PMSA
PACIFIC MERCHANT SHIPPING ASSOCIATION

December 23, 2019

Anne Halsted, Chair
Seaport Planning Advisory Committee
San Francisco Bay Conservation & Development Commission
375 Beale St., Suite 510
San Francisco, CA 94105
Delivered via E-Mail

Re: Seaport Planning Process and Bay Area Seaport Forecast (2019-2050)(*Revised Draft Final*)

Dear Chair Halsted and Seaport Planning Advisory Committee Members,

On behalf of the members of the Pacific Merchant Shipping Association (PMSA), which represents ocean carriers, marine terminal operators, and various other maritime interests which conduct business at all of California's public seaports, thank you for inviting the public to submit comments on the current Seaport Plan revision process prior to the next meeting of the Seaport Planning Advisory Committee (SPAC).

PMSA submits the following comments regarding both the BCDC-commissioned report for the SPAC entitled "Bay Area Seaport Forecast 2019-2050," as revised November 19, 2019, by the Tioga Group and Hackett Associates ("SPAC Report") and the unsolicited Oakland A's-commissioned report submitted to the SPAC entitled "Expected demand for Howard Terminal as a cargo handling facility," dated November 13, 2019, by Mercator International ("A's Report").

PMSA finds the SPAC Report and its findings, which were procured in a public contracting process directly by BCDC for the purposes of this analysis from an independent third party expert, to be credible, thorough, realistic, based on evidence and facts in the record, and consistent with other prior studies.

The SPAC Report is based on actual capacities on the ground at all of the seaport facilities within the BCDC planning area and separately analyzes the likely demand for a variety of commodities and cargo types handled by each port and terminal location.

The SPAC Report has produced a baseline of evidence and facts in the record regarding the existing uses and intensity of uses of regional seaports, including actual capacities, and then subjects the facility use evaluations to various business demand forecasts for a number of possible scenarios. These scenarios consider multiple variants for long-term growth across various sectors, applied scenario outcomes to the future use of seaport facilities. Thus, the SPAC report methodology is a comprehensive look at both existing infrastructure and equipment utilization and the feasibility of future development of new infrastructure and equipment based on likely demand.

PMSA has evaluated both the methodology and the outcomes as applied in the SPAC Report and agrees with the utilization of these forecasting scenarios. Moreover, the SPAC Report modeling considers the most important capacity limitations of all: the capacity for market demand to finance the maintenance of current facilities or to underwrite the expansion of new facilities or the basis for increasing the intensity of uses.

The SPAC Report methodology acknowledges that there is a broad range of possible outcomes to be accommodated between now and 2050, that there is no singular correct or undeniably clear projection path upon which the BCDC ought to embark, but that in the real world even if the long-term trend is properly identified, there are short-term trade-offs which may be unexpected or unplanned. For instance, the SPAC Report forecasting scenarios considered current and future trade volumes, import versus export markets, national GDP growth, and slowing and changing trends of globalization.

As a result of these methodologies, the SPAC Report projections forecasts for CAGR include a moderate growth level of 2.2% and with high growth level of 3.3% through 2050. By comparison, we would point out that these growth rates are already very aggressive when compared to the CAGR for recent years at the Port. For instance consider all of the following potential forecast benchmarks: 2009 marked the completion of the Port of Oakland's harbor deepening construction efforts, 2009-2018 CAGR was **2.46%;** 2005 is the emission inventory baseline year for Port of Oakland air quality planning efforts, 2005-2018 CAGR was 0**.88%;** 2007 was the last full year pre-recession, representing from then to present at least one full business cycle including contraction and growth periods, 2007-2018 CAGR was 0**.59%.**

Consistently, the SPAC Report conservatively assumed a sustainable utilization rate of 80% in order to avoid the unrealistic expectation that all facilities operating at 100% utilization is a feasible or sustainable operating condition in the modern supply chain. Indeed, to have made forecasts at a 100% utilization rate would not only be inconsistent with the realities of the maritime logistics industry but it would have created either or both a false planning basis for completely perfect projection of supply and demand and/or arbitrarily consistent upward pressure on demand for new facilities to be developed assuming that all capacity is always at full utilization.

The SPAC Report includes and acknowledges various supply chain and logistics capacity constraints which in and of themselves might not be viewed as a function of acreage or port and terminal space availability but are nonetheless relevant to total capacity. Two of the most important such non-acreage terminal capacity constraints are berth capacity, transportation access, and ancillary services acreage availability. BCDC and the Bay Area's seaports know the challenges of these non-acreage constraints well: port competitiveness suffers with less access to off-dock yard capacity, a lack of highway or mainline rail access, and the need for maintenance and deepening dredging for berths and navigational channels is a constant.

The SPAC Report did not commit itself to a singular vision of the utilization of equipment. As discussed at the first meeting when asked about the introduction of new technologies, the SPAC Report assumes that the adoption of new technologies would occur over time as demand dictates. In this way, the SPAC Report neither presumes nor precludes which port facilities will be using which types of equipment when or how or to what intensity. Tying the introduction of the use of new technology or enhanced capacity or specialized equipment to the relative demand for new cargo operations and facility utilization the SPAC Report builds an evaluation of market feasibility into its baseline.

This built-in feasibility component based on market demand is a critically important component of the SPAC Report. It is also consistent with prior evaluations of the potential demand for new technologies at the Port of Oakland, including one done for PMSA by the engineering firm of Moffatt & Nichol in December 2015. ***Study Attached***.

The Moffatt & Nichol Study concluded that it was likely and feasible that the Port of Oakland would utilize a combination of conventional operations and transition to a Zero-Emissions/Near-Zero Emissions with the introduction of an eRTG operating environment through 2045 with projected total annual capacities of 4.2 – 4.7 million TEUs. The Moffatt & Nichol Study also concluded that a full ASC automated high-density operation throughput level was not a likely or feasible outcome at the Port of Oakland, but that if it were applied, that total capacity would be approximately 6.2 million TEUs. These projections are in-line with the SPAC Report projections for total capacity assuming efficiency upgrades of 5.3 million – 5.6 million TEUs annually.

When considering the introduction of High Density operating mode feasibility at the Port of Oakland, the Moffat & Nichol Study concluded that Berths 35-38 and Berths 60-63 could not technically operate in a full high-density environment – and only operate with ZE/NZE yard tractors or eRTG, and that those other berths that could potentially utilize High Density operating modes (Berths 20-26, 30-32, and 55-59) would have to utilize multiple types of utilization layouts.

All told, in order to transition the following Port of Oakland container terminals to the indicated electrified operating modes to accommodate an annual Port of Oakland container terminal throughput of 6.2M TEU, the Moffatt & Nichol Study concluded that over $6 billion in additional CAPEX costs would be required through 2045:

High Density Operations Mode - Oakland			
Equipment	Electrical	Civil	Total
$4,746,699,422	$88,400,000	$1,238,000,000	$6,073,099,422

These CAPEX costs are on average 5 times hire than conventional equipment costs, meaning that the expected Capital Costs for traditional equipment through 2045 for Oakland would have been about $1.2 billion. This leaves the high-density capital expenditure price tag for Oakland at about $4.8 billion. These costs also do not reflect the costs to the Port of Oakland of the actual lost revenues from when terminal acreage is idle and not generating revenues during the infrastructure redevelopment and construction process which would take several years per terminal.

The SPAC Report does not tackle the specifics of whether, when or how terminals are redeveloped, which technology path is implemented when, or whether or not the Port of Oakland will be using electric yard tractors, eRTGs or a fully automated-stacking crane system, but its projected capacities are built around demands which may or may not require the utilization of some or all of these technologies. This is not only the most reasonable basis for projection, it reflects the realities on the ground now in Oakland.

By contrast, the A's Report and its conclusions, which were procured in private by the sole project proponent for the obvious task of advocating for a directed outcome contrary to that reached by the unbiased SPAC Report, to be facially simplistic and unrealistic, not based on any demand projections, willfully ignorant of capacity constraints, and contradictory to the facts and evidence presented.

The A's Report is conclusory and obviously produced in order to achieve a directed outcome. As outlined in its description of its capacity calculations and assumptions (pg. 9), the A's Report ignores most of the SPAC Report's work on projections of demand or feasibility or growth, and instead simply does a bottoms-up calculation of what could be achieved on a per acre basis of applying a technology assumption for automation. In short, the A's Report was intentionally and exclusively produced to only demonstrate the total amount of possible terminal capacity per acre and to provide the SPAC and BCDC with no other metrics or functional facts or evidence.

This is an exercise in math, not a study. All of the arithmetic in the A's Report might be correct regarding capacity, but none of the methodology is based in a real approximation of the realities on the ground at the Port of Oakland. The A's Report fails to evaluate overall demand versus the capacity, the costs versus the capacity, the feasibility versus the capacity, and the off-terminal capacity constraints versus the capacity.

The question facing the SPAC and the reason for commissioning the SPAC Report is to evaluate the likely need for the preservation of facility acreage under the current Seaport Plan Priority Use Designation. The A's Report is purely academic in that respect, because it does not inform the SPAC of what is likely to occur and therefore be needed, it is merely a demonstration of what could be in a world with unlimited resources and without the need for a consideration of actual market conditions or physical constraints.

For instance, even if it is academically arguable that the Port of Oakland could build the automated infrastructure to accommodate 7 million TEUs of throughput per year, could they raise an additional $4.8 billion in revenue bonds and tenant infrastructure and equipment financing commitments if the surrounding infrastructure still only accommodated 5.5 million TEUs of total throughput? No.

Likewise, the A's Report has an evaluation of services by ocean carriers at the Port of Oakland, which is an interesting line of analysis (especially to PMSA, seeing as how we represent the ocean carriers calling at this Port), but it is functionally irrelevant to the macro trends that are being evaluated by the SPAC and BCDC. What does the current ocean carrier string analysis have to do with whether or not there is a functional demand for business at the Port of Oakland at a rate of 11,400 TEUs/acre – as proposed by the A's Report – or a conventional approach to capacity of 5,000 TEUs/acre? Nothing.

Further to that end, the A's Report is fantastical in that it asks the SPAC and BCDC to plan on total TEU/Acre at the Port of Oakland at an average capacity of 11,400 TEUs/Acre (pg. 11), while noting that the total capacity of LBCT – the only existing fully-automated marine terminal on the US West Coast, and one that includes an on-dock rail facility – is only 10,540 TEUs/Acre (pg. 10). It is simply beyond belief to conclude that somehow not only would the Port of Oakland become 100% fully automated but do so in a manner which produced on-terminal efficiencies almost 10% higher than the most technologically advanced terminal in the State which also has on-dock rail handling capacities.

Finally, regarding the action and timing of the Seaport Plan amendment process, the SPAC is under no time constraints and should feel no pressure from the artificial timeline of a project sponsor in its endeavors. Instead, especially if there is truly a wide-ranging debate that needs to had regarding the scope and purpose of the SPAC, the Committee should take all due time necessary to review and to ensure that its planning is based on only the most accurate and implementable recommendations from now until the year 2050. There is no need for, nor should there be, any rush to judgment in this planning process which will set the stage for the next three decades of billions of dollars of private and public infrastructure investment in the Bay's waterfront.

Moreover, in their Application to BCDC asking for the consideration of amendments to the Seaport Plan, the Oakland A's have already acknowledged that action should only be taken "… after completion of the current environmental review efforts being undertaken by the City of Oakland." (Application at pg. 4).

Certainly, the Applicant desires an expedited environmental review, but there is no reason to anticipate that translating into a need for undue haste by the SPAC. PMSA and a wide array of Port, supply chain, and maritime industry stakeholders have provided wide-ranging, substantive and procedural comments in response to the DEIR NOP, and it is our expectation that the process for compiling a DEIR for this project will be as thorough and detailed as the CEQA processes for developing any other waterfront development project – and it is our experience that those are exhaustive, intensive and time-consuming.

Moreover, BCDC is only required to act on the potential for a Seaport Plan amendment upon the lawful certification of an EIR for this project, but even if the City were to publish a Draft EIR shortly, it would take many months or years for it to work through its approval process. And then, under state statutes specific to the Howard Terminal project site, there is an abundance of additional time granted to policymakers for consideration of the planning designations applicable to this site. First, if a city action on an EIR is challenged, a certification would not be pending for up to an additional 270 days of action after a post-publication filing deadline period, totaling an approximate 9 months. (Pub. Res. Code §21168.6.7.(c)) Then, post-certification, the legislature has provided for an additional 140 days for BCDC to determine Port priority use designations, the primary purpose of which would be a potential Seaport Plan Amendment (AB 1191, §8). Altogether, SPAC and BCDC should consider this 13-month period as a potential time constraint for any Howard Terminal-specific determinations with the Seaport Plan amendment process, not the imminent publication of a Draft EIR that is yet to be legally certified.

If you have any further questions regarding this or any other Port and maritime industry issues, please do not hesitate to contact me or anyone else at PMSA at your earliest convenience.

Sincerely,

Mike Jacob
Vice President & General Counsel

enclosure

cc: Members, Seaport Planning Advisory Committee
Larry Goldzband, Executive Director
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TECHNICAL MEMORANDUM

To: **John McLaurin, Pacific Merchant Shipping Association**

From: **Kerry Simpson**

Date: **December 4, 2015**

Subject: **Sustainable Freight Strategy Impact Study**

M&N Job No.: **8918**

1. Executive Summary

1.1 Introduction

Pursuant to an Executive Order issued by Governor Jerry Brown, the California Air Resources Board (CARB) along with other state agencies are developing a California Sustainable Freight Action Plan that will implement short- and long-term measures to decrease emissions from freight transport systems, including seaports. Part of these measures may include mandating zero/near-zero emission equipment powered by renewable energy.

To assist the state agencies in the development of a Sustainable Freight Action Plan, the Pacific Merchant Shipping Association (PMSA) retained Moffatt and Nichol in an effort to determine the potential cost to convert container terminals at the ports of Los Angeles, Long Beach and Oakland from their current operating systems to all electric systems. As a result, this Technical Memorandum documents the following:

1. The availability of zero/near-zero emission technology (electrification for the purposes of this work) that could be used on marine container terminals.
2. The associated technology challenges, and
3. The estimated capital improvement and operational rough order of magnitude (ROM) costs.

We determined that both the zero/near-zero emission technology costs and the state of the technology are significant issues.

- Zero/near-zero emission technology capital expenditure costs
  - Container terminals at the ports of Los Angeles, Long Beach and Oakland will spend $7 billion in capital expenditures (CAPEX) over the next 30 years to replace current conventional terminal operating equipment and associated infrastructure in the normal course of business.
  - Replacing current equipment with zero emission or near-zero emission equipment and supporting infrastructure will cost $23 billion, an increased cost of $16 billion.

  - Replacing current equipment with electrified high-density stacking equipment and supporting infrastructure will cost $35 billion, an increased cost of $28 billion.
- Zero/near-zero emission technology operational expenditure costs
  - Container terminals at the ports of Los Angeles, Long Beach and Oakland will spend $239 billion in operational expenditures (OPEX) over the next 30 years to maintain and operate current conventional terminal equipment in the normal course of business.
  - Zero/near-zero emission electrified equipment will cost $284 billion to maintain and operate, an increased cost of $45 billion.
  - Zero/near-zero emission electrified high-density stacking equipment will cost $260 billion to maintain and operate, an increased cost of $21 billion.
- State of the zero/near-zero emission technology
  - While eRTG technology is deployed in some U.S. locations, the eHostler technology is only in its pilot program phase in California.
  - There is no zero/near-zero emission technology equal to the Front End Loader (FEL) which is the workhorse of the conventional container handling equipment in the San Pedro Bay and Oakland port areas.

The deadline CARB could impose for these replacements is uncertain, but it is likely that marine terminals would need to replace current equipment before they would in the normal course of business. This would accelerate costs for the industry, and result in stranded assets.

This analysis is limited to costs to marine terminal operators to replace equipment and essential supporting infrastructure. The analysis does not include the additional costs related to infrastructure improvements that will need to be made by ports and utility providers to support electric RTGs and electric high-density stacking equipment. In addition, the analysis does not include marine terminal costs resulting from phased implementation of the zero/near-zero emission technology into on-going terminal operations that include increased costs resulting from reduced productivity, lost revenue from repositioned cargo to other terminals during construction, and costs of phased construction.

1.2 Challenges

The two biggest challenges for implementing zero/near-zero emission technology in the container handling industry in the ports of San Pedro Bay and Oakland are cost and the state of the technology. Together the marine terminals in these ports maintain about 2,700 container handling equipment (CHE) units that would have to be replaced by zero/near-zero emission technology units. Importantly, the technology that might make the operational transition more amenable is not currently in a desirable state for full commercial operation.

1.2.1 Cost Challenges

1.2.1.1 Capital Expenditures (CAPEX)

Absent any additional regulatory requirements, over the next 30 years, marine terminal operators will spend nearly $7 billion replacing current conventional type container handling equipment (CHE) and associated infrastructure based on the typical life span of the equipment. The cost of converting to all electric technology (eRTG and eHostler) is approximately $23 billion for the electric eRTG operational mode.

Likewise, the cost to convert to all electric high-density technology (Automated Stacking Cranes (ASC) and Automated Guided Vehicles (AGV) results in a cost of approximately $35 billion. The costs of all electric eRTG or all electric high-density equipment modes ($23 billion and $35 billion, respectively) include “inside the terminal fence” electrical infrastructure and civil works required to accommodate the electrical needs of the new equipment. However, these costs do not include infrastructure and additional costs associated with increasing the capacity of the electrical power grid. The port authorities and utility providers would incur the cost of electrical infrastructure that will be needed outside the physical boundaries of the marine terminals. In addition, the capital expenditure does not include costs resulting from phased implementation of the zero/near-zero emission technology into on-going terminal operations that include increased costs resulting from reduced productivity, lost revenue from repositioned cargo to other terminals during construction, and costs of phased construction. Thus, the total equipment (initial acquisition and replacement), civil and electrical costs for all electric eRTG and all electric high-density compared to conventional equipment is illustrated in Table 1.

Table 1: Equipment Modes and CAPEX Costs

Equipment Mode	CAPEX (Civil, Electrical & Equipment Costs)	CAPEX/TEU Annual Capacity
Conventional	$7 billion	$290
All Electric eRTG	$23 billion	$850
All Electric High-Density	$35 billion	$950

1.2.1.2 Operational Expenditures

Absent any additional regulatory requirements, over the next 30 years, marine terminal operators will spend nearly $239 billion maintaining and operating (OPEX) current conventional type container handling equipment (CHE). The operating expenditure of all electric technology is approximately $284 billion for the all-electric eRTG operational mode.

Likewise, the cost to maintain and operate all electric high-density operations results in a cost of approximately $260 billion. The related operating expenditure of all electric eRTG or all electric high-density equipment modes ($284 billion and $260 billion, respectively) includes labor, energy, and maintenance. Thus, the total related operating expenditure for all electric eRTG and all electric high-density compared to conventional equipment is illustrated as in Table 2. However, it is important to note that the increased productivity of the electric high density options makes it the preferable option.

Table 2: Equipment Modes and OPEX Costs

Equipment Mode	OPEX (Labor, Energy & Maintenance Costs)	OPEX/TEU Annual Capacity
Conventional	$239 billion	$9,700
All Electric eRTG	$284 billion	$10,400
All Electric High-Density	$260 billion	$7,100

Total capital and operating expenditures for the three study equipment operating modes for the 30 year planning horizon with respect to their respective throughput capacities is summarized in the table below.

Total CAPEX and OPEX Costs (2015-2045)			
	Conventional	**eRTG**	**Elec. High-Density**
CAPEX	$7 Billion	$23 Billion	$35 Billion
OPEX	$239 Billion	$284 Billion	$260 Billion
Capacity (TEU/yr)	24,563,000	27,155,000	36,802,000
CAPEX and OPEX per Capacity ($/TEU/yr)	$10,000	$11,300	$8,000

1.2.2 Technology Challenges

Today's conventional CHE technology is well developed. Some types of CHE are zero/near-zero emission technology compliant. For example, all of the Ship-to-Shore (STS) cranes in San Pedro Bay and Oakland are powered by electricity.

There are also two terminals in these regions that operate with electrically powered rail mounted gantry (RMG) cranes, one using them in a portion of their container yard (CY) and another in their intermodal yard (IY). Otherwise the vast majority of the current fleet of CHE in San Pedro Bay and Oakland is diesel fuel powered, not zero/near-zero emission technology based. Figure 1 illustrates the quantities of the various types of CHE in the two port areas.

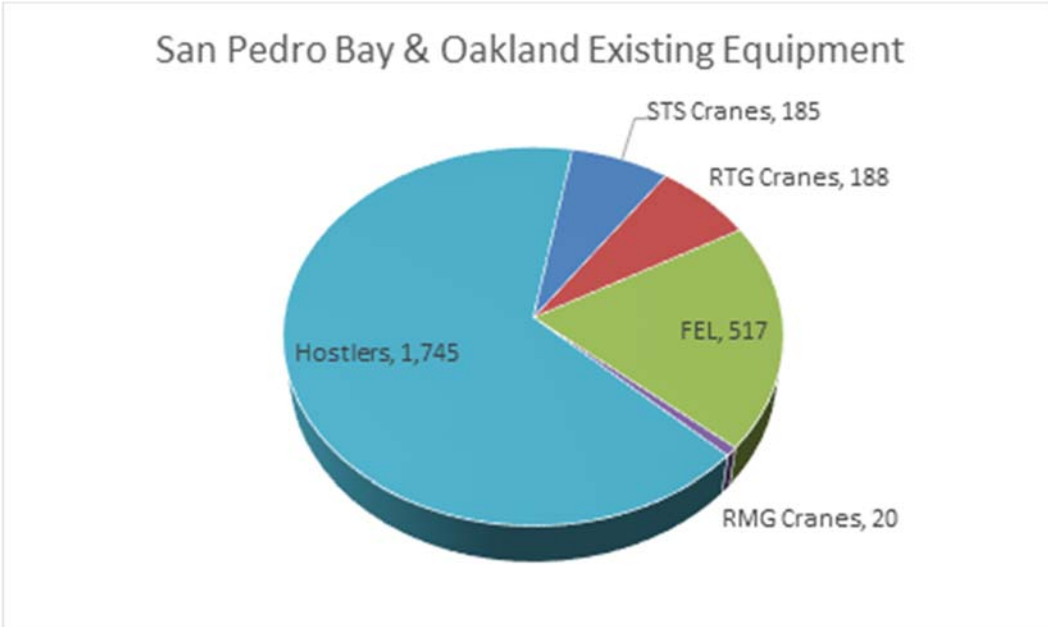

Figure 1. Distribution of Existing Equipment

As illustrated in Figure 1, the Hostlers out-number other types of equipment by about 3:1. However, it is important to note that the workhorse of the container lifting CHE fleet in San Pedro Bay and Oakland is the diesel powered front end loader (FEL), accounting for around 75 percent of container handling moves. Due to technology limitations, the FEL cannot be converted to zero/near-zero emission technology.

As previously mentioned, there are currently approximately 2,700 units of various CHE in San Pedro Bay and Oakland. This quantity does not include the ancillary equipment (pickup trucks, buses, vans, sweepers, maintenance trucks, etc.) needed for day to day operations of a container handling terminal.

Key observations of the existing equipment quantities of San Pedro Bay and Oakland regions, their relationship to zero/near-zero emission technology, potential equivalent equipment, and challenges are summarized in Table 3.

Table 3: Existing and Near-Zero Emission Technology Relationships

Equipment Type	Existing and Zero/Near-Zero Emission Technology Relationship
STS Cranes	Well established technology and electrically powered.
RMG Cranes	Well established technology and electrically powered. Only 20 currently deployed in the two Port regions. Fixed rails diminish flexibility in maneuvering within the terminal. Terminal power supply infrastructure would require an upgrade and additional terminal infrastructure would be required to deliver suitable power at each container storage block.
RTG Cranes	Electrically powered RTG Cranes exist in the industry and conventional RTG Cranes can be converted to electric power. Terminal power supply infrastructure would require an upgrade and additional terminal infrastructure would be required to deliver suitable power at each container storage block. Challenges to electrification: • There are no terminals in San Pedro Bay or Oakland that rely solely on RTG Cranes for container handling (see FEL below). • The operational cost of RTG (whether electrically powered or diesel powered) is about twice that of a FEL (primarily due to increased labor cost). • Capital cost of electrical conversion and accompanying site infrastructure. • Electrically powered RTG Cranes cost more than conventional RTG Cranes, but have lower energy and maintenance cost. • Limited maneuverability, electrification infrastructure will result in additional limitation. • There are twice as many FEL than RTG Cranes in use in San Pedro Bay and Oakland terminals (see pie chart).
Front-End Loader (FEL)	The FEL is the preferred CHE in San Pedro Bay and Oakland terminals (see pie chart). The FEL is less expensive to purchase ($600,000 vs. $1.2 million) and operate than the RTG Crane. In relation to CHE, the FEL is the most maneuverable and most deployable to any area of the CY and IY. Challenges to electrification: • Currently, there is no zero/near-zero emission technology based FEL equivalent.
Hostlers	By far the largest fleet of container handling equipment is the Hostler. In a recent Ports of Los Angeles and Long Beach study, the Hostler was identified as the CHE category responsible for the most emissions. This result is partly due to the quantity of the Hostler fleet is twice that for all other types of CHE combined. Electrically (battery) powered Hostlers are available but not currently used in the U.S. Automated Guided Vehicles (AGV) are the Hostler equivalent in an automated terminal and can be battery powered. The new Middle Harbor Terminal (MHT) in Long Beach will deploy a fleet of battery powered AGVs. Challenges to electrification: • Electric Hostlers are only now in a test phase in California. • Current battery life is restricted to one work shift. • AGV technology is restricted to automated terminals that require significant capital investment.

1.2.3 Terminal Participation

The terminals in San Pedro Bay and Oakland have met emissions standards. Additionally, the Port Authorities in both regions have developed “Green Port” initiatives, such as their Clean Air Action Plans, that go beyond what is mandated by the state (CARB) or federal (EPA) agencies. Current compliance and plans of the terminals in San Pedro Bay and Oakland include:

1. Wharf Extension Project with Cold Ironing Capability
2. Terminal Automation Consideration
3. Electric Hostler Pilot Project
4. New Equipment Acquisitions to be CARB compliant

1.2.4 Study Topics

The following study presents a more detailed explanation of:

1. Existing Operations
   a. Terminal configurations
   b. Equipment quantities, costs and life cycle
2. Current and Potential Zero/Near-Zero Emission Technology
   a. Types, costs and maturity
3. Anticipated Initial and Feasible Future Operational Modes
   a. Electrified RTG and electrified high-density scenarios by terminal
   b. Estimated capacity versus forecasted demand by region
4. Estimated Zero/Near-Zero emission technology ROM Costs
   a. Capital expenditure for equipment and supporting in-terminal infrastructure
   b. Operating expenditure for labor, energy, and maintenance

2. Introduction

The California Air Resources Board (CARB), and other state agencies are developing a California Sustainable Freight Plan that will implement short- and long-term measures to decrease emissions from freight transport systems, including seaports, airports, rail yards, distribution centers, warehouses, high traffic roads and border crossings. Implementation of this plan is under consideration and pending by the State of California. Part of these measures may include mandating zero/near-zero emission equipment powered by renewable energy.

To assist the state agencies in the development of a Sustainable Freight Action Plan, the Pacific Merchant Shipping Association (PMSA) retained Moffatt and Nichol in an effort to determine the potential cost to convert container terminals at the ports of Los Angeles, Long Beach and Oakland from their current operating systems to all electric systems.

To support PMSA's efforts, this Technical Memorandum documents the research and analysis with respect to zero/near-zero emission technology—limited to electrification for the purposes of this work—that is available for implementation on a marine terminal, the associated technology challenges, and estimated capital improvement and operational ROM costs. The electrification of the marine terminal operations and associated costs was limited to electrified equipment technology that is commercially available and has been proven to be suitable for marine terminal operations.

The Ports of Los Angeles, Long Beach and Oakland are major gateways for containerized trade between Asia and the United States. There are no canals between Asia and the US West Coast, so there is no navigational restriction on vessel size. In 2013, their throughput was as shown in Figure 2.

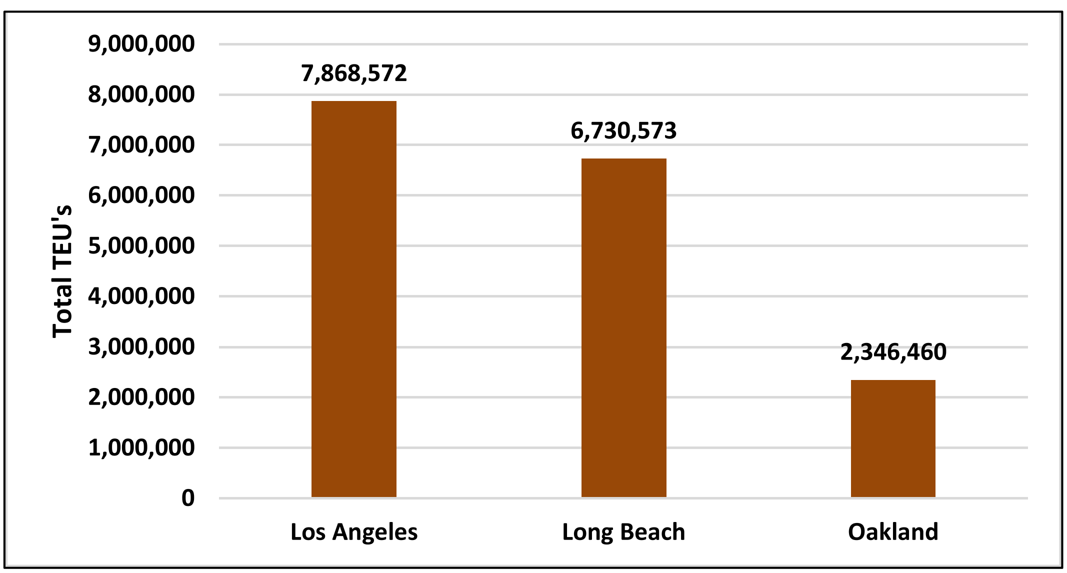

Figure 2: 2013 Containerized Throughput (as reported by the American Association of Port Authorities)

Combined, they are currently handling over 17 million TEUs, approximately 40% of total US containerized trade and about 80% of US trade with Asia. All three ports are surrounded by the robust economy and population of California, by itself the tenth largest economy in the world. All three are served by the two western Class 1 railroads, UP and BNSF and thereby are able to serve the entire US.

The ports are landlord ports, meaning that the port authorities retain ownership of the land, develop infrastructure and lease their terminals. Lessees include shipping lines, alone or in partnership with terminal operators or investors, and private stevedoring companies. Typically, the lessee (terminal operator) is responsible for furnishing all equipment, technology and labor.

Los Angeles and Long Beach are unique among ports in a number of other ways:

- Many express vessel services from Asia call only one port in North America, interchanging nearly their entire carrying capacity per call. This means that a 14,000 TEU vessel may generate up to 14,000 lifts per call. An equivalent vessel call in Europe or the US East coast would typically generate one-third to one-half that work.
- Throughput is virtually all import/export, or gateway cargo requiring delivery to/from over-the-road trucks and trains. There is virtually no vessel-to-vessel relay, or transshipment, volume. The significance of this is great in terms of the efficiency of yard storage and the amount of work performed per container.
- The San Pedro Bay port complex serves a vast complex consisting of over one billion square feet of transload and distribution centers locally, in the Inland Empire and Kern County.
- About one-half of import cargo is shipped by rail to inland points of delivery, either by loading marine containers onto trains or by trans-loading the cargo into domestic containers destined for rail. About one-third of import marine containers are transferred to trains, and about two-thirds of those are loaded onto rail cars at on-terminal rail ramps.

3. Glossary of Abbreviations

Table 4: Glossary of Abbreviations

Abbreviation	Term
ASC	Automated Stacking Crane
CARB	California Air Resources Board
CHE	Container Handling Equipment
CY	Container Yard
FEL	Front End Loader (Top or Side Pick)
IY	Intermodal (rail) Yard
OTR	Over The Road
RMG	Rail Mounted Gantry Crane
RTG	Rubber Tired Gantry Crane
STS	Ship-to-Shore

4. Existing Container Terminal Equipment

4.1 Introduction

Information relative to existing terminal operations was gathered and compiled by soliciting marine terminal operators via a questionnaire, direct correspondence, publically available pertinent port authority and member information, and knowledge of industry standards. The study was limited to marine container terminals currently in operation at the ports of Los Angeles, Long Beach and Oakland.

For the purposes of this Technical Memorandum, data was collected from the terminals (by port area) listed in Table 5 and Table 6.

Table 5: San Pedro Bay Terminals

Location		Terminal Name	Operator
Port of Los Angeles	Berths 226-236	Everport Container Terminal	Ports America
	Pier 300	Eagle Marine Services (APL) Container Terminal	EMS
	Pier 400	APM Terminals	APMT
	Berths 212-225	Yusen Container Terminal	YTI
	Berths 136-139	TraPac Container Terminal	TraPac
	Berths 100, 121-126	West Basin Container Terminal	Ports America
Port of Long Beach	Pier J North	Pacific Container Terminal	SSA Marine
	Pier J South	Pacific Container Terminal	SSA Marine
	Pier G	International Transportation Service	ITS
	MHT	Long Beach Container Terminal	LBCT
	Pier T	Total Terminals International	TTI
	Pier A	SSA Terminal	SSAT Long Beach
	Pier C	SSA Terminal	SSAT/Matson

Table 6: Oakland Terminals

	Location	Terminal Name	Operator
Port of Oakland	Berth 20-26	Ports America Outer Harbor Terminal	Ports America
	Berth 35-38	Ben E. Nutter Terminal	STS LLC
	Berth 55-59	Oakland International Container Terminal	SSAT
	Berth 60-63	Matson Terminal	SSAT
	Berth 30-32	TraPac Terminal	TraPac

4.2 Existing Container Equipment Types

Information obtained was geographically categorized by two regions with Los Angeles and Long Beach being one region, (San Pedro Bay) and the other being Oakland.

The existing operational equipment was categorized into two main groups of equipment: 1) Container Handling Equipment (CHE) and 2) Ancillary Equipment.

The following list itemizes the types of equipment that are included in the two main equipment categories:

- CHE (Wharf, Stevedoring, Container Yard and Intermodal Yard Equipment)
  - Ship-to-Shore (STS) Cranes
  - Rail-Mounted Gantry (RMG) Cranes
  - Rubber-Tired Gantry (RTG) Cranes
  - Front End Loaders (FELs)
  - Tractors/UTR (Hostlers)
- Ancillary Equipment
  - Rail Pushers
  - Forklifts (non-container handling)
  - Sweepers
  - Cone Vehicle (rail)
  - Buses
  - Vans
  - Pickups
  - Fuel Trucks
  - Flatbed Trucks
  - Service Trucks
  - Manlifts

For the purposes of this study, it is important to note that most of the equipment currently deployed within the two regions is not considered to be zero/near-zero emission type equipment. Within the two regions, the currently deployed zero/near-zero emission equipment, for the most part, is limited to the regions' entire STS Crane fleet, one terminal that uses electrified RMG cranes for rail loading purpose, and one terminal that uses electrified RMGs (ASC) in a portion of their container yard (CY).

4.3 Container Handling Equipment

4.3.1 Quantities

The CHE data that were readily available are shown in Table 7. The available data only represented a portion of the approximately 2,700 units of various CHE in San Pedro Bay and Oakland, but is assumed to be a representative sample.

Table 7: Container Handling Equipment Quantities

Port	Electric STS Cranes	RTG Cranes	Front End Loaders	Electric RMG Cranes	Hostlers
Los Angeles & Long Beach	153	170	410	20	1,535
Oakland	32	18	107	0	210
Totals	**185**	**188**	**517**	**20**	**1,745**

One important observation of the CHE data is use of the type of equipment. Of the equipment types noted, Ship-to-Shore (STS) cranes and Yard Tractors/UTR (hostlers) are consistently used and not replaceable (by another type of equipment) for their function performed. However, for functionality, the Rubber tired gantry (RTG) Cranes, FELs, and RMGs are somewhat interchangeable. The vast majority of the terminals in the two regions utilize the FEL equipment over that of the RTG or RMG cranes. Figure 3 illustrates the comparative deployment by equipment type for the two regions in the CHE category (excluding STS cranes and hostlers).

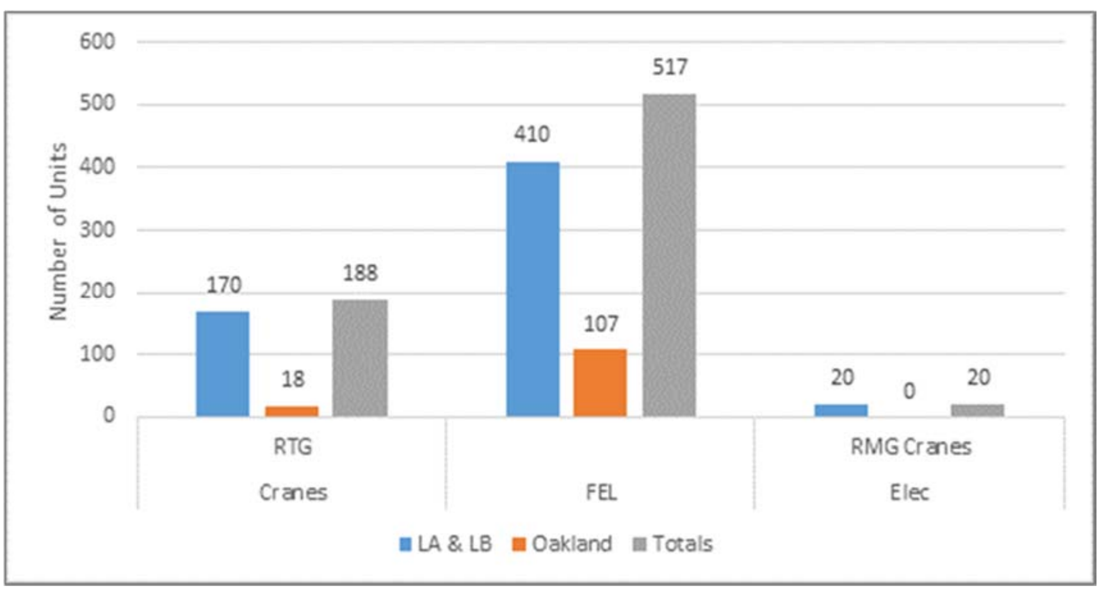

Figure 3: Container Handling Equipment Utilization

The FEL is obviously “preferred” over the use of the RTG and RMG Cranes. Several factors that contribute to the FEL preference are summarized as follows:

- Relatively high productivity (ranging from 15 to 30 moves per hour depending on task)
- Better maneuverability (relocating to different container stacks, adjusting to new hostler/over the road (OTR) truck circulation patterns, etc.)
- Less capital cost for FEL (about $600,000 vs. $1.2 million)
- Less manning required for FEL (one person vs. approximately three persons for RTG)
- Significantly less operating cost for FEL (based on manning requirements)

The configuration of how these two pieces of equipment are deployed should also be noted. The vast majority of the terminals use a combination of both RTGs and FELs. Of the 18 terminals researched for this study, only three of the terminals do not use the RTG/FEL combination.

Typically, within this combination, the FEL is used to support vessel related moves and receiving from OTR trucks. The RTG is typically used only to serve import delivery of gate moves associated with the OTR trucks due to its ability for container selectivity.

4.3.2 Container Handling Equipment - Remaining Life

Each of the CHE types has an assumed life span based on industry standards. These life spans are often extended by retrofitting and or modernizing particular components of the equipment.

Typical life spans (in years) of CHEs are illustrated in Table 8.

Table 8: Container Handling Equipment - Typical Life Spans (Years)

Equipment Type	Electric STS Cranes	RTG Cranes	FELs	Electric RMG Cranes	Hostlers
Typical Life Span (Years)	25	15	15	15	8

Since data was collected for only existing equipment , the remaining life would either be equal to the typical industry standard life span (for those equipment units acquired this year) or some lesser life. Within the two port regions, the average remaining life for the existing CHE is compared to the typical life span in Table 9.

An indication of zero for the Electric RMG Cranes reflects the use of this equipment beyond what is historically intended. As previously mentioned, life span can be increased by equipment retrofit or modernization.

Table 9: LA, LB & Oakland Container Handling Equipment Typical Life Spans Comparisons

Equipment Type	Electric STS Cranes	RTG Cranes	FELs	Electric RMG Cranes	Hostlers
Typical Life Span – Years	25	15	15	15	8
LA-LB & Oakland Averages of Remaining Life – Years	11	8	6	0	5

4.3.3 Container Handling Equipment – Capital Costs

CHE replacement requires a significant capital investment for the equipment procurement. Current per-unit costs for acquiring typical units of such equipment are summarized as follows:

Equipment	***Cost Per Unit***
STS Crane	$8,000,000 - $10,000,000
RTG Crane	$1,200,000
FEL	$600,000
RMG Crane (CY)	$2,000,000
Hostler	$100,000

The replacement cost for in-kind units in the CHE type category for the two port regions based on 2015 dollars are illustrated in Table 10. Note that there are no RMG Cranes currently operating in the Oakland region hence, the Not Applicable (N/A) designation.

Table 10: Container Handling Equipment One-Time Replacement Costs

	Electric STS Cranes	RTG Cranes	FELs	Electric RMG Cranes	Hostlers
Los Angeles & Long Beach	$1,071,000,000	$204,000,000	$246,000,000	$40,000,000	$153,500,000
Oakland	$224,000,000	$21,600,000	$64,200,000	N/A	$21,000,000
Totals	**$1,295,000,000**	**$225,600,000**	**$310,200,000**	**$40,000,000**	**$174,500,000**

The costs previously noted are based on replacing CHE one time. In a review of the capital investment cost for replacing the CHE, it is important to note that, first, these costs would not be incurred at the same time, and, second, since the existing equipment has remaining life, the costs shown in Table 10 are anticipated to be higher in the future. Higher costs are anticipated because the equipment will need to be replaced based on life span and because of inflation. Table 11 illustrates equipment cost increases based on a 5% annual inflation rate, 30 year planning horizon and if all CHE were replaced based on the average remaining life.

Actual replacement costs vary by each terminal and by individual equipment unit age. Costs in Table 11 are based on the two port areas' average remaining life for noted equipment types and where costs occur more than once, reflects additional years for required acquisitions. For example, based on the average life remaining for RTG Cranes in the two regions, they would theoretically be replaced in eight years (2023), then again in fifteen years (2038) based on the typical industry life span for RTG Cranes. Costs illustrated are based on anticipated costs for the year as indicated. These costs are shown in Table 11.

Table 11: Container Handling Equipment Replacement Costs and Timing

Type	Year	Cost
STS Cranes	2026	$2,325,633,942
RTG Cranes	2023	$349,979,646
	2038	$727,582,547
FEL	2021	$436,482,551
	2036	$907,415,875
RMG	2015	$42,000,000
	2030	$87,314,984
	2045	$181,521,580
Hostlers	2020	$233,846,689
	2028	$345,498,064
	2036	$510,457,996
	2044	$754,178,944
	Total	**$6,901,912,818**

Thus, the anticipated capital cost of replacing the "Conventional" type CHE for both regions within a 30 year planning horizon is nearly $7 billion.

4.3.4 Container Handling Equipment – Maintenance Costs

Limited maintenance cost data was submitted for the CHE types, which were supplemented by industry standards. For each equipment type, a cost per year per unit ($/yr/unit) was collected or determined by collected operational hours per year per unit (hrs/yr/unit) and/or maintenance cost per hour per unit ($/hr/unit).

Current maintenance costs per year per unit ($/yr/unit) for CHE types are summarized as follows:

Equipment	***Maintenance $/Yr/Unit***
STS Cranes	$240,000
RTG Cranes	$85,000
FELs	$90,000
RMG Cranes	$50,000
Hostlers	$40,000

The maintenance costs are intended to be typical and not reflective of specific terminal maintenance costs. Maintenance costs include parts and labor required to maintain a particular type of equipment. One observation is that the RTG Crane and FEL maintenance cost per year per unit are reported as similar. Table 12 illustrates the appropriate unit cost for maintenance applied to the total number of wharf, stevedore, CY and IY equipment types.

Table 12: Annual Container Handling Equipment Maintenance Costs

Equipment Type	Electric STS Cranes	RTG Cranes	FELs	Electric RMG Cranes	Hostlers
Maintenance $/Yr/Unit	$240,000	$85,000	$90,000	$50,000	$40,000
Total Units	185	188	517	20	1,745
Total Maintenance $	**$44,400,000**	**$15,980,000**	**$46,530,000**	**$1,000,000**	**$69,800,000**

The total annual maintenance cost figures are offered for comparison only and are not intended to be exact current values. In some instances it may not be appropriate to apply unit costs to the total number of units. For example, some terminals include STS Cranes in their quantity however, information offered indicates that not all cranes receive the same amount of use and maintenance.

For comparison, the estimated maintenance costs for the FELs is more than double that of the RTG Cranes. It should also be noted that the hostlers incur the highest maintenance expenditure. This can partly be attributed to the significantly higher number of FELs and hostlers compared to all other container handling equipment. The quantity of hostlers is about twice that of all other container handling equipment combined.

4.3.5 Container Handling Equipment - Operational Costs

Limited operational cost data was collected for the CHE, which was supplemented by industry standards. For each equipment type, a cost per year per unit ($/yr/unit) was collected or determined by collected operational hours per year per unit (hrs/yr/unit) and or operational cost per hour per unit ($/oper hr/unit). Current operational costs per year per unit ($/yr/unit) for CHE are summarized as follows:

Equipment	***Operational $/Yr/Unit***
STS Crane	$4,000,000
RTG Crane	$1,000,000
FEL	$750,000
RMG Crane	$3,000,000
Hostler	$300,000

These operational costs are intended to be typical and not reflective of specific terminal operating costs. Operational costs, in this instance, would include operational personnel (crane drivers, gang bosses, gangs, etc.) and any resources required to power a particular type of equipment (fuel, electricity, etc.). Table 13 illustrates the estimated annual cost for operations for each CHE type.

Table 13: Annual Container Handling Equipment Operational Costs

Equipment Type	Electric STS Cranes	RTG Cranes	FELs	Electric RMG Cranes	Hostlers
Operational $/Yr/Unit	$4,000,000	$1,000,000	$750,000	$3,000,000	$300,000
Total Units	185	188	517	20	1,745
Total Operational $/yr	**$740,000,000**	**$188,000,000**	**$387,750,000**	**$60,000,000**	**$523,500,000**

The total annual operational costs are provided for comparison only and not intended to be exact current values. In some instances it may not be appropriate to apply unit costs to the unit totals. For example, some terminals include STS Cranes in their quantity however, information offered indicates that not all cranes are in use the same amount of time as others. For comparison sake, the total operational costs for the FELs is nearly double of that of the RTG Cranes.

However, the per unit cost for a FEL is less than that of an RTG Cranes and the related cost of staff required to operate an RTG Crane. It should also be noted that the highest operational cost is for STS Cranes, primarily because of manpower requirements. The second highest operational cost is for Hostlers; however, there are significantly more Hostlers compared to other CHE, and the operational cost per unit for this equipment is significantly less.

4.4 Ancillary Equipment

4.4.1 Ancillary Equipment -Quantities

Available data related to ancillary equipment was limited to particular responding PMSA membership. Nevertheless, quantities from responding membership were used to determine equipment related needs for a typical container terminal as shown in Table 14.

Table 14: Typical Container Terminal, Ancillary Equipment

Equipment Type	Quantity	Equipment Type	Quantity
Rail Pusher	1	Vans	2
Heavy Forklifts	5	Pickups	100
Standard Forklifts	10	Fuel Trucks	3
Sweeper	1	Flatbed Trucks	3
Cone Vehicles	6	Service Trucks	10
Buses	4	Manlifts	4

4.4.2 Ancillary Equipment – Remaining Life

Ancillary equipment types typically have fewer productivity-related demands on them than those equipment units that have direct contact with containerized box movements. For such reasons, ancillary equipment will often exceed their typical lifespans, regardless of potential equipment upgrades. Table 15 compares the typical life span of ancillary equipment to the average life span of such equipment currently used within the two port regions. Again, note that an indication of zero reflects the use of this equipment beyond what is historically intended.

Table 15: Ancillary Equipment Typical to LA, LB & Oakland Life Spans Comparisons

Equipment Type	Forklifts	Sweeper	Cone Vehicles	Buses	Vans	Pickups	Fuel Trucks	Flatbed Trucks	Service Trucks	Manlifts
Typical Life Span (Yrs.)	10	10	10	15	15	15	10	15	15	15
LA-LB & Oakland Avg. Life Remaining (Yrs.)	6	8	6	0	5	0	4	0	0	11

4.4.3 Ancillary Equipment – Capital Costs

Based on the ancillary equipment requirements (quantities) for a typical San Pedro Bay or Oakland container terminal, Table 16 illustrates ROM capital costs. Total ancillary equipment capital cost for a typical San Pedro Bay and Oakland container terminal is approximately $6.6 million.

Table 16: Typical Container Terminal, Ancillary Equipment Capital Costs

Equipment Type	Cost	Equipment Type	Cost
Rail Pusher	$500,000	Vans	$50,000
Heavy Forklifts	$1,000,000	Pickups	$2,500,000
Standard Forklifts	$500,000	Fuel Trucks	$450,000
Sweeper	$150,000	Flatbed Trucks	$300,000
Cone Vehicles	$60,000	Service Trucks	$300,000
Buses	$400,000	Manlifts	$400,000

4.4.4 Ancillary Equipment – Maintenance Costs

Based on the ancillary equipment requirements (quantities) for a typical San Pedro Bay and Oakland container terminal, Table 17 illustrates ROM annual maintenance costs. Total ancillary annual equipment maintenance cost for a typical San Pedro Bay and Oakland container terminal is approximately $1.7 million.

Table 17: Typical Container Terminal, Ancillary Equipment Annual Maintenance Costs

Equipment Type	Cost	Equipment Type	Cost
Rail Pusher	$200,000	Vans	$10,000
Heavy Forklifts	$625,000	Pickups	$500,000
Standard Forklifts	$250,000	Fuel Trucks	$15,000
Sweeper	$10,000	Flatbed Trucks	$15,000
Cone Vehicles	$30,000	Service Trucks	$50,000
Buses	$20,000	Manlifts	$4,000

4.4.5 Ancillary Equipment – Operational Costs

Based on the ancillary equipment requirements (quantities) for a typical San Pedro Bay and Oakland container terminal, Table 18 illustrates ROM annual operational costs. Total ancillary equipment annual maintenance cost for a typical San Pedro Bay and Oakland container terminal is approximately $3.7 million.

Table 18: Typical Container Terminal, Ancillary Equipment Annual Operational Costs

Equipment Type	Cost	Equipment Type	Cost
Rail Pusher	$215,000	Vans	$20,000
Heavy Forklifts	$1,075,000	Pickups	$1,000,000
Standard Forklifts	$1,000,000	Fuel Trucks	$30,000
Sweeper	$100,000	Flatbed Trucks	$30,000
Cone Vehicles	$60,000	Service Trucks	$100,000
Buses	$40,000	Manlifts	$10,000

4.5 Existing Retrofit Projects

Terminal operators were queried as to their plans for retrofitting to zero/near-zero emission technology. The responses from this query are summarized in the narrative to follow.

1. Wharf Extension Project with Cold Ironing Capability
2. Considering Terminal Automation
3. Electric Hostler Pilot Project
4. New Equipment Acquisitions

It should also be mentioned that electrified high-density container terminals are currently being tested at the Middle Harbor Terminal site in Long Beach and in operation at the TraPac terminal in Los Angeles.

5. Current and Potential Zero/Near-zero Emission Technology

5.1.1 Introduction

Information on current and potential zero/near-zero emission technology that may be suitable for application to the existing equipment was researched. This section summarizes the electrification of rail mounted gantry cranes, IY container cranes, rubber tired gantry cranes and hostlers.

The use of automated guided vehicles (AGVs) and straddle carriers is also discussed. It should also be noted that FELs, though they cannot be electrified, are critical for existing terminal operations in San Pedro Bay and Oakland terminals.

5.1.2 Rail Mounted Gantry Crane

RMGs come in many configurations.

Automated Stacking Cranes (ASC's) such as are being deployed at Middle Harbor Terminal (MHT) and TraPac terminals are referred to as "end-loaded" RMGs because they serve horizontal transport at the ends of the storage stacks.

"Side-loaded" RMGs serve horizontal transport along the side of the stack similar to RTGs. Side-loaded RMGs typically have cantilevers to prevent trucks from having to cross gantry ways (rails).

RMGs that serve rail cars are typically side-loaded and either "portal" (without cantilevers) cranes or "cantilevered". For instance, the rail cranes at the American President Lines (APL) terminal in Los Angeles are portal cranes with relatively short spans, serving only two tracks each.

Wide-span rail RMGs, such as are being deployed at TraPac and MHT, typically have cantilevers and may serve up to eight rail tracks plus horizontal transport.

RMG cranes are typically electrically powered by motorized cable reels and medium voltage power cables with included fiber optics. They typically have regenerative braking capability per unit and per fleet of units, meaning that they can generate electrical power and feed it back into the local system whenever their hoist or gantry motors brake. Since they are mounted on rails and connected to the terminal operating system via fiber optic cables, they may be automated or remotely operated.

Photo 1: ASC (End-Loaded) with Medium-voltage cable reel

Photo 2: RMG (side-loaded) with Medium-voltage cable reel

5.1.3 Intermodal Yard RMGs

Intermodal Yard RMG Cranes are similar to CY RMGs in design and operation. Their main purpose is to place containers on trucks and/or rail cars. Cantilevered booms typically extend their operating range between road and rail. Various options exist for the electrification such as:

- Motorized cable reels for medium-voltage power cables
- Compact designed trench systems for protection of cables
- Highly flexible medium-voltage power cables with integrated fiber optic cables
- Standard heavy festoon systems
- Energy guiding chains
- Special cables for Chains,
- Special cables for spreaders
- Main medium-voltage cable reels CoverZIP cable protection Standard festoon system for trolley Intermodal

Photo 3: RMG (wide-span IY) with Medium-voltage cable reel

5.1.4 Rubber Tired Gantry Cranes (RTGs)

Modern RTGs are equipped with diesel generators that transform diesel fuel into electrical energy. This energy powers the electric motors that are necessary for the smooth movement and positioning of containers. The following section summarizes some options for electrification.

5.1.5 Electrification of Rubber Tired Gantry Cranes (eRTGs)

Converting a conventional RTG into a fully electric RTG (eRTG) means to shut down or remove the diesel generator and power the RTG with electric power only. The eRTG conversion is made possible with different unique electric power systems, some include:

- Motorized Cable Reel System
- Conductor Rail "Plug-In" System
- Conductor Rail "Drive-In" System
- Conductor Bar (Installed in the CY)

- Double Sided
  - Back to back conductor bar system including all CXW materials (steel structure, track profile, conductor bars including data transfer, pillar boxes, cables from pillar boxes to bars and associated cable trays) + installation (sub-contracted out): Ballpark ~ $650/ft (again, back to back).
  - One conductor system serves two rows/fleets of RTGs
- Single Sided
  - One conductor system serves one row/fleet of RTGs

- Drive-In Unit (Installed on the crane)
  - If the cranes are new, then the Drive-In-L unit that mounts to the crane may be supplied by the crane OEM (manufacturer).
  - If the conversion is a retrofit, then the equipment and modification costs for this unit need to be added.

Table 19: Cost Saving Comparison

	Diesel RTG	Electric RTG
Cost/Liter	$1.07 US	$0.20
10 container moves/hr (baseline for comparison)	21 Liters	40 kW
Cost/hour	$22.50 US	$8.00 US
Cost/year	$195,000 US	$64,000

Photo 4: E-RTG (Plug-in) with cable reel

5.1.6 Hostlers

Fleets of hundreds of hostlers currently operate throughout the port areas. Most of them are diesel; however, some LNG units are being tested. Hostlers move thousands of containers daily between the docks and terminal backland, and could potentially be replaced with electric vehicles. The expected cost to purchase an electric hostler is approximately $200,000 per unit. As shown in Table 20, in addition, there is significant energy and cost savings.

Table 20: Fuel Cost Saving Comparison

	eHostler	Diesel Hostler with 5 miles-per-gallon*
Energy	2 kilowatt hours of energy units per mile	Electrical equivalent of 8 kilowatt hours of energy per mile
Operation Cost	20 cents per mile	80 cents to 90 cents per mile

The following electric hostler specs were taken from a study conducted at the Port of Los Angeles in 2008.

5.1.6.1 Performance

- Maximum speed: 40 mph
- Maximum range (empty): 60 miles/full charge
- Maximum Range (fully loaded): 30 miles/full charge

5.1.6.2 Charging Specs

- Charging Time (60% charge): 1 hour
- Charging Time (100% charge): 3-4 hours
- Price per truck: $189,950 (yard hostler model); $208,500 (on-road model)
- Price of charger: $75,000, can charge 4 vehicles simultaneously
- Charger Connection: existing 440 v system (total output 80 kw)

Photo 5: Electric hostler being test at Port of Los Angeles

5.1.7 Automated Guided Vehicles

Automated guided vehicles (AGVs) are unmanned, software-controlled container transporters which provide an efficient link between the waterside STS cranes and the container stacking area in terminals that employ ASC's. The use of AGVs is applicable to San Pedro bay and Oakland terminals, as they are currently being employed at Middle Harbor Terminal at Port of Long Beach.

These AGV units typically include the following features:

- Constructed as an AGV or Lift AGV with diesel-electric or battery-electric drive unit
- Payload up to 70 tons (2 x 20' containers)
- Precise "according to plan" sequence via computer control system
- Precise control using management and navigation software and transponders in the terminal road surface
- Positioning to +/- 25 mm accuracy

Photo 6: Battery-electric drives for zero exhaust emissions in the terminal AGV fleet in the Port of Rotterdam, Netherlands

5.1.8 Straddle Carriers (electric in development)

Straddle carriers pick, lift and transport containers while straddling their load and connecting to the container's top lifting points via a container spreader. There are currently diesel-electric and diesel-hybrid models of straddle carriers on the market. Battery operated versions are currently in research and development phase. The straddle carriers typically include the following features:

- Stacking of 1-over-2 or 1-over-3 containers
- Lift capacity 40/50/60 tons

Photo 6: Automated Diesel Electric Straddle Carriers in Use at TraPac Terminal at Port of Los Angeles

5.1.9 Equipment Technology Maturity Summary

Table 21: Equipment Technology Maturity

Equipment Type	Zero/Near-Zero Emission Technology Maturity
STS Cranes	Mature technology and most terminals have electric STS Cranes. These cranes are continuing to increase in size to accommodate the larger vessels.
RMG Cranes	Mature technology and electrified RMG cranes being deployed in San Pedro Bay (Middle Harbor, TraPac)
RTG Cranes	Electric power RTG cranes are common in the industry and conventional diesel RTG cranes can be electrified. There has been recent deployment of ERTG cranes on the East Coast, particularly Port of Savannah. Connecting the rubber-tired machines to the power source via cables or bus bars is less functional than that of RMGs.
AGV (battery powered)	Mature technology and primarily used at automated container terminals. Being deployed at of AGVs at Middle Harbor Terminal, POLB. This technology typically requires additional infrastructure such as a battery exchange building and installation of transponders into the road.
Hostlers (battery powered)	New technology that is only in test phase on the West Coast.
Straddle Carriers & Shuttle carriers ***(hybrid or future battery powered)***	No current zero/near-zero emission technology based Straddle Carrier equal at this time. Battery operated versions are currently in research and development phase.
FEL	No current zero/near-zero emission technology based FEL equal at this time, though it is the preferred equipment for use in San Pedro Bay and Oakland. FEL is most maneuverable and most deployable to any area of the CY & IY of the container handling/lifting equipment and has lower manning cost than overhead cranes such as RTG’s.

5.2 Anticipated Initial and Feasible Future Operational Modes

5.2.1 Introduction

The following narrative describes the existing conventional handling mode common to both port regions. Potential future all electric eRTG and high-density container handling modes are proposed that only utilize electrified equipment technology that is commercially available and has been proven to be suitable for marine terminal operations. The feasibility and challenges of implementing the proposed potential all electric modes are discussed with respect to existing operations. Capacities of the marine terminals are estimated based on the suitable storage mode that provides the highest throughput.

5.2.2 Operational Modes

In both San Pedro Bay and Oakland, container operations function in a conventional mode of container handling. The only zero/near-zero emission technology is currently performed by the STS Cranes. The exceptions are one terminal location that uses electrified RMG cranes for rail loading purpose, and one terminal location that uses electrified RMGs in a portion of their CY. For the purposes of this study, research was performed that identifies terminal configurations for the San Pedro Bay and Oakland regions based on three operational scenarios:

1. Existing Conventional Container Handling Mode: All container terminals as currently operated with the vast majority utilizing:
    a. STS Cranes – Electric
    b. RTG Cranes – Diesel
    c. FEL – Diesel
    d. RMG Cranes – Electric (limited current operations)
    e. Hostlers - Diesel
2. Potential Future All Electric eRTG Container Handling Mode: All container terminals regardless of current operations converted to:
    a. STS Cranes – Electric
    b. RTG Cranes – Electric
    c. FEL – N/A (replaced by eRTG Cranes as no feasible Electric FEL solution currently exists)
    d. RMG Cranes – Electric (all terminals IY operation)
    e. Hostlers – Electric (Battery Powered)
    f. The exception to this mode being where an all wheeled operation currently exists, the terminal will continue as such, but with electric hostlers.
3. Potential Future Combination of All Electric High-Density Container Handling Mode for all terminals where feasible and All Electric eRTG Terminals for the remainder:
    a. All Electric eRTG Terminals as stated above
    b. All Electric High-Density Container Terminals
        i. STS Cranes – Electric
        ii. RMG Cranes – Electric
        iii. Automated Guided Vehicle (AGV) – Electric (Battery Powered)

f. The exception to this mode being where an all wheeled operation currently exists, the terminal will continue as such, but with electric hostlers.

In the All Electric eRTG Container Handling Mode the two factors that would have the biggest impact to current operations:

- Replacement of FEL equipment by Electric RTG Cranes:
    - Vast majority of terminals incorporates FEL in daily operations for most handling moves
    - There is currently no zero/near-zero emission technology that supports FEL equipment configuration
    - Productivity of the FEL and Electric RTG Cranes are similar except when supporting random gate import delivery where the OTR trucks are required to drive under the RTG Crane
    - The operational cost (principally labor cost) of the Electric RTG Crane is significantly higher than that of the FEL
    - The FEL is more versatile than the RTG Cranes when reassigning and relocating handling equipment within the yard (this reduces the quantity of equipment required)
    - For the Electric RTG Cranes, additional capital investment is required for RTG runways, and in-ground or above-ground electrical power systems
- Replacement of diesel powered Hostlers by electric (battery powered) Hostlers:
    - Current study "POLA & POLB - RTG Crane Load Factor Study (2009)" indicates the diesel powered Hostler fleet is the largest producer of emissions, due to the amount of use and size of the fleet, versus other container handling equipment (Figure 4)
    - Current zero/near-zero emission technology for Hostlers only provides for single shift capability per charge
        - Hostlers would have to be charged during breaks, and possibly require greater fleet size to cover multiple shifts. The larger fleet would result in greater capital costs per unit and infrastructure.

It is also important to note, that within the container handling industry, there are few examples of modern high-throughput marine terminals that rely solely on a single type of CHE, i.e. only eRTG.

For the All Electric High-Density Container Handling Mode significant issues are the capital investment and the phasing challenges required to convert an existing conventional mode operating terminal to full All Electric High-Density mode configuration. Perhaps the most significant issue is phasing of the extensive infrastructure required for the conversion since most terminals currently require all their available space to handle current volume. Related and significant issues for conversion to electric high-density mode are:

1. Suitable terminal characteristics, such as water depth, channel width, channel air draft, and backlands acreage, to support larger capacity vessels
2. Containerized throughput volumes and investment life to feasibly finance the required conversion to electric high-density
3. Phasing the conversion while remaining in business

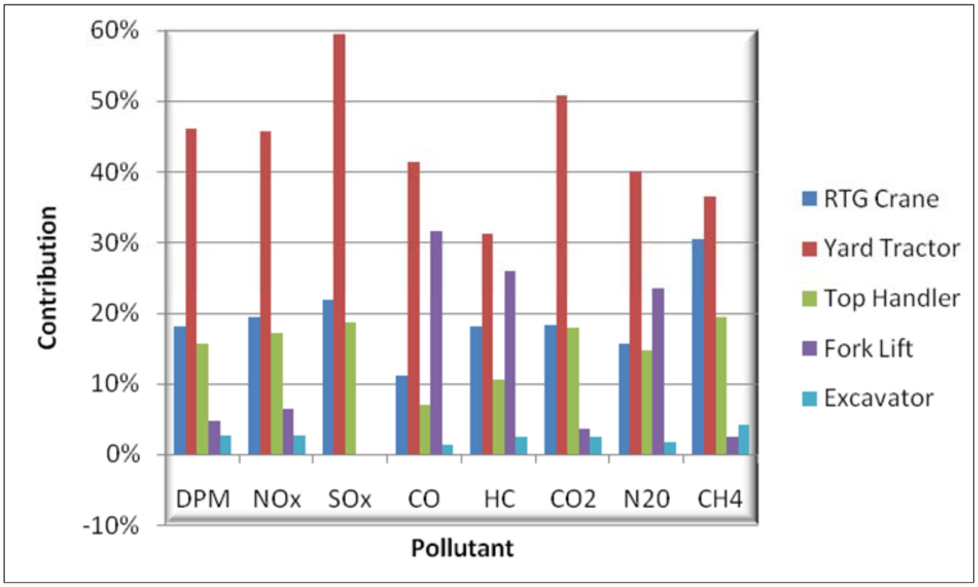

Figure 4: Emissions by Equipment Types

5.2.3 Operational Feasibility

As discussed in Section 2 above, cargo movement on the west coast of North America is unique in that throughput is virtually all import/export, or gateway cargo requiring delivery to/from over-the-road trucks and trains. There is virtually no vessel-to-vessel relay, or transshipment, volume. The significance of this is great in terms of the required yard storage area and the amount of work performed per container.

The result of these unique cargo operations is that the terminals have many landside customers and they all want exactly what they want exactly when they want it. This makes service to the landside complicated and costly. As a step to manage the landside service, most terminals in Southern California operate extended gate hours, offering several second-shift gates per week. This is primarily enabled by the PierPass program.

In addition, terminals are experiencing shortages of container storage space and difficulty managing the complicated tasks associated with landside delivery. Besides extended gate hours, other management strategies include:

- Dray-off. Import containers are discharged to chassis or to front end loader (FEL) piles and are almost immediately drayed to off-terminal yards where they are kept on wheels for delivery to landside customers.
- Peel-off. In conjunction with dray-off, import containers are discharged to FEL piles/bays with varying degrees of sorting by size and customer by bay. They are then delivered with FEL to outside drivers in the order they come out of the pile or bay without any digging.

These strategies reduce the on-terminal dwell time of containers and therefore increase the capacity of the available space and, at the same time, allow the use and realize the benefits of FEL where RTG's would have otherwise been required. These management strategies will only take the terminals so far in terms of capacity and cost. The FEL is key to these strategies and the FEL is, by necessity, diesel powered and cannot be converted to electrical power, at least there are no electric FEL projects underway at this time. The unavailability of the FEL in North American West Coast operations will result in significant impacts to the efficiency and cost of cargo movement. Efficient use of the container storage areas, effectively performing container handling work, and application of equipment best suited to perform that work is key to providing a level of service to optimize the movement of cargo through the supply chain.

The following evaluates the feasibility of the conventional and electric cargo handling modes described in Section 5.2.2 above.

5.2.3.1 Existing Conventional Container Handling Mode

West Coast container terminals have been handling containers for about 50 years and have transitioned from a predominantly wheeled operating mode to a somewhat uniform current mode that includes the following yard handling equipment uses:

CY and IY Operation	Equipment
Receive import from vessel	Front-End Loader (top pick)
Deliver export to vessel	Front-End Loader (top pick)
Deliver import to rail	Front-End Loader (top pick)
Receive export from rail	Front-End Loader (top pick)
Receive export from OTR truck	Front-End Loader (top pick)
Deliver Import to OTR truck	Peel-off: Front-End Loader (top pick) Random: RTG
Receive and deliver empties	Front-End Loader (side pick)
Railcar loading and unloading	Front-End Loader (top pick/reach stacker)

Around 75% of all in-yard handling moves are performed with front-end loaders (FEL). This is a result of the machines' container handling productivity, low capital cost, low operational cost, flexibility to move around the terminal, ability to augment RTG operations on the same stack, and favorable manning compared to RTG. A principle advantage of the FEL over overhead types of yard cranes is their ability to store containers in very large "super-stacks" up to 15 container rows deep where large sorts can be assembled such as exports and empties. In this way, this mode is able to increase the density of storage slots per acre.

Around 25% of the in-yard handling moves are performed with an RTG. This smaller percentage is principally due to the RTG's slower deployment throughout the terminal, the comparatively high initial, and higher manning costs.

The principle disadvantages of the FEL are:

- It requires container storage to be allocated by bay which reduces slot utilization.
- Bay allocation also requires bay separation (a machine working one bay closes the adjacent bays to traffic), which reduces utilization of traffic space especially during times when vessel demand is high.
- It cannot effectively be used for random delivery of imports, because it is very inefficient at digging from a pile.

With increased pressures caused by capacity, demand for landside service efficiency and demand for increased vessel productivity, combined with the anticipated mandate to electrify, the top picks days as the work horse may be numbered. There are currently only two proven electrified alternatives to the current FEL dominated operating mode;

- Increased use of eRTG's. This mode addresses electrification, but may not provide the required productivity, cost efficiency and service levels. On the North America west coast, very large vessel and call sizes (moves per call) combine with very high landside receiving and delivery demand to produce a near-constant high volume of moves per hour in the container yard. This, combined with reduced dwell time compresses the activity per time and space. In an RTG terminal, vessel and gate traffic must mix in the traffic lanes and compete for the lift machines. The result, in an all-RTG mode, would be reduced levels of service to over-the-road drivers, increased turn times and longer queues of idling trucks, thereby increasing emissions
- Development of high-density stacking and retrieval systems (ASC). This electrified mode has the potential to provide the required waterside and landside productivity at lower operating costs compared to eRTG. A principle advantage of this mode is that waterside and landside traffic is separated and each is served by its own dedicated fleet of transporters and stacking cranes.

In general, the California ports are unique in many ways from their market position, to their vessel call sizes, to labor, to financing, and landside service complexity. It would be incorrect to assume that some terminal model from another port market could simply be transplanted and succeed. Given the number of jobs involved and the importance of the maritime industry to the economy of the State, it is imperative to get it right the first time for the region as well as for each terminal.

5.2.3.2 Electric RTG Container Handling Mode

Due to the disadvantages listed below, this mode may not provide suitable service for North America west coast operations.

The proposed mode anticipates the following yard handling equipment uses:

CY and IY Operation	Equipment
Receive import from vessel	eRTG
Deliver export to vessel	eRTG
Deliver import to rail	eRTG
Receive export from rail	eRTG
Receive export from OTR truck	eRTG
Deliver Import to OTR truck	eRTG
Receive and deliver empties	eRTG
Railcar loading and unloading	eRMG

The replacement of the FEL with the eRTG, will result in the following advantages:

- Container storage to be allocated by ground slot which increases slot utilization.
- Higher storage density, which increases container storage area utilization.
- Efficient for digging from a pile for random delivery of imports.

The principle disadvantages of the eRTG are:

- Only a modest gain in productivity compared with conventional operations.
- Due to the relative inability to move around the terminal, eRTGs are deployed by container storage zone, i.e., in southern California, about one RTG for each 715 TEU of storage space, which results in an increase of the eRTG fleet size.
- eRTGs require more manning, as compared to a FEL or ASC, which increases operational costs.
- The inability to separate the waterside traffic from the landside traffic will be removed. The resulting mixing of waterside and landside traffic to be served by the eRTGs will result in significant congestion of on-terminal and OTR vehicles.
    - Congestion would result in significantly increased off-terminal and on-terminal queues of trucks and resulting increased emissions.

5.2.3.3 Electric High Density Container Handling Mode

This mode is currently implemented and suitable for North America west coast operations.

The proposed mode anticipates the following yard handling equipment uses:

CY and IY Operation	Equipment
Receive import from vessel	ASC
Deliver export to vessel	ASC
Deliver import to rail	ASC
Receive export from rail	ASC
Receive export from OTR truck	ASC
Deliver Import to OTR truck	ASC
Receive and deliver empties	ASC
Railcar loading and unloading	eRMG

The use of electrified ASC, will result in the following advantages:

- Highest productivity.
- Higher equipment movement speeds, which increase equipment productivity.
- Consistent operational productivity.
- Higher operational safety.
- Container storage stack height, and thereby storage density, is increased.
- Container storage allocation is not required which maximizes stack and storage area utilization.
- Minimizes ground space utilization which increases terminal area utilization.
- Efficient for digging from a pile for any container.
- Operations can be remote in a controlled workspace which increase labor safety and efficiency.
- Can separate waterside and landside traffic, to decrease terminal congestion and increase operational safety.
- Decreased truck turn times, congestion and idling.
- Support automated horizontal transport mode.

The principle disadvantages from an electrified high density, will result in the following disadvantage:

- Requires significant phasing challenges to implement into existing terminal operations.

5.2.4 All Electric eRTG Container Handling Mode

Regardless of the feasibility of this handling mode on the North America west coast, for the purposes of this study, it is assumed that at some point technology, operational challenges, and cost considerations would allow for all container terminals in San Pedro Bay and Oakland Regions be converted to All Electric eRTG Container Handling Mode. As previously stated, the All Electric eRTG Container Handling Mode would include in general:

- STS Cranes – Electric
- RTG Cranes – Electric
- RMG Cranes – Electric (all terminals IY operation)
- Hostlers – Electric (Battery Powered)

It is estimated that All Electric eRTG Container Handling Mode terminals would have a throughput capacity of 7,200 TEU per year per gross acre.

There is one exception for one particular Long Beach and Oakland terminal where current terminal operations are predominantly all wheeled (containers remain on chassis). Although the all wheeled operation does use FEL for some functions (for example, empty container stacking). For this analysis, it is assumed that the FEL operations would be converted to use eRTG for those same functions. The future operation anticipates that the wheeled operations continue (without RTG or RMG cranes). However, it is assumed that the diesel powered hostlers would be replaced by electric (battery powered) hostlers. It is estimated that All Electric eRTG Container Handling Mode terminals that are wheeled operations (electric hostlers only) would have an estimated capacity of about 3,500 TEU per gross acre per year capacity limit.

In some instances, terminals, while convertible to an All Electric eRTG Container Handling Mode scenario, do not have the required terminal characteristics that would support All Electric High-Density mode (see narrative to follow).

5.2.5 All Electric High-Density Container Handling Mode

Not all terminals are currently suitable for conversion to All Electric High-Density terminals. The San Pedro Bay and Oakland terminals were reviewed for capability to accommodate larger vessels in terms of water access (water depth, channel width and depth, turning basin diameter, and channel air draft) and suitable backland acreage for containerized transfer/storage. It is estimated that an All Electric High-Density terminal would require a minimum of 100 gross acres for each large vessel service. The following tables illustrate, by port area, the terminals approximate gross acres and vessel size accommodations.

Table 22: San Pedro Bay Terminals Gross Acres

	Location	Terminal Name	Approximate Gross Acres
Port of Los Angeles	Berths 226-236	Everport Container Terminal	205
	Pier 300	EMS (APL) Container Terminal	292
	Pier 400	APM Terminals	484
	Berths 212-225[1]	Yusen Container Terminal	185
	Berths 136-139[1]	TraPac Container Terminal	196
	Berths 100, 121-126[1]	West Basin Container Terminal	311
Port of Long Beach	Pier J North	Pacific Container Terminal	160
	Pier J South	Pacific Container Terminal	107
	Pier G	International Transportation Service	255
	MHT	Long Beach Container Terminal	325
	Pier T	Total Terminals International	375
	Pier A[1]	SSA Terminal	195
	Pier C[1]	SSA Terminal	59

[1]Air draft and or channel restriction.

Table 23: Oakland Terminals Gross Acres

	Location	Terminal Name	Gross Acres
Port of Oakland	Berth 20-26	Ports America Outer Harbor Terminal	204
	Berth 35-38	Ben E. Nutter Terminal	74
	Berth 55-59	Oakland International Container Terminal	270
	Berth 60-63	Matson Terminal	80
	Berth 30-32	TraPac Terminal	66

Table 24 and Table 25 illustrate the probable maximum vessel size (up to future 24,000 TEU) capability at the San Pedro Bay and Oakland terminals, respectively.

Table 24: San Pedro Bay Terminals Vessel Access

Location		Terminal Name	Max. Vessel Size (TEU)
Port of Los Angeles	Berths 226-236	Everport Container Terminal	24,000
	Pier 300	EMS (APL) Container Terminal	24,000
	Pier 400	APM Terminals	24,000
	Berths 212-225[1]	Yusen Container Terminal	14,000
	Berths 136-139[1]	TraPac Container Terminal	14,000
	Berths 100, 121-126[1]	West Basin Container Terminal	14,000
Port of Long Beach	Pier J North	Pacific Container Terminal	14,000
	Pier J South	Pacific Container Terminal	24,000
	Pier G	International Transportation Service	14,000
	MHT	Long Beach Container Terminal	24,000
	Pier T	Total Terminals International	24,000
	Pier A[1]	SSA Terminal	9,000
	Pier C[1]	SSA Terminal	9,000
[1]Air draft and or channel restriction.			

Table 25: Oakland Terminals Vessel Access

Location		Terminal Name	Max. Vessel Size (TEU)
Port of Oakland	Berth 20-26	Ports America Outer Harbor Terminal	18,000
	Berth 35-38	Ben E. Nutter Terminal	18,000
	Berth 55-59	Oakland International Container Terminal	18,000
	Berth 60-63[1]	Matson Terminal	6,000
	Berth 30-32	TraPac Terminal	18,000
[1]Terminal is likely too small to justify elec. high-density operation.			

It is estimated that All Electric High-Density Container Handling Mode terminals would have a throughput capacity of about 10,000 TEU per year per gross acre.

5.2.6 Capacity by Operational Mode

Based on the estimated annual terminal capacity (eHostler = 3,500 TEU/Ac, eRTG = 7,200 TEU/Ac and ASC = 10,000 TEU/Ac), the current gross terminal acres, and the anticipated possible terminal operating scenario, Table 26 and Table 27 were developed to illustrate the estimated potential regional capacity for San Pedro Bay and Oakland terminals.

Table 26: San Pedro Bay Potential Mode & Resulting Capacity (Annual TEUs)

	Location	Terminal Name	eHostlers	eRTG	ASC	Estimated Capacity (annual TEUs)
Port of Los Angeles	Berths 226-236	Everport Container Terminal			✓	2,050,000
	Pier 300	EMS (APL) Container Terminal			✓	2,920,000
	Pier 400	APM Terminals			✓	4,840,000
	Berths 212-225	Yusen Container Terminal		✓		1,332,000
	Berths 136-139	TraPac Container Terminal			✓	1,960,000
	Berths 100, 121-126	West Basin Container Terminal			✓	3,110,000
Port of Long Beach	Pier J North	Pacific Container Terminal			✓	1,600,000
	Pier J South	Pacific Container Terminal			✓	1,070,000
	Pier G	International Transportation Service			✓	2,550,000
	MHT	Long Beach Container Terminal			✓	3,250,000
	Pier T	Total Terminals International			✓	3,750,000
	Pier A	SSA Terminal			✓	1,950,000
	Pier C[1]	SSA Terminal	✓			206,500

[1]Terminal is likely too small to justify ASC operation.

Table 27: Oakland Potential Mode & Resulting Capacity (Annual TEUs)

	Location	Terminal Name	eHostlers	eRTG	ASC	Capacity (annual TEUs)
Port of Oakland	Berth 20-26	Ports America Outer Harbor Terminal			✓	2,040,000
	Berth 35-38	Ben E. Nutter Terminal		✓		532,800
	Berth 55-59	Oakland International Container Terminal			✓	2,700,000
	Berth 60-63[1]	Matson Terminal	✓			280,000
	Berth 30-32	TraPac Terminal			✓	660,000

[1]Terminal is likely too small to justify ASC operation.

The resulting total capacities by operational modes for the two port regions are summarized as follows in Table 28. The capacities shown are based on the assumed throughput capacities of the mode indicated in Tables 26 and 27, and the existing terminal acreage indicated in Tables 22 and 23.

Table 28: Regional Capacity by Mode of Operation (Annual TEUs)

Operations	San Pedro Bay	Oakland (annual TEUs)
Conventional Operations	20,292,000	4,271,000
eRTG Operations	22,455,000	4,701,000
ASC Operations	30,589,000	6,213,000

6. Zero/near-zero Emission Technology ROM Costs

6.1 Capital ROM Costs (CAPEX)

Introduction

The following narrative describes the anticipated Rough Order of Magnitude (ROM) comparable CAPEX costs to implement zero/near-zero emission CHE in the San Pedro Bay and Oakland regions. ROM CAPEX costs are estimated for:

- Equipment (eRTG Operations and Electric High-Density Operations modes) by terminal and totals
- Electrical Infrastructure (eRTG Operations and Electric High-Density Operations modes) by terminal and totals
- Civil Works by terminal and totals

Two cost scenarios (eRTG and Electric High-Density Operations) were developed for terminal related CAPEX costs. These scenarios consider one, the cost of electrifying a terminal to support an eRTG operation (includes eHostlers) and two, the cost of developing an All Electric High-Density terminal. Note that these ROM CAPEX costs to not include costs outside the fence line, land acquisition, environmental, or other soft cost issues.

6.1.1 Zero/Near-Zero Emission Equipment ROM CAPEX Costs

6.1.1.1 Equipment Unit ROM Costs

Table 29 summarizes the costs associated with existing equipment electrification upgrades or new equipment procurement. It should be noted that the AGV battery building cost is a required infrastructure cost to support the charging a fleet of AGV equipment, one building is required per terminal and no redundancy is included in the cost.

Table 29: Electric Equipment Unit ROM Costs

Equipment Type	Cost
ERTG Crane	$1.8 million
Diesel RTG to E-RTG	$450,000
E-RMG Crane	$2 million – $4 million
RMG Electrification	$700,000
Electric Hostler	$200,000
Automated Guided Vehicle (AGV)	$1 million
AGV Battery Building	$20 million

Based on remaining life data received from PMSA membership, the average RTG equipment unit in the San Pedro Bay and Oakland regions is at the end of its 15 year life span. Therefore, for the purposes of this Technical Memorandum, it is assumed that new eRTGs would be acquired to replace the vintage fleet in the eRTG Operations mode.

6.1.1.2 Equipment Quantity Needs by Terminal – eRTG Operations Mode

The following information was used to estimate the number of units for the eRTG Operations mode:

- Annual throughput capacity (based on 7,200 TEU/Gross Acre/Year)
- 100% of moves by eRTG equipment
    - Average productivity of 12 moves/hour
    - 5,000 operational hours per year (approximate)
- eHostler fleet requirements were sized to support the eRTG productivity
- CY peaking factor of 1.2
- CY moves per vessel move of 1.25

As previously noted, not all terminals are viable candidates for conversion to eRTG operations mode. Therefore, the following terminals are included in the ROM cost estimation but not for eRTG equipment (never the less, electrified equipment):

- Pier C, Matson, Oakland: Current Wheeled/FEL/Hostler operation conversion to Wheeled/eRTG/eHostler
- Berth 60-63, Matson, San Pedro Bay: Current Wheeled/FEL/Hostler operation conversion to Wheeled/eRTG/eHostler

The required equipment for the San Pedro Bay and Oakland regions when converted to all electric eRTG mode terminals is summarized in Table 30.

Table 30: San Pedro Bay and Oakland Electrified Equipment Needs

	Total San Pedro Bay and Oakland Regions – eRTG Operations Mode, Electrified Equipment Needs		
Region	**eRTG**	**eRMG**	**EHostler**
San Pedro Bay	928	4	1,628
Oakland	184	0	280
Totals	**1,112**	**4**	**1,908**

6.1.1.3 Equipment ROM Costs by Terminal – eRTG Operations Mode

The following estimate of ROM costs for equipment in the eRTG Operations Mode is based on the estimate of equipment needs (quantities) and the previously stated equipment ROM costs.

The electrified equipment ROM costs for the San Pedro Bay and Oakland regions when converted to all electric eRTG mode terminals is summarized in Table 31.

Table 31: eRTG Operations Mode Electrified Equipment ROM Costs All Regions

Total San Pedro Bay and Oakland Regions – eRTG Operations Mode Electrified Equipment ROM Costs			
Region	**eRTG**	**eRMG**	**EHostler**
San Pedro Bay	$1,670,400,000	$17,351,000	$325,581,000
Oakland	$331,200,000	0	$56,000,000
Totals	$2,001,600,000	$17,351,000	$381,581,000

6.1.1.4 Equipment Quantity Needs by Terminal – Electric High-Density Operations Mode

The following information was used to estimate the number of units for the ASC Operations mode:

- Annual throughput capacity (based on 10,000 TEU/Gross Acre/Year)
- 100% of moves by ASC equipment
  - o Average productivity of 17 moves/hour for end-loaded and 20 moves/hour for side loaded
  - o Hours per year of approximately 7,000
- AGV fleet requirements were sized to support the ASC productivity
- CY peaking factor of 1.2
- CY moves per vessel move of 1.25

As previously noted, not all terminals are viable candidates for conversion to .electric high-density mode Therefore, the following terminals are included in the ROM cost estimation but not for ASC equipment (never the less, electrified equipment):

- Pier C, Matson, Oakland: Current Wheeled/FEL/Hostler operation conversion to Wheeled/eRTG/eHostler
- Berth 60-63, Matson, San Pedro Bay: Current Wheeled/FEL/Hostler operation conversion to Wheeled/eRTG/eHostler
- Berth 212-225, YTI, San Pedro Bay:

The required equipment for the San Pedro Bay and Oakland regions when converted to Electric High-Density Operations Mode terminals is summarized in Table 32.

Table 32: Total San Pedro Bay and Oakland Regions – Elec. High-Density Operations Mode , Equipment Needs

Total San Pedro Bay and Oakland Regions – Elec. High-Density Operations Mode, Electrified Equipment Needs					
Location	**eRTG**	**ASC**	**AGV**	**eRMG**	**eHostler**
San Pedro Bay	56	571	563	60	486
Oakland	6	116	116	0	17
Totals	**62**	**687**	**679**	**60**	**503**

6.1.1.5 Equipment ROM Costs by Terminal – Electric High-Density Operations Mode

The following estimate of ROM costs for equipment in the Electric High-Density Operations Mode is based on the estimate of equipment needs (quantities) and the previously stated equipment ROM costs.

The electrified equipment ROM costs for the San Pedro Bay and Oakland marine terminals when converted to Electric High-Density Operations Mode terminals is summarized in Table 33.

Table 33: Total San Pedro Bay and Oakland Regions – Elec. High-Density Operations Mode , Equipment ROM Costs

Total San Pedro Bay and Oakland Regions – Elec. High-Density Operations Mode , Equipment ROM Costs					
Location	**eRTG**	**ASC**	**AGV**	**eRMG**	**eHostler**
San Pedro Bay	$100,800,000	$1,698,400,000	$563,000,000	$270,620,000	$97,126,000
Oakland	$10,800,000	$346,400,000	$116,000,000	$0	$3,400,000
Totals	$111,600,000	$2,044,800,000	$679,000,000	$270,620,000	$100,526,000

6.1.2 Electrical Infrastructure ROM Costs

6.1.2.1 eRTG Operations Mode Terminal

It is assumed that the electrical infrastructure needed to support an eRTG operation mode is based on the ROM unit costs per 100 gross terminal acres, as shown in Table 34.

Table 34: eRTG Operations Mode Terminal Electrical Infrastructure Unit Costs

eRTG Operations Mode – Electrical Infrastructure Only (per 100 gross acres)	
Switchgear	$2.5 million
Cabling and distribution	$1.5 million
Main substation	$2.5 million
Battery Charging yard vehicles	$1.5 million
Electric Utility Service	$0.5 million
Total (per 100 Gross Acres)	**$8.5 million**

The electrical infrastructure only ROM costs for all thirteen (13) of San Pedro Bay and five (5) Oakland Terminals when converted to electric eRTG mode terminals is as illustrated in Table 35.

Table 35: eRTG Mode Terminal Costs Electrical Infrastructure Only

San Pedro Bay and Oakland – eRTG Operations Mode, ROM Costs Electrical Infrastructure Only	
Location	Cost
San Pedro Bay (13 Terminals)	$267,665,000
Oakland (5 Terminals)	$57,800,000
Total	$325,465,000

6.1.2.2 All Electric High-Density Mode Terminal

It is assumed that the electrical infrastructure needed to support an Electric High-Density Operation Mode is based on the following unit ROM costs per 100 gross terminal acres.

Table 36: All Electric High-Density Mode Terminal Electrical Infrastructure Unit Costs

All Electric High-Density Terminal – Electrical Infrastructure Only (Per 100 Gross Acres)	
Switchgear	$2.5 million
Cabling and distribution	$1.5 million
Main substation	$3.0 million
Battery Charging AGVs	$2.5 million
Electric Utility Service	$0.5 million
Total (per 100 Gross Acres)	**$13.0 million**

The electrical infrastructure only ROM costs for all San Pedro Bay and Oakland terminals when converted to Electric High-Density Mode terminals is as illustrated in Table 37.

Table 37: Elec. High-Density Mode Terminal Costs Electrical Infrastructure Only

San Pedro Bay and Oakland – All Electric High-Density Operations Mode, ROM Costs Electrical Infrastructure Only	
Location	**Cost**
San Pedro Bay (13 Terminals)	$409,370,000
Oakland (5 Terminals)	$88,400,000
Total	$497,770,000

6.1.3 Civil Infrastructure ROM Costs

The following civil related infrastructure ROM costs include terminal civil improvements to support the eRTG and All Electric High-Density Operations Mode of the San Pedro Bay and Oakland regions. The ROM costs are provided on a per gross terminal acre basis as identified in the following sections.

6.1.3.1 eRTG Operations Mode Terminal

The eRTG Operations ROM civil infrastructure costs are developed with the following assumptions:

- New RTG runways
- New Bus bar system (to supply power to the eRTG)
  - Foundation system
  - Equipment
  - Bus bar electrical infrastructure
- Terminal electrical infrastructure (to support eRTG and eHostler equipment)
- Light pole relocations
- Some electrical infrastructure relocations
- New signage and striping

It is estimated that the civil infrastructure related cost to convert the existing terminals to eRTG Operations Mode terminals is approximately $350,000 per gross acre. Based on this civil infrastructure related ROM cost, the civil infrastructure costs for terminals in the San Pedro Bay and Oakland are illustrated in Table 38.

Table 38: eRTG Mode Terminal Costs Civil Infrastructure Only

San Pedro Bay and Oakland – eRTG Operations Mode, ROM Costs Civil Infrastructure Only	
Location	**Cost**
San Pedro Bay (13 Terminals)	$1,102,159,000
Oakland (5 Terminals)	$ 242,900,000
Total	$1,345,059,000

6.1.3.2 All Electric High-Density Operations Mode Terminal

The Electric High-Density Operations mode civil infrastructure-related ROM costs are developed with the following assumptions:

- New pavement for stack areas
- New Bus bar system (to supply power to the eRTG at those locations that use eRTG (see narrative to follow))
  - Foundation system
  - Equipment
  - Bus bar electrical infrastructure

- Terminal electrical infrastructure (to support ASC and AGV equipment) (eRTG and eHostler equipment at those locations that use eRTG (see narrative to follow))
- Light pole relocations
- Some electrical infrastructure relocations
- New signage and striping

As previously noted, not all terminals are viable candidates for conversion to electric high-density. Therefore, three small terminals are included in the ROM cost estimation but not for ASC equipment:

It is estimated that the civil infrastructure related cost to convert the existing terminals to Electric High-Density Operations Mode terminals is approximately $2,000,000 per gross acre. Based on this civil related ROM cost, the Electric High-Density Operations Mode costs for terminals in the San Pedro Bay and Oakland are illustrated in Table 39.

Table 39: Elec. High-Density Mode Terminal Costs Civil Infrastructure Only

San Pedro Bay and Oakland – All Electric High-Density Operations Mode, ROM Costs Civil Infrastructure Only	
Location	**Cost**
San Pedro Bay (13 Terminals)	$6,108,086,000
Oakland (5 Terminals)	$ 1,238,000,000
Total	$7,346,086,000

6.1.4 Total ROM Costs

The CAPEX costs of all electric eRTG or all electric high-density equipment modes include equipment and "inside the terminal fence" electrical infrastructure and civil works required to accommodate the electrical needs of the new equipment. However, these costs do not include infrastructure and additional costs associated with increasing the capacity of the electrical power grid. The port authorities and utility providers would incur the cost of electrical infrastructure that will be needed outside the physical boundaries of the marine terminals. In addition, the CAPEX does not include costs resulting from phased implementation of the zero/near-zero emission technology into on-going terminal operations that include increased costs resulting from reduced productivity, lost revenue from repositioned cargo to other terminals during construction, and costs of phased construction.

6.1.4.1 eRTG Operations Mode

Total initial ROM CAPEX costs to renovate terminals to operate in the eRTG Operation mode in the San Pedro Bay and Oakland are summarized in Table 40.

Table 40: eRTG Operations Mode Terminals Total Initial ROM CAPEX Costs

eRTG Operations Mode Terminals Total Initial ROM CAPEX Costs – San Pedro Bay and Oakland Regions				
Region	**Equipment**	**Electrical**	**Civil**	**Totals**
San Pedro	$3,363,332,000	$267,665,000	$1,102,159,000	$4,733,156,000
Oakland	$684,200,000	$57,800,000	$242,900,000	$984,900,000
Total CAPEX Cost	$4,047,532,000	$325,465,000	$1,345,059,000	$5,718,056,000
Initial CAPEX Cost/TEU of Annual Capacity				$211

6.1.4.2 Electric High-Density Operations Mode

Total initial ROM CAPEX costs to renovate terminals to operate in the Electric High-Density mode in the San Pedro Bay and Oakland are summarized in 41.

Table 41: Electrified Terminalc High-Density Operations Modes Total Initial ROM CAPEX Costs

Elec. High-Density Operations Mode Terminals Total Initial ROM CAPEX Costs – San Pedro Bay and Oakland Regions				
Region	**Equipment**	**Electrical**	**Civil**	**Totals**
San Pedro	$4,052,945,000	$409,370,000	$6,108,086,000	$10,570,402,000
Oakland	$764,600,000	$88,400,000	$1,238,000,000	$2,091,000,000
Total CAPEX Cost	$4,817,545,000	$497,770,000	$7,346,086,000	$12,661,402,000
Initial CAPEX Cost/TEU of Annual Capacity				$344

6.1.5 Thirty-Year Cost Comparison

The previously stated costs related to equipment, electrical infrastructure and civil infrastructure works are needed to implement an eRTG or Electric High-Density Operations mode.

Other costs to be considered are those costs associated with equipment life span as previously discussed for existing conventional equipment.

As previously estimated, the CHE owners will spend nearly $7 billion for replacing conventional container handling equipment within the next 30 years based on the typical life span of the equipment in the two port regions studied.

While the replacement cost of conventional CHEs is a significant amount of capital investment on its own, the cost of converting to and replacing, based on equipment life span, all CHE with zero/near-zero technology for the eRTG operational mode is approximately $23 billion (or more than double that of conventional). The cost includes initial equipment capital cost, electrical infrastructure and related civil works cost, and is based on a 30 year planning horizon. Likewise, the cost to convert to All Electric High-Density operations results in a cost of approximately $35 billion. The total equipment (initial acquisition and replacement), civil and electrical costs for all electric eRTG and All Electric High-Density compared to conventional equipment is illustrated in Table 42.

Table 42: 30-yr CAPEX Costs for All-electric and All Electric High-Density Compared to Conventional Equipment

Operational Mode	Equipment, and Electrical and Civil Infrastructure CAPEX Costs	CAPEX/TEU Annual Capacity
Conventional	$7 billion	$285
All Electric eRTG	$23 billion	$847
All Electric High-Density	$35 billion	$951

6.2 Operational and Maintenance ROM Costs (OPEX)

In addition to capital expenditure costs for implementing eRTG and ASC operational modes, operational expenditure (OPEX) costs were also evaluated in order to understand anticipated future re-occurring costs. The current OPEX costs were also evaluated in order to draw a comparison of OPEX related costs of conventional, eRTG and electric high-density operational modes.

The reported OPEX related costs vary from terminal to terminal. In order to provide a uniform comparison of the three operational modes, OPEX costs for current operations include the same assumptions (where feasible) as those for the future operating modes.

The following assumptions were used in order to estimate OPEX costs for current conventional and future potential eRTG and electric high-density operational modes:

- Yard moves per vessel move ratio 1.25
- On-dock rail percent 25%
- Current and eRTG equipment gross moves per hour
  - STS Crane 25
  - RTG Crane 10
  - FEL 15
  - Hostler 3
- All Electric High-Density equipment gross moves per hour
  - STS Crane 32
  - ASC Crane 12-17
  - FLT 15
  - AGV 8

- Energy cost per unit
    - Diesel $1.07/l
    - Electric $0.20/kWh
- Maintenance Cost per Lift (by Operational Mode)
    - Conventional $28
    - eRTG $21
    - ASC $17
- Labor Cost per Lift (by Operational Mode)
    - Conventional $177
    - eRTG $194
    - ASC $147

The labor, energy and maintenance (OPEX) costs are understandably less for the electric high-density container handling equipment mode than that of the conventional or current container handling mode of operations. Figure 5 illustrates the OPEX cost differences for the current, eRTG and electric high-density operational modes per 1,000,000 TEU of throughput per year.

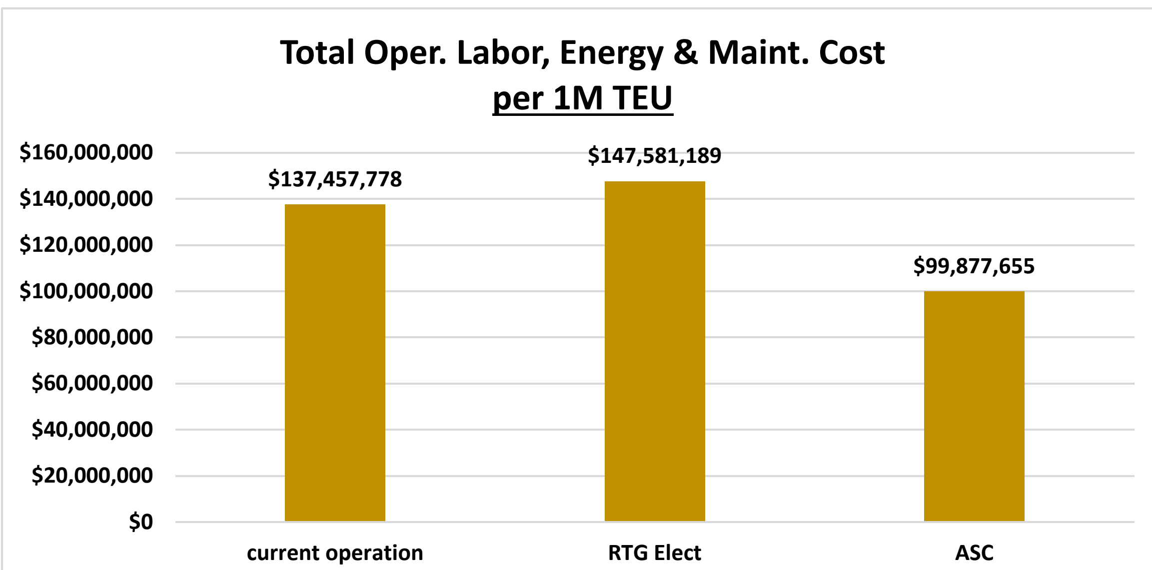

Figure 5: Total Operating, Labor, Energy and Maintenance Cost per 1 million TEU

Applying the capacity information for the various operational modes presented in a previous section of this document, results in estimated annual OPEX costs (based on current dollars) as illustrated in Table 43 (assuming that the terminals operate at capacity).

Table 43: Annual OPEX costs by Location and Operational Mode

Annual OPEX costs by Location and Operational Mode			
Location	**Conventional**	**eRTG**	**Elec. High-Density**
San Pedro Bay	$2,789,293,000	$3,313,817,000	$3,055,117,000
Oakland	$587,082,000	$693,750,000	$620,520,000
Total	$3,376,375,000	$4,007,567,000	$3,675,697,000

While the total OPEX costs appear similar, it is important to note that because the values are based on capacity, the similar values for All Electric High-Density container handling operations actually address more container handling needs (throughput). As previously stated, the estimated capacity for the various operational modes are as follows:

- Conventional (current) – 6,500 TEU/Gross Acre/Year
- eRTG – 7,200 TEU/Gross Acre/Year
- All Electric High-Density - 10,000 TEU/Gross Acre/Year

The following table illustrates the relationship of the total OPEX cost for both Port areas to the estimated capacity of the Operational modes.

Annual OPEX Costs and Capacity Estimate Relationship			
	Conventional	**eRTG**	**Elec. High-Density**
Cost (Totals)	$3,376,375,000	$4,007,567,000	$3,675,697,000
Capacity (TEU/Yr)	24,563,000	27,155,000	36,802,000
Cost/TEU of Capacity	$137	$148	$100

In other words, the OPEX cost per TEU is lowest for the electric high-density operational mode, as shown in Figure 6. Note that the eRTG OPEX per TEU cost is the largest value. In the case of the RTG or eRTG, the manning requirements for the associated equipment produces a high labor cost that cannot be mitigated by savings in energy and maintenance.

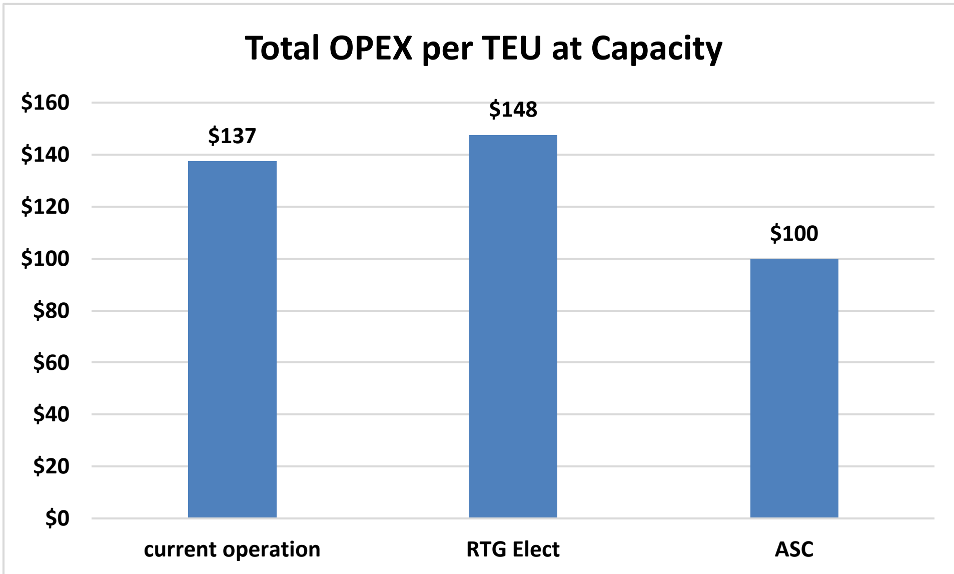

Figure 6: Total OPEX per TEU at Capacity

Where OPEX reflects more significant differential can be seen over the 30 year planning horizon. The following table illustrates the total OPEX costs that would be incurred over the entire 30 year planning horizon for the three different operational modes assuming that the terminals operate at capacity and the annual escalation rate is 5%. Converting to eRTG would result in an additional OPEX of approximately $31 billion and converting to electric high-density an additional OPEX of approximately $39 billion.

Table 44: 30-yr Total OPEX Costs (2015-2045)

30-yr Total OPEX Costs (2015-2045)			
	Conventional	**eRTG**	**Elec. High-Density**
Total OPEX	$238,914,962,000	$283,578,606,000	$260,095,223,000

6.3 CAPEX and OPEX ROM Costs

Table 45 summarizes both the capital expenditures (equipment, electrical infrastructure and civil) and the operational expenditures (maintenance, energy and labor) that would be spent by all San Pedro and Oakland terminals over the next 30 years for each of the operational modes. The total CAPEX and OPEX is compared to the throughput capacity of the terminals in both port regions. The electric high-density operations mode provides the lowest initial capital and annual operations expenditures for the throughput capacity of the terminal.

Table 45: Total CAPEX and OPEX Costs (2015-2045)

Total CAPEX and OPEX Costs (2015-2045)			
	Conventional	**eRTG**	**Elec. High-Density**
CAPEX	$7 Billion	$23 Billion	$35 Billion
OPEX	$239 Billion	$284 Billion	$260 Billion
Capacity (TEU/yr)	24,563,000	27,155,000	36,802,000
CAPEX and OPEX per Capacity ($/TEU/yr)	$10,000	$11,300	$8,000