Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles

100 Centennial Celebration

Port of LONG BEACH

The Green Port

THE PORT OF LOS ANGELES

Technical Report

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Acronyms and Abbreviations

ACTA	Alameda Corridor Transportation Authority
AQMD	South Coast Air Quality Management District
CAAP	San Pedro Bay Ports' Clean Air Action Plan
CalHEAT	California Hybrid Efficient and Advanced Truck
CARB	California Air Resources Board
CCDoTT	Center for Commercial Deployment of Transportation Technologies
CEC	California Energy Commission
CHE	cargo handling equipment
CO_2	carbon dioxide
DOE	United States Department of Energy
DPM	diesel particulate matter
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	United Stated Environmental Protection Agency
FRA	Federal Railroad Administration
GA	General Atomics
GCWR	gross combined weight rating
GHG	greenhouse gas
HC	harbor craft
HDV	heavy-duty vehicle
hp	horsepower
HSRT	high-speed, high-performance regional transportation system
HTUF	hybrid truck user's forum
ICTF	Intermodal Container Transfer Facility
LSM	linear synchronous motor
maglev	magnetic levitation
MCS	Major Corridor Study
Metro	Metropolitan Transportation Authority
MOU	memorandum of understanding
mph	miles per hour
NOx	nitrogen oxides
OCS	overhead catenary system
OGV	ocean-going vessel
PHL	Pacific Harbor Line
PM	particulate matter
ppm	parts per million
RFCS	Request for Concepts and Solutions
RFP	Request for Proposals
RL	railroad locomotive
RMG	rail-mounted gantry crane
ROW	right of way
RTG	rubber-tired gantry crane

Acronyms and Abbreviations (continued)

RTP	Regional Transportation Plan
SCAG	Southern California Association of Governments
SoCAB	South Coast Air Basin
SOx	sulfur oxides
TAC	technical advisory committee
TAP	San Pedro Bay Ports' Technology Advancement Program
TTC	Transportation Technology Center
UP	Union Pacific Railroad
USC	University of Southern California
ZECMS	Zero Emission Container Movement System

1. Introduction

For the last five years, the ports of Long Beach and Los Angeles have been evaluating zero emission goods movement technologies prompted by Boards of Harbor Commissioners that are keenly interested in leading the nation's two greenest ports into a cleaner future, by community demands for cleaner air, and by regulatory pressure to reduce the ports' "fair share" of air emissions. The purpose of this report is to provide a roadmap for moving forward with the identification, evaluation, and integration of zero emission technologies into ongoing port-related goods movement.

This report was jointly prepared by the staffs of the Port of Long Beach and Port of Los Angeles, with assistance from Starcrest Consulting Group, LLC. This report will:

- Define and clarify what is meant by "zero emission technologies" and how employing such technologies in the appropriate manner can assist the ports and the region in meeting their air quality and health risk reduction needs;
- Describe the technical and programmatic attributes of candidate zero emission technologies, including how they can be potentially integrated into goods movement;
- Explain the criteria and the process used to uniformly and impartially evaluate the technical and programmatic viability of zero emission technologies for drayage over short-haul distances and for in-terminal container handling equipment, and that will also be used for evaluation of additional technologies and other source categories in the future;
- Present the findings of the evaluation process for zero emission technologies, including constraints and opportunities related to near-term and longer-term options;
- Present recommendations for "next steps" in implementing zero emission technologies into port-related goods movement operations.

By the end of this paper, the reader should have a clear understanding of the roadmap for moving forward with zero emission technologies in port-related operations, based on the following key principles:

- The ports should pursue zero emission technologies for those segments of port operations where technically feasible and economically viable solutions are most likely to develop - on-road drayage, in-terminal container handling, and railroad locomotives.
- The ports must identify the technology options that are best suited for integration into port-related operations (e.g., duty cycle).

- The ports must preserve flexibility in their approach to allow future zero emission technology advancements to be integrated into port-related operations.
- The ports must consider the ability of any proposed zero emission strategy to scale out to the region in order to maximize port-related and regional air quality and health risk reductions.
- None of the zero emission technology options considered to date is ready for full-scale implementation. However, the ports will immediately move forward with demonstrations and collaborative efforts that advance promising technologies toward feasible real-world implementation.

Further, the ports must consider that, when evaluating the potential benefits and costs of the various zero emission technology options, resources will also be needed to help develop and implement control strategies for ocean-going vessels (OGVs) and harbor craft in order to achieve the San Pedro Bay Standards.

1.1. What are Zero Emission Technologies?

"Zero emission technologies" have been defined by the California Air Resources Board (CARB) as technologies that do not directly emit criteria pollutants, such as hydrocarbons, carbon monoxide, nitrogen oxides (NOx) or particulate matter (PM). Zero emission technologies may indirectly produce small amounts of emissions, for example, when an electric vehicle plugs into grid power to recharge the on-board batteries, therefore contributing in small part to emissions at the power plant source.

Since 2006, the ports have been evaluating opportunities for Zero Emission Container Movement Systems, or ZECMS, to move cargo through the ports and into the region using technologies that do not burn fossil fuels and therefore do not emit air pollutants "at the tailpipe".

The ZECMS title however gives the impression that there will be a "one-size-fits-all" zero emission option that will apply in all port-related operations. As will be discussed more fully below, such a concept is misleading and limiting, and does not fully address the needs of the various mobile sources involved in port-related operations. Accordingly, for the purposes of this paper and moving forward, with the exception of references to past activities, these technologies will be referred to by the more general and appropriate terminology of "zero emission technologies".

1.2. The Need for Zero Emission Technologies

The economic benefits of port-related activity are felt throughout the nation. However, the fact that the environmental impacts of trade are disproportionally felt in the local region led to the joint ports' landmark environmental initiative, the 2006 Clean Air Action Plan (CAAP). In the 2010 CAAP Update, the ports underscored their commitment to air quality improvement with the adoption of the San Pedro Bay Standards, which are comprised of two components: 1) reduction in health risk from port-related diesel particulate matter (DPM) emissions in residential areas surrounding the ports, and 2) "fair share" reduction of port-related air emissions to assist the region in achieving federal air quality standards. These components reflect the ports' stated goals of reducing health risks to local communities from port-related sources and reducing emissions to support the attainment of health-based ambient air quality standards on a regional level.

Specifically, the ports' Health Risk Reduction Standard is to reduce the population-weighted cancer risk of ports-related DPM emissions by 85% by 2020, relative to 2005 conditions, in highly impacted communities located near port sources and throughout the residential areas in the port region. The Emission Reduction Standards, relative to 2005 conditions are, by 2014, to reduce emissions by 22% for NOx, 93% for sulfur oxides (SOx), and 72% for DPM, and, by 2023, to reduce emissions by 59% for NOx, 93% for SOx and 77% for DPM.

While the ports have already made significant progress toward meeting these goals, as reflected in each port's annual emissions inventories, emissions forecasting indicate that the currently known emission reduction strategies will not be adequate to achieve the aggressive goals of the San Pedro Bay Standards. As a result, the ports must stay focused on identifying and reducing sources of port-related emissions. Staff believes that implementation of zero emission technology options could provide significant benefits to the ports, bringing them closer to achieving these goals, and in turn, assist the region in meeting national attainment standards.

Further, the South Coast Air Quality Management District (AQMD) has stated that in order to achieve the proposed federal ozone standards, the majority of land-based mobile sources will need to utilize zero emission technologies. The proposed U.S. Environmental Protection Agency (EPA) revised standards would reduce the 8-hour primary standard for ozone to a level between 0.070 and 0.060 parts per million (ppm), down from the 2008 standard of 0.075 ppm. The proposed rule also includes a separate cumulative "secondary" standard to protect the environment, especially plants and trees. If the proposed federal ozone standard is adopted, significant changes will be needed throughout all industries, as well as by private consumers, to meet these stringent air quality requirements for the region.

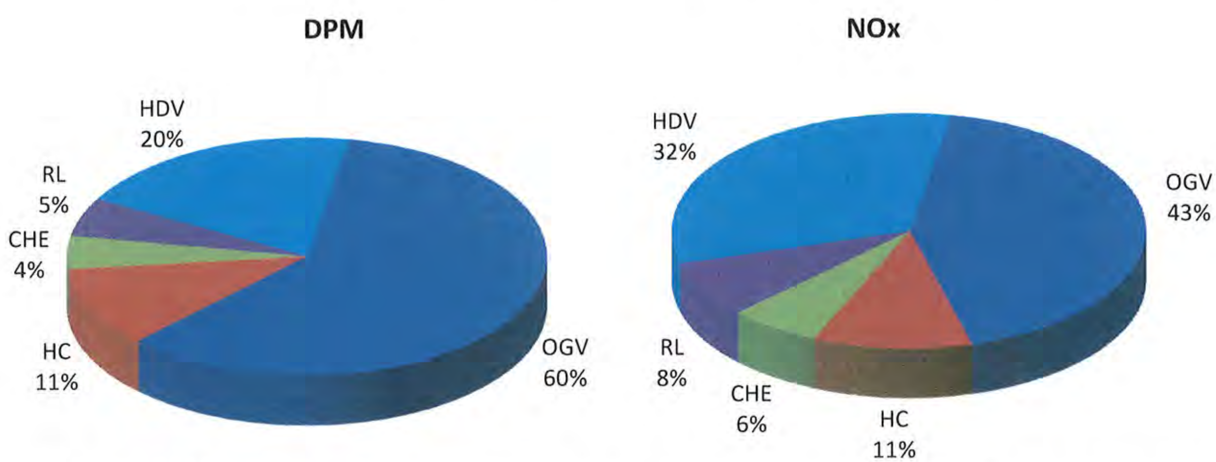
Additionally, utilization of zero emission technologies could be a significant strategy for reducing greenhouse gas (GHG) emissions. Each port, in cooperation with their respective City, has initiated a process to quantify, evaluate and implement strategies to reduce GHG emissions from their administrative operations as well as from port-related activities of their tenants and customers.

Finally, energy security (i.e., reducing dependence on foreign oil) is also a significant consideration as the ports transition into the future. Uncertainty about potential future supplies of oil and rising costs provide another reason for moving away from technologies that rely on fossil fuels to technologies that are powered by electricity ideally produced using renewable energy sources.

1.3. Potential Air Quality Benefits from Implementing Zero Emission Technologies at the Ports

The emissions source categories involved in port-related goods movement operations are OGVs, cargo handling equipment (CHE), drayage trucks (HDVs), rail locomotives (RL), and harbor craft (HC). Figure 1 is derived from each port's 2009 emission inventories and shows the relative contribution of emissions broken down by the source categories associated with such port-related sources.

Figure 1: 2009 DPM and NOx Emissions by Port Source Contribution



While the CAAP includes measures to mitigate air pollutant emissions from each of these major source categories, not all source categories are good candidates for transition to zero emission operation. For example, outside of at-berth operations (i.e., shorepower), it is not practical at this time to pursue zero emission operation of OGVs that call at the ports or harbor craft that operate within port waters due to technical and operational constraints.

The emissions standards being promulgated for OGVs and harbor craft by the regulatory agencies (International Maritime Organization, EPA, and CARB) do not require, nor even approach, zero emission levels. Secondly, and most importantly, zero emission technologies for commercial marine vessels do not currently exist and no practical zero emission technology solutions have been identified. While the goal of "zero emissions" is not appropriate for these source categories, technology options are being developed and implemented to mitigate emissions from OGVs and harbor craft, including the six OGV measures and one harbor craft measure included in the 2010 CAAP Update[1]. In fact, Foss Maritime operates the world's first hybrid-electric tugboat, demonstrating the opportunity for technology migration across applications. While not technically a zero emission tugboat, significant reductions in emissions and fuel consumption are being realized as a result of this advanced technology, which relies on earlier technology developments in the zero emission vehicle market.

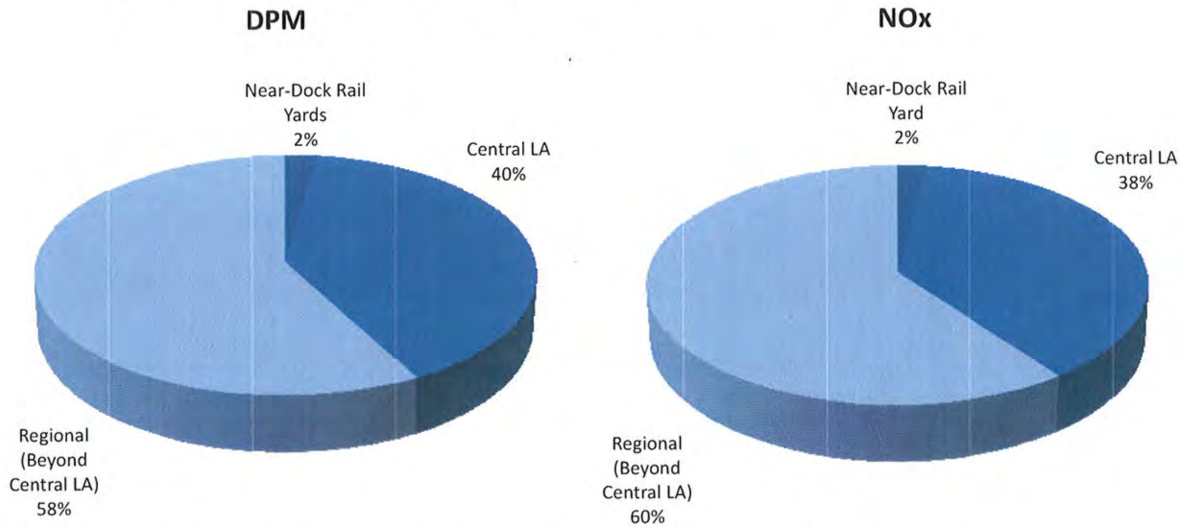
Additional emission reduction technologies for OGVs and harbor craft are being demonstrated under the ports' Technology Advancement Program (TAP). However, even with the successful implementation of these marine vessel emission reduction strategies, OGVs and harbor craft will remain the dominant source of port-generated emissions and the largest source contributor to community health risk for the foreseeable future. These two source categories represent 71% of total port DPM emissions and 54% of total port NOx emissions as documented in the 2009 emissions inventories. Therefore, while the ports must be diligent in their efforts to advance zero emission technologies, they must also be mindful that considerable resources will be needed to significantly reduce emissions from OGVs and harbor craft to achieve the San Pedro Bay Standards.

Technically feasible and economically viable zero emission options are most likely to develop for on-road container drayage conducted between the ports and destinations throughout the region, in-terminal container handling, and rail locomotives used in switching and line-haul operations.

In 2009, on-road drayage trucks produced 20% of total port-related DPM and 32% of total port-related NOx emissions. Of note, these percentages are anticipated to be reduced over the next few years with implementation of the Clean Trucks Programs at the ports. As shown in Figure 2, on-road drayage trucks emit the majority of their emissions during trips throughout the region. In 2009, *on-road truck emissions associated with the transport of cargo between port terminals and the Intermodal Container Transfer Facility (ICTF) represented 2% of total truck DPM emissions and 0.4% of total port DPM emissions.* On-road truck emissions associated with regional drayage represented 98% of total truck DPM emissions and 19% of total port DPM emissions in 2009. Therefore, while near-term efforts should move forward to develop technologies that can reduce emissions from on- and near-port drayage truck operations, ultimately, to provide the greatest benefits, zero emission technologies must be implemented on the regional scale.

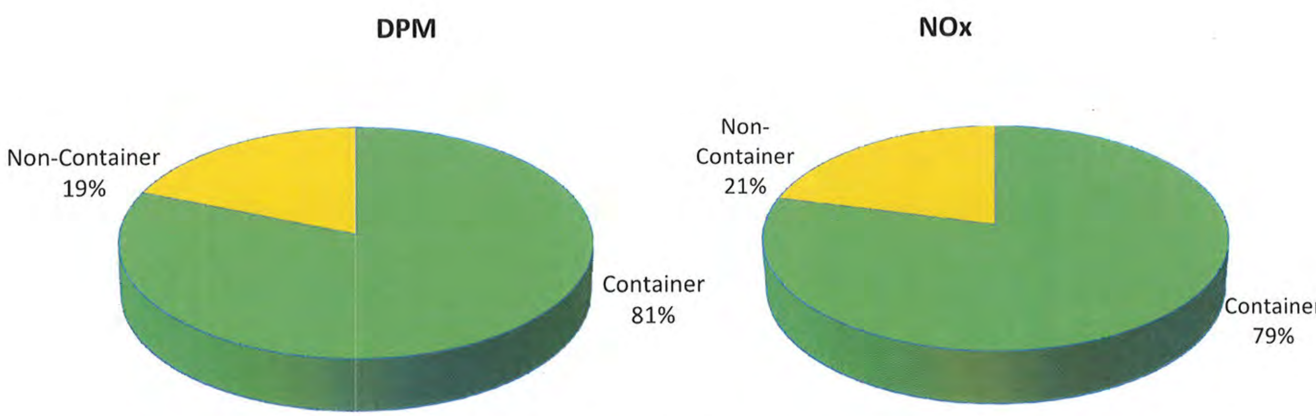
[1] 2010 CAAP Update includes the following OGV Measures: Vessel speed reduction (OGV1); At-berth emissions reductions (OGV 2); Low-sulfur fuels in OGV auxiliary engines and boilers (OGV 3) and in main engines (OGV4); Cleaner OGV Engines (OGV 5); and OGV Engine Emissions Reduction Technology Improvements (OGV 6). Harbor craft CAAP measure is HC1 – Performance Standards for Harbor Craft.

Figure 2: 2009 On-Road Drayage Truck DPM and NOx Emissions Contribution, by Mode



Cargo handling operations at marine terminals and intermodal facilities in close proximity to the ports generate 4% of total port-related DPM and 6% of total port-related NOx emissions. Figure 3 provides the breakdown of DPM and NOx emissions from CHE operations during 2009 at container versus non-container terminals. Since the majority of emissions from CHE are produced at container terminals, greater emissions benefits can be achieved by prioritizing implementation of zero emission technologies for CHE operations at container terminals.

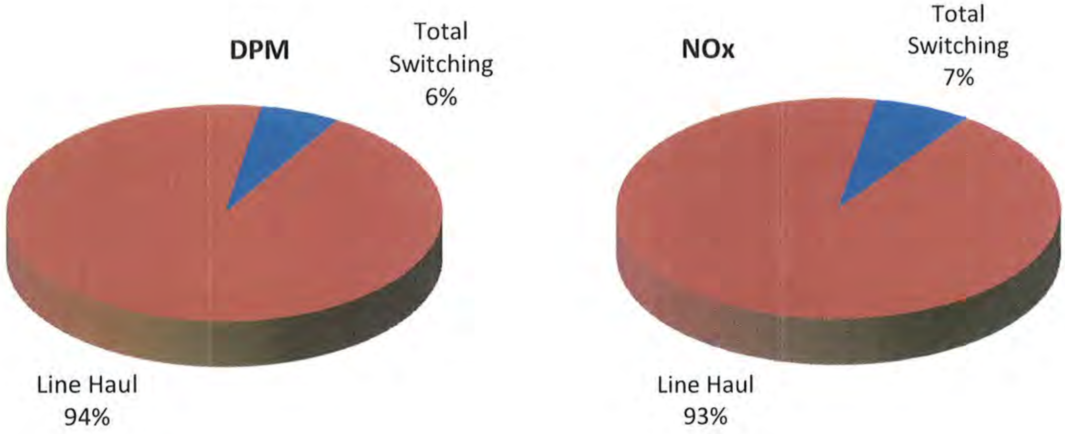
Figure 3: 2009 DPM and NOx Emissions Contribution from CHE by Terminal Type



Port-related rail operations generate 5% of total port DPM and 8% of total port NOx emissions. Rail locomotive emissions are primarily from line haul operations. As shown in Figure 4, 94% of DPM emissions and 93% of NOx emissions associated with port-related rail operations in 2009 were generated by the line-haul locomotives. Rail locomotive emissions are a regional source of air pollution;

thus, to maximize the emissions benefits, zero emission options targeting locomotive emissions should be pursued on a regional scale.

Figure 4: 2009 DPM and NOx Emissions Contribution by Rail Mode



The above analysis of port source emissions is the basis for seeking zero emission options for both port-scale and regional-scale goods movement. On the port scale, zero emission options will target emissions generated by short-haul container drayage and marine terminal operations. On the regional scale, zero emission options will target emission reductions from medium-haul drayage and rail.

Thus, for a zero emission technology to be an effective strategy in achieving the San Pedro Bay Standards, it must have scalability and connectivity throughout the region, and not applied only at discrete marine terminals or intermodal facilities within port boundaries. A zero emission option that connects only point "A" to point "B" within the ports, without the flexibility for expansion is not a viable zero emission solution for meeting the ports' goals.

1.4. The Ports' Role in Advancing Zero Emission Technologies

While the ports are principally interested in zero emission options to help them meet their health risk and "fair share" emission reduction commitments, the ports are also in a unique position to make additional, substantive contributions on a regional, national, and potentially global scale through developing, demonstrating, and supporting deployment of zero emission technologies.

Through the advancement of zero emission technology options, the ports are positioned to assume a lead role in the demonstration of zero emission transportation technologies and serve as a "regional test bed". Because port-related operations typically involve rigorous duty cycles, zero emission technologies that demonstrate the requisite levels of durability and reliability at the ports of Long Beach and Los Angeles can be replicated not only at other ports, but also in other non-marine applications.

Additionally, the pursuit of zero emission technologies provides an opportunity to serve as a "regional catalyst", stimulating both the pace of technology development as well as promoting economic development in Southern California. Currently, at least two zero emission vehicle manufacturers have established their businesses within the greater Los Angeles area, with the expressed intent of manufacturing zero emission on-road drayage trucks and off-road yard tractors for the port-related industry at commercial production rates. To ensure these technologies are carried beyond the ports, these efforts must be conducted with the support and collaboration of the regional planning agencies, including Metropolitan Transportation Authority (Metro), Southern California Association of Governments (SCAG), Gateway Cities Council of Governments, and AQMD.

2. Progress Toward Zero Emissions – Accomplishments to Date

Since 2006, the ports have advanced zero emission technologies through multiple pathways, investing over $4 million to date in this effort. The TAP has focused on numerous technologies, including zero emission options, which are ready for prototype demonstration in port-related applications. In addition, staff have also explored longer-term and larger-scale zero emission options through the ZECMS process.

2.1. Technology Demonstrations through the Ports' TAP

The mission statement for the ports' TAP is *"...to accelerate the verification or commercial availability of new, clean technologies, through evaluation and demonstration, to move towards an emissions-free port"*. The TAP is currently evaluating and demonstrating technologies that could eventually lead to deployment of zero emission technologies for sources in port-related operations. Some of those technologies represent interim or transitional technologies that help to significantly reduce air emissions, but are not yet emission free. Nonetheless, the deployment of these technologies in the near term will help the ports reduce air emissions and associated health risks while continuing to strive for full deployment of zero emission technologies in the appropriate areas of port-related goods movement for the future.

In 2007, the Port of Los Angeles and AQMD initiated a demonstration of the Balqon lead-acid battery electric truck. After initial testing, design upgrades were proposed for the battery management system, including an upgrade to a lithium-ion battery. In 2008, the Port of Los Angeles approved moving forward with phase 2, to purchase and test the upgraded systems for terminal applications, and phase 3, to purchase and test units made specifically for drayage. Phase 2 testing is currently underway. In addition, in an effort to further increase the range of the Balqon trucks, Port of Los Angeles is moving forward with combining the lithium-ion battery truck with Vision Motor Corporation's hydrogen fuel cell. Phase 3 of the system is anticipated to proceed in 3rd Quarter 2011. The tests for phases 2 and 3 will use upgraded lithium ion battery packs, which increase the energy capacity of the units.

The joint ports' TAP demonstrations for the Vision Motor Corporation's hydrogen fuel cell/plug-in electric on-road truck and terminal tractor began in late-2010, with testing of the two prototype vehicles anticipated to begin in 3rd Quarter 2011. The performance of these vehicles will be tested in various terminal and short-haul operations to evaluate their hauling capacity, range, speed, and reliability in the various duty cycles over an 18-month period.

The ports are also actively working with other technology developers as they prepare proposals for consideration through the TAP and anticipate additional zero emission technology demonstration projects to be brought forward for Board consideration later this year.

While these technology projects are underway, until they have successfully completed their prototype testing and are being produced for the commercial market, they are not yet considered viable options[2].

Further, through the TAP, the ports participated in regional and national efforts to develop advanced, lower emissions truck technologies including the national Hybrid Truck Users Forum (HTUF) and the California Hybrid Efficient and Advanced Truck (CalHEAT) research groups. Finally, the ports developed a port drayage truck duty cycle to provide technology developers with a detailed technical understanding of the performance requirements for a typical drayage truck.

2.2. The Ports' ZECMS Process

The concept of Zero Emission Container Movement Systems (ZECMS) has been under investigation for many years. The ports have been actively engaged or the lead agency in these evaluations.

In 2006, the ports evaluated various zero emission technologies through a Request for Proposals (RFP) process. The resulting evaluation report, issued in early 2008 by Cambridge Systematics, identified that

[2] TIAX LLC, *Technology Status Report – Zero Emission Drayage Trucks*, Prepared for the Port of Long Beach and Port of Los Angeles, June 2011.

none of the 13 technologies evaluated was deemed ready for deployment at that time. The process, however, provided valuable insight into the range of ZECMS approaches that could be pursued. As a follow-up to the RFP, and in response to unsolicited proposals by technology vendors, the Port of Long Beach (POLB) performed a right-of-way study to evaluate various routes for a potential fixed guideway system, identifying two potentially feasible routes between the ICTF and POLB's Pier A terminal. In mid-2009, the ports issued a Request for Concepts and Solutions (RFCS) which encouraged submissions of proposals to design, build, and operate a ZECMS between Pier A and the ICTF. The ports, aided by an independent team of technical experts from the Keston Institute for Public Finance and Infrastructure Policy at the University of Southern California (USC), reviewed seven proposals ranging from magnetic levitation (maglev), to linear-synchronous motor (LSM), to vacuum-propulsion technologies.

The USC Keston Institute presented their findings in mid-2010, concluding that none of the proposals were sufficiently mature to commit to a full-scale operational deployment or demonstrated they could deliver a reliable and financially sustainable system at this time. While the general level of proposed systems may have demonstrated experimental proof of concept in a laboratory environment, they all had shortcomings including immature technology, technology that was not proven or tested in port duty cycle applications, and/or technology that lacked a viable financial plan. Debrief interviews with several of the RFCS respondents indicated that additional research and development were needed on their proposed technology, as well as coordinated planning efforts with other regional stakeholders, including regulatory and transportation agencies.

2.3. Regional Zero Emissions Efforts

2.3.1 Metro's Freeway Major Corridor Study

In March 2005, following an extensive technical review and community outreach process, Metro completed the I-710 Freeway Major Corridor Study (MCS). The study analyzed existing and predicted congestion and mobility along the I-710 corridor in order to develop transportation solutions to preserve and enhance the quality of life of surrounding neighborhoods and communities. The study took into account projected increases in container volume at the ports of Long Beach and Los Angeles, the corresponding increase in container truck traffic volume along the I-710, as well as the physical condition of the I-710 freeway infrastructure. Priorities identified by stakeholders during the MCS process included:

- Improve air quality in communities adjacent to the I-710;
- Improve mobility, congestion and safety along the freeway corridor; and
- Assess alternative, "green" goods movement technologies.

The I-710 EIR/EIS studied 18 miles of the I-710 freeway between the Ports and the Pomona Freeway (SR-60). Four alternatives were analyzed in the EIR/EIS:

- No Build Alternative - As required by federal law, the "No Build Alternative" includes transportation improvement projects already programmed or committed to be constructed by the EIR/EIS planning horizon year of 2035;
- Ten Lane Facility - Widen the I-710 freeway to ten lanes for the length of the corridor;
- Ten Lanes and Four Separate Freight Lanes - Widen the freeway to ten general purpose lanes throughout the length of the corridor and add four separated freight movement lanes for exclusive use by conventional trucks;
- Freight Lanes Dedicated to Zero Emission Trucks - Includes all the improvements in the previous alternative, but requires use of zero emission technology to move goods in the freight lanes.

The results of the I-710 Corridor Project EIR/EIS were published in January 2009 in Metro's *Alternative Goods Movement Technology Analysis –Initial Feasibility Study Report*[3].

Two categories of zero emission technologies were assessed for potential I-710 application: automated fixed-guideway systems and battery electric trucks. The report characterized each category of alternative technology in terms of guideway requirements, propulsion, energy consumption, command and control, terminal interfaces, switching, sorting and storage, system operations, and system assurance.

In light of the apparent property requirements for deployment of an automated fixed-guideway technology at the ports and intermodal rail facilities, a new type of battery electric truck technology was considered that would interface with ports and rail terminals as conventional trucks do today, but would operate on a dedicated guideway subject to controls that safely optimize capacity. The report concluded that such a technology does not exist as a commercial product today, but would incorporate characteristics of existing freight and passenger technologies. It was also conceived that drayage trucks powered by electric motors could draw wayside electric power along the corridor and operate on battery power at the ports and intermodal rail facilities.

2.3.2 SCAG's Goods Movement Plan

The SCAG's Regional Transportation Plan (RTP) represents the "long-term investment framework for addressing the region's transportation and related challenges"[4]. An important effort under the 2008

[3] Final Report: Alternative Goods Movement Technology Analysis –Initial Feasibility Study Report, WBS ID:160.10.60, Los Angeles County Metropolitan Transportation Authority, January 6, 2009.

[4] 2008 Regional Transportation Plan, *http://www.scag.ca.gov/rtp2008/pdfs/finalrtp/f2008RTP_ExecSum.pdf*

RTP is development of SCAG's Comprehensive Regional Goods Movement Plan and Implementation Strategy which seeks to optimize the region's transportation system with the application of new technologies. This plan will include evaluation of all freight modes relative to economic efficiency, congestion mitigation, air quality improvements, and system security enhancements. The regional goods movement system defined through this plan will "feed" the upcoming 2012 RTP, which is also under development.

Specifically, SCAG's vision includes the introduction of a high-speed, high-performance regional transport system (HSRT). An HSRT system could potentially include new alternative, zero emission, technology-based systems that can provide enhanced throughput and reliability from the ports of Long Beach and Los Angeles to an inland port facility. The system would capitalize on the synergy of multiple uses on a single infrastructure by operating on shared alignments with a HSRT passenger system. Significant additional evaluation is required, especially with regard to the location of an inland port facility and the associated costs. In the 2008 RTP, SCAG estimated the cost to connect the ports to the HSRT to be $18 billion, with an implementation target of 2020.

3. Recommended Direction – A Roadmap to Zero Emissions

3.1. Candidate Source Categories

As described in Section 1, the ports identified the source categories where zero emission technologies best apply – specifically, container drayage conducted between the ports and destinations throughout the region, container handling at marine terminals, and locomotives used in switching and line-haul operations.

For the purpose of this discussion, container drayage is grouped into two modes:

- Short-Haul Drayage - This operation involves very short container moves from two to six miles in length. Cargo moves between the port terminals and the ICTF, which functions as the Union Pacific (UP) near-dock rail terminal, or nearby container yards are included within this category;
- Medium-Haul Drayage
    - Local Drayage - A high concentration of warehouses and truck terminals, as well as a major rail yard (Hobart), exist within 20 miles of the ports. These terminals include distribution centers in downtown Los Angeles, Compton, and Rancho Dominguez. For the purposes of this report, local operation is defined as cargo moves originating or terminating at the ports and having the other end point between six and twenty miles distance from the ports. According to drayage truck origin and destination surveys, approximately 50 - 60% of port drayage truck activity is captured in this range;

- Regional Drayage - At distances greater than twenty miles from the ports but within the South Coast Air Basin (SoCAB), large warehouse facilities are common and may be used to transfer goods for interstate delivery.

Container handling within a marine terminal involves a wide range of specialized CHE, each type of equipment performing a specific function. This equipment includes vehicles such as yard tractors, top handlers, side picks, and rubber tired gantry cranes. A review of the combined ports' emissions inventories indicates that 50% of CHE operating at the San Pedro Bay Ports consists of yard tractors that move containers within the marine terminals and intermodal facilities.

Locomotive activities include switching activities to build trains, occurring primarily within the port boundaries and intermodal yards, and line-haul activities, transporting trains along the rail corridors, typically to destinations outside of the SoCAB.

These four container movement modes – short-haul drayage, medium-haul drayage, cargo handling equipment, and rail locomotives – represent the four highest priority pathways on the road to zero emissions. The sections that follow will discuss the identification and evaluation of candidate zero emission technology options relative to these four priority container movement modes, culminating in recommended next steps in the zero emission roadmap.

3.2. Process to Identify Zero Emission Technology Options

As described in Section 2, the ports employed a structured process to develop the recommended roadmap to zero emissions, first identifying and screening, then evaluating the applicability, compatibility, feasibility, and economic viability of zero emission options at each step in a container's movement through the ports and into the region. Consistent with the principles identified in Section 1, this process included the following key components:

- Development of Operational and Performance Requirements – Characterization of the operations and performance of each segment of container movement, both in-port and on a regional level. This assessment included conducting detailed analytical studies of container drayage and yard tractor duty cycles to define performance requirements.
- Identification of Zero Emission Technologies - A compilation of technical and programmatic information relative to candidate zero emission technologies, including near term technologies undergoing development and demonstration through the TAP, as well as longer-term technologies identified during the ports' ZECMS RFCS process. In addition to technical and programmatic information provided by technology providers, the ports conducted independent

research and evaluation[5] of zero emission options to better understand their level of technical maturity, feasibility, and potential for near term commercialization.

- Evaluation of Candidate Zero Emission Technologies - For the candidate zero emission technologies identified as potentially applicable and compatible within a segment of port-related container movement, a detailed evaluation was performed using the evaluation criteria presented in Section 3.3 below.
- Recommendations – Recommendations relative to specific zero emission technologies that should be advanced by the ports at this time, including next steps.

Through this process, it became clear that due to differences in operational requirements and implementation issues encountered in various segments of goods movement, *there is no single zero emission technology solution that currently exists or is anticipated to become available that satisfies all of the stated principles and evaluation criteria.* A zero emission option for marine terminals will be different from a zero emission technology applied to container movement on a regional scale. This is because the operational requirements of container movement within a marine terminal environment are very different than those associated in moving containers along rail corridors to the edge of the SoCAB boundary or along public roadways from the terminal to the ICTF, downtown Los Angeles, or the Inland Empire. Unfortunately, there are no zero emission technology "silver bullets" that will provide a single solution that serves all stakeholder interests or requirements.

That being said, the port staff identified opportunities in which a zero emission technology that is not included in the near term zero emission roadmap could have a potential role in the longer term. Zero emission technologies being advanced in the near-term will preserve flexibility for future innovations. There are also paths along the roadmap that identify the incremental expansion of zero emission technologies across multiple goods movement segments and multiple source categories. Thus, while no single solution exists for a near term solution, technologies that are not fully developed today may have a more defined role in the future.

It is important to recognize that the identification and evaluation of zero emission options is a dynamic and ongoing process. The roadmap does not identify a specific end point or future state of technology – it is intended to identify steps in the ports' transition to zero emissions that can be supported today with the understanding that advancements in technology readiness and availability will continue to evolve and must be continually assessed. Thus, it is essential that the ports establish and work within a process framework that allows for technology assessment and reassessment, and fosters collaboration with port tenant, customer, regional, and regulatory stakeholders. The ports' TAP is the key element in this ongoing, dynamic process. Through the TAP, the ports will accelerate the verification or commercial

[5] Technology Status Report - Zero Emission Drayage Trucks, Draft Report, TIAX LLC, May 2011.

availability of zero emission technologies across all applicable source categories, through identification, evaluation, and demonstrations. *However, the principal objective of the zero emission roadmap is to identify next steps and get started now.*

3.3. Criteria for Evaluating and Prioritizing Zero Emission Options

In order to evaluate and prioritize candidate technologies and options for inclusion in the ports' roadmap for zero emissions, the ports defined seven decision criteria. These criteria were used to assess competing technologies for short-haul drayage and in-terminal container handling equipment. The evaluation criteria were developed under the guidance of the ports' principles and also derived from criteria used for the TAP to be consistent with the San Pedro Bay Standards. The criteria also favor options that could bring more immediate benefits and that faced fewer technical, operational, economic and implementation obstacles. Finally, the criteria will be used to uniformly evaluate additional technologies and other source categories in the future.

In developing recommendations, the port staff employed the following criteria:

- **Emissions Reduction and Health Risk Benefits** – the zero emission option's anticipated port-related emission and health risk reductions and contribution toward achieving the San Pedro Bay Standards. The magnitude of benefits derived from the zero emission solution should be commensurate with the investment required, i.e., evaluated on a "cost/benefit" basis with preference given to technologies with higher ratios of benefits to cost;
- **Constructability** – including infrastructure and utility requirements, availability of required space, and Right of Way (ROW) acquisition requirements with preference given to projects that can be integrated into the existing infrastructure or those with fewer barriers to construction;
- **Technology Readiness** – the level of technical maturity and feasibility, demonstrated reliability/durability, and commercial availability with preference given to more mature technologies so as to speed the pace of implementation;
- **Operations Compatibility** – the capability of candidate zero emission technologies to be integrated into ongoing port operations and duty cycles, as well as compatibility with existing operations with preference given to technologies that can more easily be integrated into existing operations;
- **Regional Scalability** – the ability of a port-scale zero emission solution to be incrementally expanded to a regional scale (i.e., in-port, port to ICTF, and expansion along corridors like I-710 between ports and downtown Los Angeles and beyond to the Inland Empire) favoring technologies that can be readily expanded to the regional scale;

- **Cost and Economic Sustainability** – the capital, operational, and life cycle cost, need for incentives or subsidies, and the potential to become economically competitive and sustainable relative to conventional container movement operations with preference given to cost-competitive projects;
- **Timeline** – the expected timeframe for zero emission technology demonstration, commercialization, regional expansion, etc. While the timeline is not used as a criterion to approve or reject technologies, it is used to prioritize actions. For the purpose of the zero emission roadmap, discrete timeframes were defined as follows:
  - Near Term timeframe: Within 3 years
  - Longer Term timeframe: Beyond 3 years

3.4. Zero Emission Options for Short-Haul Container Drayage

Two distinct options emerged from the ports' efforts to identify candidate zero emission options to replace or augment short-haul container drayage currently performed by trucks:

1. Deployment of on-road zero emission trucks, including but not limited to battery-electric trucks, zero emission hybrid-electric trucks, electric trucks powered by an overhead catenary system, or electric trucks using wayside power or LSM embedded in existing roadways or dedicated truck lanes;
2. Construction of an automated fixed guideway system incorporating technologies such as maglev or the adaptation of LSM to existing railroad tracks.

These options are described below, specifically the performance requirements and technology status for each, in addition to a recommended approach for moving forward.

3.4.1. Performance Requirements for Short-Haul Drayage Trucks

To successfully develop advanced zero emission trucks for short-haul drayage, vehicle manufacturers must understand the duty cycle requirements of port drayage trucks. To characterize port drayage duty cycle requirements in analytical terms, the ports developed and published detailed duty cycles for drayage trucks serving both the Port of Long Beach and Port of Los Angeles[6] using data obtained from instrumented trucks in actual container drayage service.

[6] Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles; Final Report, TIAX LLC, February 2011.

A typical short-haul drayage duty cycle includes three distinct driving modes:

Creep → Low Speed Transient → Short High Speed Transient

In analytical terms, the requirements of a typical short-haul container dray can be represented as follows:

- Average Duration of Short-Haul Container Dray: 39 minutes
- Average Truck Speed: 7.7 mph
- Maximum Truck Speed During Haul: 42.2 mph
- Average Short-Haul Distance from Port: 5 miles
- Number of Stops During Dray: 31 stops (traffic control, etc.)
- Percentage of Time Spent Idling: 44%

The short-haul duty cycle requirements were then used to define the minimum performance requirements for zero emission drayage truck:

- 80,000 lbs. gross combined weight rating (GCWR)
- 50+ mph top speed with full load
- 20% or greater gradeability at vehicle launch
- 6% gradeability[7] at 40+ mph and 80,000 lbs. GCWR
- Operating time between refueling or recharging must allow for one complete shift (approximately 8 hours) or have comparable fill times as diesel trucks.

Note that the gradeability at 40+ mph is based on the characteristics of the three major bridges in the port area (Gerald Desmond Bridge, Vincent Thomas Bridge, and Commodore Schuyler F. Heim Bridge). It is possible to use other routes to avoid the steep grades on the bridge, possibly lowering the specified grade requirements.

3.4.2 Development Status of Zero Emission Short-Haul Trucks

Vehicles employing partially electrified drive trains have seen dramatic growth in the light-duty market over the last ten years with the commercialization of various hybrid-electric passenger cars. The medium- and heavy-duty markets have also shown recent trends toward electrification of drive trains in

[7] Based on Gerald Desmond Bridge approach grade, Gerald Desmond Bridge Replacement Project Traffic Impact Study, October 2009

both on-road and off-road applications. Several manufacturers are pursuing commercialization of heavy-duty electric trucks that have the potential to meet the basic operational requirements for short-haul drayage trucks.

As identified earlier, two electric truck manufacturers, Balqon and Vision Industries, are currently working with the ports to test prototype on-road electric trucks that meet the CARB definition for zero emission. The Balqon and Vision Industries prototype technologies are being used as examples to characterize the current state of development for zero emission trucks that are potentially suitable for short-haul drayage service at port terminals.

- Balqon Corporation Battery-Electric Drayage Truck - In 2007, the Port of Los Angeles and AQMD entered into a contract with Balqon Corporation to develop and demonstrate a battery-electric truck that could operate within and outside terminal facilities in both on-road and off-road applications. The initial prototype truck, the Nautilus E-30, was completed and tested in early 2008, primarily as an off-road yard tractor. Based on an assessment of the prototype truck's performance by port and AQMD staff, it was determined that an upgraded version of the E-30 had the potential to meet the performance requirements for an on-road short-haul drayage truck. In June of 2008, the Port of Los Angeles approved Resolution Number 08-6571[8], thereby entering into a multi-phased test program with Balqon that ultimately includes the purchase and delivery of five E-30 battery electric on-road drayage trucks that could be used for short-haul operations. This multi-phased test program has been underway primarily focusing on enhancements to the batteries and battery management system. Initial tests have been conducted on yard tractors. Because yard tractors and short haul drayage trucks have similar electric drive system components and duty cycles, many of the lessons learned and potential enhancements, including those made to the batteries and BMS, would assist in the development of the on-road units. Balqon is currently in production of the first on-road unit for short-haul operations, which will be delivered in the third quarter of 2011.

- Vision Industries Hybrid-Electric – The Vision Industries Tyrano™ on-road truck is a special type of zero emission hybrid-electric vehicle that uses battery power for propulsion and an on-board hydrogen fuel cell system to recharge the vehicle's batteries. The vehicles being tested under the ports' TAP include a plug-in option for recharging the batteries; however Vision has stated that the fuel cell can be relied upon to recharge the batteries in lieu of plugging into the electrical grid. The vehicle's performance characteristics, including horsepower, torque, gradeability, etc., are substantially similar to the Balqon E 30 described above. Based on Vision's preliminary vehicle specifications, the Tyrano™ hybrid drive system has the potential to provide adequate horsepower and torque to meet the needs of drayage service. Vision engineers report

[8] *http://www.portoflosangeles.org/Board/2008/June/061908_Special_Meeting_Item1_trans.pdf*

that the Tyrano™ will have a rated gradeability of 13% when fully loaded at 80,000 GCWR; this should enable it to meet all grades that will be encountered in short-haul drayage trucking. One potential performance-related issue is that the Tyrano™ day cab tractor weighs approximately 17,500 pounds; this is approximately 2,000 pounds heavier than a comparable diesel tractor. However, Vision engineers point out that the Tyrano™ tractor's weight distribution has been optimized to help prevent overloading of the front axle when heavy loads are moved. In July 2011, Vision delivered the demonstration unit and the 18 month in-use demonstration was initiated.

Battery and zero emission hybrid electric trucks are expected to initially cost more than double that of a conventional diesel Class 8 on-road drayage truck. The majority of the incremental cost is associated with the battery storage system. Most heavy-duty electric truck manufacturers specify advanced lithium chemistry batteries. These batteries offer the benefits of high levels of electrical energy storage capacity, long life, and lower weight as compared to other battery types. However, at today's production rates, lithium chemistry automotive batteries are the single most expensive component of the electric drive system. As additional hybrid electric and battery electric passenger cars enter the marketplace, it is anticipated that increased production rates, production automation, and competitive market forces will result in economies of scale that ultimately lower the cost of electric vehicle batteries. This is already being seen as it pertains to lithium-ion batteries entering the marketplace.

The reliability and durability of heavy-duty electric trucks in a short-haul port duty cycle have yet to be proven. While the prototype electric trucks are anticipated to be capable of meeting the combination of payload and grade performance requirements necessary for local drayage operation, testing of the initial Balqon units have shown inadequate speed at grade while under load and limited range, indicating further design improvements are needed. To assess the technical capability of the Balqon and Vision Tyrano, a test program is being developed for the TAP demonstration that employs the truck over an extended period of time in actual, fully loaded container drayage service on typical routes.

While Balqon and Vision are used as examples in this report because they are currently being evaluated by the ports, they are not the only Class 8 zero emission truck options in development. The AQMD is currently funding the development of Class 8 battery electric trucks, and manufacturers of Class 5 - 7 battery electric trucks have expressed confidence that existing electric drive systems are scalable to meet Class 8 container drayage operational requirements. Thus, it should not be construed that staff is recommending any specific vendor or vehicle – the reference to electric trucks in the zero emission roadmap includes all electric trucks that meet port requirements and is not limited to these two options.

With respect to electric trucks designed to operate using an off-board electric power source, such as electric trucks powered by an overhead catenary system (OCS) or wayside power, these technologies are not being dismissed as options. These off-board power systems may offer the potential to extend the range of the zero emission trucks beyond what can be provided by the on-board battery system, and can be developed based on the successes and/or lessons learned from the current electric or hydrogen-electric hybrid projects. However, it is important to recognize that commercially available linear induction/linear synchronous motor technologies do not currently exist. While OCS has been widely used in on-road transit bus applications, the need for and benefits of OCS as compared to electric trucks using on-board energy storage (i.e., batteries) for *short-haul drayage* have yet to be identified or evaluated for operation at the San Pedro Bay ports. It is recommended that the ports view the zero emission option of electric drayage trucks as inclusive of all electric power technologies, recognizing that the implementation timeline of each technology will vary, and that some currently infeasible technologies may become viable in the longer term or for range extension, as long as there is flexibility in the implementation to allow for future advancements.

3.4.3. Performance Requirements for Fixed Guideway Systems

The construction of a *fixed guideway* to connect marine terminals with near-dock intermodal facilities as an alternative to zero emission trucks was the predominant theme in the responses received under the ports' RFCS. Technologies proposed for operation on a fixed guideway include maglev propulsion systems, linear induction motor technology (without levitation), vacuum propulsion systems, and OCS. While the details of each propulsion technology vary, the common attribute is that containers are conveyed along a dedicated guideway that requires construction of new port infrastructure.

Because a fixed guideway represents new infrastructure and provides dedicated connectivity between the port terminals and near-dock rail facilities, the typical duty-cycle requirements corresponding to short-haul drayage operations do not necessarily apply. Instead, container movement requirements for a fixed guideway can be specified in terms of connectivity and throughput. To replace short-haul drayage service currently performed by drayage trucks, a fixed guideway option will need to have the following attributes:

- Connect the 13 existing marine container terminals spread throughout both ports to multiple near-dock intermodal facilities;
- Not impede existing on-dock rail or other operations at port terminals or operations at near-dock intermodal facilities;
- Be cost competitive in a reasonable timeframe with existing short-haul drayage services;
- Offer container throughput capacity that equals or exceeds marine terminal drayage requirements.

3.4.4. Development Status of Fixed Guideway Systems

During the ports' RFCS process, an evaluation team comprised of staff from each port, the Alameda Corridor Transportation Authority (ACTA), and a panel of experts selected by the Keston Institute of USC concluded:

- None of the systems proposed are sufficiently mature to commit to a full-scale operational deployment at this time;
- Additional testing that simulates the port environment is needed;
- A full understanding of port duty cycles was absent from all responses;
- None of the submissions adequately addressed the risks of insufficient market demand; and
- Technology and financial risk cannot be fully evaluated until the robustness and reliability of the systems have been demonstrated.

It is possible, and even likely, that issues involving insufficient technology maturity can be resolved through additional research and development. However, constraints imposed by ongoing operations at port terminals present integration issues that may render a fixed guideway solution impractical compared to trucks for short-haul.

To effectively replace current container movement operations, a fixed guideway would need to provide connectivity to at least 13 marine terminals and several near dock intermodal facilities which would require a virtual "web" of dedicated guideways. The method to deliver containers to the guideway, load containers onto the guideway at the marine terminals, and unload containers at the near-dock intermodal facility is currently undefined and must be resolved so as to not adversely impact port terminal and rail yard operations. In addition, construction of a fixed guideway, including elevated guideways, would require acquisition of terminal right-of-way and potentially acquisition of private right-or-way which may be impractical and prohibitively expensive.

Further and very importantly, a fixed guideway solution does not provide regional scalability and connectivity. In order to significantly reduce emissions and make progress toward meeting the ports' goals identified in the San Pedro Bay Standards, a zero emission option must have scalability and connectivity throughout the region, and not be applied only to discrete marine terminals or intermodal facilities near the ports. A zero emission option that is only able to capture operations between the marine terminals and intermodal facilities will, at best, only be able to reduce 0.4% of port-related DPM emissions; whereas if the zero emission option is scalable to the region, it could be capable of reducing 19% of port-related DPM emissions.

From an economic feasibility perspective, a fixed guideway option must compete with current drayage services performed using trucks. If the cost to use the fixed guideway option is greater than the drayage truck rates, then it will not be able to compete in the market, and will therefore not be financially viable. Fixed guideway concepts are the most expensive zero emission options, requiring significant capital investment for construction costs, acquisition of right of way, and loss of revenue for physical land area dedicated to the loading stations. Some of the respondents to the RFCS understated these costs. Hence, the RFCS review team concluded that the commercial financing assumed by some of the respondents may not prove to be readily available at terms that would enable a financially sustainable technology deployment. The conclusion of the port evaluation team was that, under best case assumptions regarding growth in container volume and share of container drayage market capture and absent environmental regulation or significant subsidies, a fixed guideway option will have difficulty competing economically with conventional truck drayage.

A variation on the fixed guideway concept is to adapt LSM to be integrated into existing rail tracks connecting marine terminal on-dock rail facilities with near-dock intermodal rail facilities. This concept offers the potential benefits of lower capital development costs and eliminates right-of-way acquisition issues. LSM technology will be further discussed in Section 3.7 – Zero Emission Options for Regional Rail Locomotives.

3.4.5 Evaluation of Zero Emission for Short-Haul Drayage

The two zero emission options for short-haul drayage, electric trucks and fixed guideway system, were evaluated using the evaluation criteria defined in Section 3.3. The result of this evaluation is provided in Table 1 and discussed below.

Table 1: Assessment of Zero Emission Options for Short-Haul Drayage

Evaluation Criterion	Electric Trucks	Fixed Guideway
Emissions and Health Risk Reduction	Excellent	Excellent
Constructability	Excellent	Poor
Technology Readiness	Satisfactory	Poor
Operations Compatibility	Good	Unacceptable
Regional Scalability	Satisfactory	Unacceptable
Cost and Economic Sustainability	Good	Unacceptable
Timeline for Implementation	Satisfactory	Poor

Excellent Good Satisfactory Poor Unacceptable

Each evaluation criterion is discussed below relative to the two general options:

- Emissions and Health Risk Reduction – both an electric truck and fixed guideway system offer zero emission container transport. It should be noted, however, that a fixed guideway system implementation timeline is significantly longer than the deployment of electric trucks; thus, emission and health risk reductions will be realized sooner under the electric truck option, contributing to achievement of the San Pedro Bay Standards;
- Constructability – Battery electric trucks operate on existing roadways and require no additional right of way or significant infrastructure development. Electric trucks using an OCS or wayside power would require construction of additional infrastructure; however, this is a potential longer term option for short-haul drayage if needed to extend the range beyond what can be provided by the on-board battery system. A new fixed guideway requires acquisition of right of way both within and outside of port boundaries as well as construction of the actual guideway which must connect to all 13 container terminals, the near-dock rail yard and possibly other near-port destinations;

- Technology Readiness – battery electric trucks are being demonstrated today with the goal of moving towards commercialization. Fixed guideway technologies, such as maglev and LSM are in the initial research and development stage of technical readiness;
- Operations Compatibility – Electric trucks, especially those powered by an on-board energy source such as batteries, can be seamlessly integrated into ongoing short-haul drayage operations assuming they have adequate range to perform the work and can be recharged in an acceptable amount of time. A fixed guideway solution would require significant changes to container handling practices within a marine terminal environment, including but not limited to container loading and unloading from the fixed guideway;
- Regional Scalability – Electric trucks, when operational, may be deployed throughout the SoCAB, and development of technology to extend the operational range of electric trucks is ongoing. A fixed guideway would be isolated to the specific locations where it is connected, and therefore does not offer the same level of flexibility and regional scalability;
- Cost and Economic Sustainability – Electric trucks currently carry a price premium and successful deployment of large numbers of zero emission trucks will most likely require funding incentives on an interim basis. It is assumed that such incentives will be made available, as they have been in the past for alternative fuel vehicles. Economies of scale, especially in high cost components such as batteries, will reduce the incremental cost of an electric truck as compared to a conventional diesel vehicle. A fixed guideway system requires significant capital development expenditure and must compete with drayage trucks performing short-haul drayage. The results of the ports' RFCS evaluation suggest a fixed guideway system is not economically competitive for short-haul drayage and not financially sustainable barring significant on-going cost subsidies;
- Timeline for Implementation – Electric trucks are undergoing demonstration in port duty cycles now and more zero emission truck concepts are expected to be demonstrated in the near future. A fixed guideway solution will require many additional years of research and development, design, environmental planning, and construction.

3.4.6 Recommendations for Short-Haul Drayage

The first critical piece in the zero emission roadmap is to continue the demonstration and refinement of zero emission, battery electric trucks for short-haul drayage operations by conducting technical evaluations and testing under the TAP. The goal of these efforts is to ensure the technologies can meet the demands of the port duty cycle, provide the technology developers with a test bed to refine their system designs, and ultimately to accelerate commercialization of zero emission trucks for port operations. *Demonstration and commercialization of zero emission trucks is the #1 priority as it relates to implementing zero emission technologies for short-haul drayage.*

Electric trucks offer:

- Seamless integration into ongoing port operations and offer the highest level of operational flexibility;
- Can be incrementally integrated into port drayage operations;
- Offer flexibility for scaling up to meet the regional needs;
- Do not require construction of new infrastructure or acquisition of right-of-way; and
- Appear economically viable with a high likelihood of self-sustainability as anticipated economies of scale and market forces lower vehicle acquisition costs.

In the near term, the demonstrations of zero emission trucks that are currently underway through the TAP are designed to address the need for zero emission, battery electric technologies for short-haul drayage. The Vision Tyrano truck was delivered in July 2011 and the Balqon truck will be delivered by 3rd Quarter 2011. Both trucks will undergo an 18-month demonstration period in accordance with an approved Demonstration and Test Plan. In addition, the ports will continue to evaluate new technology options by proposers through the TAP. Industry representatives will participate in these projects as demonstration partners and in an advisory capacity, along with the TAP Technical Advisory Committee (TAC), which includes the ports, EPA, CARB and AQMD.

In the longer term, the ports could:

- Continue to move forward with TAP demonstrations of advanced zero emission technologies for short-haul drayage, including conducting broader operational and durability testing, as needed;
- Promote improvements in battery technologies through the TAP;
- Identify funding support for additional demonstration tests;
- Work with industry to evaluate operational compatibility of larger-scale zero emission truck deployment;
- Assist with identifying funding support for purchases of zero emission trucks;
- Assess the need for battery charging and hydrogen fueling infrastructure with larger-scale zero emission truck deployment, and assist as needed and appropriate; and
- Evaluate overhead catenary or other wayside power systems for short-haul drayage, considering at a minimum, the benefits that could be offered beyond the capabilities of a zero emission truck with an on-board battery system, the cost, and the operational constraints.

3.5. Zero Emission Options for Medium-Haul Container Drayage

Medium-haul drayage has been defined as having two subcategories: local drayage, within 20 miles of the ports, and regional drayage, to destinations 20 miles beyond the ports but within the SoCAB.

The implementation of zero emission options beyond the ports' boundaries presents an array of challenges far greater than those associated with short-haul container movement. Outside the ports, issues such as right of way, jurisdictional authority, infrastructure requirements, and particularly cost become primary issues that must be resolved before any specific zero emission option can be deemed fully viable. The implementation of zero emission options beyond the ports' boundaries will require the coordinated efforts of multiple regional stakeholders, including but not limited to Metro, SCAG, Gateway Cities, and AQMD. Therefore, staff recommends that collaboration with regional stakeholders be the first step in a zero emission roadmap for medium-haul container drayage.

3.5.1 Performance Requirements for Medium-Haul Drayage

Medium-haul drayage consists primarily of the movement of cargo along local and regional freight corridors. Typically, medium-haul drayage includes container moves originating or terminating at the ports and having the other end point of the move between six (6) and 60 miles in length - this range effectively covers drayage operations between the ports and distribution centers in the Inland Empire.

While short-haul drayage can be typically characterized by a single duty cycle, medium-haul drayage, from an operational and performance requirements standpoint, is comprised of two duty cycles, represented as follows:

Local Dray (6 to 20 miles) - Creep → Low Speed Transient → Long High Speed Transient

Regional Dray (20+ miles) - Creep → Low Speed Transient → High Speed Cruise

The primary difference between the local and regional cycles is the duration of the high speed portion of the duty cycle. However, as shown below, the average length of a regional medium-haul dray is *five times* that of a local haul:

	Local Haul	Regional Haul
• Average Duration of Container Dray:	64 minutes	118 minutes
• Average Truck Speed:	10.2 mph	27.3 mph
• Maximum Truck Speed During Haul:	48.7 mph	57.6 mph
• Average Medium-Haul Distance from Port:	11 miles	54 miles
• Number of Stops During Dray:	46 stops	33 stops
• Percentage of Time Spent Idling:	41%	25%

The duty cycle requirements for medium-haul drayage, especially those conducted along regional corridors, are significantly more demanding on a truck compared to the short-haul duty cycle discussed in the preceding section. Medium-haul increases the range requirements of a zero emission technology by an order of magnitude compared to short-haul, and in the case of electric trucks, pushes the limits on range that can reasonably be expected from today's state-of-the-art battery-electric drive systems.

Also, drayage truck operations on a local or regional scale are conducted with greater periods of sustained, high speed operation. High speeds under heavy loads quickly consume energy stored within a vehicle's battery pack, dramatically reducing the electric truck's overall range.

3.5.2. Technology Development Status for Medium-Haul Drayage

To expand the capabilities of zero emission drayage trucks beyond the short-haul duty cycle, the introduction of additional zero emission technologies that substantially increase the vehicle's range will be required. Candidate zero emission technologies to extend the range of an electric truck include:

- Extended range battery packs through advanced battery technology, additional storage, or maximizing battery efficiency;
- Augmentation of on-board battery storage, such as hydrogen fuel cells; and
- Use of wayside power, including OCS and incorporation of linear inductive motors or LSM embedded in the roadway pavement.

Current battery technologies do not provide adequate range at a reasonable cost. While efforts are being made to improve battery technologies, no cost-effective options are expected to become available for the Class 8 truck application in the near term. Using an on-board fuel cell as a range extender will be tested by the ports Vision Tyrano truck project starting later this year and continuing for an 18-month demonstration period, however reliability in the short-haul application must first be proven before proceeding with a longer range test. OCS has been used for buses that travel along fixed routes. While the technology is potentially applicable to zero emission Class 8 trucks, further testing would be necessary to determine how such a system could be integrated into existing operations given the wide variety of routes and destinations for drayage trucks throughout the region. Further, an electric truck would be needed to connect to the system, and as stated previously, no such truck is commercially available at this time. A demonstration of this technology could be a logical follow-on after the short-haul drayage truck demonstrations have been conducted. Finally, application of wayside power embedded in the roadway to power electric trucks has never been tested for this type of operation. Development of a system would require significant research and development work before it could be implemented on a large scale.

3.5.3 Evaluation of Zero Emission Options for Medium-Haul Drayage

The criteria established by the ports to evaluate candidate technology options could be used to evaluate technologies for medium-haul drayage. As identified above however, medium-haul drayage is not just a port issue and criteria development and technology evaluation must be conducted in collaboration with regional stakeholders such as Metro, SCAG, Gateway Cities, and AQMD. The ports will seek to work with these and other stakeholders to develop collective criteria to evaluate regional zero emission technology options.

3.5.4 Recommendations for Medium-Haul Drayage

Zero emissions options addressing medium-haul drayage must be compatible with other solutions being developed for the region. Therefore, development of strategies will require a broad-based partnership to make zero emission options a reality.

In the near term, the ports should focus their efforts on the following:

- Establish a regional partnership including Metro, SCAG, Gateway Cities, AQMD, and others and work together to define regional zero emission freight transport needs and develop criteria for evaluating options for moving forward with zero emission technology on a regional scale;
- Build on and leverage the technology platform demonstrated for short-haul drayage;
- Work collaboratively with the regional partners to identify and evaluate specific range extension options for zero emission truck technologies, including hybridization, in-road LSM and OCS; and
- Work with the regional partnership to identify potential funding sources.

In the longer-term, the ports should work with the regional partnership to implement the agreed upon regional strategy, which could include:

- Work on regional zero emission freight strategy implementation, including demonstrating transitional technologies and technologies to extend zero emission truck range;
- Assist with zero emission truck deployment by identifying funding opportunities and assisting with charging, wayside power or hydrogen fueling infrastructure as appropriate; and
- Collaboration on further improvements in battery technologies.

3.6. Zero Emission Options for Cargo Handling at Marine and Intermodal Terminals

Container movement through a marine or intermodal terminal is currently performed by various types of CHE. CHE includes all vehicles and equipment that move cargo, containers, and bulk materials to and from marine vessels, railcars, and on-road drayage trucks.

At existing marine or intermodal terminals, the pathway to zero emission operations is likely to occur through the incremental transition of existing types of CHE and vehicles to zero emission operation, similar to the path recommended for electric short-haul drayage trucks. It is also probable that a terminal that transitions its fleet of conventional CHE to electric operation would at some point consider electrifying the terminal and/or converting some portion of their terminal to a semi-automated container movement system.

3.6.1 Zero Emission Cargo Handling Equipment

Due to the diversity of cargo handling requirements within a marine or intermodal terminal, there is a wide range of specialized CHE, each type of equipment performing a specific function. The majority of the CHE can be classified into one of the following equipment types:

- Forklift
- Rubber Tired Gantry (RTG) crane
- Side Pick
- Other equipment[9]
- Sweeper
- Top Handler
- Yard Tractor

A breakdown of CHE operating at the San Pedro Bay Ports is shown in Table 2[10]:

Table 2: CHE Composition at the San Pedro Bay Ports

CHE Type	POLB		POLA		Combined Ports	
	# of units	% of CHE Fleet	# of units	% of CHE Fleet	# of units	% of CHE Fleet
Forklift	252	19%	538	27%	790	24%
RTG	89	7%	108	5%	197	6%
Side Pick	34	2%	40	2%	74	2%
Sweeper	22	2%	15	1%	37	1%
Top Handler	154	11%	154	8%	308	9%
Yard Tractor	713	52%	962	48%	1,675	50%
Other	94	7%	183	9%	277	8%
Total	1,358	100%	2,000	100%	3,358	100%

[9] Other equipment includes but is not limited to construction-related equipment, non-container moving cranes, miscellaneous warehouse equipment, and utility and support vehicles.

[10] Source: 2009 POLA and POLB Emissions Inventories

The relative contribution of each type of CHE to the emissions at the combined ports is shown in Table 3. Yard tractors that comprise 50% of the CHE fleet account for 51% of total CHE DPM and 42% of total CHE NOx emissions. Top handlers, which comprise only 9% of the total CHE fleet, account for 22% of total CHE DPM and 27% of total CHE NOx emissions. In contrast, forklifts which account for 24% of all CHE represent only 5% of total CHE DPM and 8% of total CHE NOx emissions.

Table 3: Relative Emission Levels of CHE Types at the Combined Ports

CHE Type	DPM (tpy)	% DPM of Total CHE Fleet	NOx (tpy)	% NOx of Total CHE Fleet
Forklift	2	5%	102	8%
RTG	4	9%	142	11%
Side Pick	1	2%	41	3%
Sweeper	0	1%	8	1%
Top Handler	9	22%	350	27%
Yard Tractor	22	51%	560	42%
Other	4	10%	115	9%
Total	42	100%	1,318	100%

3.6.2 Performance Requirements for Cargo Handling Equipment

A challenge with implementing zero emission technologies for CHE is the diversity of CHE duty cycle requirements, which vary by type of equipment. Performance requirements for specific types of CHE are shown below in Table 4:

Table 4: Typical Performance Requirements for Port Cargo Handling Equipment

			POLA			POLB		
CHE Type	Typical Duty Cycle	CHE Operations Description	Engine Size (avg. HP)	Load Factor	Average Hours per Year	Engine Size (avg. HP)	Load Factor	Average Hours per Year
Forklift	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to move cargo, truck chassis, or other equipment short distances for placement on or removal from stacks	105	0.3	848	106	0.3	426
RTG	Operate two 7-hours shifts, 4 days per week.	Used to stack containers, or move containers on and off yard trucks	543	0.2	1,155	682	0.2	970
Side Pick	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to stack containers, move containers from one area of the terminal to another, or move containers on and off yard trucks	208	0.59	1,055	181	0.59	602
Sweeper	Operate two 8-hour shifts per day, 5-6 days per week.	Used to clean paved areas in the yard	128	0.68	293	118	0.68	397
Top Handler	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to stack containers, move containers from one area of the terminal to another, or move containers on and off yard trucks	290	0.59	1,534	294	0.59	1,450
Yard Tractor	Operate two 8-hour shifts per day, 5-6 days per week.	Used to move containers to and from ships or rail, move containers within the terminal, and move containers to and from RTG cranes for placement on or removal from stacks	215	0.39	1,699	189	0.39	1,301
Other	Various special purpose duties	Includes a variety of equipment types including aerial lifts, rail-car movers, and heavy duty off-highway trucks	37 - 401	0.43 - 0.55		37 - 401	0.43 - 0.55	

It is noteworthy that the duty cycle requirements for yard tractors have some similarities to the near-dock/short-haul duty-cycle for on-road drayage trucks discussed in preceding sections. This similarity in operational requirements suggests that zero emission technology solutions that are feasible for short-haul drayage have a high probability of being applicable to yard tractors within a marine terminal.

3.6.3 Technology Status for Zero Emission Cargo Handling Equipment

All of the ship-to-shore gantry cranes in both ports are powered by electricity. In addition, the ports have aggressively advanced technologies that reduce or eliminate emissions from other CHE operating within the terminals. This includes demonstration of bridge technologies on the path towards zero emissions, such as diesel-electric hybrid. These technologies not only provide incremental emission reduction benefits in the near-term, they can provide useful information to benefit the development and demonstration of future advanced technologies. Low emission technology CHE projects undergoing demonstration through TAP are summarized below in Table 5:

Table 5: Interim Technologies Toward Zero Emissions Demonstrated Through TAP

Technology Category	Project	Anticipated Emission Reductions
Hybrid Technologies	Vycon REGEN System for RTGs	25% DPM; 30% NOx; 30% CO2
	Capacity Plug-In Hybrid Yard Tractor	60% CO2
	Diesel-Electric Hybrid Yard Tractor	93% DPM; 5% NOx
	Railpower EcoCrane RTG	75% DPM and NOx
Alternative Fuel Technologies	LNG Yard Tractors (2005 Model Year)	100% DPM; +21% NOx; 18% CO2
	APT Emulsified Biodiesel	40% DPM
Retrofit and Exhaust After-treatment Technologies	Rypos Active Diesel Particulate Filter	85% DPM

In addition, the ports are also conducting demonstrations of zero emission technologies, as identified below:

- Balqon Lead-Acid Battery Yard Tractor;
- Balqon Lithium-Ion Battery Yard Tractor;
- Balqon Lithium-Ion Battery Yard Tractor integrated with a Vision Motor Hydrogen Fuel Cell; and
- Vision Motor Hydrogen Fuel Cell/Plug-In Electric Yard Tractor.

As discussed in Section 3.4.2, the Port of Los Angeles and AQMD contracted with Balqon to develop and demonstrate a battery-electric truck. The Port of Los Angeles has ordered Nautilus E-20 units with lead acid batteries and is currently releasing them in a demonstration program at non-container terminals where the duty cycle is less demanding. The next generation E-20 units are equipped with lithium ion batteries, some with range extending hydrogen fuel cells for on-board charging. These next generation E-20 units will be released for demonstration at a trucking company-based container facility with plans to demonstrate them at marine container terminals thereafter. Vision Motor's Hydrogen Fuel Cell/Plug-In Electric Yard Tractor is currently being produced and is expected to be tested at a trucking company-based container facility in 2011.

Manufacturers of conventional diesel yard tractors have also expressed interest in offering electric versions of their existing product line; thus, it is anticipated that additional manufacturers will enter the electric yard tractor marketplace in the future.

For RTGs, electric conversion kits are commercially available and have been used in other countries. RTGs can be electrified by retrofitting the units with a kit (cable reel, transformer and interface) to allow the RTG to utilize grid electricity. The Port of Los Angeles is currently pursuing an electric RTG crane project with one terminal operator; two terminal operators in Port of Long Beach had initially pursued RTG crane electrification projects and were awarded $2.5 million grants from the port in 2007, however both projects were cancelled due to financial constraints and/or a decision by the terminal operator to wait until the project would better fit into future terminal plans.

Similar to electric RTGs, rail mounted gantry cranes or RMGs, are also powered by electric grid power. RMGs travel forward and backward along a fixed rail. RMGs are currently in use in rail yard operations at ICTF and terminal operations at APL in Port of Los Angeles.

3.6.4 Evaluation of Zero Emission Technologies for Cargo Handling at Marine Terminals

The evaluation criteria introduced in Section 3.3 were applied to individual CHE types at the "vehicle level" to identify and prioritize zero emission CHE opportunities for existing marine and intermodal terminal operations. Note that the evaluation included only those equipment types for which staff had information at this time on electrification or zero emission technology options. As part of recommended next steps, zero emission technologies will be identified and advanced for all CHE types. Note that the "regional scalability" evaluation criterion does not apply when evaluating zero emission options for CHE, since these vehicles are a captive fleet at a terminal. The evaluation results are provided below in Table 6.

Table 6: Evaluation of Marine and Intermodal Terminal Cargo Handling Options

	Zero Emission Cargo Handling Equipment			
Evaluation Criteria	**Yard Tractor**	**RTG**	**RMG**	**Forklift**
Emissions and Health Risk Reduction	Excellent	Excellent	Excellent	Good
Constructability	Excellent	Good	Good	Excellent
Technology Readiness	Satisfactory	Excellent	Excellent	Satisfactory
Operations Compatibility	Good	Good	Satisfactory	Good
Regional Scalability	N/A	N/A	N/A	N/A
Cost and Economic Sustainability	Good	Good	Good	Good
Timeline for Implementation	Satisfactory	Good	Good	Satisfactory

Excellent Good Satisfactory Poor Unacceptable

A discussion regarding CHE relative to each criterion is provided below:

- Emissions and Health Risk Reduction – All of the zero emission CHE offer significant emissions reduction. It should be noted, however, that many of the forklifts already operate on propane, and a few of the smaller forklifts are battery powered. Therefore, the emissions reduction potential for forklifts is slightly less than for the other diesel equipment.

- Constructability – Zero emission yard tractors and forklifts would operate on the existing terminals and would only require installation of electric battery charging capabilities, if necessary. Electric RTGs and RMGs would require construction of electrical infrastructure, potentially guard rail systems to protect the infrastructure and, in the case of RMGs, construction of rail tracks.

- Technology Readiness – Zero emission yard tractors are in the development stage, as battery-electric and zero emission hybrid-electric yard tractor prototypes are undergoing development and demonstration in port-related operations. Zero emission forklifts are commercially available for the smaller horsepower range (~100 hp), but development work is needed to apply zero emission technology to heavy-duty forklifts in port container terminal operations. Electric RTG retrofits, electric RMGs and forklifts are commercially available and have been used in port-related operations.

- Operations Compatibility - Electric yard tractors and forklifts offer a high level of compatibility with ongoing terminal operations and can be seamlessly integrated into a marine or intermodal terminal incrementally. Accommodation will need to be made for recharging, as needed; however a goal of the TAP demonstrations will be to evaluate any impacts on operations from recharging. When integrating electric RTGs and RMGs into operations, some of the current flexibility offered by traditional diesel-powered RTGs will be lost. In particular, the installation of electric infrastructure and rail tracks for RMGs requires that the electric RMGs be fixed to a specific location which will limit the ability to make adjustments to yard configurations. Some terminal operators have stated that this inflexibility is incompatible with their current operations, and therefore further evaluation on how this technology could be integrated into existing operations may be needed in some cases. Converting an RTG to electric requires electrical infrastructure, but it is only semi-fixed and therefore provides greater flexibility for future yard re-configuration. In addition, as an interim measure, the ports are continuing demonstration of low-emission technologies for RTGs that are not converted to a zero emission configuration.

- Cost and Economic Sustainability – In the near term, electric CHE will most likely require incentives to partially offset the higher capital acquisition costs of battery electric vehicles and equipment. From a life cycle cost perspective, it is anticipated that the terminal operators will realize lower operating costs tied to lower fuel costs and lower equipment maintenance costs.

  Electric yard tractors also share common technology and components with electric short-haul drayage trucks; this commonality leverages prior investments and should generate manufacturing economies of scale, reducing future costs for vehicle acquisition. It is also expected that electric drive system designs and components developed for yard tractors can and will be adapted to other types of CHE, such as top handlers and side picks. This transferability will further leverage zero emission technology investments.

- Timeline for Implementation – Electric yard tractors are undergoing demonstration in port duty cycles now and more concepts are anticipated to be demonstrated in the near future. Electric RTGs, RMGs and smaller forklifts are commercially available. Electric RTGs or RMGs are currently being implemented in new or redeveloped terminal projects.

3.6.5 Recommendations for Cargo Handling Equipment

The ports recommend the following near-term course of action:

- Continue to sponsor the demonstration of electric CHE by port tenants in cargo handling operations. Electric yard tractor prototypes are currently under development through the TAP program, and the priority of port staff is to demonstrate the capabilities of electric yard tractor technologies in meeting port duty cycle requirements. These demonstration tests will also need to determine overall integration into operations, including battery charging/fueling requirements. The advanced lithium-ion battery Balqon yard tractor is undergoing preliminary testing and will be delivered for testing in container terminal operations by 3rd quarter 2011. The prototype Vision Motors zero emission yard tractor is also anticipated to be delivered for testing by 3rd quarter 2011. Both units will immediately begin an 18-month demonstration period in accordance with an approved Demonstration and Test Plan. The goal is to have zero emission yard tractors fully developed, tested, and commercially available within the next 2 -3 years.

  The top priority is to bring electric yard tractor technologies successfully through the development and demonstration phase, including operational integration, resulting in the commercial availability of zero emission yard tractors in the near term.

  Advanced yard tractor technologies, such as diesel hybrid electric, have also been successfully demonstrated under the TAP. These technologies have the potential to achieve near-term emission reductions from diesel-fueled yard tractors and can serve as bridge technologies until electric yard tractors are fully commercialized.

  Because battery electric yard tractors are anticipated to carry a cost premium compared to conventional diesel yard tractors, the availability of financial incentives to buy down a portion of the incremental capital cost of the electric technology may be necessary in the near term. Dedicated electric yard tractor recharging infrastructure may also be required and will add additional cost. Costs for equipment maintenance however are expected to be reduced from conventional equipment. To fully or partially offset the incremental cost for zero emission technologies that reduce emissions above and beyond the CARB Cargo Handling Equipment rule, the ports should encourage agencies such as the Department of Energy (DOE), California Energy Commission (CEC), EPA, CARB and AQMD to make financial incentives available.

- Continue to work with terminals operators to select additional zero emission CHE technologies for demonstration through the TAP process, with oversight by the TAC.

- Working with a terminal operator in the Port of Long Beach, the ports commissioned the development of performance specifications for yard tractors. The final specification information, which was completed in 2009, is posted on the ports' CAAP website. The ports continue to work with terminal operators to develop performance specifications for additional equipment types, operational requirements, and integration strategies for zero emission cargo handling equipment.

- Continue to facilitate the electrification of RTGs. Kits that convert diesel generator powered RTG cranes to grid electricity are commercially available. The ports should continue to facilitate implementation of this technology for port terminals, where feasible, through ensuring adequate electrical capacity and infrastructure at the terminals. The ports should also encourage the agencies, such as DOE, CEC, EPA, CARB, and AQMD, to make financial incentives available to offset incremental costs. The ports can also apply for grants from government agencies on behalf of port terminal operators as needed.

- Expansion of RMGs into terminal operations, as feasible and appropriate, should also be encouraged. Typically, because RMGs require installation of rail tracks, implementation of RMGs will be more appropriate during new terminal construction or renovation of existing terminals. The ports are currently requiring electric RTGs or RMGs in new or redeveloped terminal projects.

- As needed, the ports can also apply for grant funding assistance on behalf of terminal operators to support zero emission CHE demonstration and deployment at marine and intermodal terminals. Each port has previously provided this type of support to their terminal operators for equipment retrofit, replacement and repower projects by applying to grant programs that are only available to government entities.

In the longer term, the ports could also:

- Continue to move forward with TAP demonstrations of advanced zero emission technologies for all CHE, including broader operational and durability testing. The ports should pursue the demonstration of electric technology applied to other types of CHE, specifically container top-handlers that comprise 9% of the ports' CHE equipment inventory but account for 22% of total CHE DPM emissions and 27% of total CHE NOx emissions;
- Continue to facilitate electrification of RTGs and RMGs, and work with marine and intermodal terminals to identify additional opportunities for integrating and implementing zero emission terminal operations;
- Promote ongoing improvements in battery technologies through the TAP;
- Assess the need for battery charging or hydrogen fueling station infrastructure with larger-scale zero emission CHE deployment, and assist as needed and appropriate;
- Assist with identifying funding support for purchases of zero emission equipment and/or terminal electrification, which may include applying for grants on behalf of terminal operators.

3.7. Zero Emission Options for Regional Rail Locomotives

The ports understand that locomotive emissions impact communities near the port complex and along goods movement rail corridors within the SoCAB. Thus, there is a compelling need to address locomotive emissions both at the in-port and regional levels. While the challenges presented in adapting zero emission technologies to rail locomotive operations are considerable, they are by no means insurmountable.

The ports, in partnership with rail stakeholders from both government and industry, must develop a recommended course of action to substantially reduce emissions from rail locomotives at both the in-port and regional levels. It is essential that any zero emission rail concept identified for possible implementation be developed and demonstrated with the cooperation and concurrence of several key stakeholders, particularly the U.S Department of Transportation Federal Railroad Administration (FRA) and the Class 1 railroads that serve the ports, BNSF Railway and UP Railroad. Further, it must be understood that due to the complexities associated with zero emission rail technologies, the timeframe for zero emission integration with rail operations is substantially longer compared to technology options for other sources discussed in this report. Therefore, the ports must continue to pursue the CAAP strategies in the interim for reducing rail emissions, even as they work to identify viable and feasible zero emissions options for the long term that could be integrated into railroad operations.

The application of zero emission technologies to rail locomotive operations within and beyond port boundaries is a far more complex task than for short-haul drayage and CHE. First, the technical and programmatic assessments conducted by the ports relative to port-related rail operations revealed that implementation challenges will exist related to right of way entitlements and future track capacity to accommodate optimized or high frequency container moves by rail between marine terminals and near-dock intermodal facilities. Second, the ports' authority as it pertains to rail operations is limited, specifically on the Alameda Corridor and particularly beyond port boundaries. However, despite these challenges, the long-term implementation of zero emission technologies for rail operations must be pursued in cooperation with all stakeholders to address in-port and regional locomotive emissions.

3.7.1 An Overview of Rail Operations at the San Pedro Bay Ports

Port rail emissions represent 5% of the combined ports' total emissions inventory for DPM and 8% of the NOx emissions. Port efforts to further reduce port-related rail emissions remain a main concern. In fact, the effort to utilize best available control technologies to mitigate locomotive emissions is a priority of the ports' TAP.

Railroad operations at the ports are typically described in terms of two different types of operation, line-haul and switching. Line-haul refers to the movement of cargo over long distances (e.g., cross-country) and occurs within the port as the initiation or termination of a line-haul trip, as cargo is either picked up for transport to destinations across the country or is dropped off for shipment overseas. Switching refers to short movements of rail cars, such as in the assembling and disassembling of trains at various locations in and around the ports, sorting of cars of inbound cargo trains for subsequent delivery to marine terminals, and short distance hauling of rail cargo within the port complex.

The ports are served by three rail companies:

- BNSF Railway
- UP Railroad
- Pacific Harbor Line (PHL)

BNSF and UP are designated Class 1 railroads[11] and operate both within and outside of the port boundaries. Both operate national fleets under the regulations and scrutiny imposed by the FRA. PHL is the switcher locomotive operator within the port boundaries, controlled under operating agreements with both ports. Locomotives used for line-haul operations are typically equipped with large, powerful engines of 4,000 horsepower (hp) or more, with each railroad operating a variety of different locomotive models. Switcher locomotives are smaller, typically having one or more engines totaling 1,200 to 3,000 hp.

3.7.2 Ongoing Efforts to Reduce Locomotive Emissions

The 2010 CAAP Update includes measures targeting continued reductions in locomotive emissions. Specifically, CAAP Measure RL3 ("New and Redeveloped Near-Dock Rail Yards") outlines the strategy to achieve significant reductions in locomotive emissions through the accelerated turnover of the existing locomotive fleet, replacing existing locomotives with newer, lower emitting models. The goal of this measure is to have the Class 1 railroads incorporate the cleanest locomotive, CHE, and HDV technologies into near-dock operations. Measure RL3 establishes the goal that the Class 1 locomotive fleet associated with new and redeveloped near-dock rail yards meets a minimum performance requirement of an emissions equivalent of at least 50% Tier 4 line-haul locomotives and 40% Tier 3 line-haul locomotives when operating at the port properties by 2023, to support CARB's published goal of 95% Tier 4 line-haul locomotives serving the ports by 2020. In addition, RL3 will implement idling restrictions, the use of cleaner fuels and evaluation of cleaner locomotive technologies.

[11] The Surface Transportation Board defines a Class I railroad in the United States as "having annual carrier operating revenues of $250 million or more" after adjusting for inflation using a Railroad Freight Price Index developed by the Bureau of Labor Statistics.

Additionally, the ports amended PHL's operating agreements in 2006 to provide funding assistance for the replacement of PHL's existing locomotives with new locomotives meeting Tier 2 emission standards. The locomotives purchased under the amended agreements were delivered during 2007 and 2008; and immediately thereafter, PHL retired the last of the pre-Tier 2 locomotives. Since 2009, PHL's fleet has consisted of 16 Tier 2 locomotives and six "multi-engine genset switcher" locomotives that are powered by three relatively small diesel engines rather than one large engine. These multi-engine genset switcher locomotives use Tier 3 engine technologies. Further, under subsequent amendments to the operating agreements in 2010, PHL is now moving forward with repowering the 16 Tier 2 locomotives with engines that meet even cleaner Tier 3 + standards prior to the end of 2011.

Finally, the ports and UP are participating in an emerging technology demonstration of a Johnson Matthey diesel particulate filter retrofit device for locomotives, anticipated to reduce DPM emissions by over 85%. The project is being funded by a combination of a grant from CARB secured by the ports and TAP funding.

3.7.3 Jurisdictional Authority

The vast majority of line-haul trains bound for destinations outside the port utilize the Alameda Corridor, a 20-mile dedicated rail line running between the San Pedro Bay area and downtown Los Angeles. The ports' ability to impose zero emission requirements on Class 1 locomotives that use the Corridor is substantially limited by the 1988 Alameda Corridor Use and Operating Agreement between the Cities of Los Angeles and Long Beach, ACTA, BNSF and UP.

Beyond the Alameda Corridor Use and Operating Agreement, the ports also have long-term agreements with BNSF and UP that guide track use. These "Use of Tracks" agreements contain long-term conditions that cannot be changed via lease or tariff.

Further, Class 1 locomotives and rail transportation are regulated on a federal level by the EPA, FRA and STB. The EPA adopts emission standards for new and re-manufactured locomotive engines and approves state implementation plans under the Clean Air Act. CARB has entered into voluntary Memorandums of Understanding (MOUs) with the Class 1 railroads to achieve emission and health risk reductions through accelerated turnover of older locomotives with newer, cleaner locomotives and through measures to reduce impacts from railyard operations.

Given the existing agreements and jurisdictional limitations, development and demonstration of zero emission technologies and measures to implement these technologies are most effectively accomplished through a cooperative partnership with the railroads and participating railroad authorities.

3.7.4 Status of Zero Emission Technologies Applicable to Rail Locomotives

As discussed in Section 1, 94% of DPM emissions and 93% of NOx emissions associated with port-related rail operations in 2009 were generated by line haul locomotives. Port-related locomotive emissions are a regional source of air pollution; thus, zero emission options targeting locomotive emissions should be primarily pursued on a regional scale, with the prospect that these options may potentially be applicable to in-port operations.

All zero emission options identified for regional rail use electricity. Rail electrification options that may need to be explored include, but are not limited to:

- Incorporation of LSM technologies into existing rail beds;
- OCS to power electric or dual-mode locomotives; and
- Battery electric tender car.

There are significant operational issues that must be addressed when contemplating the use of rail-related zero emission technologies on a regional scale within the SoCAB, specifically availability of electrification infrastructure and use of dedicated electric-powered locomotives. For example, it must be determined how a dedicated electric-powered locomotive will continue to operate beyond the end of the SoCAB's geographic boundary, if its power source does not continue beyond the SoCAB. The railroads have expressed concerns about any zero emission option that requires a change out of locomotives upon entering or leaving the SoCAB. This presents a serious operational constraint to advancing dedicated electric-powered locomotives as a viable option.

When considering these operational constraints, LSM technology has several potential advantages that warrant further consideration:

- LSM can be adapted to existing rail beds, but does not require electrification of the rails themselves. This propulsion system consists of concrete-encased motor winding modules mounted between rails that provide a magnetic field. Permanent magnets are attached to the bottom of a standard rail car carrying a fully loaded single or double-stacked container. This all-electric approach is free of any exposed high-voltage third rails or OCS wires. Power is provided only to the area of track around each vehicle by using solid-state electronic switches. There is no conflict with conventional diesel locomotives using tracks retrofitted with LSM.
- Conventional rail cars can be used on LSM-equipped track with minimum modifications. A standard rail car is equipped with two wheel "bogies" (the truck that secures the steel wheels and suspension components). Each rail car bogie is modified with the installation of a magnet

module containing arrays of permanent magnets. These magnet arrays interact with the magnetic field induced in the LSM motor modules and provide the thrust to move and stop the rail car. The system as conceived will be capable of propelling very large loads, including multiple double-stacked railcars. The width of the LSM modules and the length of the magnet arrays will be based on the specifics of the application, but hold the potential to propel complete trains. No modifications are required on the locomotives themselves.

- LSM can be integrated into existing rail beds incrementally. On LSM-equipped track, the locomotive can operate in a zero emission mode; then at the end of the LSM line, the diesel locomotive engine can be started and continue in a conventional operations mode;
- LSM is an option that is ready for prototype development and demonstration. A demonstration will provide valuable data to better understand how LSM could apply to regional, and potentially in-port, rail operations.

There are some challenges with LSM however that must also be addressed during any evaluation, especially if the technology will be considered for application between the port terminals and the near-dock rail yards. For example, incorporating automation, or self-propelled rail cars, into an LSM option is currently prohibited by the United States Department of Transportation and the FRA, and no LSM technology has been safety certified by the FRA. Further, the existing rail system within the port complex may not have sufficient capacity to accommodate optimized container routing in either an automated or crewed operation mode. Detailed rail simulation and on-dock railyard capacity analysis, based upon current rail planning, indicated that by 2020, there will be insufficient capacity to handle additional LSM rail car moves to and from near-dock railyards beyond normal movement on on-dock trains and other switching movements. Therefore, a thorough understanding of these issues, and the opportunities to overcome them, is an important aspect of the LSM evaluation.

It is also important to note that consistent with the zero emission technology "process approach" and a commitment to preserve flexibility to allow for integration of future advancements, in addition to LSM, other zero emission rail options will continue to be actively identified, evaluated and demonstrated. The TAP will be utilized for this purpose.

3.7.5 Recommendations for Rail Locomotives

The ports' technical and programmatic screening assessment of zero emission technologies for existing rail operations did not identify any solutions that can reasonably be implemented within the near-term (three years). Thus, implementation of CAAP Measure RL3 discussed in Section 3.7.2 is the recommended primary near-term option to address rail locomotive emissions. *Therefore, for near-term in-port and near-dock rail emission reductions, the ports should continue efforts to reduce switch and line-haul locomotive DPM and NOx emissions through implementation of CAAP Measure RL3.*

Both BNSF Railway and UP Railroad have proposed projects forthcoming that will require new or re-negotiated leases. The ports have adopted policies that their leases shall be compliant with the CAAP, and the Boards of Harbor Commissioners have discretion at the time of lease approval to include among the negotiated lease conditions, CAAP Measure RL3 as a lease condition. The Boards have discretion to include other lease conditions, such as a provision that the Class 1 railroads work with the ports to jointly advance zero emission technology demonstrations, and evaluate new feasible technologies for implementation e.g. every seven years (lease reopener). Concurrent with technology demonstrations, collaboration with the railroads and other regional transportation stakeholders should be initiated to identify and better define issues and challenges to implementing zero emission technologies along regional rail corridors from in-port to the edge of the SoCAB.

As regards rail-related zero emission technologies, there is considerable interest to assess the technical feasibility and programmatic viability of applying LSM technology to existing rail infrastructure. AQMD is currently developing a proposal with General Atomics (GA) for demonstration of LSM technology on conventional rail tracks with a single rail car at GA's test facility located in San Diego. The proposed Phase 1 demonstration, or Proof of Concept, is expected to be initiated by 4th Quarter 2011 and would be conducted over an 18-month period. Other partners in this demonstration project could include the Lawrence Livermore National Laboratory and the Center for Commercial Deployment of Transportation Technologies (CCDoTT).

It is envisioned that this first phase Proof of Concept demonstration would be followed by a second phase, 18-month demonstration, with multiple railcars at a rail research and development testing site that can provide FRA certification. The FRA and American Association of Railroads jointly sponsored Transportation Technology Center (TTC) in Pueblo, Colorado offers such a testing site and the Ports, AQMD, and CCDOTT have had exploratory discussions with TTC. To provide technical input and consistency, TTC may participate as a technical observer/advisor in the Phase 1 test at the GA facility.

Staff recommends that discussions continue with all involved parties regarding a near term Proof of Concept demonstration of LSM technology at an offsite test facility. As the proposed demonstration project matures, a staff recommendation for participating in the project as a stakeholder will be brought forward to each port's Board of Harbor Commissioners for consideration, which may include financial participation. It is anticipated that this recommendation will be brought forward to the Boards within the next few months.

Further, if the Phase 1 testing proves that the LSM technology is promising, the ports could participate in the Phase 2 demonstration of the LSM technology applied to multiple rail cars, as appropriate.

The ports should also collaborate with the rail companies and other stakeholders to further evaluate additional zero emission rail technologies, including LSM, OCS, and a battery electric tender car.

In the longer term, beyond three years, the ports should continue to participate, with a stakeholder collaborative, in existing or proposed zero emission rail demonstration projects, as appropriate; continue to collaborate with rail companies and other stakeholders to evaluate strategies for integrating and implementing zero emission technologies into port-related rail operations on a voluntary basis; and work with stakeholders at the local, state and federal levels to secure funding for zero emission rail technologies.

4. Conclusions and Recommendations

As emphasized throughout this report, there is no single off-the-shelf technology or stand-alone strategy to achieve zero emissions at the ports. Instead, attaining zero emission port-related operations will require multiple pathways of action, strong collaborations and regional partnerships, and support – technical, operational and financial – to advance technological innovation and evolution. It is also a dynamic and ongoing process, a framework approach to transition to zero emissions starting with options that can be supported today.

The roadmap defined in this paper is ambitious. It requires near-term commitments and longer term actions from a broad cross-section of stakeholders. Most of all, this roadmap requires flexibility to accommodate new technologies and approaches alongside a commitment to the end goal – achieving the San Pedro Bay Standards – while addressing and overcoming the myriad challenges identified in this report. If successful, however, this roadmap has the potential to dramatically improve air quality for local communities and throughout the region.

The recommendations proposed here – targeting short- and medium-haul drayage trucks, cargo-handling equipment, and rail – adhere to the key principles identified in Section 1.

Recommended near-term and longer term actions are summarized in Table 7.

Table 7: Recommendations for Zero Emission Technology Implementation

Timeline	Source Category	Actions
Near Term **(within 3 years)**	On-Road Drayage	Conduct Technology Advancement Program (TAP) demonstrations of Vision Motors hybrid electric/hydrogen fuel cell and Balqon lithium-ion battery zero emission drayage truck technologies in short-haul port-related operations following approved testing protocols and within specified timelines. Both manufacturers will deliver trucks for testing by 3rd Quarter 2011. Industry representatives will participate in these demonstrations in an advisory capacity, along with the TAP Technical Advisory Committee (TAC), which includes the ports, Environmental Protection Agency (EPA), California Air Resources Board (CARB) and South Coast Air Quality Management District (AQMD); Select additional zero emission truck technologies for demonstration through the TAP process, with input from industry and the TAP TAC; Seek grant funding assistance and industry partnerships to support zero emission truck demonstration and deployment, as needed; Establish regional partnership with the Los Angeles Metropolitan Transportation Authority, Southern California Association of Governments, Gateway Cities, South Coast Air Quality Management District (AQMD), and others. Work together to define regional zero emission freight transport needs and develop criteria for evaluating options for moving forward with zero emission truck technologies on a regional scale; Working with the regional partnership, identify and evaluate specific range extension options for zero emission truck technologies, including hybridization, in-road LSM, and overhead catenary; Work with the regional collaborative to identify potential funding sources.

Timeline	Source Category	Actions
Near Term **(within 3 years)**	Cargo Handling Equipment	Conduct TAP demonstrations of Vision Motors hybrid electric/hydrogen fuel cell and Balqon lithium-ion battery zero emission yard tractor technologies in port-related operations following approved testing protocols and within specified timelines. Both manufacturers will deliver yard tractors for testing by 3rd Quarter 2011; Working with terminal operators, select additional zero emission cargo handling equipment technologies for demonstration through the TAP process, with TAC oversight; Working with terminal operators, develop performance specifications, operational requirements, and integration strategies for zero emission cargo handling equipment; Continue to facilitate electrification of RTGs and RMGs by ensuring adequate electrical capacity is available at marine terminals and require their use in new and redeveloped terminal projects; Apply for grant funding assistance to support zero emission cargo handling equipment demonstration and deployment at marine terminals, as needed.
	Rail Locomotives	Participate (with AQMD, the Center for Commercial Deployment of Transportation Technologies, and other stakeholders) in a proposed Proof of Concept demonstration of LSM technology applied to a single rail car test at the General Atomics facility in San Diego. The project is anticipated to be initiated by 4th Quarter 2011; Collaborate with rail companies and other stakeholders to further evaluate zero emission rail technologies, including LSM, overhead catenary, and battery electric tender car; As appropriate, participate in a Phase 2 demonstration of LSM technology applied to multiple rail cars. The phase 2 test would be conducted at a testing center equipped to provide Federal Railroad Administration certification, such as the Transportation Technology Center rail test site in Pueblo, Colorado.

Timeline	Source Category	Actions
Longer Term **(>3 years)**	On-Road Drayage	Conduct broader operational and durability demonstration testing of advanced zero emission drayage truck technologies in short-haul port-related operations, as needed; Working with industry, evaluate operational compatibility of larger-scale zero emission truck deployment; Work with regional partnership on regional zero emission freight strategy implementation, and on demonstration projects for transitional technologies and technologies to extend zero emission truck range, including hybridization, in-road LSM, and overhead catenary; Assist with zero emission truck deployment by identifying funding opportunities and assisting with charging, wayside power or hydrogen fueling infrastructure as appropriate; Promote on-going improvements in battery technologies through TAP.
	Cargo Handling Equipment	Conduct broader operational and durability demonstration testing of advanced zero emission technologies for all cargo handling equipment, as needed; Assist with zero emission equipment deployment by identifying funding opportunities and assisting with charging or hydrogen fueling infrastructure as appropriate; Promote on-going improvements in battery technologies through TAP; Continue to facilitate electrification of RTGs and RMGs, and work with marine terminals to identify additional opportunities for integrating and implementing zero emission terminal operations.
	Rail Locomotives	Continue to participate, with a stakeholder collaborative, in existing or proposed zero emission rail demonstration projects, as appropriate; Continue to collaborate with rail companies and other stakeholders to evaluate strategies for integrating and implementing zero emission technologies into port-related rail operations; Work with stakeholders to secure funding for zero emission rail technologies.