the future workforce.

The report is outlined as follows:

- A literature review encompassing electrification of bus-transit technology, ZEV infrastructure advancements, and current zero-emission CHE;
- Labor Market Analysis of current career pathway trends and identification of occupations related to designing, developing, operating, and maintaining ZEVs and related infrastructure; and

- Case Study analysis of electrification in the port environment from a global perspective, with relation to the POLB focus.

Below, Table 1 outlines the hierarchy of workforce opportunities at POLB and the implications of large investment in the ZEV blueprint on employment. Decisions made by the port regarding the ZEV blueprint and future plans for development have wide-ranging implications for the individual bodies which make up the POLB network. Understanding the structural workings provides insight into how systems will change and the new normality that the current workforce will need to adapt to.

Stakeholders	Overview	ZEV Blueprint Implications
Port of Long Beach	Governed by the City of Long Beach Harbor Division, the port authority does not own or operate port equipment systems but rather owns the land and leases the land to cargo/terminal tenants who occupy the various piers, berths, and terminals. POLB is responsible for developing and maintaining landside infrastructure.	POLB has set policy goals to work with operators to transition to zero-emissions vehicles and to construct the necessary infrastructure upgrades on terminal tenants in accordance with the ZEV blueprint.
Terminal Tenants	Encompassed under four categories of cargo operations: • Containerized • Dry Bulk • Liquid Bulk • Break Bulk & Roll On-Roll Off These POLB clients have their own employees; some are company-hired but workforce across the port is represented largely by the International Longshore & Warehousing Union (ILWU).	Transformation to ZEV requires specifying the required infrastructure to support the new vehicles and designing plans for roll-out of the new equipment when it is purchased and becomes available. New vehicles have new implications for workforce training, as workers must become fluent in occupational health and safety associated with working on high voltage systems.
Terminal Vendors		Terminal vendors, including Original Equipment Manufacturers (OEMs), supporting ZEV operations may require upskilling and training of new hires for retrofitting or manufacturing new equipment, and for operator and technician jobs in maintenance and infrastructure installation (Long Beach City College (LBCC) draft report for CEC, *Zero-Emissions Terminal Equipment Transition Project*, 2018).
Organized Labor	The ILWU (Local 13) represents the longshore workers of Long Beach.	Equipment operators will need to become familiarized with standard procedures for new technology, perhaps requiring a

	There are no pre-requisites for most of these blue-collar jobs, as the union and terminals provide training for longshoreman and similar positions. Many workers will be employed for over a decade as casuals before moving up to leadership roles and part-time/full-time presence. The International Association of Machinists (IAM) represents mechanics at some terminals. Mechanics must be certified and go through a more rigorous pre-qualification process. POLB has on-going partnership with the International Brotherhood of Electrical Workers (IBEW) in Long Beach. This is where workers are often sourced for POLB infrastructure installation projects (Port of Long Beach, 2017). IBEW Local 11 offers paid apprenticeships through the Electrical Training Institute of Southern California.	completely new training curriculum to be implemented by the Pacific Maritime Association (PMA), which handles training for ILWU current and prospective employees. Mechanics will require new training in zero-emissions equipment maintenance. The potential for a decrease in certain employment prospects may encourage ILWU or IAM to upskill incumbents to retain jobs. IBEW union labor contracted by electrical firms will continue to install infrastructure. Workforce competencies required include high voltage safety; battery and charging station installation, operation and maintenance skills; and working with electrical systems in a corrosive environment (LBCC 2018).
External Bodies	Contractual workers make up another considerable portion of on-site operations for POLB. These jobs are generally specialized trade qualification roles and/or collaborations with other companies.	ZEVs require less regular maintenance. There is large potential for increase in outsourcing vehicle maintenance and part replacement to manufacturers and specialized electric vehicle experts. New renewable energy-generating infrastructure such as the planned solar carport projects – large in scale – will create opportunities and require external contractors for installation. Collaboration with experts in environmental policy will be required for auditing compliance with sustainability targets and standards. For example, the US Green Building Council (USGBC) has awarded Leadership in Energy and Environmental Design (LEED) ratings to completed middle harbor projects.

	Public utilities such as Southern California Edison monitor and regulate the supply and associated costs of providing electricity to POLB.	An increase in electricity demand from the grid as POLB shifts towards zero-emissions operation will put pressure on public utilities and new standards will have to be developed regarding tariffs and regulation, i.e. operations during peak usage hours.

Table 1: Hierarchy of workforce operations at POLB and the implications of ZEV blueprint on workforce groups

3. Literature Review

3.1 Commercializing electrification of bus transit industry

Acknowledging changing alternative fuel trends in other industries provides insight into barriers facing the adoption of ZEVs. Electric buses are particularly applicable when drawing a parallel with ZEV CHE, as the required infrastructure is similar in respect to changing workforce norms. For example, industry leaders in California have developed safety awareness and familiarization courses for operators transitioning to electric drive operations, and a lot can be learned from these processes as the port prepares for implementing ZEVs across their terminals.

The commercialization of medium-duty (MD)/ heavy-duty (HD) ZEV substitutes has been led by the increasing market for BEBs and their integration into the public transit fleet. In the early 2000s, the emerging use of BEBs was undermined by the lack of technological advancement in battery range and charging infrastructure. Additionally, investigations showed that the initial price premium of buying alternative fuel buses would not be offset by fuel savings over the vehicle's lifetime, and incentives were lacking with regard to utility subsidies (North-east Advanced Vehicle Consortium (NAVC), 2005).

However, changing trends in legislation, environmental outlook and the utilities market—coupled with advances in BEB range and charging capability—brought alternative fuels back into the limelight as a feasible solution to a large emissions issue. Battery-electric technology has become a clear favorite regarding overall efficiency, reliability, and reduction of life-cycle environmental footprint. Commercialization trials have increased in scale and begun establishing more extensive potential for charging infrastructure throughout the U.S. Furthermore, BEB manufacturing companies have seen increasing orders for fleets (Eudy, Prohaska, Kelly, & Post, 2016). This rise in demand occurs as issues relating to battery exchange from a decade prior are being satisfied by technological advancement. Now the high initial price premiums are offset by life-cycle fuel and emissions savings (not to mention Vehicle 2 Grid (V2G) savings benefits); however, the price of purchasing a new BEB is much higher than that of a commercial diesel engine bus, and, therefore, large fleet industry companies must pave the way for electrification to make a broader integration (Ercan, Mehdi, Zhao, & Tatari, 2016).

The emerging electrification market highlights a new area for workforce development in which jobs in installation and maintenance of charging facilities will be required as infrastructure grows. During BEB training in safety awareness and familiarization, drivers have been found to adapt to the new technology well. Mechanics required extra training in how to service and troubleshoot electric propulsion components and understanding on-board diagnostics, increasing their skill set (NAVC, 2005). Furthermore, during commercialization trials, charging stations have been found to require maintenance and monitoring, opening up a new area of expertise for operators and electricians/mechanics alike (Eudy, Prohaska, Kelly, & Post, 2016).

The capacity for these vehicles to compete with that of the commercially accepted combustion engines continues to increase. At the forefront, the Proterra E2 BEB is capable of storing 660kWh of energy and holds the world record for having travelled 1000 miles on a single charge in November 2017 (Miller & Hye-Jin, 2018). Findings continue to portray electric-battery alternatives as having higher efficiency, lower maintenance costs and more environmental appeal. As manufacturers move BEB products through commercialization trials, the operations and maintenance responsibilities move to the fleet operators, creating new positions and training standards (Eudy, Prohaska, Kelly, & Post, 2016). A parallel growth in manufacturing, maintenance and support workforce opportunities can be expected as technology continues to grow in other industries, such as port operations cargo-handling and hauling equipment.

3.2 Vehicles

Rubber Tyred Gantry (RTG) cranes, top handlers, and yard tractors (gasoline and diesel) represent a large portion of the terminal operations fleet and resulting emissions. Similar to the bus transit industry, these vehicles have begun to be superseded by electric-battery alternatives and solutions. RTGs can now be retrofitted for use in a zero-emissions environment, wherein they will operate via connection to the port electrical grid and only use diesel power during block changes and maintenance requirements (Vujicic, Zrnic, & Jerman, 2013). As POLB continues to roll-out more conventionally operated ZEVs over the coming years, there are also terminals at both POLB and POLA using automated ZEVs. At Middle Harbor, diesel RTGs have been replaced by electric Automated Stacking Cranes (ASCs), and Diesel yard tractors (hostlers) are competing with the emerging use of Automated Guided Vehicles (AGVs). Battery powered AGVs operate autonomously in cooperation with ASCs and provide increased efficiencies in time management and utilization of space and greatly reduced environmental impacts due to reducing human interaction - not to mention greatly reducing hazards caused by human error. This growing trend will see more specialized roles become available in remote operations and monitoring from the port's control center for automated terminals (Marine Terminals Corporation, 2017). Interaction between automated systems and manned machines such as street trucks still requires remote control intervention from a human operator at the Terminal Operating System (TOS), relying on the use of cameras, lasers, and other precision instruments. Although this technology may seem to have serious implications for the workforce population, large-scale automated systems like the one at Middle Harbor are only viable for tenants with long term contracts, and are hence unlikely to be implemented amongst the majority of terminal tenants. In addition, electric top handler and forklift operators will still be required for specialized manual operations, and those operators will require training in safety awareness and familiarization with new zero-emissions operating systems. This ensures an on-going presence of conventional CHE equipment and operators.

Overall, there are many jobs in the port terminal environment which require close interaction between workers and machines or containers (Marine Terminals Corporation, 2017):

- Container securing devices known as "inter-box connectors" (IBCs) or "cones" are used to hold containers in place on waterborne vessels and can only be effectively handled by workers.
- Refrigerated containers ("reefers") must be connected and disconnected to shore power outlets by human workers.
- Most terminals require workers to check the status of reefers while in storage.
- CHE frequently needs close attention by mechanics for routine diagnosis, maintenance, and repairs, as well as for swapping specialized cargo-handling hardware.

Figure 1: Autonomous container terminal system. AGVs and ASCs pictured.
(Dekker & Rotterdam, 2016)

Consolidation in the container business has seen ships grow in capacity. Successes in instances such as the APMT and RWG automated container terminals at Port of Rotterdam are inspiring new port developments and spurring growth in the market for automation (Dekker & Rotterdam, 2016). This opens up new workforce opportunities for engineers, architects and scientists in supply chain logistics, as there are still many hurdles to overcome in automated design/artificial intelligence. Furthermore, increased inbound container capacity requires increased outbound capacity in the trucking sector, wherein heavy-duty drivetrain technology will face the movement to zero emissions. The ZEV blueprint is establishing the port as a site for cutting edge innovations in this technology.

At the Toyota Warehouse (at POLB), the new generation of hydrogen fuel-cell semi-trucks are being built, which have a 300-mile range between refills. Infrastructure for these vehicles is being established by the construction of the Toyota zero-emission power plant project and the hydrogen fueling stations in Ontario, to support the trucking routes and begin establishing a support network for the new vehicles (Evarts, 2018). The California Air Resources Board (CARB) assists in funding this project by supplying approximately 50% of the required $82 million funding, which also includes new hydrogen forklifts and zero-emissions yard tractors to adhere to POLB zero-emissions standards (Evarts, 2018). This expands hydrogen fuel cell equipment at the port and contributes to growing the POLB micro-grid through producing renewable energy, increasing the ZEV fleet, and establishing alternative fuel infrastructure, which can be used as the building blocks for ZEV network growth.

3.3 Infrastructure

Smaller businesses in the U.S. currently have unclear incentives for installing ZEV charging facilities or establishing new fast-charge service stations to support the growing electric vehicle population. In California, the current 12,000 (approximate) publicly accessible charging stations falls short of the infrastructure required to support Governor Brown's goal of 1.5 million in-use electric vehicles by 2030 (Elkind, 2017). However, as seen in the evolving bus-transit industry, larger businesses can lead the way as utility services adapt to the new paradigm shift in technology.

At Long Beach Container Terminal (LBCT), which is almost entirely zero-emissions, an international engineering collaboration between European and American engineers and builders designed and constructed a Battery Exchange Building (BXB) (Farrell & McKie, 2016) to support battery-powered automated guided vehicles. This project provides insights into the kind of jobs which may become available as the POLB carries out planned projects for more similar ZEV charging stations and infrastructure. Those jobs mainly include:

- Engineering: robotics, mechanical, electrical, thermal and construction
- Specialized trades: refrigeration mechanics, electricians and builders
- Automotive technicians specializing operations and maintenance of alternative fuel vehicles.
- Environmental impact inspection and auditing

Figure 2: 3D schematic visualization of the BXB at the LBCT

Furthermore, plans for constructing large-scale solar energy generating facilities at the port open up opportunities for jobs in installation and maintenance. The time scale for these new jobs moves to more of a contractor scope rather than permanent port employment; however, there are already multiple projects planned throughout 2019-2021, and more will be created as the ZEV fleet grows.

It is the culmination of renewable energy solutions, V2G technology, and energy storage facilities on-site, such as BXBs that support the port's microgrid and zero-emissions initiative (Ercan, Mehdi, Zhao, & Tatari, 2016). Supporting the microgrid infrastructure and capacity of POLB also increases the efficiency of shore power (or "cold ironing") as an emissions reducing solution. Legislative mandates administered by CARB regulate energy use at-berth and require shipping lines to transition their vessels to shore power capabilities. This transition is incentivized as regulations increase each year, and violation of these laws incur harsh penalties for fleet operators. This is a good example of policy driving change and setting new standards for sustainable port operations. Furthermore, utilities can hopefully be expected to follow suit. Southern California Edison has indicated that new utility rate tariffs will be changing in response to demand and the new structure will incorporate higher expenses for MD/HD electric vehicle classes. Therefore, it is in POLB's best interests to streamline electrification and take advantage of current neutralization of demand tariffs as rate structures change, hopefully driving growth in jobs for electrification and renewables.

4. Case Studies

The impact of technology is evident across all avenues of businesses today, and the port sector is no exception. The future of a port complex will rely on hyper-connected environments comprised of devices sharing data in real-time, simultaneously improving knowledge, understanding, and productivity. A representative from the Agriculture Transportation Coalition (AgTC), the largest national trade organization for agriculture and forest product exporters, said in an interview with the Long Beach Business Journal that "technological advances and automation are not an option or a choice; they're a requirement" (Belk, 2015. *Technology Will Inevitably Change Labor's Role At Local Ports But With Long-Term Benefits*, p.1). Jobs are therefore becoming more mechanical and technology-oriented with rapid disruptions to the regular structure of work.

Low-carbon electrification options are driving demand for new skills to facilitate the transition to ZEVs in infrastructure. Given that these trends are global, it is important to garner information about strategies adopted and practiced by other ports around the world as primary leaders in energy management.

In a report published by the United Nations Conference on Trade and Development (UNTCD), global maritime trade is said to increase at the rate of 3.2 percent annually between 2017 and 2022. Cargo flows across all segments, especially containerized and dry bulk, will record the fastest growth (UNCTAD, 2017). This growth adversely impacts the environment via harmful emissions. Hence, there is a growing need to decarbonize the ports with a view towards sustainable energy practices within the port complex.

In this section of the report, three case studies are identified that describe innovative and consistent approaches to port electrification with the aim of decarbonizing.

4.1 Port of Rotterdam – Netherlands

The Port of Rotterdam is the largest port in Europe. It contributes nearly 3.3 percent of Netherlands' gross domestic product and moves approximately 13.7 million twenty-foot equivalent units (TEUs) of freight annually. As a leader in the maritime world, the port has committed to cut its carbon emissions 95% by 2050, from the baseline year of 1990 (The Port of Rotterdam, 2017).

Energy is the lifeblood of the port for non-stop operations. Low-carbon electrification requires dedicated efforts by port officials and private sector partners. The port has established seven themes along which it will implement energy transition programs.

- **Energy through biomass**: The port is committed to produce energy using biomass as a raw material. Biomass originates from vegetable or animal material, as well as from waste streams from agriculture and production processes. It is a good replacement for fossil fuels in applications such as liquid fuels and chemicals. The Port of Rotterdam houses the world's largest industrial cluster that uses biomass as raw material.
- **Energy efficiency practices**: The port is on a constant search for effective energy efficiency practices through optimizing processes and introducing new technologies such as improved heat integration, insulation, and process optimization, potentially resulting in an additional 20% of energy savings.
- **Investment in onsite and offsite renewable energy**: The port has installed nearly 200 mega-watts (MW) of onsite wind energy and will add another 150 MW of wind power to its energy mix. There is also an effort to maximize solar power onsite. The port is working with a private sector partner to explore large scale energy generation of wind power at sea with the option of converting the power into hydrogen. The port is also in its pilot phase of testing ultra-deep geothermal power.

- **Circular economy**: The port aims to be a center for reusing all products and substances effectively. It is committed to using waste as a raw-material to other industrial synergistic processes and aims to potentially reduce introduction of any new raw materials. In a circular economy, production and consumption are as clean as possible.
- **Alternative fuels:** The port has envisioned transportation to become more electric and carbon free. There is an initiative to support alternative fuels such as biomass, hydrogen, and emission free propulsion systems.
- **Energy infrastructure:** The port is developing a central infrastructure for residual heat, steam, and CO_2. The large quantities of heat and steam that are released in the port can thus be reused effectively, and CO_2 can be transported to locations for storage or reuse.
- **Large scale electrification:** Industrial companies in the port mainly use energy to generate heat for their production processes. By 2050, industry will switch to a new energy system. Electrification based on solar or wind power or produced from hydrogen will then be an important energy carrier.

There are over 40 projects at various stages of development at the Port of Rotterdam that administer clean and sustainable energy (Port of Rotterdam, 2017).

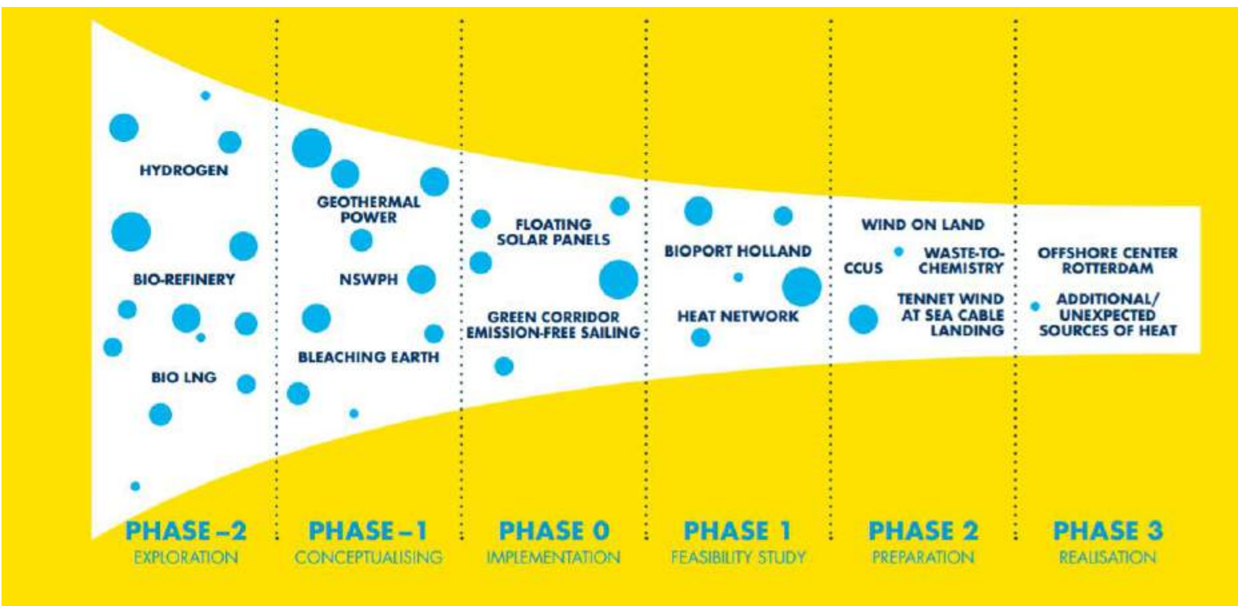


Figure 3: Chart representing various phases of energy strategy at the Port of Rotterdam (Port of Rotterdam, 2017)

The Port of Rotterdam has a clear energy pathway that presents several new workforce opportunities in the fields of renewable energy, energy infrastructure, hydrogen fuel research, alternative fuel research, and innovative industrial waste applications.

4.2 Port of Metro Vancouver – Canada

The Port of Metro Vancouver and related tenants and terminals are working to reduce port-related air emissions that affect air quality and contribute to climate change. They have set up the following goals for the sustainability of the port complex:

- Protect air quality through the reduction of criteria air contaminants such as sulphur oxides, nitrogen oxides, and particulate matter emissions;
- Reduce port contributions to climate change through reduction in greenhouse gas emissions and black carbon;
- Promote a culture of continuous improvement and energy conservation throughout the port, with a focus on operational efficiency and clean technologies; and,
- Collaborate with government and industry on the development of goals and objectives, performance monitoring, and progress reporting.

The Vancouver gateway moves more than 120 million tons of cargo annually, and this activity needs sustainable sources of energy. The port sources its electricity from BC Hydro, which uses 98 percent renewable sources, thereby reducing life-cycle emissions. In 2014, 50 shore power equipped container vessels visited this port for a total of 156 calls, increasing from 92 calls in the previous year (Port of Metro Vancouver, 2017). This has spurred the port to begin offering shore power to berths at the end of 2017, incentivizing this process through the EcoAction Program. This program offers shippers discounted harbor rates and creates an incentive mechanism to transition to shore power. The Port of Metro Vancouver is part of a larger coalition with Port of Seattle-Tacoma, forming the Northwest Ports Clean Air Strategy.

Internally, the port is also engaging in energy efficiency practices such as replacing and retrofitting LED lights in most of its property and performing electrical energy assessments to identify opportunities.

Figure 4: Shore power services at Port of Metro Vancouver
(The Port of Metro Vancouver, 2017)

4.3 Asian Ports – China, Singapore, and Malaysia

The ports in the Asia have taken a cue from their counterparts in the west like in Rotterdam, Long Beach, and Los Angeles. Shanghai's Yangshan Port has a fully automated terminal that is aiming for zero emissions and has cut overall energy consumption by 70%. According to World Resources Institute, China will see 493 berths equipped with shore power by 2020 due to government subsidies (Green Port, 2018). This shore side electrification is extending to port CHE, such as ship-to-shore (STS) cranes.

In Southeast Asia, the Maritime and Port Authority of Singapore (MPA) launched the Sea Transport Industry Transformation Map (ITM). ITM's goal is to make port operations more efficient by capitalizing on emerging technologies to achieve faster clearances. MPA hopes to grow the maritime sector by $4.5 billion and create over 5,000 jobs by 2025 (Green Port, 2018).

The port authority also signed a memorandum of understanding with Shell to advance clean fuel technologies, including greater automation to reduce emissions. For its part, PSA Singapore is installing an eco-friendly 4MW solar photovoltaic system. Built by Sunseap Group, the clean energy system will power five PSA facilities, including terminal buildings, gates, and a maintenance base.

The Port of Tanjung Pelepas (PTP) in neighboring Malaysia has installed new cable reel technology to provide electrical power for high-reach STS cranes. The reels will boost green efficiency by optimizing productivity and reducing the environmental impact of CHE operations.

Johor Port Authority (JPA) has teamed up with Universiti Teknologi Malaysia to develop an online Ship Emission Management System (SEMS). Terminal operators, such as PTP, are required to report ship activities using SEMS, which helps JPA to monitor, calculate, and regulate emissions through web-based and mobile applications (Green Port, 2018).

These case studies are global examples of port infrastructure that have showcased strategic direction in achieving port efficiencies with low-carbon priorities. While it is natural to address the port sector alone, it is imperative to highlight the innovations in energy infrastructure as well. Newer and more modern forms of electrification, such as microgrids, are a successful model for ports to adopt in their own journey towards increasing capacity and reducing risks associated by connecting to the grid.

4.4 Case of Microgrids

The U.S. Department of Energy defines a microgrid as "a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously" (U.S. Department of Energy, 2014. *How Microgrids Work*, p.1). A microgrid not only provides back up in case of emergencies, but acts as a mechanism to be energy independent and environmentally friendly. There are about 1,900 microgrid systems in the US that are operational as of 2018, and their numbers are expected to grow. Microgrids can power a single facility like the Santa Rita Jail in California, or they can power a larger area such as Fort Collins in Colorado (U.S Department of Energy, 2014).

Microgrids attempt to use renewable sources of generating energy such as solar PV, small-scale wind, natural gas, fuel cell, biomass, and rice husk, with storage options ranging from batteries to thermal. The Stone Edge Farm microgrid in Sonoma, California boasts of five separate forms of storage.

Figure 6: UCLA Energy and Environment Climate Lab
(Roberts & Chang, 2018)

The Port of San Diego has demonstrated the use of microgrids in its energy mix. The CEC along with the Port of San Diego has provided funds to set up a 700-kilowatt solar power microgrid with an equal storage capacity. This project is expected to cut the port's energy costs by 60% (Micro-grid Knowledge, 2018). This project is expected to test how well a microgrid can operate independently from the grid and eliminate nearly 300 metric tons of carbon dioxide from being released into the community adjacent to the port. A representative from the Port of San Diego articulated California's leadership role in the implementation of policies surrounding clean energy and vehicles stating, "With more electric vehicles at the port, this project can support transportation electrification by providing demand response when demand for grid electricity is high, taking the port offline for a few hours, if necessary" (Cohn, L. 2018. *Port of San Diego to Demonstrate How Microgrids Benefit Ports Worldwide*, p.1).

While the aforementioned new technology boasts improvements in sustainability and efficiency, zero-emissions systems must be managed properly to ensure optimization of cost-benefits after implementation. The need for expertise in energy policy and management has highlighted a gap in the workforce, which has influenced the emergence of new education disciplines, particularly in California. The following case study outlines the emerging energy engineering pathways available in California's higher educational institutions.

4.5 Case for Energy Engineering Profession

During peer exchange webinars (Section 6.3), industry professionals identified some critical roles not yet being met regarding ZEVs in the transit industry. Two of these roles were managing and optimizing the new electrical systems and complying with the regulations related to the new ZEV fleet. The job title that best fits both these roles was referred to as an "energy engineer." CITT chose to designate particular attention to this emerging job title and skill set as the expertise will be complementary to other engineering roles at POLB.

Energy engineering is a relatively new discipline that has developed as an academic response to emerging technologies and increasing demand placed on utilities for power generation. New educational pathways deal with energy efficiency management, alternative energy technologies, and environmental compliance. Transit industry professionals emphasized difficulty navigating the regulations in this new field of ZEV and were planning to hire full time employees to focus purely on the regulations-related skills gap. Also, battery life is a particular challenge facing management of ZEVs. With training in basic engineering concepts as well as efficiency standards and environmental compliance with regard to ZEVs, energy engineers can serve a pivotal role in facilitating a smoother transfer to commercializing ZEVs. Additionally, the BLS projected a 9.2% growth in demand for energy engineers between 2016 and 2026 nationwide so the availability of energy engineering educational programs could logically be expected to increase as well (Bureau of Labor Statistics, 2018).

Two energy engineering bachelor's degree programs are currently offered in California at Stanford and UC Berkeley. Undergraduate programs in energy engineering at Stanford[1] and UC Berkeley[2] aim to build foundational knowledge and engineering skills such as resource assessment, carbon management, and a basic technical and scientific background all engineers should possess. With this skill set, students have the ability to contribute in the energy industry immediately or pursue graduate studies. Students are required to study courses such as "Optimization of Energy Systems" that may be particularly beneficial to ports on their paths to becoming more energy efficient. Students are also required to take numerous courses addressing the broader issues related to the energy industry that will provide them with an understanding of the regulatory framework that is currently in place.

Beyond undergraduate studies, there are a number of relevant master's programs offered at Stanford, UC Davis[3], San Francisco State University (SFSU)[4], and University of San Francisco (USF)[5]. These graduate programs cater their curriculum to students of different undergraduate backgrounds. While the programs at Stanford and SFSU are focused on educating engineering graduates, the programs at UC Davis and USF are accessible to both engineering and business/management graduates. These programs also offer opportunities for professionals interested in energy systems to upskill and help meet the increased demand for energy engineers in coming years.

Energy engineers can serve two pivotal roles, both of which make them critical to the success of the zero-emissions initiative: they will be well-versed in both technology relevant to increasing energy efficiency and in the new regulatory standards of large scale zero-emissions equipment-use. An understanding of energy efficiency will be crucial to suppressing utility costs at the port while reducing waste and emissions and will be an emerging green skill as industry changes.

[1] https://exploredegrees.stanford.edu/schoolofearthsciences/energyresourcesengineering/#bachelorstext
[2] https://engineering.berkeley.edu/academics/undergraduate-guide/degree-requirements/engineering-science/energy
[3] https://energy.ucdavis.edu/education/energy-graduate-group/for-prospective-students/
[4] http://engineering.sfsu.edu/academics/graduate/engineering/coursework_es.html
[5] https://www.usfca.edu/arts-sciences/graduate-programs/energy-systems-management/program-details

5. Labor Market Analysis

There are multiple occupations for workers in the ZEV and charging infrastructure workforce, encompassing both the electric-battery and hydrogen fuel-cell vehicle options: the OEM engineers and architects who research, innovate and design alternative fuel drive technology, the manufacturing technicians who build the vehicles, and the electro-automotive maintenance workers who operate and maintain the vehicles. Most of these occupations require specialized training or work experience in ZEV manufacturing and/or maintenance.

Employment growth is expected in most occupations in the ZEV industry, according to a study by the Center for Entrepreneurship and Technology at the University of California, Berkeley (Draper, Rodriguez, Kaminsky, Sidhu, & Tenderich, 2008). Growth is expected in manufacturing industries and the domestic energy sector as the need for batteries and charging stations increases; as a result, the demand for grid support also increases. New automobile manufacturing jobs will be created; however, many of these jobs will be filled by current manufacturing employees or those that were displaced by recent downsizing of the automobile manufacturing industry (Hamilton, 2011).

Using the Labor Insight/Jobs™ tool from Burning Glass Technologies and drawing data from the Bureau of Labor Statistics (BLS), we conducted an occupational deep-dive to understand the job profiles associated with zero-emission and sustainable-focused jobs within the port sector. We investigated existing jobs to understand new jobs that will emerge, based on changing infrastructure and administrative requirements. Looking into future projections for zero-emission jobs, we have correlated the demand for key positions within the ZEV field with industries relating to port operations to make an educated prediction of occupations that will be critical to the ZEV blueprint at POLB.

Additionally, utilizing keywords from research and industry professional peer-exchanges, we used O*NET OnLine occupation searches to identify those jobs which are classified as “Green Jobs” and predicted growth in the near future. This “Green Jobs” mantle is given to those occupations that are increasing in demand due to economic activities and technologies which support environmental sustainability. This categorization further assisted our decision making process, shortlisting critical workforce opportunities relative to the ZEV blueprint, as identified in Table 2.

5.1 Methodology

We conducted an initial analysis of the labor market with a focus on professions requiring a four-year higher education degree due to the innovative, cutting-edge nature of the developing ZEV industry. This methodology identified professions in engineering, architecture, and scientific development. While these jobs are still relevant to port operations, many are at the managerial and administrative levels and account for a small percentage of the port workforce. After conducting group peer exchanges with professionals across the transit, port, and education industries, new avenues of research relating to the ZEV job market emerged. Discussion of workforce development highlighted the following gaps: expertise in the field of electro-automotive technicians (mechanic and electrician roles with high-voltage experience), energy efficiency planning, and utility policy. There was also noteworthy mention of potential for a steady rise in infrastructure installation and maintenance technician positions, with discussion revolving significantly around community college-based trade and technical education as the dominant qualification.

Using Labor Insight/Jobs™ Burning Glass, commonalities in job titles posted (relating to ZEVs) were discerned across multiple industries relating to the port environment and across a range of education/certification levels. Frequency of key terms used in our peer-exchange transcripts were plotted alongside conclusive notes to develop baseline keywords for the Labor Insight/Jobs™ occupation searches.

- Input keywords used as a baseline dependent variable were as follows:
  - Zero emission
  - Battery electric
  - Hybrid vehicle
  - High voltage
  - Renewable energy
- Furthermore, the following BurningGlass filters were applied as constant influencing factors:
  - Green Jobs
  - STEM
  - Hybrid Tech
  - Middle Skill
  - Advanced Manufacturing

Chart 1 was created in Labor Insight/Jobs™ and depicts job postings within the 365 days of 2018, according to the aforementioned baseline inputs. With the exception of Electrical Engineer, there is less demand for jobs which require university level education, even though those positions are still applicable to the criteria. Professions such as Electrician and Maintenance Technician are in highest demand, as the requirement for more individuals in these fields is increasing. Furthermore, variations of automotive mechanic professions are present, supporting opinions from our peer-exchange (section 6.3) that electro-automotive skills will be highly desirable in the ZEV-related job market.

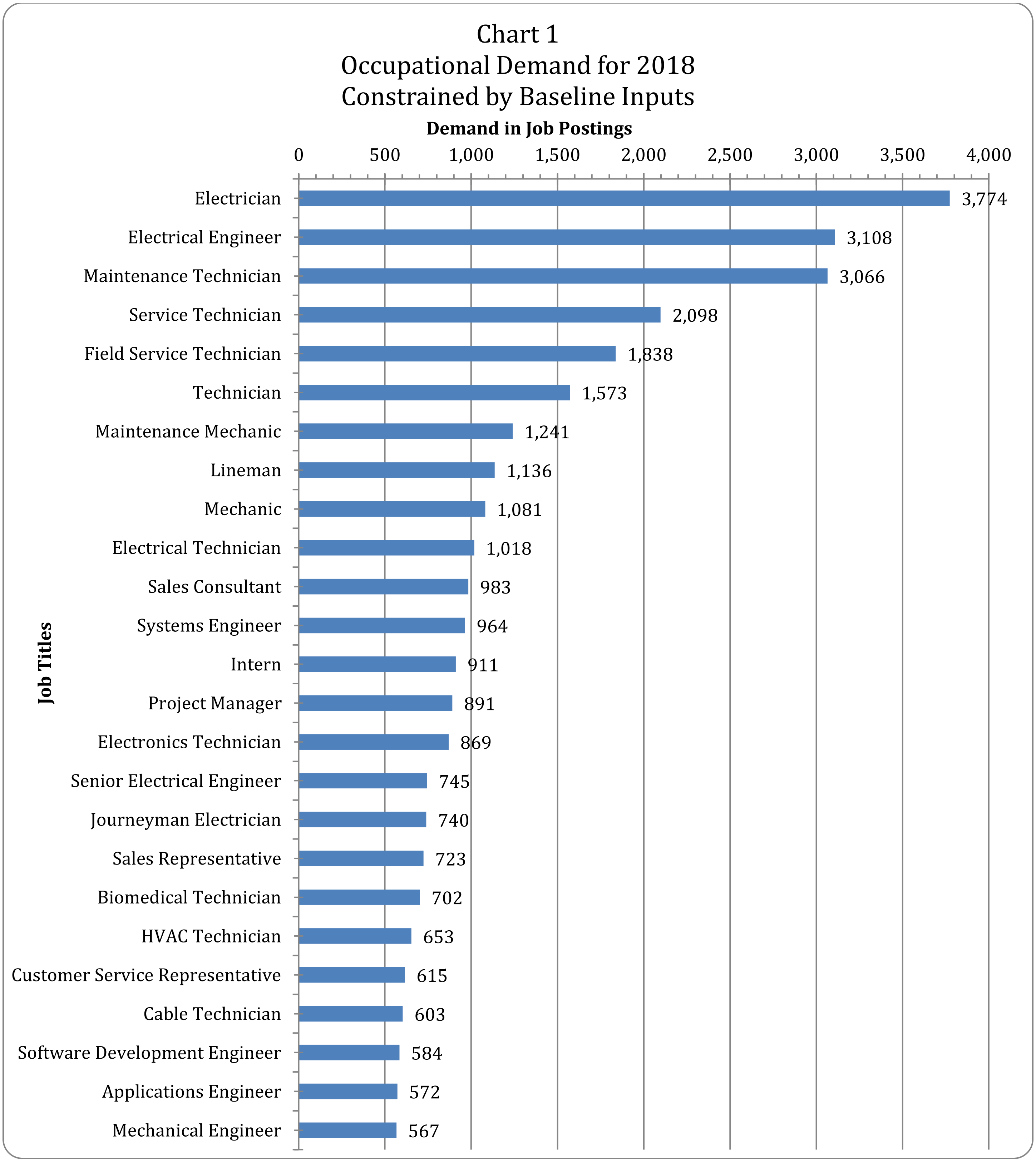


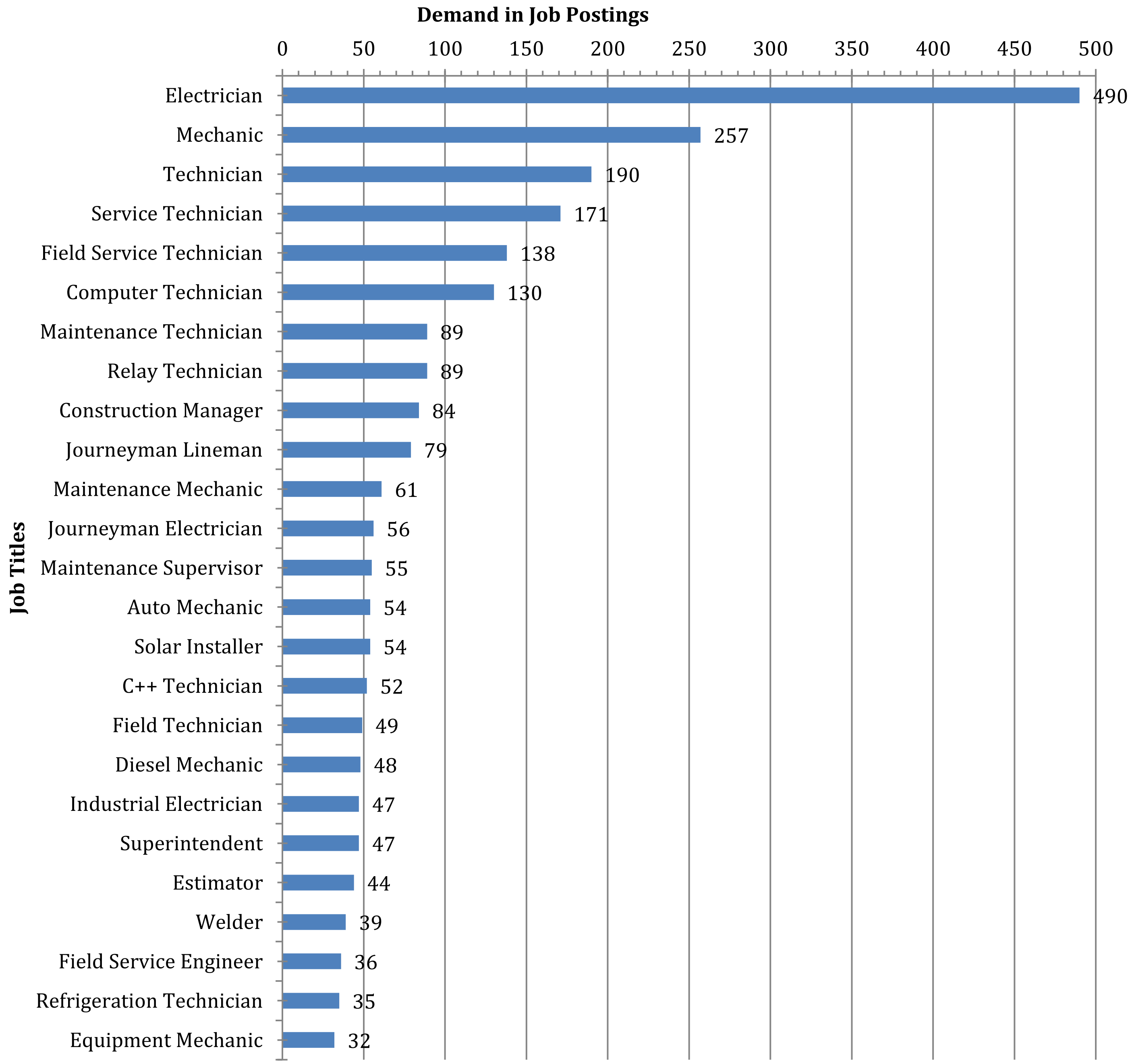
Chart 1
Occupational Demand for 2018
Constrained by Baseline Inputs
Demand in Job Postings
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Job Titles
Electrician 3,774
Electrical Engineer 3,108
Maintenance Technician 3,066
Service Technician 2,098
Field Service Technician 1,838
Technician 1,573
Maintenance Mechanic 1,241
Lineman 1,136
Mechanic 1,081
Electrical Technician 1,018
Sales Consultant 983
Systems Engineer 964
Intern 911
Project Manager 891
Electronics Technician 869
Senior Electrical Engineer 745
Journeyman Electrician 740
Sales Representative 723
Biomedical Technician 702
HVAC Technician 653
Customer Service Representative 615
Cable Technician 603
Software Development Engineer 584
Applications Engineer 572
Mechanical Engineer 567

Search criteria filters were further applied to the aforementioned BurningGlass output, in an attempt to represent the job market directly relating to port operations. The following filters were applied using the "OR" Boolean operator in order to identify positions which may relate to port operations across different combinations of these constraints and thereby provide an output of the most common positions in-demand for this research focus. Level of education was kept open to encompass all pathways, and time window was constrained to the 365 days of 2018 in order to gain a contemporary snapshot of this labor market: this eliminated the influence of trends in the job market for previous years when activity in the green economy was different from the current climate.

- Industry:
    - Professional, Scientific, and Technical Services
    - Transportation and Warehouse
    - Utilities
- Occupation:
    - Construction, Extraction, and Architecture
    - Maintenance, Repair, and Installation
- Skills
    - Energy and Utilities
    - Supply Chain and Logistics
    - Architecture and Construction
    - Education and Training
    - Environment
    - Information Technology
    - Science and Research
    - Engineering.
- Education:
    - Any level of education

Chart 2 portrays the occupational demand within 2018, constrained by any combination of the above categories relating to port operations. Reflecting the opinions conveyed by industry professionals during our industry professional peer-exchanges (see section 6.0), Electricians, Mechanics, and Technicians have polled highest as roles required for ZEV fleet roll out. Although the top three constitute very broad job titles, those positions become more specialized moving down the chart, as Service Technician, Maintenance Mechanic, and Industrial Electrician are specified. Other interesting occupation fields include information technology roles, such as Computer Technician and C++ Technician, as well as installation roles, such as Solar Installer. These are areas of the workforce that have often been referred to in our research and are pertinent to POLB developments projected for 2019-2022. Some of these positions may require advanced college education, however the majority of these roles require trade-technical expertise, as expected.

Chart 2
Occupations Demand
Constrained by Relevant Industry, Education, and Skills (2018)



Using O*NET OnLine, the previously mentioned keywords were then used in an occupation search. Job titles relating to the “green economy” and “bright outlook” were identified for correlation with Labor Insight/Jobs^{TM} results.

Green jobs are subdivided into three categories by O*NET:

- **Green Increased Demand**
  Green economy activities and technologies are likely to increase the employment demand, but will not lead to significant changes in the work and worker requirements.
- **Green Enhanced Skills**
  Green economy activities and technologies are likely to cause significant change to the work and worker requirements. New tasks, skills, knowledge, credentials may be needed. Employment demand remains the same, but there is potential for increase
- **Green New and Emerging**
  The impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements, which results in the generation of new occupations.

The above sub-categories, reflect our goal to find jobs that are new, existing, or require upskilling, for a complete understanding of the current potential in the ZEV-related labor market.

We used the Employment Projections data tool on the BLS website to gather the employment change predictions for the time span: 2016 – 2026 (the maximum future projection provided). The following table depicts our developed job title shortlist, including O*NET codes, green occupation status, projected employment change, 2017 median wage, entry-level education requirement, and on-the-job training required.

On the following page, Table 2 displays shortlisted ZEV-related professions with a range of different factors affecting career pathways. Electrical and automotive backgrounds are predominant requirements for the majority of positions here; however, entry-level education can range from high school diploma to college-level degrees. Coupled with the predicted increase in workforce demand relating to the green economy, there is a positive outlook for individuals looking attain ZEV-related occupations.

Percentage employment increase data provides insight into how large that particular job demand is predicted to grow. For example, Solar Photovoltaic Installers are predicted to see 104.9% growth in available jobs over the 2016-2026 decade. However, this only accounts for 11,800 individuals. Conversely, Electrician jobs are predicted to grow 8.9% over the same period, accounting for 59,600 job openings. This data and research into port operations has assisted us in predicting growth and critical importance to POLB, as well as identifying viable pathways to the positions we have selected for submittal, outlined in Section 7.0.

Table 2. Shortlisted Critical ZEV-Related Occupations, Relevant Statistics and Prerequisites							
Occupation	O*NET Code	Green Occupation Category	Employment Change 2016-2026 (increase in thousands)	Percentage Increase (%)	Median Wage (USD)	Typical Entry-Level Education	Typical On-The-Job Training
Electricians	47-2111.00	Green Increased Demand	59.6	8.9	54,110	High School Diploma or Equivalent	Apprenticeship
Electrical Engineers	17-2071.00	Green Enhanced Skills	16.2	8.6	95,060	Bachelor's Degree	None
Automotive Engineers	17-2141.02	Green New & Emerging	25.3	8.8	85,880	Bachelor's Degree	None
Automotive Specialty Technicians	49-3023.02	Green Enhanced Skills	45.9	6.1	39,550	Post-Secondary non-degree award	Short Term On-The-Job Training
Electro-Mechanical Technicians	17-3024.00	Green Enhanced Skills	0.5	3.5	56,740	Associate's Degree	None
Transportation Vehicle, Equipment and Systems Inspectors	53-6051.07	Green Enhanced Skills	1.7	5.9	72,140	High School Diploma or Equivalent	Moderate Term On-The-Job Training
Energy Engineers	17.2199.03	Green New & Emerging	8.5	6.4	97,250	Bachelor's Degree	None
Software Developers, Systems Software	15-1133.00	Green Increased Demand	47.1	11.1	107,600	Bachelor's Degrees	None
Electric Power-line Installers and Repairers	49-9051.00	Green Increased Demand	16.8	13.9	69,380	High School Diploma or Equivalent	Long Term On-The-Job Training
Computer Systems Engineers/Architects	15-1199.02	N/A	26.6	9.3	88,510	Bachelor's Degree	None
Solar Photovoltaic Installers	47-2231.00	Green New & Emerging	11.8	104.9	39,490	High School Diploma or Equivalent	Moderate Term On-The-Job Training
Maintenance Technician	49-9071.00	Green Enhanced Skills	112.5	7.9	37,670	High School Diploma or Equivalent	Moderate Term On-The-Job Training

6. Inferences on Workforce Impacts

6.1 Questions Raised Through Research

Although research has outlined the potential trends in the growing shift to zero emissions, there are still gaps in literature pertaining to how companies are managing or planning for the change in workforce skills requirements. In particular, case studies have reflected a strategic approach to managing, generating, and innovating energy resources in and around port complexes. A key takeaway from the approaches adopted by the ports indicates that ports use incremental efficiency methods like retrofits, shore powering ships, and process improvements to generate swift results. Ports also take long term sustainability approaches that incorporate technology-based innovative carbon management and energy capacity improvements that redefine traditional management techniques.

Although not immediately evident, this trajectory of strategic approach has altered the fabric of port workforce needed to handle, maintain, and manage future energy systems. Some of the implicit questions that emerge include the following questions:

- Are any private companies retrofitting diesel engine CHE to electric-power in Southern California? Is POLB considering this alternative to new ZEV fleets?
- Are any companies already prepared for upskilling their workforce to safety awareness and familiarization with ZEVs?
- Who is currently providing ZEV training for maintenance and operations at POLB? How can current ZEV training for maintenance and operations at POLB further develop to meet current and future demand? OEMs (Train the Trainer programs), contract training, community colleges, unions (in particular, the IBEW), employers through Employment Training Panel (ETP)-funded workforce development, and Long Beach USD through Linked Learning pathways can provide ZEV training. Recommendations include providing short-term training to new hires as well as incumbents to meet the immediate needs of industry and piloting new curriculum that can be integrated into existing credit-bearing certificates and degrees (LBCC draft CEC workforce gap analysis report).
- Are there currently any POLB partnerships with educational institutions for promoting supply chain management pathways in the engineering and technical trade divisions?
- What is the current climate of relationships with organized labor? Is there pushback or concerns raised regarding the future of longshoreman positions?
- How do ports train or retrain existing energy managers to adapt to the changes in the energy dialogue at port complexes?
- Are there skill sets that ports adopt when hiring for a strategic position - for example, positions that will be responsible for attaining the energy goals for 2050?
- How have competencies changed with respect to hiring in energy management?

6.2 Initial Stakeholder Workshop Meeting

On October 24th 2018, CITT attended a stakeholder workshop which was designed to bring involved parties up to date with the POLB zero-emissions blueprint and to conduct a think tank for voicing concerns as the project moves forward. Participants were provided with current statistics for port equipment, infrastructure, and emissions goals, as well as progress updates for current projects and cost forecasts. Furthermore, a brief questionnaire provided insights into industry opinions concerning operational change, equipment availability, and facility readiness in the face of the transition to zero emissions.

Key findings from this stakeholder workshop meeting encompassed concerns for fleet operators regarding the ZEV blueprint. Definitive results from the questionnaire were as follows:

- Price and availability of ZEVs from manufacturers are the primary concerns for fleet operators/owners;
- 100% of terminal operators state there is a requirement for significant training changes;
- Supervisors feel the mindset of operators needs to be changed from diesel combustion systems to the new alternative-fuels norm;
- No mechanics are considered ready to service ZEV equipment;
- Majority of respondents did not know if there is currently spare capacity for more ZEVs at the port;
- External funding for ZEVs is available on a limited basis; and
- 84% of respondents agreed there is a competitive advantage for "going green."

This discussion group served to create a dialogue for how the needs of fleet operators are being met and raised questions which could be addressed when CITT moves forward in deploying surveys and convening interviews with targeted industry stakeholders. Major questions left open for deliberation were as follows:

- How does the ZE transition impact the workforce?
    - What new skills are required and how will they be developed into a curriculum and taught?
- Where is the data on operations and maintenance? Do standards for maintenance need to be developed to gather this information and portray viability of ZEVs at the port?

6.3 Industry Professional Peer Exchange Webinars

In December 2018, two peer exchange webinars were hosted by CITT to discuss the topic "Workforce Impacts of Zero-Emission Technology." These webinars included industry professionals from the public transit industry, OEM representatives, educational partners, POLB Harbor Division, and workforce experts. Facilitated by CITT Executive Director Dr. Thomas O'Brien, participants were introduced to one another, provided with an overview of this study, and invited to discuss their experiences with ZEV technology and opinions regarding current and future workforce impacts.

These sessions largely outlined difficulties currently being managed by commercializing ZEV buses in the transit industry. Inherently, BEBs are causing a shift in operations and infrastructure management, and there is a growing need for expertise in efficient energy-use planning. Furthermore, there is a skills gap in utilities law/policy and an extensive need for electro-automotive technicians with experience and training working with high-voltage systems – findings which are applicable to the consensus that trade and technical certified jobs would be in the greatest demand for ZEVs.

6.3.1 12/17/28 Session

Participants from:

American Public Transit Exams Institute, APTREX

Northeast Transportation Workforce Center, NETWC

Foothill Transit

Center for International Trade and Transportation

Key Findings:

- Lack of sufficient operating and maintenance manuals from OEMs has hindered the development of standardized industry training thereby slowing down the upskilling of the current workforce to work with ZEVs. Safety awareness and familiarization training is needed for the ZEV workforce.

- Range of ZEVs creates a focus on efficient operating standards. Expertise in energy planning and conservation will allow for optimization of vehicle and infrastructure use.
- Standard electrical knowledge is a necessary new skill, and new training is required for existing operators and technicians.
- Senior management are finding they lack the necessary knowledge regarding legal and regulatory framework for energy planning.
- City maintenance workers will see an increase in work responsibilities as electric vehicle charging infrastructure grows, and those technicians will require standardized upskilling in order to work with the high voltage systems.

6.3.2 12/18/18 Session

Participants from:

City of Long Beach, Harbor Division

City of San Joaquin, Regional Transit

LA Metro Transit, Environment and Sustainability

Proterra, Inc

Center for International Trade and Transportation

Key Findings:

- Although a lot of the technology already exists for zero-emissions operations in the port environment, the trucking field will see a slower gradual transition regarding fuel type. Natural gas currently has a more viable efficiency because of its long range, as an alternative to diesel.
- New skills and expertise relating to ZEVs will likely be applicable both inside and outside of the port. Therein, new jobs are expected to be contractor-based in nature, while the existing longshoreman population will undergo upskilling.
- It is questionable as to whether it is worth upskilling the older workforce who will be retiring as California zero-emissions goals come to fruition in 2030 – 2040 (the majority age bracket of transit operators and significant portion of longshoreman). However, developing new training programs for the next generation of workers who will use zero-emission technology and upskilling the current younger workforce will be necessary.
- Technical trade expertise and skills obtained at 2-year community colleges will be more relevant for filling a larger quantity of positions; however, there will be some requirement for four-year college-educated professionals in the energy engineering/planning/management fields.
- Expertise in Information Technology and Geospatial Software may be required to manage infrastructure and plan vehicle routes, especially where automation is present.
- There is a shortage of high-voltage system knowledge and experience among electricians in the transit industry - a skill set which is essential to working with ZEVs and charging infrastructure. This may also be true for electrical professionals at POLB and is a major factor influencing an individual's ability to safely work on ZEVs and infrastructure.

7. Training for Upskilling Incumbent Workers at POLB

The following courses of study outline training programs which have been identified as being particularly beneficial to both current and future workforce needs at POLB. Each of these programs are relevant to incumbent workers who already have technical skills in electrical, mechanical, or automotive disciplines. As a suggestive action item, this upskilling method has been highlighted as potentially critical to the ZEV technology transition.

Long Beach Community College's draft report for CEC's Zero-Emissions Terminal Equipment Transition Project identifies several competencies based on stakeholder-identified skill set needs: battery safety, battery theory, operating and maintaining charging components and electrical connections in corrosive environments, equipment maintenance, general electrical and mechanical aptitude, and skills in zero-emission technology (LBCC 2018). Many of these competencies are included in the training programs identified by CITT, as described below.

7.1 Electric Vehicle Infrastructure Training Program (EVITP)

This is a 24-hour class (completed over three days) addressing the requirements, regulations, products, and strategies which enable contractors and electricians to master professional customer relations, installations, and maintenance of electric vehicle and plug-in hybrid electric vehicle infrastructure. Graduates will have theoretical and practical application knowledge of the following EV infrastructure subjects:

- EV prospect/customer relations and experience
- Automobile manufacturer's charging performance integrity specifications
- EV battery types, specifications, and charging characteristics
- Utility interconnect policies and requirements
- Utility grid stress precautions including demand response integration technologies
- Role of electrical storage devices as charging intermediaries
- Installing, commissioning and maintaining electric storage devices
- Charging station fundamentals including brand/model-specific installation instructions for:
    - Level 1: 120 VAC 15 amps
    - Level 2: 120-240 VAC 60 amps
    - Level 3: 480 VAC 125 amps or 600 VDC 550 amps
- Service-level assessments and upgrade implementation
- Integration of electric vehicle infrastructure with distributed generation
- Understanding Internet Protocol (IP) networking of charging stations
- National Electrical Code (NEC) standards and requirements
- National Fire Protection Association (NFPA) 70E and OSHA regulations
- National Electrical Installation Standards (NEIS) for electrical equipment
- First responder safety and fire hazard measures
- Next generation charging
- EVSE troubleshooting, repair, and commissioning
- Facility based energy storage

This program is offered through various training agencies throughout Southern California, however it is most readily available at POLB through partnership with the IBEW's Local 11 union branch. Electrical workers and electricians at the port can take this 3-day course to gain the highest standard of certification for the installation of electric vehicle infrastructure and implement this training at POLB as new infrastructure is established.

7.2 Energy Storage and Microgrid Training and Certification (ESAM-TAC)

This is a program and credential which prepares electrical workers and electricians for the safe and effective assembly, testing, commissioning, maintenance, repair, retrofitting, and decommissioning of energy storage and microgrid (ESM) systems. ESAM-TAC consists of both theoretical and hands-on practical components. Modules include:

- Business drivers of microgrid and energy storage systems
- Microgrid systems and components (generation)
- Battery safety and arc flash protection
- DC power systems (DC theory)
- Battery enclosure, rack components and requirements
- Installation of batteries into racks and enclosures
- Connections between batteries
- DC power conductors and connections
- Grounding and bonding of ESM systems
- DC control conductors and connections
- Situational assessment of installed ESM systems

Offered through various training agencies throughout Southern California, electrical workers and electricians at the port can take this course in order to upskill and qualify for working on the various energy storage systems throughout the port and grid-connected plant at POLB.

7.3 Certified Electric Vehicle Technician (CEVT) Training Program

This 16-week certification program is designed to prepare automotive service technicians with the skills required to work in the production, repair, and maintenance of electric vehicles. It covers comprehensive advanced alternative fuel vehicle theory and practices:

- Introduction to advanced vehicle technologies
- Development of electric vehicles
- High voltage electrical safety
- High voltage vehicle safety systems
- Hybrid engines
- AC induction electrical machines
- Permanent magnet electrical machines
- Power inverter systems
- Electric circuit systems
- Electric propulsion sensing systems
- DC-DC converter systems
- Transaxles, gears, and cooling systems

- Energy management hardware systems
- Battery construction and technologies
- Latest development in battery technologies
- Nickel-metal hydride technologies
- Lithium ion battery
- Battery management systems
- Hybrid vehicle regenerative braking systems
- Electric car and hybrid climate control systems
- Computer aided design (SolidWorks software)
- Design and making an adapter for an electric motor (workshop)
- Design and making a fiber-glass battery box (workshop)
- Conversion of an internal combustion car into a 100% electric car (workshop)
- First responder safety for emergency situations
- Basic electric car maintenance

Although this course of study is much longer and more involved than the aforementioned programs, there are considerable POLB-applicable skill sets to be gained from completion of the courses outlined. This certification would be particularly beneficial to those mechanical and automotive maintenance technicians who are already proficient in combustion engines and wish to become fluent in working on alternative-fuel systems. Resulting expertise have applications across port operations, in retrofitting, electric battery vehicles, hybrid engines, and charging stations.

7.4 Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP)

Administered by the Energy Commission's Fuels and Transportation Division, the ARFVTP invests in a broad portfolio of transportation and fuel transportation projects throughout the state, leveraging public and private investments, and;

- Expedites development of conveniently-located fueling and charging infrastructure for low- and zero-emission vehicles.
- Accelerates advancement and adoption of alternative fuel and advanced technology vehicles, including low-and zero-emission medium- and heavy-duty vehicles;
- Expands in-state production of alternative, low-carbon renewable fuel from low-carbon pathways; and support manufacturing and workforce training to help meet the needs of the state's growing clean transportation and fuels market; and
- Supports manufacturing and workforce training to translate clean technology investments into sustained employment opportunities.

The Clean Energy Transportation Initiative (CETI), California Community Colleges Chancellor's Office (CCCCO), Employment Development Department, and Employment Training Panel (ETP) are public partners of this program.

7.5 Electrical Technology Programs through the California Community Colleges

The California Community Colleges offer Electrical Technology Programs in Construction Technologies and Construction & Maintenance, providing A.A. or A.S. degrees.

8. Top 5 Critical ZEV-Related Occupations

Narrowing down the top five critical occupations involved reconciling our shortlisted LMA results (Section 5.3) with findings from the peer-exchange webinars (Section 6.3). Our choices have been further validated by BLS literature and both historical and projected employment data. The following titles represent occupations with a range of prerequisite educational, professional, and experience relating to zero-emissions goals at POLB.

8.1 Electricians – (O*NET 47-2111.00)

Although this occupation title is encompassed by many fields of industry that may not be necessarily port-related, the expertise is directly applicable to many of the job titles that have been deemed critical to future operations within the POLB ZEV blueprint. Employment in this field is likely to increase in demand as a direct result of new green technology and economic activity (O*NET OnLine). At POLB in particular, this will relate to inspecting, troubleshooting, and testing the on-going continuity of new and existing infrastructure at the port such as charging stations, vehicle batteries, and renewable energy generating systems.

Fluency in working with high-voltage systems has been identified as critical knowledge when working with electric vehicle systems, so the expertise gained through an electrician apprenticeship pathway would be key to working with the latest POLB developments in ZEV technology. Additional knowledge and work experience may lead individuals down more specialized pathways (further elaborated upon below); however, the Electrician profession entails a set of skills that will be vital to working with ZEV systems on the whole. BLS statistics show a significant nationwide employment increase for this occupation (60,000 between 2016 and 2026).

Career Pathway (Figure 7)

In California, electricians must complete apprenticeship and certification requirements in order to become a qualified journeyman electrician. Beginning at the high school graduate level, job seekers can enroll in pre-apprenticeships and apprenticeships with the goal of attaining a certificate or associate's degree in Electrical Construction and Maintenance. Furthermore, they need to register as an electrician trainee with the California Department of Industrial Relations before applying for admission into an apprenticeship program. Commencing an apprenticeship can occur before attending trade/technical classes, however apprentices must be registered as trainees with the state and there must be a combination of both classroom and hands-on learning comprising the apprenticeship. Completion of sufficient education units in addition to at least 8,000 hours of apprenticeship work experience (within 5 years) qualifies an individual to sit for the journeyman certification exam. Passing this exam establishes the incumbent as a qualified electrician in California, and as such, requires demonstrable capability to interpret/implement technical diagrams, comply with National Electrical Code (NEC) local regulations, and install, repair, and maintain electrical systems and distribution equipment.

After journeyman certification, the qualified electrician decides which discipline of the profession to pursue. Pertaining to zero-emissions operations at POLB, the IBEW Local 11 offers the electric vehicle infrastructure training program (EVITP outlined in section 7.1) in addition to the traditional apprenticeship path. This is the state's highest standard in training and certification for installation, repair, and maintenance of electric vehicle infrastructure.

8.2 Solar Photovoltaic Installer – (O*NET 47-2231.00)

Expecting demand to grow rapidly in the next several years by over 100% (BLS, 2016) due to the impact of the developing green economy, this role and the on-going maintenance involved with it is directly related to POLB and the planned developments in solar energy generation projected for the coming years. Projects such as the 300kW solar carport at the POLB security center will require outside contractors for solar installation. This project may also engage consultants to optimize solar systems and locations of new projects, as well as to integrate solar energy generation with micro-grid infrastructure. This job may also involve electrician expertise in dealing with high-voltage systems. The BLS classifies this position as entry level, requiring a high school diploma or equivalent and accompanied by on-the-job training. This is a position which may also be specialized with additional credentials and work experience in other industries.

Career Pathway (Figure 8)

There are multiple pathways to this field of employment. Job-seekers with some background in construction or trade-related work can find work as a laborer or assistant in the solar installation industry. There are also sought-after skill sets and education pathways that can enhance a career in solar installation. Electricians or people with electrical technology certifications are highly desired in this industry, so completing an apprenticeship and specializing as a journeyman electrician for solar is a way to earn a higher salary. Furthermore, completing a bachelor's degree in engineering and having pertinent work experience can qualify a person to become a solar engineer, also taking advantage of a higher wage bracket and the demand for expertise in this field.

8.3 Automotive Specialty Technicians – (O*NET 49-3023.02)

This specialized role is applicable to automotive technicians who have enhanced skills in working with alternative fuel systems such as CNG, Electric-battery, Hydrogen Fuel Cell, and Hybrids. They will be able to troubleshoot, fix, replace, and retrofit vehicles with zero-emissions solutions (O*NET, 2018). This role requires trade/technical certification, on-the-job training experience, and is expected to see an increase of 45,900 of qualified individuals between 2016 and 2026. This is the only occupation the BLS included in their report of critical occupations in the EV industry pertaining to electric vehicle maintenance (Hamilton, 2011).

Career Pathway (Figure 9)

Becoming an automotive specialty technician requires an associate's degree in advanced transportation technology and electric vehicles at Long Beach City College (LBCC) which requires 20 units of major-specific courses, 19 units of G.E. courses, and 21 elective units to complete. This degree prepares students for a career working with hybrid, fuel-cell, and electric vehicles (LBCC, 2019). Graduates will be able to service, maintain, and repair light/medium and heavy duty vehicle systems, the latter of which is applicable to zero-emission CHE at POLB. Further certification through the CEVT program (Section 7.3) is also recommended for incumbent automotive technicians in order to become specialized in working with alternative fuel vehicle systems.

8.4 Electrical Engineer – (O*NET 17-2071.00)

This occupation is involved in designing, developing, testing, and supervising the manufacture of new electrical systems directly related to electricity use and efficiency and is in high demand. In the port environment, this position will address renewable energy generation, smart-grid development, retrofitting combustion engine equipment, and consulting on new green energy projects. This resonates with BLS statistics predictions of an 8.6% nationwide growth in electrical engineer positions by 2026, despite being highly specialized.

Career Pathway (Figure 10)

Prospective students must gain admission to an electrical engineering university program, wherein during the first two years, transfer requirement courses encompass mathematics, physics, and general education. In the third year of the bachelor program, students will complete core components of electrical engineering and prepare for specialization in their fourth year, when students choose a specific elective sequence pertaining to an area of specialization and complete a senior design project. Engineering graduates are encouraged to find internships and gain work experience as engineers. POLB offers engineering internships and has identified a current need for electrical engineering expertise. It is in the engineering candidate's best interest to specialize in a port-related elective sequence during their final years of higher education. After having gained sufficient work experience, a graduate engineer can get a professional engineering license and gain seniority in their field.

8.5 Electrical Power-line Installer and Repairer (Lineman) – (O*NET 49-9051.00)

The BLS has deemed electrical power-line installers and repairers as critical occupations in the infrastructure development for the EV industry (Hamilton, 2011). BLS Projected Employment data further substantiates this claim with a 13.9% projected growth rate of the profession from 2016-2026. These individuals are responsible for installing cable for electrical power distribution and maintaining grid efficiency, which will serve an instrumental role in POLB realizing their zero-emissions blueprint goals. Increased energy demand requires a vastly greater power grid to support electric CHEs and charging stations. A Proterra technical trainer expressed to CITT that they had noted a significant a shortage of workers comfortable working with high voltage systems in the public transit system. Therefore, we are keeping high voltage requirements in mind as we continue to develop educational pathways to critical occupations. The BLS states credentials required to attain this job are a high school diploma or equivalent, basic math and reading skills, and 1 to 5 years of on-the-job training.

Career Pathway (Figure 11)

To become a power-line installer and repairer, pathways are similar to that of the electrician. However, due to the strenuous physical demands and the high-risk nature of this work, the wage bracket is higher for linemen than any other electrical field. Entry to this apprenticeship program may be competitive, and there are a few highly desired prerequisites. To increase likelihood of being accepted into a lineman apprenticeship program, obtaining line school admission, first-aid/CPR certification, and flagging/traffic control certifications should be of high priority. Maintaining good physical fitness and gaining technical electrical work experience is also highly desirable. Apprentices must accumulate approximately 7,000 hours of work experience, progressing through the seven stages (increasing wage brackets) of the program. Completion of the journeyman certificate exam in California allows linemen to work in the highest-paying median wage bracket for electricians in the country. Growth of support infrastructure for electric vehicles and large initiatives such as the ZEV blueprint is pushing the demand for this skill set as charging infrastructure needs to be connected to the grid.

Appendices: Career Pathways

The following example diagrams represent essential education and experience requirements for entering the occupations outlined in section 7. These career pathways have been developed using data and research gathered from the BLS and not only depict the selected top five critical occupations, but also the prerequisites for developing those positions into more senior positions.

Entry level pathways and requirements for promotion to senior level positions were researched by examining job vacancies specific to large companies in California that are in the solar energy, alternative fuel vehicles, energy planning, or public utilities (electricity) industries.

Figure 7. Electrician (California)

	RELEVANT TRAINING, COURSEWORK, AND KNOWLEDGE	CAREER PATHWAY: Program of Study	CAREER PATHWAY: Work Experience	RECOMMENDED CERTIFICATION	JOBS & WAGES
ADVANCED LEVEL	**Trade Experiences:** • Read blueprints and technical diagrams for electrical plans. • Install, repair, and maintain electrical systems and distribution equipment. • Learn compliance with National Electrical Code and local regulations.	Electrician Journeyman Certification		EVITP[4] ESAM-TAC[5] CHEPVT[6]	**Advanced Level** • **Journeyman Electrician (Transportation)[3]** **Annual Salary:** $72,380 – 96,290[3]
INTERMEDIATE LEVEL	**Required Courses for Associate's Degree in Electrical Technology[1] (LATTC)** • Fundamentals of DC Electricity • Hand Tools and Wiring Practices • Elementary Circuit Practices • Industrial Control Systems • Fundamentals of Alternating Current • Principles of Industrial Electric Power • Industrial Power Application • Industrial Electric Control Systems • Applications of Electrical Devices • Construction Wiring • Introduction to Electrical Codes • Electrical Wiring Techniques • Installation of Electrical Wiring	Additional Specializations (Recommended) ↑ Associate's Degree in Electrical Technology	Accumulate at least 8,000 hours work experience under an electrical contractor ↑ Begin electrician apprenticeship	EVITP ESAM-TAC CHEPVT	**Intermediate Level** • **Apprentice Electrician[2]** **Annual Salary:** $32,870 – 61,190[2]
ENTRY LEVEL	**Obtained During High School** • Pass basic algebra with "C" or better • Enhance written and oral communication skills • Build mechanical knowledge • Develop manual dexterity and coordination • Maintain physical fitness **Work Experience** • Technical trade-based discipline	High School Diploma or Equivalent (One course titled "Algebra" required)	Register as an electrician trainee with the California Department of Industrial Relations ↑ Up to two years work experience desired	N/A	**Entry Level** • **Construction Helper/Worker** • **Electrician's Helper** **Annual salary:** $29,724 – 42,306[7]

[1] *Electrical Construction & Maintenance*. (2019). Retrieved from Los Angeles Trade-Technical College: http://college.lattc.edu/cmu/program/electrical-construction-maintenance/

[2] Electricians School Edu. (2015). Electrician Salaries in California. Retrieved from Electricians School Edu: https://www.electricianschooledu.org/california/california-salary/
Salary interpreted from 2015 BLS statistics for apprenticeship electricians in the Los Angeles-Long Beach-Glendale locality

[3] Electricians School Edu. (2015). Electrician Salaries in California. Retrieved from Electricians School Edu: https://www.electricianschooledu.org/california/california-salary/

Salary interpreted from 2015 BLS statistics for electrical and electronics repairers specializing in transportation equipment.

[4] Electric Vehicle Infrastructure Training Program (EVITP)

[5] Energy Storage and Microgrid Training/Certification (ESAM-TAC)

[6] Certificate of Hybrid and Electric Plug-in Vehicle Technology (CHEPVT)

[7] Salary obtained from 2nd and 3rd quartile ranges for Construction Helper/Worker in California on Burning Glass.

Figure 8. Solar Photovoltaic Installer

	RELEVANT TRAINING, COURSEWORK, AND KNOWLEDGE	CAREER PATHWAY: Program of Study	CAREER PATHWAY: Work Experience	RECOMMENDED CERTIFICATION	JOBS & WAGES
ADVANCED LEVEL	**Bachelor's Degree Courses[5] (CSULB):** • Digital System Design • Signals and Systems • Analog Electronic Circuits • Energy Conversion Principles • Electromagnetic Fields • Control Systems • Communication Systems I • Digital Signal Processing • Design of Power System Components • Power System Analysis • Protection of Power Systems • Solid State Electronic Devices • Fractals in Engineering	Professional Engineer License Bachelor's Degree in Engineering (or equivalent residential solar experience)	6 years of qualifying experience	Professional Engineer License	**Advanced Level** • **Solar Service Technician[2]** • **Solar Engineer[2]** **Annual Salary:** $79,700 – 127,600
INTERMEDIATE LEVEL	**Electrical Technology Courses[1] (LBCC):** - Electrical Mathematics - OSHA Standards for Construction Safety - Fundamentals of DC - Algebra & Trigonometry for Technicians - Introduction to Renewable Energy - Fundamentals of Motors/Generators - Introduction to the National Electrical Code - Solar 1 – Grid-Tied Solar Photovoltaics - Fundamentals of AC Electricity - Electric Motor Control 1 - Solar2 – Advanced Solar Photovoltaics - AC Principles and practices - Electrical Code – Commercial, Industrial, and Grounding	If continuing toward engineering degree, complete transfer requirements Associate's Degree in Electrical Technology	Electrician Journeyman Certification Accumulate at least 8,000 hours work experience under an electrical contractor Begin electrician apprenticeship	ESAM-TAC[6]	**Intermediate Level** • **Journeyman Electrician for Solar[2]** • **Solar Photovoltaic Installer[3]** **Annual Salary:** $39,490 – 61,580[3]
ENTRY LEVEL	**Obtained During High School** • Enhance written and oral communication skills • Build mechanical knowledge • Develop manual dexterity and coordination	High School Diploma or Equivalent	While it is desired for Solar Photovoltaic Installers to have an electrician background, relevant work experience will suffice.	CoA SPID[7]	**Entry Level** • **Solar Inspection Technician[2]** • **Solar Laborer[2]** **Annual salary:** $28,500 – 60,860[4]

[1] LBCC. (2019). *Electrical Technology: Curriculum guide for academic year 2018-2019*. Retrieved from Long Beach City College: https://www.lbcc.edu/sites/main/files/file-attachments/18-19-electrical-tech- curguide.pdf

[2] Semper Solaris. (2019). *Careers: Open Positions*. Retrieved from Semper Solaris Solar and Roofing: https://www.sempersolaris.com/careers/
These were job titles posted on solar company Semper Solaris' hiring page.

[3] Bureau of Labor Statistics. (2018). *Occupational Outlook Handbook: Solar Photovoltaic Installers*. Retrieved from United States Department of Labor - Bureau of Labor Statistics: https://www.bls.gov/ooh/construction-and-extraction/solar-photovoltaic-installers.htm
Job title derived from the BLS.

[4] Bureau of Labor Statistics. (2018). *Occupational Outlook Handbook: Construction Laborers and Helpers*. Retrieved from United States Department of Labor - Bureau of Labor Statistics: https://www.bls.gov/ooh/construction-and-extraction/construction-laborers-and-helpers.htm#tab-5
Wage derived from median to 90th percentile annual wage statistics for 2017.

[5] *Electrical Engineering, B.S.* (2019). Retrieved from California State University Long Beach University: http://catalog.csulb.edu/preview_program.php?catoid=2&poid=598

[6] Energy Storage and Microgrid Training/Certification (ESAM-TAC)

[7] Certificate of Achievement in Solar Photovoltaic Installation & Design (CoA SPID)

Figure 9. Automotive Specialty Technician

	RELEVANT TRAINING, COURSEWORK, AND KNOWLEDGE	CAREER PATHWAY	RECOMMENDED CERTIFICATION	JOBS & WAGES
ADVANCED LEVEL	**Incumbent Workforce:** Automotive technicians already in the industry will most-likely be able to upskill with zero emissions technology-specific technical certifications, particularly if they already have technical electrical expertise. This also provides current employees at POLB a way to upskill and stay fluent in all relevant vehicle drivetrains. **Training:** Qualified Electricians and Automotive Specialty Technicians will need to participate in CEVT in order to develop the skills specifically related to servicing, maintaining, and operating EV-CHE. These trainings offer a way for professionals currently working in related fields to upskill and join the POLB Labor Force. A full list of these trainings may be found in the report. Additionally OEMs also offer relevant training pertaining to their products.	**Program of Study** Industry-Specific Technical Certification	CEVT[3]	**Advanced Level** • **EV-CHE Specialty Technician** **Annual Salary:** $35,940 – 52,304[1]
INTERMEDIATE LEVEL	**Required Courses[2] (LBCC):** • Introduction to Hybrid and Electric Vehicles • Introduction to Alternative Fuels • Advanced Hybrid & Electric Vehicles • Advanced Hybrid Diagnosis & Repair **Recommended Electives[2] (LBCC):** • Heavy Equipment Electrical Systems • General Engines • Auto Emission Controls • Forklift Safety & Operation • Introduction to Metal Working • Introduction to Welding	Associate's Degree in Advanced Transportation Technology – Electric Vehicles	CEVT	**Intermediate Level** • **Automotive Specialty Technician** **Annual salary:** $35,940 – 52,304[1]
ENTRY LEVEL	**Obtained During High School** • Enhance written and oral communication skills • Build mechanical knowledge • Develop manual dexterity and coordination	High School Diploma or Equivalent (or aged 18 or older)	N/A	**Entry Level**

[1] Salary obtained from 2nd and 3rd quartile ranges for Automotive Service Technician/Mechanic California on Burning Glass.

[2] LBCC, (2019) Curriculum Guide for Academic Year 2018-2019. *Advanced Transportation Technology, Electric Vehicles*. Long Beach, California, United States of America: Long Beach City College.

[3]Certified Electric Vehicle Technician Training Program (CEVT)

Figure 10. Electrical Engineer (EE)

	RELEVANT TRAINING, COURSEWORK, AND KNOWLEDGE	CAREER PATHWAY: Program of Study	CAREER PATHWAY: Work Experience	RECOMMENDED CERTIFICATION	JOBS & WAGES
ADVANCED LEVEL	**Engineering Demonstrable Knowledge** • Work experience in field(s) of engineering with sustainability-motivated projects. • Wield the ability to "prepare, sign and seal, and submit engineering plans and drawings to a public authority for approval, or seal engineering work for public and private clients."[6] • Perform work with an emphasis towards sustainable planning and environmentally conscious practices. • Demonstrate understanding of new technology, working towards zero emissions future, such as electric vehicles and charging infrastructure.	Professional Engineer License	6 years of qualifying experience	Professional Engineer License	**Advanced Level** • **Principal Electrical Engineer** • **Senior Project Manager** **Annual Salary:** $100,000+
INTERMEDIATE LEVEL	**Bachelor's Degree Courses[3] (CSULB)** • Digital System Design • Signals and Systems • Analog Electronic Circuits • Energy Conversion Principles • Electromagnetic Fields • Control Systems • Communication Systems I • Digital Signal Processing • Design of Power System Components • Power System Analysis • Protection of Power Systems • Solid State Electronic Devices • Fractals in Engineering	Appropriate certifications to meet personal career goals Bachelor's Degree in electrical engineering	Some supervisory experience preferred for Planner III/Senior Planner positions Up to six years planning experience required	Fundamentals of Engineering Exam Energy Efficiency Practitioner Certification from AEE	**Intermediate Level** • **Electrical Engineer** • **Energy Efficiency Specialist[6]** **Annual Salary:** $52,528 – 110,258[1]
ENTRY LEVEL	**Transfer Requirements[5] (ASSIST.org)** • EE Circuits • Calculus I, II, and III • Applied Math/Differential Equations • Physics (Mechanics, Electricity & Magnetism, and Modern) • Oral Communication • Reading & Composition • Critical Thinking • Life Science • Arts & Humanities • Social Sciences • Lifelong Learning & Self-Development	Complete transfer requirements at a community college or first two years of a Bachelor's Degree program at a university.	Up to two years work experience desired	N/A	**Entry Level** N/A

[1] Salary obtained from 2nd and 3rd quartile ranges for Electrical Engineer and Energy Efficiency Specialist in California on Burning Glass.

[2] Occupation title from Burning Glass.

[3] *Electrical Engineering, B.S.* (2019). Retrieved from California State University Long Beach University: http://catalog.csulb.edu/preview_program.php?catoid=2&poid=598

[4] 2018-2019 General Education Requirements California State University General Education-Breadth. (2019). *Long Beach City College 2018-2019 Course Catalog*. Long Beach, California, United States of America: Long Beach City College.

[5] *ASSIST Report: LBCC 16-17 CSULB Articulation Agreement by Major*. (2019). Retrieved from ASSIST: http://web2.assist.org/web-assist/report.do?agreement=aa&reportPath=REPORT_2&reportScript=Rep2.pl&event=19&dir=1&sia=LBCC&ria=CSULB&ia=LBCC&oia=CSULB&aay=16-17&ay=16-17&dora=EE

[6] *Advantages of Licensure*. (2019). Retrieved from National Society of Professional Engineers: https://www.nspe.org/resources/licensure/why-get-licensed/advantages-licensure

Figure 11. Electrical Power-Line Installer and Repairer (EPIR)

	RELEVANT TRAINING, COURSEWORK, AND KNOWLEDGE	CAREER PATHWAY: Program of Study	CAREER PATHWAY: Work Experience	RECOMMENDED CERTIFICATION	JOBS & WAGES
ADVANCED LEVEL	**Apprentice Program Coursework[2] (CNJATC)** Saturday classes once per month, plus week-long intensive training courses throughout the apprenticeship program: • Work Methods Training • Underground Training • Rubber Glove Training • Hot Sticks Training • Crane Certification Class	Lineman Journeyman Certification		ESAM-TAC[5] First Aid/CPR (CNJATC) OSHA[6] (CNJATC)	**Advanced Level** • **Journeyman Lineman** **Annual Salary:** $104,140 – 123,160[3]
INTERMEDIATE LEVEL	**Skills Developed During Powerline Mechanic Training Program[4] (LATTC)** • Overall safety considerations • Power pole climbing skills • Knowledge of the basic tools and materials involved with the electrical line crafts • General construction standards • Basic rigging principles • Basic electrical theory	Additional Specializations (Recommended) Power Lineman Certification (Recommended)	Accumulate approximately 7,000 required hours and pass through 7 stages of the apprenticeship program[1] Begin lineman apprenticeship	First Aid/CPR (CNJATC) Flagging/ Traffic Control (CNJATC)	**Intermediate Level** • **Apprentice Lineman** **Annual Salary:** 60%-90% of Journeyman Salary. Pay increases 5% roughly every 6 months.[1]
ENTRY LEVEL	**Obtained During High School** • Pass basic algebra with "C" or better • Enhance written and oral communication skills • Build mechanical knowledge • Develop manual dexterity and coordination • Maintain physical fitness **Work Experience** • Technical trade-based discipline	High School Diploma or Equivalent (One course titled "Algebra" required)	Apply to lineman apprenticeship program Up to two years work experience desired	First Aid/CPR (CNJATC) Flagging/ Traffic Control (CNJATC)	**Entry Level** • **Construction Helper/Worker** • **Electrician's Helper** **Annual salary:** $29,724 – 42,306

[1] CNJATC. (2019). *The Apprenticeship Process*. Retrieved from California / Nevada Joint Apprenticeship Training Committee: http://www.calnevjatc.org/templates/template12/?page=130

[2] CNJATC. (2019). *Lineman Program Description*. Retrieved from California / Nevada Joint Apprenticeship Training Committee: http://www.calnevjatc.org/templates/template5/?page=45

[3] Electrician School Edu. (2015). *Electrician Salaries in California*. Retrieved from Electrician School Edu: https://www.electricianschooledu.org/california/california-salary/
Median to 90th percentile annual range of salaries for journeyman EPIR positions in California.

[4] *Powerline Mechanic Training Program*. (2019). Retrieved from Los Angeles Trade-Technical College: http://college.lattc.edu/cmu/program/electrical-lineman-training-program/

[5] Energy Storage and Microgrid training and Certification (ESAM-TAC)

[6] Occupational Safety and Health Administration (OSHA)

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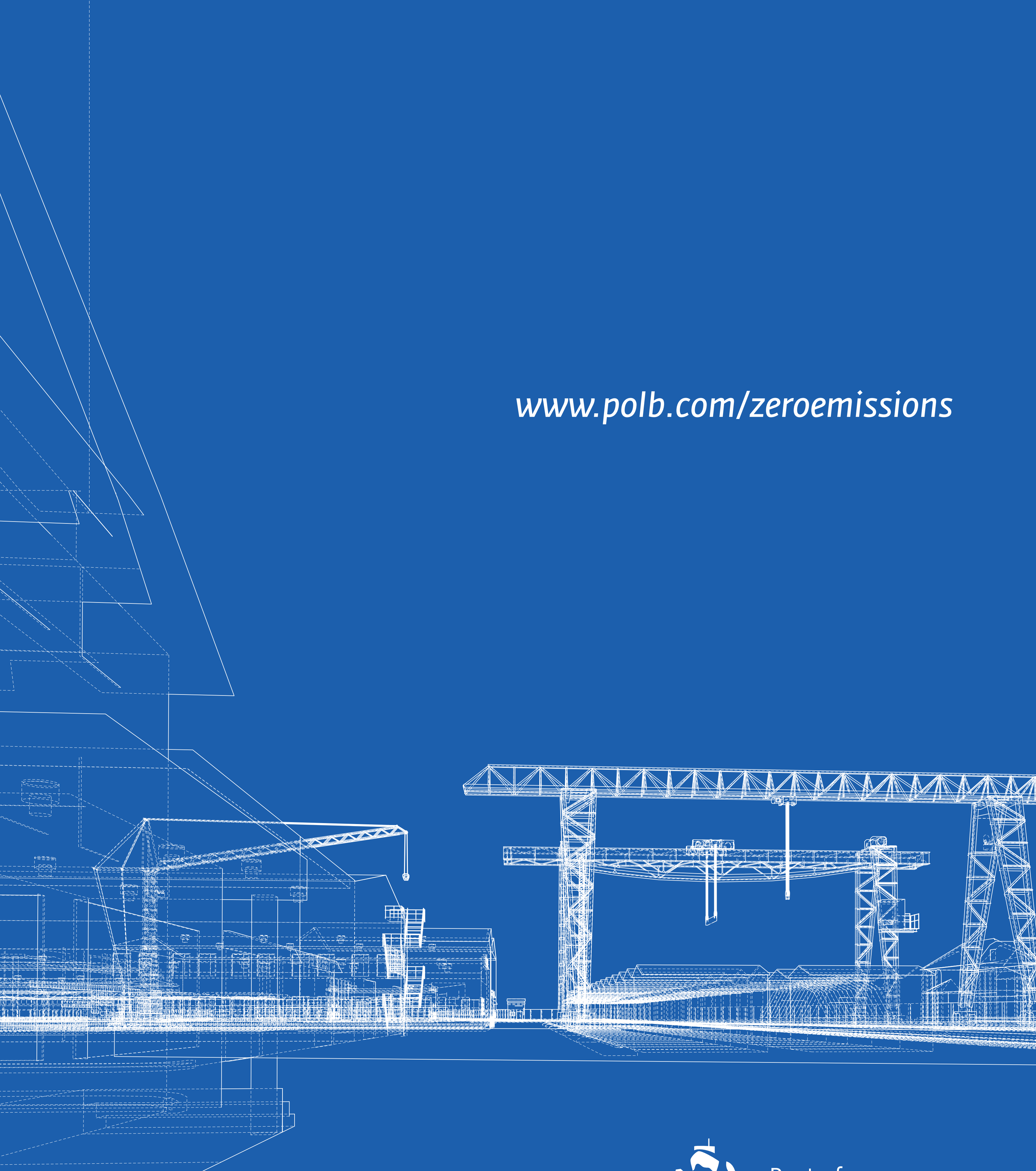

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