DRAFT

Zero Emission White Paper

HIGHLIGHTS

Commitment and Progress

- In 2006, the Ports of Los Angeles and Long Beach, under the direction of their Boards of Harbor Commissioners established their Clean Air Action Plan (CAAP) for maritime goods movement sources to achieve both a significant health risk reduction and air emissions reduction targets.
- While the CAAP has been very successful at encouraging substantial emission reductions, further reductions are needed as port throughput continues to increase in the coming years.
- In 2011, the City of Los Angeles Harbor Department (Harbor Department) and the Port of Long Beach released a Zero Emission Technologies Roadmap to establish an initial plan for identifying technologies to pursue demonstrations to advance zero emission technology development. With important greenhouse gas reduction deadlines approaching in the next few years, the Harbor Department has identified ***zero emission equipment*** as an important element to be integrated into marine related goods movement in the future.
- To support this effort, the Harbor Department has provided ***over $7 million*** in funding for projects aimed at developing zero emission technology for short-haul drayage trucks and on-terminal yard tractors. These past, current, and planned zero emission technology demonstration projects consist of 14 on-road drayage trucks and 16 yard tractors (6 ongoing, 16 planned, and 8 completed).
- Initial zero emission vehicle testing showed mixed results, but more recent progress has been made that reinforces the Harbor Department's belief that zero emission container movement technologies show great promise for helping to reduce criteria pollutant and greenhouse gas emissions in the future.

Moving Forward

- The Harbor Department, working collaboratively with the Port of Long Beach and several stakeholders and partnerships, is committed to expanded development and testing of zero emission technologies, identification of new strategic funding opportunities to support these expanded activities, and new planning for long-term infrastructure development to sustain developed programs, all while ensuring competitiveness among the maritime goods movement businesses.
- By 2020, the Harbor Department hopes to have facilitated testing and development of up to 200 additional zero emission vehicles at the Port of Los Angeles, and to have these vehicles evaluated using a standardized testing protocol developed in partnership with a regional stakeholder group.

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July 2015

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1.0 Introduction

In July 2011, the staffs of the Ports of Los Angeles and Long Beach presented their Board of Harbor Commissioners with a preliminary plan entitled "Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles" (Roadmap). Its purpose was to provide an initial course of action for identifying, evaluating, and integrating zero emission technologies into maritime goods movement related activities in a manner that continues to reduce emissions, while still taking into account port customer competitiveness. Most significantly, the Zero Emission Technologies Roadmap concluded that while none of the zero emission technology options evaluated at that time were ready for full-scale implementation, the Ports should move forward with demonstrations and collaborations to advance these promising technologies.

2011 Zero Emissions Roadmap Principal Recommendations

- *Pursue zero emission technologies where technically feasible and economically viable*
- *Identify and demonstrate the technology options that are best suited for integration into port operations*
- *Preserve flexibility in approach to allow future zero and near-zero emission technology advancements to be integrated into port operations*
- *Consider the ability of any proposed zero emission strategy to scale out to the region in order to maximize health risk and emission reductions*
- *Immediately move forward with demonstrations that advance promising technologies toward feasible real-world implementation*

Since publication of the Roadmap, the Ports of Los Angeles and Long Beach have continued to carry out demonstrations of zero emission vehicles and equipment with the goal of advancing these technologies to a point that they can be used effectively by the port's terminal operations customers. Because the fastest means of deploying zero emission technologies is to replace existing customer equipment with similarly-capable zero emission versions, the Harbor Department's efforts have focused on development of equipment that is already widely applicable in the port environment. As terminal operators continue to modify and improve their operations, the Harbor Department expects that the zero emission equipment it promotes will be more optimally integrated into future terminal configurations, including potentially more efficient versions of today's terminals that include dedicated infrastructure for zero emission equipment. Customers may also develop partly or fully automated terminals that have slightly modified versions of the same zero emission technologies and dedicated infrastructure to support it.

Altogether, fourteen drayage trucks and yard tractors have been tested by the Harbor Department since 2008, separately or in collaboration with others, with four drayage trucks and two yard tractors currently operating in service as part of field demonstrations. In general, these projects have been able to demonstrate that the basic technology concept works, even though the early models tended to experience power inverter, battery and battery management issues, including eight units being returned to the vehicle or equipment developer for further development. Subsequent models have been able to show longer field demonstration time, and achieve better battery and operating consistency, though so far none of the vehicles has undergone long term testing in the maritime goods movement environment to determine if the technology can perform successfully in those applications.

Table 1 shows that the accumulated demonstration activity of yard tractors and drayage trucks tested to date falls far short of matching even a year's operation for a single yard tractor or drayage truck.

Table 1 – Comparison of Accumulated Demonstration Activity to Typical Fleet Operation

Description	On-Road Drayage	Off-Road Yard Tractor
Total units in past demonstrations	0	8
Number of units in field demonstration **today**	4	2
Total accumulated demonstration activity to date (the sum of all vehicle/equipment demonstration activity, including current (4) and past (8) demonstration units)	~8,900 miles	~1,000 hours
Average annual activity of a typical short-haul drayage truck in operation at the port (i.e. miles/year or hours/year)	~12,000 miles	~1,700 hours

Longer-term evaluations of these technologies are still needed to establish the technical viability, operational reliability and the ability to attract participation from established original equipment manufacturers (OEMs) that will lower acquisition and maintenance costs and allow this equipment to become commercially viable. The need for alternative fuel (i.e., hydrogen) and electric infrastructure to support these vehicles must also be explored and planned for.

With this in mind, the Harbor Department has new projects slated to begin over the next several months that will consist of 16 additional demonstration units that, once built, will undergo extensive field demonstration and evaluation in a maritime goods movement related environment. The current and planned demonstrations are designed to achieve a minimum of between one and two full years of operational experience of each demonstration unit in the marine environment, which has unique challenges (i.e., corrosive sea air, rigorous terminal area, heavy vibrations during loading, etc.). In addition, as will be described more fully in this White Paper, staff recommends that zero emission related infrastructure planning should commence right away and be considered as the Harbor Department makes decisions for capital investment programs going forward. Finally, staff recommends that for the near-term, local, state, and even federal funding sources should be sought to help fund testing of this equipment for the next few years while, for the long term, capital and operating cost considerations are evaluated by potential zero emission equipment operators as they determine how they can integrate this equipment into their operations.

The remaining sections of this paper will:

- Summarize the actions undertaken by the Harbor Department over the past several years of testing zero emissions equipment, and examine successes as well as the "lessons learned" from the initial zero emission technology demonstration efforts;
- Describe how the Harbor Department should expand its leadership role as a regional test bed to assess the feasibility of electric vehicles and infrastructure, including development of vehicle performance requirements, uniform testing procedures and assessment of infrastructure needs and design requirements;
- Provide insight into the business issues, including the need for federal, state, and regional government incentives (subsidies), associated with deploying advanced technology vehicles at the port from the perspectives of both vehicle manufacturers and operators; and
- Set forth a refined implementation strategy and schedule for testing of this equipment.

2013 Clean Truck Program Reductions

A cornerstone of the CAAP is the Port of Los Angeles Clean Truck Program, which has proven instrumental in reducing emissions from all three harmful air pollutants cited below. In its first year alone, the Port of Los Angeles Clean Truck Program reduced port truck diesel particulate matter (DPM) emissions by greater than 70%. More impressively, for the period from program inception to the most recent 2013 emissions inventory (EI), reductions in the three most critical air pollutants directly attributable to the Clean Truck Program are as follows:

- *Particulate Matter: 93% Reduction*
- *Nitrogen Oxides: 80% Reduction*
- *Sulfur Oxides: 91% Reduction*


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2.0 Role of Zero Emission Technologies at the Port

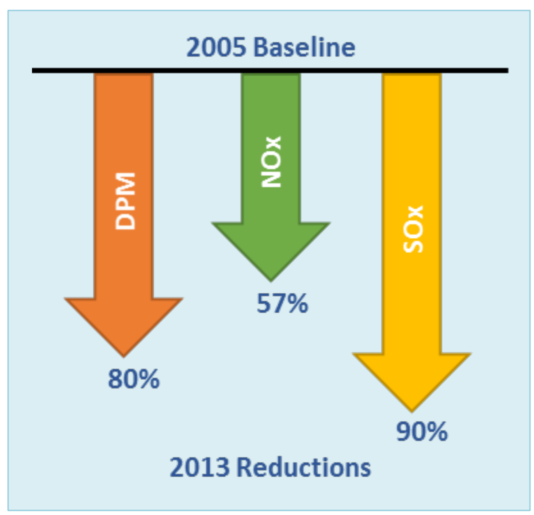
The economic benefits of port activity are felt throughout the nation, but much of the environmental impact is felt in the region surrounding the port. Recognition of these environmental health consequences led to the joint Port of Los Angeles and Port of Long Beach landmark environmental initiative, the 2006 Clean Air Action Plan (CAAP), which was updated in 2010[1].

In the 2010 CAAP Update, the Ports of Los Angeles and Long Beach underscored their commitment to air quality improvement with the adoption of the San Pedro Bay Standards, comprised of two components:

- **Reduction in Health Risk from Port-Related Diesel Particulate Matter (DPM) Emissions.** Specifically, the Ports' Health Risk Reduction Standard is to reduce the population-weighted cancer risk of maritime goods movement related DPM emissions by 85% by 2020, relative to 2005 conditions, in highly impacted communities located near maritime goods movement sources and throughout the residential areas in the port region; and
- **Reduction of Maritime Goods Movement Related Air Emissions in the Local Region.** Relative to the base year 2005, reduce maritime goods movement related emissions:
  - 22% for nitrogen oxides (NOx), 93% for sulfur oxides (SOx), and 72% for diesel particulate matter (DPM) by 2014
  - 59% for NOx, 92% for SOx and 77% for DPM, by 2023.

In the period since the development of the first annual Port of Los Angeles Emission Inventory (EI) in 2005 to the most recently published EI for calendar year 2013[2], the Port of Los Angeles and stakeholders' efforts led to achievement of the following air quality improvements:

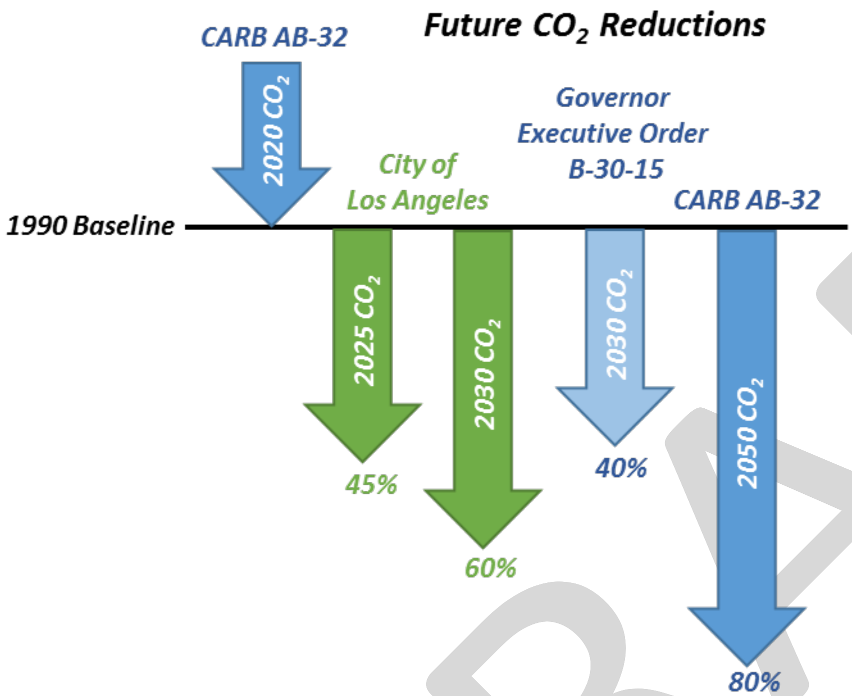
- **80%** reduction in DPM – an air pollutant classified as a known carcinogen
- **57%** reduction in NOx – the principal ingredient in the formation of ozone, or smog
- **90%** reduction in SOx – responsible for respiratory diseases such as emphysema and bronchitis



Clearly, the Port of Los Angeles has made significant progress toward meeting the 2010 CAAP goals, as reflected in its annual air emissions inventories, but the ports will need to continue working to advance the industry to maintain these CAAP reductions as growth in cargo throughput occurs in the coming years.

[1] The 2006 Clean Air Action Plan and the 2010 CAAP Update were developed and adopted jointly with the Port of Long Beach.
[2] *www.portofla.org/pdf/2013_Air_Quality_Report_Card.pdf*

In addition, new goals for greenhouse gas (GHG) emissions reductions have also been set by federal, state, and local agencies in recent years that offer even more daunting challenges. Under Assembly Bill -32 (AB-32), the State of California[3] has set the goal to reduce GHG emissions to 80% of 1990 levels by 2050. The California Air Resources Board (CARB) is required by AB-32 to adopt regulations that achieve these levels of reductions. More recently, Governor Brown set a new 2030 reduction target of 40% below 1990 levels in Executive Order B-30-15[4]. To put that in perspective, in 2013 the Port of Los Angeles emissions inventory indicated that port-related GHG emissions were at 15% below 1990 levels. This means GHG emissions will need to further decline another 25% in the next 15 years and 65% over the next 35 years.



While continued incremental emissions reduction from existing combustion-based sources at the port will help maintain compliance with CAAP goals as the port grows, these combustion-based sources will still generate greenhouse gas emissions. For this reason, more and more zero emission equipment will need to become integrated into maritime goods movement related activities as this equipment becomes technologically and commercially viable in the future.

There are three principal reasons why the Harbor Department must continue its environmental leadership to reduce maritime goods movement related truck and container movement emissions:

1. *Continue to maintain health risk and air emissions reduction targets laid out in the 2010 CAAP Update.*
2. *Reduce impacts on surrounding communities and support green growth of Port cargo terminals.*
3. *Contribute toward greenhouse gas reduction targets set by the California Air Resources Board and the City of Los Angeles.*

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[3] Assembly Bill 32 – The California Global Warming Solutions Act, 2006. *www.arb.ca.gov/cc/ab32/ab32.htm*
[4] Executive Order B-30-15, 2015. *gov.ca.gov/news.php?id=18938*

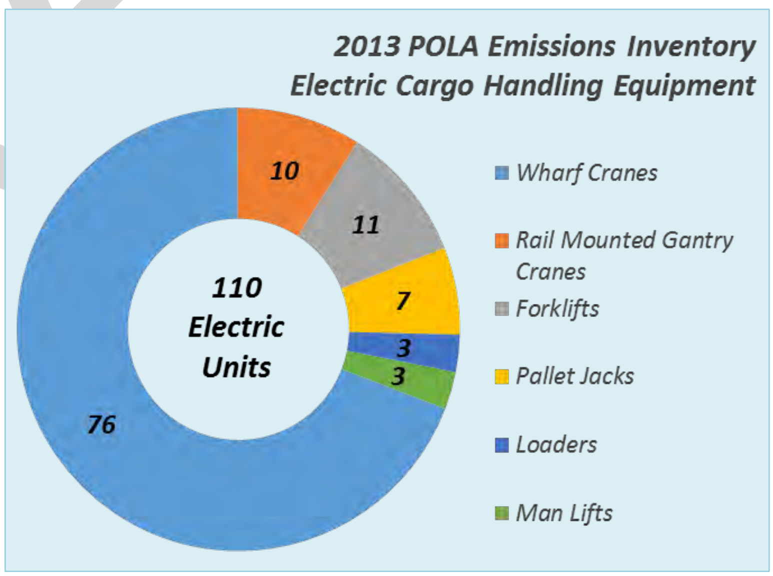
3.0 Technology Options Undergoing Evaluation at the Port of Los Angeles

This section provides a brief overview of zero and near-zero emission technologies that have been or are currently being tested at the Port of Los Angeles.

3.1 Zero Emission Vehicles and Equipment

2013 POLA Emissions Inventory Diesel Cargo Handling Equipment Population	
Bulldozer	*3*
Crane	*9*
Excavator	*1*
Forklift	*159*
Loader	*15*
Man Lift	*16*
Material Handler	*12*
Miscellaneous	*7*
Rail Pusher	*3*
Rubber Tired Gantry Crane	*108*
Side Pick	*34*
Skid Steer Loader	*8*
Sweeper	*9*
Top Handler	*160*
Truck	*21*
Yard Tractor	*874*
Total	***1,439***

Since it is a commonly used term, for this paper, "zero emission" refers to vehicles and equipment that have zero exhaust (tailpipe) emissions of criteria and greenhouse gas air pollutants, though staff believes this expression is actually a misnomer. While for the purposes of this paper, power plant, refinery, or other fuel cycle-generated emissions are not quantified or assigned to the zero emission truck or equipment, staff recommends that life-cycle emissions should always be considered when establishing emissions inventories that involve vehicles and equipment that have zero tailpipe emissions of criteria and greenhouse gas air pollutants. Nonetheless, electricity derived from renewable sources with the lowest possible power generation emissions is far preferable to today's current mix of fuel sources that include coal and other out of state electricity sources that do not have the same controls as those within the State of California.



As will be described below, zero emission vehicles and equipment include those powered by battery packs, certain hybrid vehicles or equipment, and even vehicles or equipment that rely wholly or partially upon an external power source. Zero emission vehicles and equipment have great potential for application at the Port of Los Angeles, especially zero emission yard equipment, though at this stage of their development, no demonstration unit has shown it can come close to the range (500 – 600 miles for a conventional drayage truck versus 120 miles for a zero emission drayage truck) and acquisition cost of conventional vehicles and equipment ($135,000 for a brand new diesel truck versus $300,000 to $500,000 for a zero emission vehicle). For this reason, zero emission vehicles have so far only been tested in applications with limited mileage needs and the tests have largely been funded by grant money. Trucks, both on-road drayage and off-road yard tractors, which meet the definition of "zero emission," include battery-electric, fuel cell, inductively-charged, and overhead catenary electric trucks.

Other zero emission technologies are being tested or used in other maritime goods movement equipment at the Port, such as rubber tire gantry cranes, rail mounted gantry cranes, and more.

Yard Tractor - an off-road mobile utility vehicle used to carry cargo containers with or without chassis. Also referred to as terminal tractor, yard tractor, utility tractor rig (UTR), yard goat, yard hostler or prime mover

3.2 Near-Zero Emission Technologies

Near-zero emission vehicles and equipment are often defined as having exhaust (i.e., tailpipe) emission levels approximately 90% lower than the United States Environmental Protection Agency (US EPA) 2010 heavy-duty emission standards[5]. This equates to NOx emissions less than or equal to 0.02 grams per brake horsepower-hour (g/bhp-hr) as measured on a chassis dynamometer under the Urban Dynamometer Driving Schedule (UDDS). Also, particulate matter emissions would be negligible under the "near-zero" definition.

Today, commercially available alternative fuel heavy-duty trucks such those fueled by natural gas already have approximately 50% lower measured NOx emissions when compared to current emissions standards[6]. The South Coast Air Quality Management District (SCAQMD) has set an interim goal of 0.05 g/bhp-hr (75% lower NOx emissions) for the next generation of heavy-duty natural gas engines. Interestingly, this level has been demonstrated in medium-duty diesel engines, and diesel engine manufacturers predict they will produce "near-zero" vehicles and equipment within the next five years. Smaller displacement heavy-duty engines have already achieved emission levels approaching the 0.02 g/bhp-hr "near-zero" NOx levels using natural gas fuel.

With prices starting at $140,000 for natural gas trucks, these vehicles offer lower acquisition cost and greater range, when compared to the zero emission prototypes tested thus far, which may make certain near-zero emission technologies good options in the near term for container transport to destinations outside of the immediate port area. The most common near-zero truck technologies and configurations include:

- **Liquefied and compressed natural gas trucks** – heavy-duty trucks equipped with an engine configured to operate on natural gas (methane) fuel as opposed to conventional diesel fuel. These trucks are expected to be commercially available at near-zero emission levels for a cost of about $40,000 above conventional diesel-fueled vehicles. Most of this incremental cost is associated with the natural gas fueling system and on-board fuel storage tanks; and

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[5] *www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers#goods*
[6] US EPA's 2010 standards are the current (i.e., most stringent) standards for heavy-duty engines.

- **Hybrid and plug-in hybrid trucks** – heavy-duty trucks equipped with a hybrid drivetrain configuration combining an electric motor with an internal combustion engine powered by conventional or alternative fuel. Conventional fuels are petroleum derived, such as gasoline and diesel. Alternative fuels include compressed and liquefied natural gas (CNG, LNG), liquefied petroleum gas (LPG, i.e., propane), ethanol, methanol, dimethyl ether (DME), hydrogen, and non-petroleum biodiesel fuels. Hybrid configuration drayage tractors, such as those currently undergoing development and demonstration under the sponsorship of the Harbor Department, are not only expected to achieve near-zero emissions, but could also offer true zero emission operations. Referred to as having a "zero emissions mode," these trucks could operate on battery alone while on Port property and potentially within future port-defined boundaries. Near-zero hybrid truck technology still has the high incremental cost of zero emission technology, since on-board energy storage and electric drive train components are required for hybrid configurations, though these incremental costs are expected to be somewhat less than for zero emission technology, since smaller on-board energy storage (i.e., battery packs) is required. These higher costs may be worth the extra benefit of hybrid technologies, which are expected to be better able to meet duty cycle requirements of medium- to long-haul drayage.

In addition, given the rate of development of these technologies, diesel trucks with commercial engines that are *between 75% and 90% lower NOx emitting* than today's state of the art diesel drayage trucks are likely to enter the marketplace soon. Their long-distance range, coupled with their more straight-forward infrastructure needs, will make them suitable for all container drayage operations spanning short-haul to near dock rail yards as well as container hauling to distribution centers located in the Inland Empire and beyond. However, while non-hybrid near-zero technologies are promising and do not pose the cost issues that zero and hybrid near-zero emission equipment pose, *near-zero technologies that rely on combustion-based technologies still emit greenhouse gases*. Therefore, they cannot be considered a long-term solution for short-haul and regional goods movement seeking to reduce not only criteria pollutants but also greenhouse gases.

3.3 Summary of Testing Activities

The Zero Emission Technologies Roadmap identified short-haul heavy-duty vehicles and cargo handling equipment as areas for targeted initial zero emission technology testing and demonstration. As such, the Port of Los Angeles, many times in partnership with the Port of Long Beach, SCAQMD, and other agency stakeholders, has carried out a series of zero emission vehicle tests and demonstrations, with some starting prior to the Zero Emission Technologies Roadmap, as early as 2008. Thirty electric drayage truck and yard tractor projects have been completed, are ongoing or are about to get underway. Table 2 provides a summary of ongoing and planned projects and their current status. Table 3 provides a summary of completed projects; please refer to Table A1-2 for additional detail regarding completed project results.

Table 2 – Ongoing electric truck and yard tractor demonstration project status, as of May 31, 2015

Demonstration Vehicle Description	Timeframe	Unit Count	Field Trial Operation Today?	Planned Testing Term	Test Site	Status
TransPower electric yard tractors (off-road) for the AB 118 Air Quality Improvement Program	2014-2016	2	Yes	2 years	SA Recycling, Dole Dist. facility (San Diego) until moved to Eagle Marine	Unit #1 accumulated 436 miles since placed in service on 10/14/14 and Unit #2 accumulated 1,179 miles since placed in service on 12/15/14. Once charging station complete, the units will move to Eagle Marine.
TransPower ElecTruck™ (On-road Unit 1) for the Zero Emission Cargo Transport (ZECT) I Program	2014-2016	1	Yes	2 years	SA Recycling	Field test began 10/1/2014. Accumulated 3,330 miles, ongoing Battery Management System (BMS) issues, poor reliability thus far, unit returned to TransPower for upgrades.
TransPower ElecTruck™ (On-road Unit 2) for the ZECT I Program	2014-2017	1	Yes	2 years	TTSI	Field test began 1/20/15. Accumulated 3,904 miles each, improved reliability using redesigned BMS
TransPower ElecTruck™ (On-road Units 3 & 4) for the ZECT I Program	2014-2017	2	Yes	2 years	TTSI	Unit #3 accumulated 1,124 miles since placed in service on 3/24/15 and Unit #4 accumulated 592 miles since placed in service on 4/13/15.
TransPower ElecTruck™ (On-road trucks - Units 5-7) for the ZECT I Program	2014-2017	3	Not Yet	2 years	TTSI, SA Recycling	Units will have new BMS design. Final drive system testing and systems integration underway. Expected field testing date September 2015.
Balqon electric trucks with Li-Ion batteries and new BMS	2015-2016	6	Not Yet	1 year	APMT (3 units) and Evergreen (3 units)	Field testing expected to start late Spring 2015 after charging infrastructure is complete.
4 e-trucks with fuel cell range extenders, 1 fuel cell truck), 1 diesel hybrid and 1 CNG hybrid truck, with pantograph for the ZECT II Program	2015-2018	7	Not Yet	2 years	TTSI	Contract negotiation underway, vehicle design and development has not yet begun.

Table 3 – Completed electric truck and yard tractor demonstration projects

Demonstration Vehicle Description	Timeframe	Unit Count	Field Trial Operation Today?	Testing Duration	Test Site	Status
Balqon battery-electric Terminal Tractor	2009	2	No	< 1 week	YTI	Unit returned to the manufacturer.
Capacity Plug-In Hybrid Electric Terminal Tractor	2010	1	No	Two 3-week trials	Trial #1: Ports America, TTI; Trial #2: YTI	Unit returned to the manufacturer.
Hybrid Yard Tractor Development & Demonstration	2010	3	No	6 months	LBCT	Units returned to the manufacturer.
Balqon Lithium-Ion Battery Demonstration in a Yard Tractor	2011	2	No	3 months	Cal Cartage	This 3rd generation battery system achieved a range of 12 hours/charge (however, not on a consistent basis); A one-day demonstration confirmed a range of over 150 miles on a single charge.
Vision Fuel Cell Hybrid Electric Terminal Tractor	2012	1	No	Unit not built	NA	Vision no longer in business.
Vision H2 Fuel Cell Hybrid Drayage Truck	2012	1	No	Not completed	NA	Vision no longer in business.
Balqon Lithium-Ion On-Road Truck	2012	1	No	1 month	Port & Rail Yards	Unit returned to the manufacturer for further development.

The early projects resulted in limited, if any, field demonstration time, with all nine of the original test units (one planned Vision truck was never built) being returned to the vehicle or equipment designer for further development. These early projects were able to demonstrate the basic technology concept, but experienced significant inverter, battery and battery management system issues, falling well short of stated performance goals. The inability of these units to demonstrate satisfactory time between charges (i.e., range) meant that in-service operation could not be achieved in sufficient quantity to even begin to assess overall vehicle reliability and durability.

More recent projects have demonstrated greater promise and more performance potential, including longer battery life and fewer operational failures. While encouraged by these more recent results, Harbor Department staff is concerned that the total amount of testing – for all of the test vehicles and equipment combined – is still less than the average annual operating miles/hours of a single typical short-haul drayage truck or yard tractor performing in a maritime goods movement environment[7].

[7] See Table 1.

For these reasons, new projects slated to begin over the next several months will consist of 16 additional demonstration units from a number of different companies, which once built, will undergo extensive field demonstration and evaluation. As battery and battery management system technology continue to evolve, it is anticipated that these new demonstration units will be able to achieve longer range between charge, and longer operational periods between repairs. The current and planned demonstrations are designed to achieve between one and two full years of operational experience for each of the demonstration units, with the hope of logging activity that is equivalent to typical annual operating activity of conventional technologies. These long-term evaluations of the various technologies are critical to establishing technical viability and operational reliability, as well as the ability to attract participation from established vehicle manufacturers (i.e., OEMs) that will help to lower costs and lead to eventual commercial availability of this equipment.

3.4 Lessons Learned

The preceding section describes a broad range of electric vehicle and equipment technology projects conducted by the Harbor Department under the auspices of the CAAP Technology Advancement Program (TAP) and in partnership with the Port of Long Beach. Over $7 million in Harbor Department funding[8] was or is being matched by over $30 million in funding from project stakeholders to implement a wide range of zero and near-zero technologies. These projects[9] have the common objective to facilitate the development, evaluation, and demonstration of electric and hybrid-electric drayage trucks and on-terminal tractors.

Though the more recent tests have shown greater promise, what has become clear is that the transition from conventional diesel combustion technology to new zero emission technology will take time to demonstrate the long term reliability and confidence that is necessary for this equipment to begin to replace its diesel counterparts. Important "lessons learned," include:

- **Limited demonstrations are not enough to jump start full-scale commercialization.**
  The Harbor Department has had previous experience with the introduction of new technologies (i.e., AMP, LNG drayage trucks). In both cases, the AMP and LNG truck technologies were utilized by industry before they had been rigorously tested and the initial purchasers of the first generation equipment dealt with unforeseen performance problems. For this reason, the Harbor Department supports the belief that thorough multiple unit demonstrations with rigorous in-use operation are needed to provide port operators with confidence in the technology and developers with data for performance claims and warranty provisions. In short: first, the equipment must meet minimum performance standards. Next, it must undergo long-term testing and demonstration to assure it is reliable in a maritime goods movement environment, which is more rigorous than typical goods movement distribution centers.

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[8] Harbor Department funding includes $5 million to Balqon Corporation for 14 electric yard tractors and one electric drayage truck. The early generation units have been returned to Balqon for further development, but the 3rd generation units are part of an upcoming demonstration project (see Appendix A1).

[9] Appendix 1 provides detail regarding completed and ongoing TAP projects, including project scope highlights.

- **Smaller advanced vehicle technology developers do not always have an understanding of the operational profiles of vehicles and equipment operating in a port environment.**
  In particular, duty cycle requirements were not always known, leading to prototypes that failed to achieve minimum performance requirements, especially pertaining to vehicle range and hours of continuous operation.
- **Original Equipment Manufacturer truck manufacturers and component suppliers are ultimately needed.**
  To date, most of the companies that have participated in zero emission technology development and demonstration are relatively small. These small companies may be able to design and build a prototype, but they may have difficulty attracting sufficient investment to sustain ongoing business through years of iterative testing and demonstration. New projects have now been planned that will include some of the OEMs, which the Harbor Department hopes will help advance this technology further.
- **Matching technology to duty cycle may be advantageous.**
  Some duty cycles and uses in a maritime related goods movement environment may lend themselves to certain zero or near-zero emission technologies more than others. For example, at least in the near term, certain hybrid and plug-in hybrid near-zero emission vehicles may be better suited for duty cycles where particularly heavy loads are required to be moved, since these applications might drain the battery on a zero emission vehicle too quickly.

As will be described more fully in the following subsections, widespread introduction of this equipment will depend upon the success of long-term tests to establish technical viability, operational reliability, reasonable cost, as well as the availability of infrastructure to support their operation.

3.5 Near Term Challenges

In addition to the need for continued testing and development of this equipment, several challenges remain for this technology that must be overcome before we will see widespread deployment. These include:

- The projected cost of zero emission vehicles is $150,000 per unit or more above conventional drayage truck and yard tractor cost, though the cost differential for near-zero hybrid technologies is expected to be somewhat less than for zero emission vehicles, since smaller on-board energy storage is needed. This high cost differential makes them uncompetitive. Without government incentives, conventional diesel-fueled vehicles and equipment offer thoroughly demonstrated performance, reliability, and 2010+ certified emissions (as previously noted, diesel manufacturers anticipate they will reach “near-zero” emissions levels within the next five years) at one-third to one-quarter of the price of the comparable zero emission vehicles and equipment. Economies of scale may eventually lower prices for zero emission equipment, but for large-scale production – and the consequent lowering of prices – to occur, a market must develop.
- The availability of less expensive alternatives, together with the lack of a regulatory imperative to push the marketplace toward this equipment, results in no incentive for OEMs to invest in heavy-duty zero emission vehicle and equipment development. As a result, at this time and for these reasons, there is no widespread demand for this equipment.

- As described in the preceding section, several smaller, insufficiently capitalized companies have attempted to address local interest in heavy-duty zero emission trucks, but most have had a difficult time sustaining themselves financially. Prototype vehicles developed by these small companies have lacked the engineering and development resources available for OEM vehicles. This is evidenced by the fact that not one of the early demonstration units accumulated more than a few months of intermittent operation in the field.
- This field testing is critically important since a marine terminal operating environment is unique to any other. The sea air causes accelerated corrosion and the tractors are subject to rigorous vibration as containers are dropped onto bomb carts for relocation.

A further challenge is simply the need for demonstrated long-term performance, reliability and durability. These vehicles must do more than just function; they must perform[10] at the level of their conventional technology counterparts, which have well over a century of experience behind them. Zero emission vehicles at the port need to be able to execute the same tasks as their conventional combustion-based counterparts with a similar level of reliability, in the rigorous marine environment. As the maritime goods movement sources at the port continue to be the drivers of global trade for the nation, containers must move from ships to regional distribution centers quickly and efficiently every day, without fail. Introducing any new technology that has a limited track record of operation and reliability can jeopardize the flow of global trade and have repercussions across the economy.

Consequently, the technical bar for zero emission trucks being considered "ready" must be high. Any new vehicle must not just have a few weeks or months of testing, but years of seamless, reliable operation in its real-world environment. As discussed further in Section 4, working with partners to define when a zero emission vehicle is truly ready for operation is a fundamental role the Harbor Department can play. Working to bridge the economic and experiential gaps to make these vehicles acceptable to customers must then follow.

In addition to economic and technical barriers, staff believes the lack of regional infrastructure to support charging of heavy-duty zero emissions equipment looms as another significant challenge for wide scale use of zero emissions vehicles and equipment for the near future. At this time, there are less than ten charging locations for heavy-duty electric vehicles and equipment in or near the port area. The proliferation of appropriate infrastructure to support zero emission technologies will need regional planning and resource allocation. Just as the standardization of charging infrastructure for passenger vehicles and ocean-going vessels (OGVs) each took many years to develop, infrastructure for heavy-duty zero emission vehicles is also likely to be complicated and time consuming.

Based on past experience with OGVs, the Harbor Department knows that infrastructure planning for zero emission technology will require major design and collaboration efforts. For instance, ensuring adequate power for a fleet of heavy-duty battery powered trucks will require work with the local utility and physical revision to the grid-supplied power systems that serve the port. For each terminal using heavy-duty battery-electric yard tractors, dedicated charging areas on the terminal will need to be set aside and equipped with appropriate power supply technology. These major planning efforts should be conducted in a manner that accounts for future needs and technology evolution.

[10] This will be assessed utilizing the test protocol described in Section 4.

For these reasons, staff believes *near*-zero emission technologies are likely to play an important role in maritime goods movement activities in the near term, while zero emission technology and infrastructure considerations are resolved and advanced. Attainment of a 75% to 90% reduction in smog-producing ozone precursor emissions, and the virtual elimination of carcinogenic toxic air contaminant particulate emissions, will help to negate the adverse health risks attributable to container transport. These health-related benefits are likely attainable on a larger scale, at lower cost, and within a much shorter timeframe as compared to the eventual transition to large-scale use of zero emissions equipment and vehicles. Further, a 75% to 90% reduction in ozone precursor emissions will help the SCAQMD in attaining mandated ozone reductions to meet 2032 regional air quality standards.

The Road to Standardization: High Voltage Shore Connection System International Standard

Started as a joint effort in 2006 with the Port of Long Beach, the two Ports sought to establish an international standard for ship-to-shore connection systems for ships plugging into shore power to reduce emissions. Three international standard organizations were engaged, including: International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), and the Institute of Electrical and Electronics Engineers (IEEE). The process included the following key steps:

- *Established a Publicly Available Specification (PAS)*
- *Appointment of a convener (lead advocate for the project)*
- *Project approved by vote of members*
- *Established a Working Group*
- *Produced committee draft and comment documents*
- *Addressed all comments*
- *Committee Draft for Voting (CDV)*
- *Central office released PAS*
- *A PAS is reviewed after three years, in which it is: reconfirmed for another 3 years, revised to become an International Standard, or withdrawn*

The PAS was published in April 2009 by ISO and IEC. The CDV was completed and circulated in August 2010 and voting results were completed by January 2011. A CDV meeting was held in February 2011 and a final Draft International Standard was published in 2011 containing edits from ISO, IEC, and IEEE. The final draft International Standard was completed in August 2011 and the International Standard was drafted in October in 2011 and published in July 2012. The process took over six years from start to publication of the International Standard. It is reasonable to expect that similar time frames would be required to develop standards related to infrastructure support for zero and near-zero emission technologies.

3.6 Ongoing Development

Staff nevertheless recommends that the Harbor Department continue its forward looking approach to air quality improvement due to the daunting greenhouse gas emissions reduction goals we face over the next 15 to 35 years. Zero emission technology testing and development must not be slowed. In fact, the Harbor Department must play a larger role in facilitating the development of these technologies by encouraging more wide spread testing in order to generate important technical and operations data for these technologies. This will involve including more port stakeholders, such as terminals and other potential users of this equipment, in testing and development. The ability of these stakeholder partners to evaluate the effectiveness of advanced vehicle technologies is critical to ensure that technologies adopted by these stakeholders will meet the rigorous demands of maritime related goods movement activities. Accordingly, staff proposes that a stakeholder group be formed – including ports, industry partners, agencies and environmental groups – to evaluate the results of zero emission test activities in the coming years.

Several projects are ongoing that will serve as a starting point for an increased role by the ports. Currently, the Harbor Department is co-funding five major technology development projects in partnership with federal, state, and local agency authorities and a variety of electric truck technology development companies. For these five projects, over $1.1 million in Harbor Department funding is being matched by the projects' partners in excess of $27 million, resulting in 22 short-haul drayage and yard tractor units developed, or being developed for long-term in-use demonstration. Project objectives range from a hybrid retrofit that allows all-electric range within or near a terminal to hydrogen fuel cell range extenders on zero emission trucks. Appendix 1 provides detail regarding the Harbor Department's ongoing zero and near-zero emission truck demonstration projects.

These Harbor Department efforts also align with regional priorities and efforts. Two SCAQMD-led projects are underway that will further contribute to the Harbor Department's experience and knowledge base. The first is a demonstration with Siemens Industry Inc. to develop and demonstrate a one-mile overhead catenary system to support zero emission trucks transiting along Alameda Street, in Carson. This $13.5 million project includes funds to develop and demonstrate a hybrid-electric Class 8 drayage truck and retrofit a total of four trucks with pantograph systems enabling them to connect to the overhead catenary system. The second is a $2.4 million project with Volvo Technology of America, Inc. to develop and demonstrate a plug-in, hybrid-electric, Class 8 drayage truck that will include the capability to operate in 100% all-electric mode during in-port operation.

Successful implementation of zero emission port vehicles and equipment will depend on a well-coordinated strategy to evaluate and assess readiness of the technology to meet operational needs on a day-in, day-out basis. The Harbor Department, in cooperation with its stakeholder partners, will play an important role in this technology assessment to ensure port operator requirements are met.

Finally, some stakeholders have pointed to recent automated terminal projects and suggested they be established as the goal for all zero emissions testing and development. Depending upon operational choices for automated equipment, these terminals can indeed achieve full zero emissions operations for their terminal yard equipment. This is a welcome achievement, and while it may be applicable for certain types of terminals – notably the larger ones that have substantial cargo throughput and can withstand the high capital cost – it is not something that is applicable for all port terminals. Full zero emissions operation for terminal yard equipment is nevertheless achievable for terminal operations of all kinds. Given appropriate testing and development, yard trucks, top picks, fork lifts, sweepers, gantry cranes, and other types of terminal equipment can all begin to transition to near-zero and eventually zero emissions technologies within the next ten years. As terminal operators continue to modify and improve their operations, the Harbor Department expects that the zero emission equipment it promotes will be integrated into future terminal configurations of all kinds, whether automated or not.

3.7 Periodic Status Reporting

Progress reports are an important part of our ongoing demonstrations. As a result, Harbor Department staff commits to report to the Board of Harbor Commissioners once a year on the status of ongoing zero emission testing. Each report will provide the following status for each vehicle tested:

- **Technical Viability** – Staff will report on the technical viability of the zero emission vehicle(s) being tested. This will include its ability to perform minimum test guidelines (see Section 4), its ability to handle different types of duty cycles, dynamometer testing results; and its ability to successfully operate in the port environment on a day to day basis, without any shortfalls compared to conventional technology.
- **Operational Reliability** – This part of staff's report will present information regarding the tested vehicle's or vehicles' operating record, including whether and how often it had to be repaired or was otherwise out of service. Operator feedback will also be discussed, with a report on how the terminals are adapting to this new technology. Operational reliability also contributes to the overall implementation cost of the new technology, since any failure to meet operational needs will require an increase in a fleet's spare ratio, which increases cost;
- **Availability of Supporting Infrastructure** – As vehicles pass the technical viability and operational reliability benchmarks, staff will provide an infrastructure availability status report. This report will assess infrastructure - available or needed - to support maximum vehicle use; and
- **Cost** – Staff will report on the projected costs of the tested vehicle(s), including upfront capital cost, fuel and maintenance cost, and any other applicable costs and fees. This section of the report will include information on the technology vendor's apparent commitment to long-term market support (i.e., do they plan to sell the trucks, and if so, as an OEM, or as a supplier/partner with an OEM, etc.)

Each report will conclude with a feasibility assessment regarding the potential of the tested vehicles to move into wider use (beyond testing) in maritime goods movement related activities based on the forgoing criteria when making its recommendation.

4.0 Zero/Near-Zero Truck Testing and Demonstration Guidelines

As described above, staff recommends that the Harbor Department play a larger role in facilitating the development of zero emission technologies. Specifically, one key area where the Harbor Department must focus its efforts is in the development of consistent and equitable zero emission testing and demonstration evaluation standards.

An important lesson learned from demonstration projects sponsored by the Harbor Department over the past few years is that advanced vehicle technology developers do not always have adequate understanding of the operational profiles of vehicles and equipment operating in a port environment. For example, a fundamental requirement is that an electric yard tractor reliably demonstrate the ability to conduct two, eight-hour shifts per day. This is partly due to limited knowledge of maritime goods movement operational profiles and partly due to inconsistency in performance measurement parameters, techniques, and reporting.

These issues all have straightforward remedies and indicate key roles for the Harbor Department. First, because maritime goods movement related operations typically involve rigorous duty cycles that manufacturers may be unaware of, the Port of Los Angeles can provide a venue to conduct testing and demonstration of zero and near-zero emission vehicles and technologies in a rigorous maritime goods movement environment. By doing this, the Harbor Department will advance its own air quality improvement commitments while serving as a "regional catalyst," stimulating both the pace of technology development as well as promoting economic development in Southern California.

Second, the Harbor Department can continue to play a central role in developing performance measurement and reporting guidelines. As a key facilitator in zero and near-zero emission heavy-duty vehicle development, the Harbor Department would like to ensure advanced technology developers use standardized engineering practices for vehicle manufacture – including design validation, performance verification, and vehicle durability testing. To that end, the Port of Los Angeles, in partnership with the Port of Long Beach, the South Coast Air Quality Management District (SCAQMD), and CARB, is working to develop guidelines for the technical evaluation, performance testing, and durability validation of electric, hybrid-electric, and other advanced technology trucks and terminal tractors designed to transport shipping containers within port marine terminals and to other regional destinations. The "Zero/Near-Zero Emission Truck Testing & Demonstration Guidelines" are currently in the draft stage with publication expected in the fourth quarter of 2015.

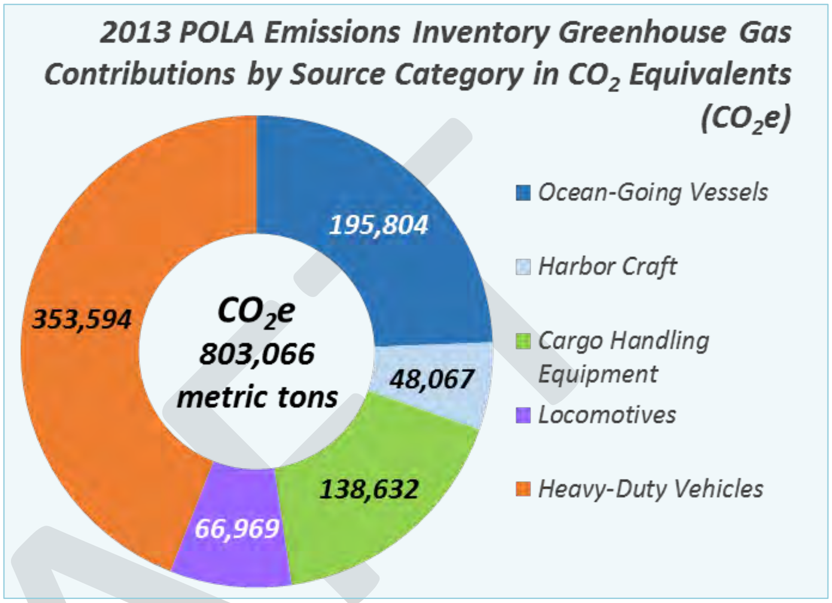
These "Zero/Near-Zero Emission Truck Testing & Demonstration Guidelines" will include:

- Minimum vehicle design, regulatory compliance, and performance requirements for Class 8 drayage trucks and on-terminal yard tractors operating at the ports, with the intent to serve as guidance to zero and near-zero emission truck designers and manufacturers;
- Guidelines for the preparation of a vehicle technical specification, vehicle performance specification, as well as laboratory and chassis dynamometer testing requirements; and
- A Zero/Near-Zero Emission Truck Demonstration Plan. The guidelines include recommendations for vehicle acceptance testing, on-road testing, on-terminal testing, and in-service/revenue testing.

The Harbor Department can actively disseminate this set of consistent guidelines to advanced technology truck manufacturers, marine terminals, and licensed motor carrier demonstration partners. The Harbor Department can also provide outreach to ensure a clear understanding of port requirements and expectations pertaining to vehicle performance, operability, and durability. Without such consistency, it is difficult to compare technologies and verify that zero or near-zero emission trucks meet the minimum performance requirements within the port environment. The adoption of uniform testing procedures will allow an "apples to apples" comparison of vehicle performance, while minimizing uncertainties in the testing processes.

5.0 Zero Emission Technology Planning

The 2011 Zero Emission Technologies Roadmap identified short-haul, or near dock, heavy-duty vehicles and cargo handling equipment as areas for targeted initial zero emission technology testing and demonstration. This is because these source categories offer the most straightforward platform for testing and they may provide the earliest potential for a market to develop, thereby attracting manufacturers. As discussed below, this is especially true for cargo handling equipment, due to its relative technical simplicity and its widespread use around the world in goods movement related activities. Additionally, the 2013 emissions inventory shows that heavy-duty trucks and cargo handling equipment make up more than 60% of goods movement related greenhouse gas emissions in the port's emission inventory. Thus, successful zero emission technology implementation in these categories will meaningfully support the Harbor Department's effort to meet challenging GHG reduction goals.



5.1 Zero Emission Technology Options

Zero emission technologies come in three basic forms, each with its own merits and drawbacks:

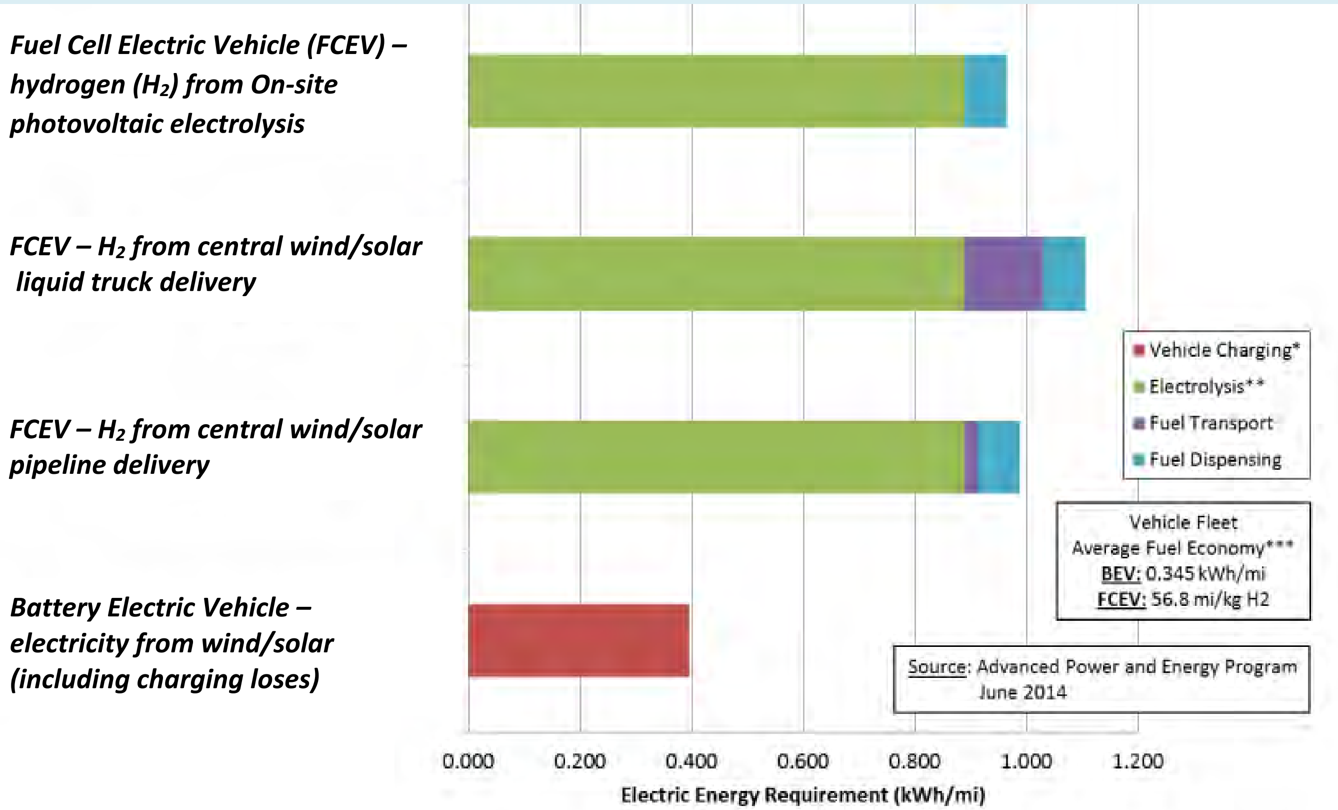
1. **Battery-electric trucks:** Using the simplest configuration of technologies, battery-electric trucks are prototype-ready from several companies, but large lithium-ion batteries make them very expensive and range-limited.

2. **Battery-electric trucks with direct (catenary) or inductive grid connection:** Adding a catenary or inductive connection to a battery-electric truck improves the range over a specific route and may reduce the battery size required and the capital cost of the individual battery-electric trucks. Additional technical complexity raises maintenance costs, however, and complex catenary or inductive infrastructure may add substantial cost (i.e., the one-mile demonstration of the catenary system along the Alameda Corridor is budgeted at ~$10 million) to the system, while limiting operations to a pre-defined route.

3. **Fuel-cell trucks:** Fuel cell vehicles promise range and flexibility but sacrifice both vehicle and system simplicity, while adding infrastructure cost (i.e., hydrogen fueling in addition to charging equipment). Fuel cell trucks also require over double the amount of energy needed to travel the same distance.

Sustainability of Fuel Cell & Battery Electric Power

For appropriate applications, battery-electric power will always be more sustainable than hydrogen fuel cell power because the process to make hydrogen needed to power fuel cells ends up requiring around 2.5 times the electricity to accomplish the same work. While this premium may be worth the price to achieve longer range than batteries will ever allow, the energy cost difference ensures that battery-powered trucks will continue to be favored for limited-range operations.



* Includes energy required to overcome losses in electric vehicle charging equipment in addition to the vehicle energy requirement.
**Represents entire electrolyzer system including balance-of-plant for current state-of-the-art systems as tested by NREL.
***Fleet-wide average fuel economy is the representative fuel economy of the average vehicle in the light-duty vehicle fleet. This is a weighted average of the fuel economy of different size vehicles. Each vehicle class is weighted by their contribution to the total light-duty vehicle fleet according to the CARB EMFAC model.

For more information see: "Well-to-Wheels Greenhouse Gas Emissions of Advanced and Conventional Vehicle Drive Trains and

While the Harbor Department is generally neutral regarding particular types of zero emission technology applications, for budget reasons and long term practical deployment reasons staff recommends that testing be carried out with technologies that do not require more elaborate infrastructure support. For this reason, the battery-electric and fuel cell vehicles and equipment are areas where staff recommends the Harbor Department focus its efforts and resources. Staff also recommends continued testing of hybrid near-zero equipment that is capable of operating in "zero emissions mode" for extended periods, since this equipment has the potential to evolve toward a full zero emissions vehicle over time, as battery technologies improve.

The attributes of these technologies vary, depending upon the intended application, but they share a key similarity: each has an electric drive system. This means that any electric drive technology that is deployed in the short-term at the port will provide fundamental information that ***will transfer*** to future technology applications.

In addition, their flexibility will allow them to be tested without substantial disruption or change to existing operations. Other zero emission technologies will continue to be investigated and demonstrated concurrently by the Harbor Department in coming years, but battery-electric, fuel cell trucks and near-zero equipment that can operate in extended zero emissions mode offer the most straightforward option for testing in the near term.

Ultimately, battery-electric and fuel cell trucks and equipment may well be the best option for many maritime goods movement operations in the long term as well. As battery technologies improve, range will increase and costs will likely decrease. Once this occurs, catenary and inductive charging corridors could serve as effective range-extenders for battery-electric trucks. As fuel cells become reliable and cost effective, the unlimited range potential of a fuel cell will allow the electric equipment to perform more like the current diesel truck fleet and serve areas that are out of battery-electric truck range. For applications where battery-powered trucks are well suited, they will always be more ***sustainable*** because battery-powered trucks require much less energy than fuel cell trucks to do the same work.

While these reasons support a strong focus on battery-electric, fuel cell vehicles and near-zero with extended zero emissions mode equipment in the near term as a means to support deployment of all types of zero (and potentially zero) emission heavy-duty trucks, it is not the only focus. The Harbor Department will continue to support its agency partners in their efforts to assess and demonstrate other promising zero emission technologies.

5.2 Yard Tractor Focus

Heavy-duty on-road vehicles, such as those used in short-haul drayage, encompass a range of types that are capable of hauling heavy containers and are the mainstay of port drayage operations. Heavy-duty yard tractors move containers in the terminal environment and heavy-duty drayage trucks haul containers from the port terminals to other regional locations. Despite the variety of configurations and activities associated with these vehicles, the fundamental requirements for power, versatility and durability are common to both.

The Harbor Department staff believes that short-haul drayage and on-terminal container handling equipment are the two areas of maritime goods movement operations where zero and near-zero emission solutions are most likely to develop in the near-term. While short-haul drayage remains a key pursuit, staff recommends that increased emphasis be placed on the development and demonstration of zero and near-zero on-terminal yard tractors and container handling equipment. This is because staff expects that increased expenditures focused on developing off-road zero emission yard tractors would help to *accelerate* the commercialization of on-road short haul drayage trucks by providing for technology transfer at the component level and a proving ground for zero emission technology in a more controlled environment.

There are several additional reasons why zero emission yard equipment development makes sense for the Harbor Department in the near term, but they can generally be summed up with three words: simplicity, cost, and control. Developing zero emission yard tractors will ultimately support the development of all types of zero emission vehicles, but in the short term, electric yard tractors are simpler in design and operation and lower in cost. Yard tractors operate within the port's domain and within consistent, constrained, and regimented environments. Based on these basic ideas, and as recommended in the Zero Emissions Roadmap,[11] zero emission yard tractors are an appropriate initial focus for the Harbor Department for the following reasons:

- **Demonstration is easier in the terminal operating environment.**
  Demonstrating any prototype vehicle can be complex, expensive, and time-consuming. For instance, if the vehicle breaks down on a public roadway when hauling a fully loaded container across the Vincent Thomas Bridge -- it can pose a safety concern, cause congestion, and be expensive to troubleshoot, repair, or retrieve.

  The environment within a marine terminal is fixed and controllable. Container movement operations are continuous, but they are performed within an area measured in feet as opposed to miles. Vehicle operations are conducted in a professional, controlled environment - isolated from the public roadways with no interaction with the nonprofessional motoring public. Operationally, this controlled, safe environment is ideally suited to the demonstration of prototype vehicles, and yet represents a good test bed for an otherwise demanding maritime goods movement operating environment.
- **Off-road requirements are less stringent, reducing cost and complexity.**
  Pre-commercial on-road heavy-duty trucks, often equipped with experimental drive systems, must be configured to comply with all state and federal Department of Transportation requirements and must demonstrate necessary safety when operating on public roadways. For yard tractors, the Harbor Department can require that all prototype units participating in a Harbor Department-sponsored demonstration fully comply with all requisite operational safety requirements.
- **The limited range of terminal environments reduces electric vehicle "range anxiety."**
  A perennial ailment that electric vehicle manufacturers are trying to cure is what they refer to as "range anxiety." This is the concern that an electric vehicle will become stranded if a driver doesn't correctly estimate a vehicle's range. It is even more concerning for large trucks that are difficult to move or manage if they become powerless due to battery drain or system failure. On the terminal, not only are trucks always nearby their charging stations, they are always in relatively flat, controlled areas with other large vehicles around that can help move them. Successful electric yard tractor will be able to operate two 8-hour shifts per day, five to six days per week with reliability that is similar, and hopefully better than, their diesel fueled counterparts.

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[11] Port of Los Angeles, Port of Long Beach, "*Roadmap for Moving Forward with Zero Emissions Technologies at the Ports of Long Beach Los Angeles, Technical Report*," updated 2011, page 34. *www.cleanairactionplan.org/reports/default.asp*

Electric vehicle technology is favored in environments where diesels are least efficient. Unlike normal combustion engines that lose overall efficiency during quick start/stop operation, electric trucks will regenerate power with each braking event. In addition, zero emission vehicles will operate at maximum efficiency as soon as they start moving. This is echoed by studies[12] that show how electric vehicles are far better suited to city versus long-haul driving. The most common application for mid-sized electric trucks is currently with short-distance delivery and hauling. In environments where a diesel engine would otherwise have to wait at idle and lose efficiency during each speed change, electric vehicles are optimal. Terminal operations provide the ideal environment for realizing the benefits of an electric drive system.

- **Wide applicability of yard equipment to industrial facilities around the world.**
  Yard equipment can be used anywhere – at ports, rail yards, warehouses, and many other types of industrial facilities. With the potential for a large market, original equipment manufacturers may be more attracted to this type of equipment, thereby speeding up the development process to allow potential commercialization of this equipment sooner. For this reason, testing and demonstration of this equipment is expected to have greater impact on the marketplace.
- **Longer-term payback may be more acceptable to operators.**
  Drayage truck operators typically operate on a tight margin[13]. The decision for a small business to make a capital purchase hinges on a favorable return on investment within just a few years. This is especially important if the electric vehicle has limited range or flexibility as an asset. The larger the company, the more access they will have to capital, and the more tolerant they might be of investments that take longer to show a positive return. Yard tractors are largely single purpose vehicles that spend their operating life in one place doing largely the same thing. They are owned and operated by large companies that are often subsidiaries of even larger corporations. These corporations might be in a better position to make long-term financial decisions if the benefit is clear.
- **Developing electric yard tractors complements the development of all heavy-duty trucks.**
  Off-road trucks and equipment can be used as a platform for demonstrating broader capabilities of heavy-duty zero emission technologies that would apply anywhere. Many of the same components that will undergo testing and demonstration during yard tractor trials are directly compatible with on-road trucks. With some of the companies currently developing on-road drayage trucks also developing off-road yard tractors, proving the capability of these technologies in the yard tractor application will have a direct benefit in the development and perceived integrity of a company's other on-road drayage product application.

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[12] Pelletier, Samuel, Jabali, Ola, Laporte, Gilbert, "*Battery Electric Vehicles for Goods Distribution: A Survey of Vehicle Technology, market Penetration, Incentives and Practices,*" September 2014, CIRRELT-2014-43.
[13] Husing, John E., Brightbill, Thomas E., Crosby, Peter A., "San Pedro Bay Ports Clean Air Action Plan: Economic Analysis – Proposed Clean Truck Program," September 2014, and The Boston Consulting Group, "San Pedro Bay Ports Clean Truck Program – CTP options analysis," March 2008. *www.portoflosangeles.org/ctp/idx_ctp.asp*

5.3 Short Haul Drayage

Short-haul drayage includes two types of operation:

- **Near Dock Operation -** This type of operation involves very short cargo moves from four to eight miles in length (one way), generally originating at the marine terminal. Cargo moves to the Intermodal Container Transfer Facility (ICTF) or nearby container yards are included within this category; and
- **Local Operation -** local operation refers to cargo moves originating or terminating at the ports and having the other end point of the move between six and about 12 miles from the port (up to 25 miles round trip).

This short-haul drayage operation is responsible for only a very small subset of overall drayage emissions at the port. Nonetheless, short-haul drayage emissions have received increased attention in recent years due the operation of these trips in close proximity to the local community. Further, short-haul drayage provides the opportunity to evaluate zero emission drayage truck technology without extensive infrastructure support throughout the region. As noted above, demonstration of short-haul drayage technology will directly benefit from zero emission yard tractor demonstration successes, so the two project categories have excellent synergy (i.e., common electric drive train components, batteries, etc.). As such, zero emission short-haul drayage trucks, when developed, may become critically important for development and use in certain key areas around the port.

More broadly however, zero emission drayage trucks have some drawbacks. Zero emission on-road drayage trucks, whether fuel cell or battery powered, face range limitations in the near term when compared to their diesel counterparts. They are also very dependent upon access to hydrogen (or other) fueling or electric charging infrastructure. This is a key handicap in Southern California due to the long distances trucks must often travel to conduct business. Therefore, zero emission on-road vehicles are likely to be focused on short-haul duty for the near term, with this being limited to trips to and from the near dock rail yards, or other very close by warehouses or yards – ideally in areas where charging infrastructure is never too far away. This limited flexibility may slow opportunities for commercial development of this equipment, as manufacturers will have to look for a market that will absorb a high cost, limited-range vehicle. Nevertheless, staff recommends that short-haul drayage trucks be included in testing programs due to the need for them in certain areas around the port.

6.0 Infrastructure Planning

In recent months, the Harbor Department has seen the first meaningful results from early demonstration project vehicles. Active demonstration units are achieving increased usage between charges and are ready for further testing. This success illuminates the important need for supporting infrastructure, which was not previously developed because there were no test vehicles that could reliably utilize it. In anticipation of continued success, Harbor Department staff recommends that a well-coordinated infrastructure plan be developed, as this is critically important for successful implementation of zero and near-zero emission trucks.

Successful deployment of significant numbers of heavy-duty container movement trucks – on-road and off-road - is contingent upon compatible and accessible supporting infrastructure. For electric technologies, this implies a network of electric heavy-duty vehicle charging stations. Hybrid electric or other alternative fuel near-zero emission vehicles, such as hydrogen and natural gas, would require their own unique refueling infrastructure.

The issues of designing, siting, and constructing this network of supporting infrastructure are very complex - in many ways more complex that the deployment of the vehicles themselves. Due to this complexity, Harbor Department staff proposes, as part of a multi-agency stakeholder effort, development of a zero and near-zero emission **Infrastructure Plan**.

When completed, this Infrastructure Plan would present the Board of Harbor Commissioners and fellow stakeholders with options and advice related to the technical and programmatic elements of a large-scale infrastructure implementation program. Most importantly, the Infrastructure Plan would contain recommendations for the Board of Harbor Commissioners as to the preliminary design, prospective funding mechanisms, and roles and responsibilities of the Harbor Department and stakeholder partners deemed necessary to construct the enabling network of refueling and support infrastructure. It is expected that this plan would also look at regional electric vehicle infrastructure needs.

Though Harbor Department staff is already familiar with electric infrastructure requirements – even electric infrastructure needed to support large numbers of simultaneous high-use applications such as OGVs connected to shore power – charging a large fleet of vehicles will be an entirely new challenge. While commercial electric passenger vehicles may tout the simplicity of charging a single car from common household plugs, infrastructure for large scale deployment of heavy-duty equipment, especially for industrial applications, is much more complex.

State-of-the-art electric vehicle charging equipment must include technologies that enable vehicles to communicate their status to the charging system. This communications capability is primarily designed to ensure safety of both the vehicle and the charging system, but it also allows the charging network to optimize how it delivers charge. Known as a *Smart Grid*, this type of optimization reduces the overall charging system's impact on the grid and reduces energy costs.

Smart Grid

The use of smart grids will be essential to the Harbor Department's ***Infrastructure Plan*** *and its zero emission vehicle strategy. Recharging a large battery pack on a heavy-duty drayage truck presents a high load on the electrical grid, but with the smart grid, vehicle charging can be scheduled for periods of reduced load or reduced electricity costs. A well-optimized grid could even allow a vehicle battery to supply energy back to the grid at periods of peak demand.*

To instill the grid with these kinds of "intelligent" features, the Society of Automotive Engineers (SAE International) is developing a range of standards for energy transfer to and from the grid, including SAE J2847/1 publication entitled "Communication between Plug-in Vehicles and the Utility Grid." The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are also developing standards that will significantly impact the future designs of a vehicle-to-grid communication interface. These standards, and others yet to be developed, will ultimately influence the design and deployment of any future EV charging network at the Port.

Understandably, these issues become exponentially more complex when multiple heavy-duty electric vehicles – potentially hundreds of yard tractors at a terminal, for example - are connected simultaneously to a charging network. While an in-depth discussion of the technical features, issues, costs and complexities of charging and other infrastructure is beyond the scope of this paper, these are among the issues that would be considered by Harbor Department staff as part of the Infrastructure Plan and may at some point be presented to the Board for future discussion.

Staff is developing a strategy for the network of infrastructure essential to a zero emission vehicle fleet. Currently, Harbor Department staff has begun to identify various options that would ensure that the port's infrastructure growth matches and promotes zero emission vehicle acquisitions by port tenants and drayage trucking companies.

These options include the Harbor Department assuming primary responsibility for the design, procurement, construction, and ongoing management of the network of heavy-duty vehicle charging or refueling infrastructure. Construction costs may be offset through user fees. Under this scenario, the Harbor Department retains primary control of facilities, equipment, and utilities placed on port property for use by port tenants and port drayage truck concessionaires.

Alternatively, the Harbor Department may elect to work with port tenants and other stakeholders to establish uniform infrastructure specifications that ensure compatibility with the majority of zero and near-zero emission vehicles operating at the port. The Harbor Department would retain a leadership role by recommending uniform standards and system design for consistency and efficiency for potential incorporation into future lease and concessionaire agreements. Infrastructure design, construction, and maintenance, however, would be the responsibility of the implementing marine terminal or drayage trucking company.

Finally, a "middle of the road" approach for consideration is to have the Harbor Department assume responsibility for development of an initial, limited network of vehicle recharging or other enabling infrastructure to initially meet the needs of a moderate number of port tenant or port concessionaire zero emission vehicles. This approach allows the Harbor Department to install a network of recharging and refueling stations with uniform, compatible specifications upfront, but rely upon the vehicle operator community to fill network gaps as the vehicle population expands and charging demands grow.

These options, and likely others, will be evaluated for cost and operational feasibility and optimization with all stakeholders as part of development of the Infrastructure Plan.


California United Terminals
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7.0 Zero Emission Heavy-Duty Vehicle Costs

This section explores the major costs of heavy-duty zero emission battery-electric vehicles compared to conventional diesel vehicles using yard tractors and drayage trucks as examples. Understanding the scope of investment required from both the manufacturers' and operators' perspectives to place battery-electric vehicles into operation will help frame the goals and expectations for zero emission policies and incentive programs. Because costs associated with battery-electric trucks are currently unclear and changing regularly, this cost discussion emphasizes *categories* of cost considerations, as opposed to specific costs.

7.1 Fundamentals of Battery-Electric Technology Costs

The main obstacle to deploying any type of battery-electric truck is the up-front purchase cost, which is much more than the approximately $100,000 cost of an equivalent diesel yard tractor or the $125,000 cost of an on-road diesel truck. This high cost for electric trucks is dominated by the cost of batteries. There is no way around the fact that big trucks need big batteries, and big batteries are expensive. While these costs are expected to decrease over time with larger production volumes, the cost of materials and the complexity of integrating batteries into a demanding operation will ensure that a battery-powered truck is going to be more expensive than its diesel-fueled counterpart.

This is not to say that battery-electric trucks could never be more appealing than diesel trucks on the basis of cost alone. Most electric vehicle manufacturers will point to the potential savings in energy costs over the life of the truck as a major advantage. With electric vehicles having lower maintenance and fewer moving parts to wear and fail, their life will almost certainly be longer than the life of a diesel truck. Even so, lifetime savings from lower energy costs is no certain proposition. It requires low electricity costs and high diesel fuel costs to even begin to strike a balance.

Replacing the Diesel Tank with a Battery Bank

With every gallon of diesel equating to approximately 15.8 kWh[*] of required battery size, a diesel yard tractor that normally uses between 1-2 gallons of diesel per hour of operation would theoretically require between 15.8 and 31.6 kWh of battery capacity per hour, or between 125 and 250 kWh of installed power for an 8 hour work period. At a current price of between $700 and $800 per kWh of fully integrated battery capacity, the battery cost to achieve 200 kWh would be between $140,000 and $160,000. Even if battery prices drop to the forecast $400 per kWh of fully integrated power, the battery pack alone would still cost nearly as much as a current diesel yard tractor.

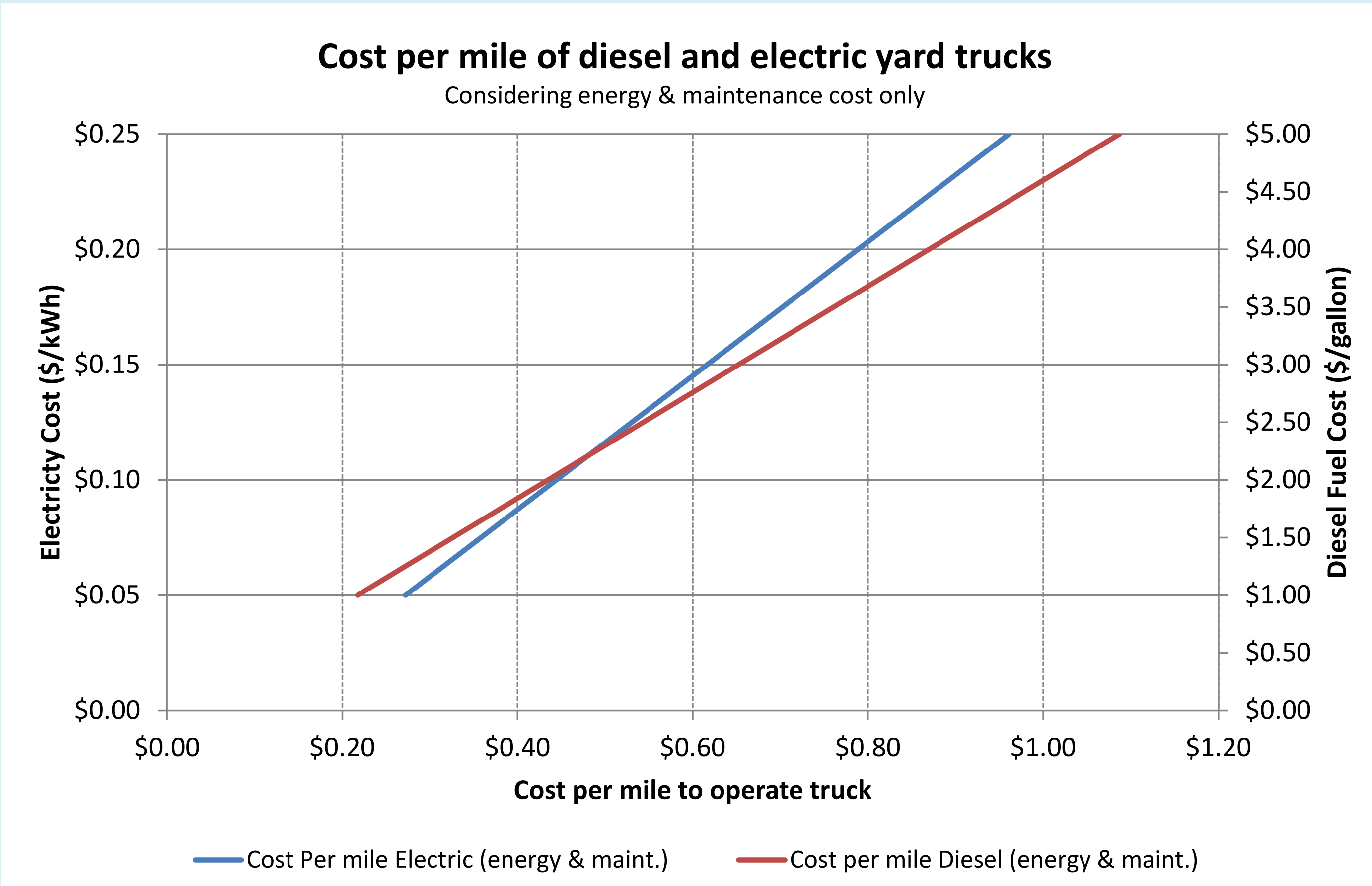
For heavy duty, Class 8 trucks that are required to pull loaded containers, manufacturers are offering prototypes with batteries that range in size from 80 to 220 kWh and low-volume costs that range from $160,000 for a yard tractor with an 80 kWh battery to over $450,000 for an on-road truck with a 215 kWh battery.[**] Even though these battery capacities may not reflect the maximum capacity required based on the energy equivalents described above, manufacturers assert that other operational efficiencies such as regenerative braking and zero energy use at idle will further reduce the overall capacity needed. Even if a $250,000 truck with a 160 kWh battery can effectively replace existing yard tractors, there is still a $160,000 premium over the cost of a diesel yard tractor.

** Electric drives operate with approximately 2.6 x the thermal efficiency of diesel. (139,000 Btu/gal diesel)/(3413 Btu/kWh electric)/2.57 = 15.8 kWh needed*

*** Prices for OrangeEV's standard T-series yard tractor and Transpower's ElecTruck on-road truck.*

Comparing Energy Costs: Diesel vs. Electric

Many commercial EV manufacturers will make the case that high capital cost differences can be largely offset by lower energy and maintenance costs. As shown in the illustration below, the potency of this argument strongly depends on the costs of diesel fuel and electricity. With high diesel fuel prices and low electricity prices, the energy savings of EVs can be substantial. But with higher electricity costs and low diesel fuel costs, the difference can be negligible, even opposite. For instance, with electricity at $0.15 per kWh and diesel at $4.00 per gallon, a diesel yard tractor would cost ~$0.25 more per mile to operate than an electric yard tractor.



Further, where energy cost savings are expected to balance higher capital costs over time, there is usually an assumption that those same batteries that make the truck so expensive in the first place will last the full life of the truck. However, as we have learned from cell phones and laptops, batteries do not hold consistent charge over time under heavy use. For trucks, heavy use and limited battery "cycle life" means additional capital investment may be needed to replace batteries at least once and possibly twice, during an electric truck's life.

7.2 Manufacturer Perspective

For this cost assessment, the manufacturers' perspective is simple. A manufacturer must sell a vehicle for a price that covers the basic costs of materials and production and includes enough additional revenue to support current overhead, recoup past development investment, and demonstrate future profitability.

For the two types of battery-electric trucks being considered (on-terminal tractors and short-haul drayage), Figure 1 illustrates a theoretical breakdown of the projected unit prices advertised by two manufacturers.[14]

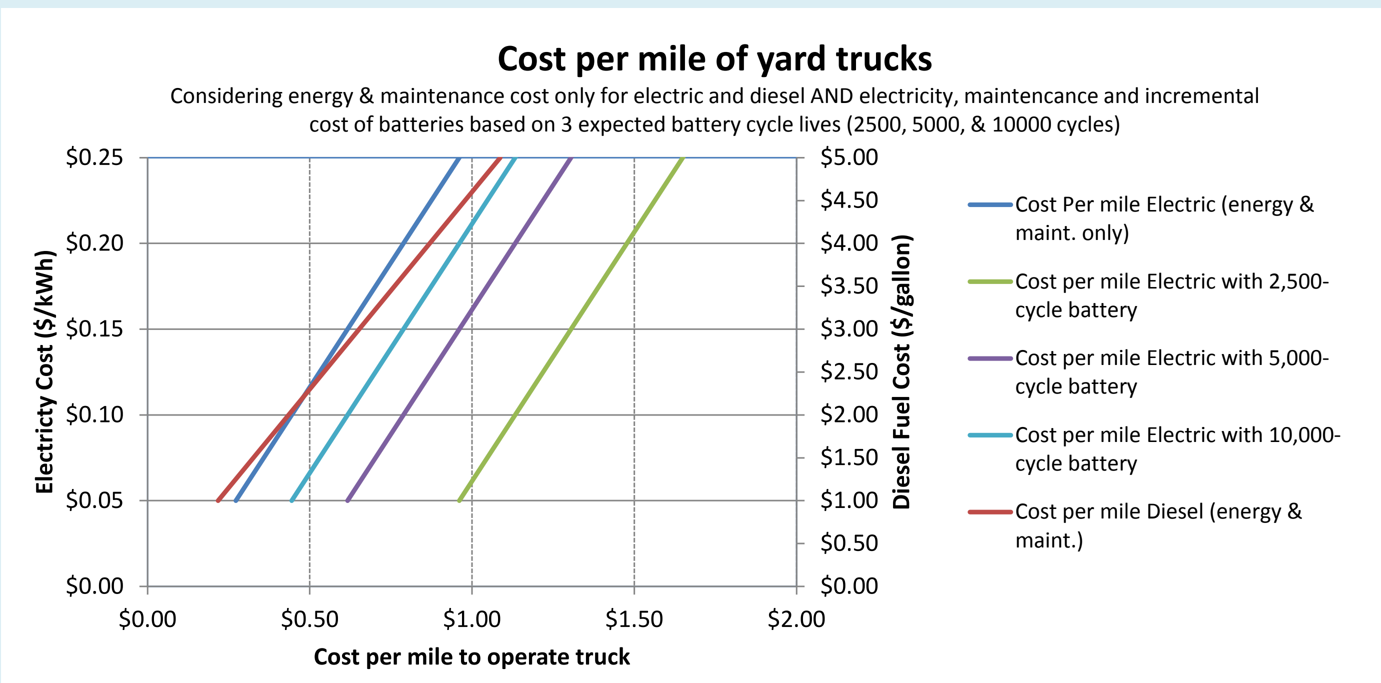
Figure 1: Sample Breakdown of Battery-Electric Truck Manufacturing Costs

[14] Capital costs are based on reported equipment prices from two major equipment manufacturers with detailed information provided through personal communication. The general values shown are estimates for the sake of demonstrating relative contributions, but they are not actually so clear cut. For instance, production costs will overlap with chassis and drivetrain costs as well as battery integration.

Accounting for the Cost of Future Battery Replacements

Batteries are a key component of the high capital cost and intrinsically tied to the vehicle's use. Modern commercial electric vehicles use some variant of the Lithium Iron Phosphate (LiFePO4, or LFP) battery. The most common variant is the lithium-ion chemistry. Manufacturers conservatively advertise LFP batteries as having a life of at least 2,500-cycles, though tests of recent LFP battery technologies show a life of over 8,000 cycles. This distinction is critical. At 20,000 miles per year, a 2,500-cycle battery in a yard tractor will only last about five years. A battery is technically considered "used up" when it is only able to charge to 80% of its original capacity, even though it remains perfectly functional. When it needs to be replaced, a new battery pack could cost $96,000-$128,000, allowing an additional five years, or 100,000, miles of operation.

The cost of battery replacement upends the idea that higher mileage can offset capital costs. In fact, after the original battery pack that comes with the original purchase price of the truck, additional mileage should also consider the incremental cost of the new batteries. The following graph builds upon the previous cost comparison by adding the incremental cost of future replacement batteries. At $4 per gallon of diesel, the cost per mile of a diesel yard tractor is the same as the cost per mile of an electric yard tractor with a 10,000 cycle battery when electricity is $0.15 per kWh. If the electricity cost is lower (or the diesel cost higher), the electric truck is cheaper to operate. With a 2,500-cycle battery, there is almost no reasonable point at which the electric truck can compete with the diesel truck. Diesel would have to be over $5 per gallon and electricity would have to be $0.05 per kWh for the electric truck to be less expensive to operate.



For more information, see:
www.sklep.asat.pl/pl/p/file/b82d9c09831c75890e5e8b74dc8829f7/Product-presentation_Sony-Energy-Storage-Station.pdf

The current prices of the battery-electric trucks are based on initial market volumes in the low double-digits, requiring a nearly custom-build production environment. Efficiencies of volume allow for more streamlining and automation of the production process in addition to lower component prices. With these savings, increased production of both trucks and batteries would be expected to lower overall costs by 10% over the next few years with orders totaling approximately 100 units and 25% in five to ten years with orders reaching 2,500 units.

Prospects of declining price will no doubt improve the marketability of electric trucks in the long run, but the main concern of any prospective manufacturer will be how to sustain consistent and growing sales in the meantime. This could vary depending upon the application.

For example, with drayage trucks, the limited range of current battery technology and lack of regional charging infrastructure make a large market for these vehicles unlikely to form in the near term (five to ten years). Vehicle manufacturers seeking large volume sales must first complete prototype testing and wait until a regional infrastructure is developed. Sales of smaller numbers of vehicles for specialized needs may still proceed in certain areas, but those buyers may not be able to count on manufacturers to offer these vehicles at low prices right away due to lack of high volume sales.

By contrast, the market for yard tractors could potentially form sooner. Prototype testing would still need to occur over the next few years, but infrastructure issues would be focused toward facility capital investment requirements. Also, battery technology development may not face as much of a challenge with yard tractors due to smaller range requirements. For these reasons, zero emission yard tractor manufacturers seeking large volume sales may find a market forming sooner, once prototype testing is completed. Buyers may also be able to see prices start to come down due to economies of scale sooner than may be the case with drayage trucks.

How Many Electric Trucks Could Operate at the Port of Los Angeles?

Cost concerns aside, the needs of the Port of Los Angeles could easily support production of both yard tractors and short-haul trucks through the initial stages of production. With ~1,000 yard tractors in operation at POLA terminals, gradual turnover of the yard tractor fleet with battery-electric versions could ensure the viability of at least one EV truck manufacturer.

For short-haul drayage trucks, the needs are more complex. Drayage trucks from the Port serve three general areas: the Intermodal Container Transfer Facility (ICTF), the BNSF Hobart Railyard, and other regional warehouses. The ICTF and Hobart yards currently require approximately 10% of the ~10,000 trucks currently in active drayage service to make the 350,000 annual trips from POLA terminals. Both of these yards, at approximately three and 24 miles respectively, are within ranges that could theoretically be served by electric trucks. With some of the trucks that serve these two areas being under-utilized and many being used for trips to other areas, the actual number of trucks needed to serve just these two areas under a well-optimized plan could be as low as 500-600. As with yard tractors, these volumes again imply there is a strong potential role the Port could play in helping to create a viable market for EV truck manufacturers.

Closer Look at the Variables Used to Compare Electric & Conventional Technologies

Calculations and graphs used in this cost assessment rely on two simple categories of costs: capital costs and operating costs. The conclusions that can be made by comparing these are also simple: capital costs are much higher for electric, labor costs are similar, and non-labor operating costs are lower. The actual calculations done for this estimate incorporate a large number of estimated variables, from average annual hours of operations to relative thermal system efficiencies. The following table shows the average or "best guess" values used, but the actual values of every variable are likely to be different for any given application. There are mathematical methods for examining the ranges of these values to describe the effect of their uncertainty on the overall cost equation. This type of analysis is not useful here simply because no reasonable estimate of any of the values would change the overall conclusions and relationship. For reference, the following is a list provides the main variables used in calculations in this report:

Fuel Price (per Gallon diesel)	*$4.00*
Electricity (per kWh)	*$0.15*
Average Diesel Truck fuel economy (miles/gal)	*4.6*
New diesel truck fuel economy (miles/gal)	*>5*
Yard tractor diesel use (gal/hr.)	*1.7*
Short haul truck kWh per mile	*3.6*
Yard tractor battery kWh required per hour of operation	*28.5*
Future replacement battery cost (160kWh)	*$80,000*
Thermal efficiency, diesel	*35%*
Thermal efficiency, electric	*85%*
Yard tractor, annual operating hours	*2,500*
Battery cycle life (to 80% DOD)	*2,500*
Diesel truck life (years)	*10*
Electric truck life (years)	*15*
Diesel cost per mile, maintenance	*$0.14*
Electric cost per mile, maintenance (Insurance, tires, DMV fees, inspections, etc.)	*$0.05*

Values are based on averages reported by manufacturer literature, individual presentations, and major reports, including:
"Liquefied Natural Gas (LNG) Yard Hostler Demonstration and Commercialization Project, Final Report" CALSTART, August 2008
"Hybrid Yard Hostler Demonstration Project, Final Report" CALSTART, January 2013
"Port of Los Angeles, Inventory of Air Emissions 2013" Starcrest, July 2014
"An Analysis of the Operating Costs of Trucking, a 2012 Update" ATRI, September 2012

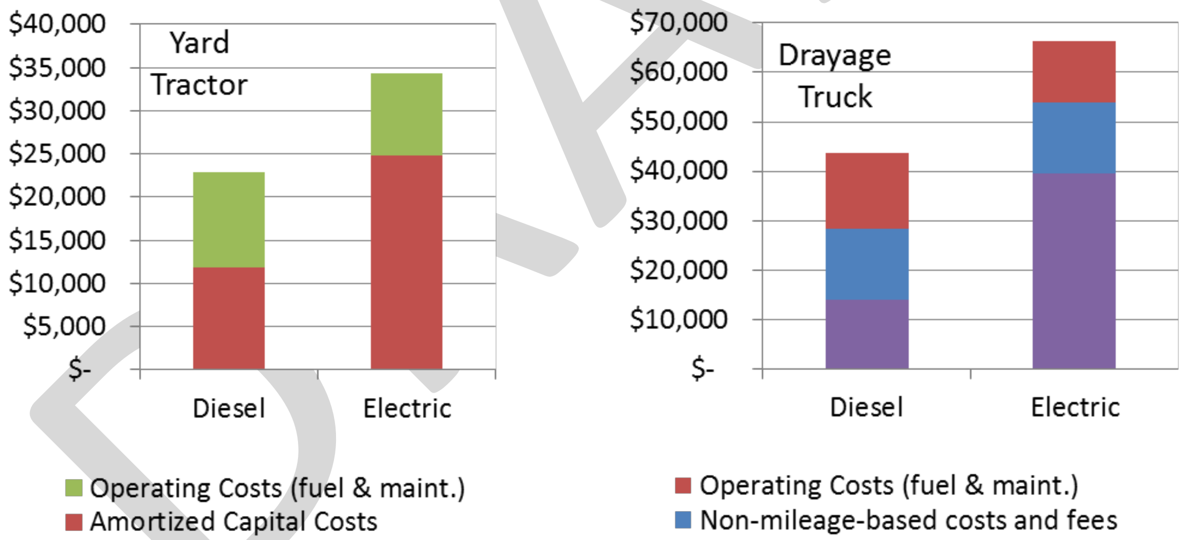
7.3 Operator Perspective

While the manufacturer of the electric short-haul truck and the electric yard tractor could be the same entity, the operators of these two types of trucks differ substantially. Currently, the total number of drayage trucks registered in the drayage truck registry is approximately 13,750 vehicles, with approximately 10,170 trucks actively making 265,010 truck trips at the port per month. These trucks are operated by over 630 private local companies, most of which own fewer than 20 trucks. Major investments for these small businesses are difficult in the best of circumstances, but investment that does not show a clear potential for short term returns would be prohibitive.

Yard tractors are operated by private terminal companies that are generally subsidiaries of much larger companies. Yet even though their size gives them access to larger capital resources and the ability to accept longer delays on investment returns, they share with the small trucking companies a fundamental need to maintain profitability in their operations in order to maintain sustainability. Currently, the total number of yard tractors operating at the port is 874.

For both types of operators, the cost assessment for a zero emission vehicle is simply a matter of using current diesel-powered trucks as a baseline and comparing a range of projected variables associated with their electric counterparts. Drawing from current data and making reasonable estimates as needed, Figure 2 compares the average annual cost of diesel and electric technologies for both applications.

Figure 2: Estimated Major Annual Costs of Operating Yard Tractors[15] and Container Drayage Trucks[16]



[15] Assumes 2,200 hours of operation, $4.00/gallon diesel at a rate of 1.7 gal/hr, and $0.20/hr for maintenance. Capital cost amortization of $85,000 over 10 year expected life at 5% with a $10,000 salvage value. Electric yard tractors are assumed to cost $250,000 with a 15-year life, $20,000 salvage value, $0.15/kWh electrical costs, and $0.10/hr for maintenance costs. Assuming the same life for both trucks raises the red bar of the electric truck higher, but does not change the overall relationships and conclusions.

[16] This annualized view puts costs in a context that is easier to compare to near-term finances. The general relationships in the graph look similar when conducted as a net present value, summing total costs over the life of the truck. The graph assumes that diesel trucks have a life span of ten years and electric trucks have a life of 15 years. Assuming equal ten-year lifespans will only raise the purple bar of the electric truck.

For both applications, overall costs are substantially higher for the battery-electric technology. Notably, the difference is largely due to the increased capital cost. Even though the calculated values will vary with different assumptions, at this time, it is hard to conceive of a scenario where the overall economics of the battery-electric truck can be cost effective for drayage operators due to the typically low operating margins in the drayage business, which make available revenues for debt service very small. An increased number of gate moves would help this equation, for example in a short haul to near dock rail yard scenario, but even in those cases the fee for the short haul is less, so the revenue available for debt service is still relatively low.

With yard tractors, versatility combined with low capital and operational cost is central to battery power's appeal. However, even a slight increase in costs, or an increase in operational complexity would quickly change their utility in the eyes of the operator. Moreover, in a yard tractor scenario, no increased gate moves are available to positively affect the cost equation.

The Driver-Side Economics of Moving Containers

Working five days a week, an average daily income of $280 amounts to ~$70,000 per year, or just under $6,000 per month. It is believed that 90% of truck drivers serving the Port are independent contractors responsible for their entire business expense. In addition to paying their own compensation and taxes, they must use these revenues to pay for all costs of operating a truck. Regular monthly operating expenses, which include insurance, licensing, radio rental, and other costs begin at $1,200 per month. Based on 80 miles per day driven, fuel and maintenance add another $1,140. Leasing a used truck fit for drayage service will add at least $1,000 per month and could cost over $2,000. In the best case scenario with a low-cost lease, after all of these expenses are paid, truckers are left with approximately $121 dollars for working a 10-12 hour day and still need to cover personal taxes, health insurance, and any other benefits.

7.4 Operating Scenarios

This section takes a closer look at the issues and variables that influence the near-term economic viability of battery-electric technologies. The objective is to answer the fundamental question: What will it take to make this work? In other words, what set of economic and operating conditions must be in place to meet the business case needs of both the vehicle manufacturers and trucking and marine terminal operators, while adhering to Harbor Department policies and constraints? Three promising operating scenarios are presented for battery-electric technologies:

- Zero emission trucks used in a short haul drayage application from a marine terminal to a container storage yard, commonly referred to as a "Peel Off yard;"
- Zero emission yard tractors deployed within marine terminal operations; and
- Battery-electric drayage trucks performing short haul drayage to a near dock rail facility such as the ICTF.

For each scenario, the current operating and economic conditions are presented, then analyzed to determine the necessary incentive levels and, where appropriate, operational enhancements that would allow the substitution of battery-electric vehicles to be financially workable in the near term.

7.4.1 Zero Emission Container Drayage to a Peel Off Yard

Launched on February 25, 2015, the "Peel Off" Program expedites cargo transport by streamlining container moves and speeding up operations at the port. The program involves "peeling off" containers of high-volume customers to a near-dock yard where they are sorted for destination to inland distribution centers.

Under Peel Off, import containers belonging to high-volume shippers are stacked together in a block upon arrival at the port. By design, the terminals expedite trucks through their gates to retrieve the containers and deliver them to the near-dock yard less than two miles away where they are sorted. The same trucks would then loop back to the terminals for the next inbound container. The trucks keep containers moving by delivering outbound containers on the return leg. As a result, truck trip lengths, gate waits, and idling are reduced, allowing each truck to make more "turns"[17] in a shift.

Currently, one motor carrier is participating in the Peel Off Program, although the program may be expanded to other carriers. This initial motor carrier is a larger transportation firm, and it is anticipated that new companies joining the program will also consist of large carriers, as opposed to smaller carriers or independent owner operators.

[17] A turn is defined as one complete container movement, from pickup at a marine terminal to drop-off at a destination.

The Peel Off scenario offers a unique opportunity for the immediate demonstration of battery-electric trucks for the following reasons. First, a primary demonstration advantage of the Peel Off scenario is shorter container dray distances. The distance from a marine terminal to the Peel Off yard, on average, is between two and ten miles one-way. A round trip that includes one loaded dray and one empty container return is approximately four miles total. This short distance is traversed at a relatively low speed – on average less than seven miles per hour – although return trips with an empty container may achieve higher speeds for a short distance. The net effect, however, is a significantly less rigorous duty cycle compared to longer distance container movements at higher average speeds. Thus, the less rigorous duty cycle associated with the Peel Off scenario allows the battery-electric truck to be designed to incorporate a smaller battery pack, reducing vehicle cost. While less capable, a battery-electric truck configured for operations to a Peel Off yard is potentially less costly to acquire, but still capable of satisfactorily accomplishing the intended mission.

A second operational consideration that supports the use of battery-electric trucks for container movement to the Peel Off yard is the increased number of turns accomplished in an average shift due to expedited marine terminal entry and reduced wait times. Increasing the number of turns increases revenue generated by the truck, a key factor in a motor carrier's business case assessment for potential use of a more expensive vehicle.

Finally, because the larger motor carrier currently participating in the Peel Off Program operates from a centralized facility adjacent to the port, installation of necessary electric vehicle (EV) support equipment (EVSE, i.e., EV chargers) would take advantage of construction-related economies of scale, such as common trenching and other facility infrastructure that can support multiple EV charging units. Further, collocated, integrated vehicle chargers can more readily incorporate "smart charging" techniques to optimize the charger to vehicle ratio. The result is a lower overall cost for EV charging infrastructure, compared to a distributed, nonintegrated EV charging network.

As noted above, the initial Peel Off participant is a larger firm. From a financial perspective, larger trucking firms usually have better access to credit and at lower interest rates compared to smaller firms or individual owner operators. Multiple truck acquisition and deployment is potentially easier and more financially practical for a larger carrier.

Given these operational factors and financial considerations, what will it take to successfully integrate meaningful numbers of battery-electric trucks into drayage operations under the Peel Off scenario? The qualitative answer is that the lifecycle economics of the zero emission trucks must be on par, from both a cost and risk perspective, when compared to the acquisition and operation of conventional trucks. This means that the successful completion of battery-electric truck demonstration projects currently in progress, as well as those in the planning phase, is critical to any future larger scale truck deployments – the end users must have confidence that the trucks will reliably perform and offer performance, durability, and maintainability comparable to conventional drayage trucks.

Quantitatively, the economics of a successful deployment under the Peel Off scenario can be illustrated using the following example, which assumes a 20-truck deployment of short-haul, Peel Off battery-electric trucks.

This scenario assumes the Peel Off operator is a larger motor carrier with sound financial standing, has reasonable to good credit, and access to lower interest rate loans. As a large purchaser of new Class 8 semi tractors, these firms have established business relationships with truck vendors and as a volume purchaser have the ability to negotiate favorable purchase or lease terms.

If a larger motor carrier was going to purchase 20 conventional trucks today to support container movement to a Peel Off yard, the transaction might be as follows:

Vehicles to be Purchased:	Model Year 2015 Class 8 day cab semi-tractor
Per Truck Cost:	$98,500 - $115,000
Down Payment:	10%
Interest Rate (APR):	4.99%
Term of Loan:	7 years

Under a 20-truck purchase, a larger motor carrier would likely negotiate a lower per vehicle price. Assuming a retail price of $100,000 per truck, and adding in sales and federal excise taxes and license fees will raise the cost by approximately 25%. The actual "out the door" price for a new Class 8 semi-tractor is on the order of $125,000 each. A purchase of 20 vehicles will cost approximately $2.5 million.

Assuming a down payment of 10%, and a seven-year loan at 4.99% APR, the monthly cost for the 20 trucks is on the order of $31,790 per month for 84 months.

Amortized Capital Costs for 20 Conventional Diesel Trucks:	Approximately $31,790 per month

The operating costs for the fleet of 20 new trucks include fuel, maintenance, and insurance. The diesel-fueled trucks operating under the Peel Off scenario will have a fuel economy of approximately five miles per gallon (5 mpg). This is a conservative assumption; today, fleets are reporting new diesel truck fuel economy on the order of eight (8) miles per gallon under the Peel Off duty cycle. Assuming diesel fuel costs $4.00 per gallon – the average price per gallon over the past several years, the fuel costs associated with the truck are on the order of $0.80 for each mile of operation.

Also, according to the 2013 update of the American Transportation Research Institute's "An Analysis of the Operational Costs of Trucking," maintenance and repair costs, on a per mile basis, are on the order of $0.14. Other operating costs include insurance, tires, DMV fees, inspections, etc.; these account for an additional cost of approximately $0.30 per mile.

Operating Costs of Conventional Diesel Truck:	Approximately $1.24 per mile

Under the Peel Off operating scenario, drayage trip lengths are short – on the order of two to ten miles per trip. Idling times are kept to a minimum. Thus, from an operations cost perspective, Peel Off is likely one of the lowest operating cost truck drays. Occasionally, however, the trucks primarily intended for use between marine terminals and the Peel Off yard will be used to perform longer drays to a near-dock rail facility or other destination. On average, the trucks should be able to accomplish six turns per day – a turn being a round trip container dray – under Peel off operating conditions. The average one-way trip distance is approximately six miles.

Given the short trip distance, and assuming that on occasion the trucks will be required to perform longer drays, the total daily per truck mileage is relative low in the context of heavy-duty trucking – on the order of 72 miles per day. Assuming 25 days of use per month, this equals approximately 1,800 miles per month per truck, or 36,000 miles per month for the fleet of 20 Peel Off trucks.

At an operations cost rate of $1.24 per mile, the monthly operations costs associated with the Peel Off scenario are on the order of $44,640 per month. When added to the monthly capital costs, the total monthly costs to deploy 20 new short haul conventional fuel trucks is approximately $76,430. This is the out of pocket costs the motor carrier is responsible for each month, not including costs associated with the drivers.

Monthly Cost for 20 Conventional Diesel Trucks:	Approximately $76,430

Thus, to make a near term deployment of 20 zero emission battery-electric drayage trucks a viable economic option, the monthly out-of-pocket costs must be comparable to ~$76,430 per month. Using this value as a benchmark, the following is the Peel Off operating scenario using battery-electric trucks.

The current cost of a battery-electric drayage truck varies by manufacturer; however, on average the cost associated with trucks currently undergoing demonstration and testing is approximately $400,000. Under the Peel Off scenario, however, it is feasible to utilize a vehicle that is configured for shorter range. Given that battery costs are the predominant factor in the cost of a heavy-duty battery-electric vehicle, reducing the onboard energy storage capacity (i.e., the number of batteries installed) can significantly reduce the vehicle cost. Thus, for the Peel Off operating scenario, a battery pack approximately ½ - ¾ the size of a typical short-haul battery-electric drayage truck is assumed. This assumption reduces the capital cost of today's electric truck by approximately $50,000, resulting in a per-truck cost on the order of $350,000.

Also, for a 20-truck purchase, it is reasonable to assume that certain purchasing discounts and manufacturing economies of scale will be available – a 15% reduction in capital costs due to improved production efficiencies. This has the effect of lowering the battery-electric truck cost to approximately $300,000 each.

However, two additional factors must be taken into account – the need for truck recharging infrastructure (EVSE) and an extended vehicle warranty. A five-year warranty for an electric drayage truck in the near term adds approximately 15% back into the purchase cost of the vehicle. The purchase of an extended warranty offers financial protection in the event of a premature failure of the vehicle's battery system, the most expensive subsystem of a battery-electric truck.

The cost of installing necessary recharging infrastructure for a 20-truck fleet is estimated at approximately $200,000, or amortized over 20 vehicles, $10,000 per truck. Thus, the approximate purchase cost for a short-haul electric truck configured for Peel Off operation is on the order of $355,000, or approximately $7.1 million. Assuming the same terms and interest rates, and a $250,000 down payment, the monthly costs to acquire the 20 electric trucks and supporting infrastructure and five-year warranty equal approximately $96,785 per month.

Amortized Capital Costs of Battery-Electric Truck:	Approximately $96,785 per month

Relative to operating costs, the cost of electric "fuel" is approximately $0.15 per kWh, and a short haul electric truck has a "fuel economy" on average of approximately 2.25 kWh per mile. Thus, the fuel cost per mile for the electric truck is about $0.34, or one-third the cost of a diesel truck.

Maintenance costs should be lower for the electric truck, compared to the conventional diesel fuel vehicle – no oil changes, less frequent brake replacements, etc. The five-year extended warranty will cover most, if not all, unscheduled maintenance. Maintenance will therefore include vehicle inspections and minor repairs, estimated at $0.05 per mile, compared to $0.14 per mile for the diesel truck. Tires, insurance, etc. are assumed to be similar for both the electric and conventional vehicles.

Thus, for the purpose of this assessment, the operations costs on a per mile basis for the electric truck are estimated to be approximately $0.69 per mile.

Operating Costs of Battery-Electric Truck:	Approximately $0.69 per mile

At 36,000 miles per month for 20 trucks under the Peel Off scenario, the monthly operating costs for the battery-electric trucks are about $24,840. When added to the amortized capital costs of $96,785 per month, this equates to a total monthly cost of ownership of $121,625.

Monthly Cost for 20 Battery-Electric Peel Off Trucks:	Approximately $121,625

The bottom line is that to make the Peel Off scenario work, the motor carrier needs to reduce his costs associated with the 20-truck purchase by approximately $45,195 per month. It is unrealistic to assume a port motor carrier will voluntarily opt for the electric drayage truck given these financial consequences. A per truck "buy-down" incentive will be required to make this scenario economically viable, at least in the near term.

How much would this incentive need to be? Under the Peel Off scenario presented above, the incentive necessary for the motor carrier to breakeven is on the order of $160,000 per electric truck, or an upfront incentive of approximately $3.2 million for a fleet purchasing 20 electric trucks.

Peel Off Scenario Incentive Amount: Approximately $160,000 per Electric Truck

7.4.2 Zero Emission Yard Tractors Deployed at Marine Terminals

The economics of yard tractors deployed within a marine terminal has both operational and economic similarities to the Peel Off Yard. Marine terminals are owned and operated by companies with financial stability and access to either internal financial resources or readily available credit. The yard tractors operating at a marine terminal do so in a controlled environment. However, while each container movement is a relatively short distance and at a low speed, marine terminals expect their yard tractors to operate continuously for a full eight-hour shift, and at times, two shifts. Thus, the duty cycle of a marine terminal yard tractor can be quite rigorous if the vehicle operates continuously for a full shift or longer. To ensure a yard tractor is capable of completing a shift without having to stop and recharge, the onboard battery pack must be sufficiently sized. For the purpose of this assessment, the onboard battery storage capacity of a yard tractor is assumed to be the same as that of a vehicle configured for the Peel Off operating scenario.

The yard tractor acquisition cost is likely lower as compared to an on-road Class 8 truck - approximately $15,000 – $25,000 lower cost for the off-road tractor compared to the on-road tractor.

The economic analysis of the marine terminal yard tractor scenario is similar to the Peel Off scenario. The following assumes a deployment of 20 new diesel yard tractors:

Vehicles to be Purchased:	Model Year 2015 4x2 Yard Tractor
Per Vehicle Cost:	$98,000 - $108,000
Down Payment:	10%
Interest Rate (APR):	4.99%
Term of Loan:	7 years

The assumption is that the out-the-door price, including sales taxes, other taxes, etc., is $110,000 per yard tractor. With a 10% down payment, the capital cost amortized over 84 months yields a monthly payment of approximately $27,975 per month.

Operationally, a conventional diesel yard tractor uses, on average, approximately 1.7 gallon per hour. Thus, in a single shift, the yard tractor will consume about 13.6 gallons of fuel. At $4.00 per gallon, this equates to a daily cost of about $55 per yard tractor; $1,088 per day for 20 tractors, or $27,200 per month assuming 25 days of operation.

Maintenance costs for the yard tractors should be similar to their on-road counterparts used in Peel Off operation; though other operating expenses, such as insurance, likely will be somewhat lower than an on-road drayage truck. For the purpose of this assessment – and to be conservative – it is assumed the operating costs associated with standard maintenance and expenses are the same as for the short-haul drayage trucks. As such, the monthly operating costs associated with 20 new conventional diesel yard tractors is as follows:

Capital Costs Amortized over 84 Months:	$27,975 per month
Fuel Costs:	$27,200 per month
Maintenance costs, etc.:	$15,840 per month

Thus, the total monthly cost for the 20 yard tractors amortized over an 84-month life cycle is approximately $71,015 per month.

Monthly Cost for 20 Conventional Diesel Yard Tractors:	Approximately $71,015

The near-term capital acquisition costs for a battery-electric yard tractor, including a five-year warranty (15% upcharge), and $10,000 EVSE pro rata share, and assuming a 20-unit purchase, is on the order of $300,000 per yard tractor. Assuming $220,000 down payment at 4.99% APR for 84 months, the monthly payment for the 20 yard tractors is approximately $81,666 per month.

Amortized Capital Costs for 20 Battery-Electric Yard Tractors:	Approximately $81,666

Operations costs include fuel, maintenance, and other costs such as insurance, etc. Each yard tractor is estimate to consume approximately 107 kWh in an eight-hour shift. At $0.15 per kWh, this equates to approximately $16.05 per yard tractor; $321 per day for 20 tractors; or $8,025 per month assuming 25 days of operation.

Scheduled maintenance associated with the battery-electric yard tractor is expected to be lower than the conventional fuel vehicle – no oil changes, etc. Applying the same maintenance cost profile as for the on-road Peel Off electric truck, monthly costs associated with maintenance are estimated at approximately $12,600.

Capital Costs Amortized over 84 Months:	$81,666 per month
Fuel Costs:	$8,025 per month
Maintenance costs, etc.:	$12,600 per month

Summing the capital acquisition costs, electricity costs, and scheduled maintenance yields a monthly cost of ownership of approximately $102,291.

Monthly Cost for 20 Battery-Electric Yard Tractors:	Approximately $102,291

What level of incentive is required to make the marine terminal scenario economically viable? The monthly cost to the marine terminal must be similar for both the conventional and electric yard tractor. In this case, a per-yard tractor incentive on the order of $110,675 per vehicle will result in a monthly payment of approximately $71,015 – the same payment had the marine terminal purchased conventional yard tractors.

It should be noted that there is uncertainty in the input data, as exact values are not known. Also, the scenarios assume that no out-of-warranty battery replacements are required – the primary reason the five-year extended warranty is purchased for the battery-electric vehicles upfront.

The bottom line – to make the Peel Off and marine terminal operating scenarios pencil out economically, a buy-down incentive on the order of $110,000 per yard truck, and approximately $160,000 for a Peel Off-configured drayage truck will be required in the near term.

7.4.3 Battery-Electric Drayage Trucks Performing Short Haul Drayage to a Near Dock Rail Facility

What about an operating scenario that has a longer dray, potentially performed by a small carrier or single truck owner-operator? What level of incentive is needed to make this operating scenario economically viable for zero emission operation?

Container movement to a near dock rail facility, such as the ICTF, is considered a short haul dray. While similar to the Peel Off scenario, the distance between the marine terminal and the near dock rail facility is greater. Unlike the Peel Off Program, all types of motor carriers currently support container movement to the ICTF, from large carriers to individual owner/operators.

The economics of container drayage for a small or independent drayage truck operator are much different than a larger company. Small carriers often have difficulty securing low interest rate loans, and often purchase used trucks being retired from larger motor carriers. Thus, the level of incentive that would be necessary to deploy zero emission battery-electric drayage trucks is vastly different for a small company than a large motor carrier. The question, however, remains the same – what would it take to make battery-electric trucks financially viable for all operators, including independent truckers?

Firstly, small drayage operators typically purchase used trucks, often at a cost that is less than ½ that of a new Class 8 truck. The cost is on the order of $45,000 for a 2007 or newer used truck that satisfies the Harbor Department's Clean Truck Program.

Access to low interest rate loans is usually more difficult for smaller drayage operators. While a larger motor carrier with good credit can obtain a loan at approximately 5% interest, the small or independent operator is likely to only have access to higher interest rate loans – 6% or 7% - sometimes higher. For this assessment, the assumptions include the following:

Vehicle to be Purchased:	Model Year 2009 Class 8 Day Cab Semi Tractor
Per Truck Cost:	$45,000
Down Payment:	$10,000 (typically previous vehicle as trade-in)
Interest Rate (APR):	6.99%
Term of Loan:	7 years

The monthly payment on the truck would be approximately $611 for a period of 84 months.

Amortized Capital Cost of Conventional Diesel Drayage Truck:	Approximately $611 per month

Like the previous scenarios, operating costs include fuel, maintenance, insurance, etc. While a smaller carrier or independent owner operator may conduct short haul drayage as their primary route, it is likely that they would accept longer container drays as available. Assuming three ICTF turns each day, plus one longer 10 mile dray, the daily container movement mileage is likely to be 50 miles or greater.

Also, smaller trucking companies are typically not collocated at the port. Travel to and from the company facility, or in the case of an independent trucker, travel to and from one's home, can add significant daily mileage. For this scenario, it is assumed that the additional "commute" distance is a total of 30 miles daily, for an average daily duty cycle of approximately 80 miles. Using the previously derived factor of $1.25 per mile for fuel operating expenses, the daily operating costs are likely on the order of $100. Assuming 25 days of work each month, this operations cost equals approximately $2,500 per month. Note that maintenance costs for the used vehicle will likely be higher as compared to a new truck that is under the manufacturer's warranty; therefore, the $1.44 per mile may be optimistic.

Monthly Cost of Used Conventional Diesel Drayage Truck:	Approximately $3,111 per month

The new battery-electric truck must be configured to perform the mileage requirements of the near dock rail scenario, as well as transport to and from the company facility. The cost of a new battery-electric truck with sufficient onboard battery storage capacity is likely on the order of $350,000 -$400,000. Assuming the lesser value, the addition of a five-year warranty raises this cost by approximately 15% to $437,500, not including EVSE. Installing a single EVSE at an offsite location will typically cost on the order of $15,000 - $20,000. Note that a single EVSE installation, such as that needed by a single owner/operator of an electric drayage truck, does not benefit from the economies of scale that a 20 truck EVSE charging network installed at a motor carrier facility would likely enjoy. Thus, the total cost of the battery-electric truck is likely to be on the order of $450,000, minus the trade in value of the old truck, assumed to be valued at $10,000[18].

It is highly unlikely that any lender would offer a loan on the order of $440,000 to a company with less than outstanding credit; thus, this scenario is more of an analytic exercise than a viable financial strategy. The goal, however, is to identify what level of incentive would allow a small or independent trucker to acquire a new battery-electric drayage truck.

Amortized Capital Cost of Battery-Electric Drayage Truck:	Approximately $6,640 per month

Operating costs would be similar to the Peel Off scenario at $0.69 per mile, or approximately $1,380 per month.

Monthly Cost of Battery-Electric Peel Off Truck:	Approximately $8,020 per month for 84 months

What level of incentive would likely be needed to enable a small, independent short-haul drayage operator to purchase a new battery-electric truck? Based on the above scenario, the incentive would need to be on the order of $300,000 per truck, twice the level of incentive as compared to the Peel Off and marine terminal/yard tractor scenarios.

[18] Note that typically, incentive programs require the destruction of the vehicle being replaced with an incentive-funded vehicle, in which case, this trade-in value would be zero.

Thus, for the small independent operator, the majority of the incremental cost – the difference in price between the used diesel truck and the new battery-electric truck – will need to be subsidized to allow the operator's monthly costs and income to remain constant in the near term. In the longer term, the incentive amount needed will likely be lower, as battery-electric truck production rates increase, battery costs are reduced, and overall electric truck costs come down. In the near term, however, independent owner operators will require substantial assistance to make the purchase of new battery-electric trucks financially viable.

7.4.4 Strategy Moving Forward

In the near term, a substantial buy-down incentive will likely be necessary to place electric trucks into port container movement operations. The level of incentive needed to satisfy the business case requirements vary depending on the vehicle operating scenario and the type of operator deploying the vehicles. As discussed above, the estimated vehicle buy-down incentive can vary by a factor of two or more between a marine terminal operator deploying zero emission yard tractors and an independent trucker purchasing a battery-electric drayage truck; this incentive amount is likely to fall within a range of $110,000 to $300,000 per vehicle.

To maximize the effectiveness and efficient use of any potentially available incentive funds while limiting technical and programmatic risks, the Harbor Department should consider adopting a targeted deployment strategy. This approach could be implemented as follows:

- Continue the Harbor Department's involvement in current and planned electric vehicle demonstration and testing. Electric vehicle demonstration and testing is essential to prove out vehicle performance capabilities, reliability, and durability. Any future larger-scale electric vehicle deployment is predicated on first validating candidate vehicles and technologies;
- Adopt a "Phased Deployment" strategy, initially focusing on marine terminals and Peel Off short haul drayage since these vehicles are less expensive on a per unit basis. This will maximize the number of vehicles deployed for a given amount of incentive funding, while allowing the initial larger scale vehicle deployments to be operated in a more controlled environment. Some opportunities could exist for early introduction of short haul drayage though the costs will be higher due to the different operational profiles and requirements.

In the longer term, zero-emission trucks can be integrated into smaller fleets and individual owner operators. However, this follow-on electric vehicle deployment phase should only occur:

1. When vehicle performance and reliability has been sufficiently proven; and
2. When manufacturing rates are sufficiently high to allow economies of scale to be realized and vehicle acquisition costs to be substantially reduced.

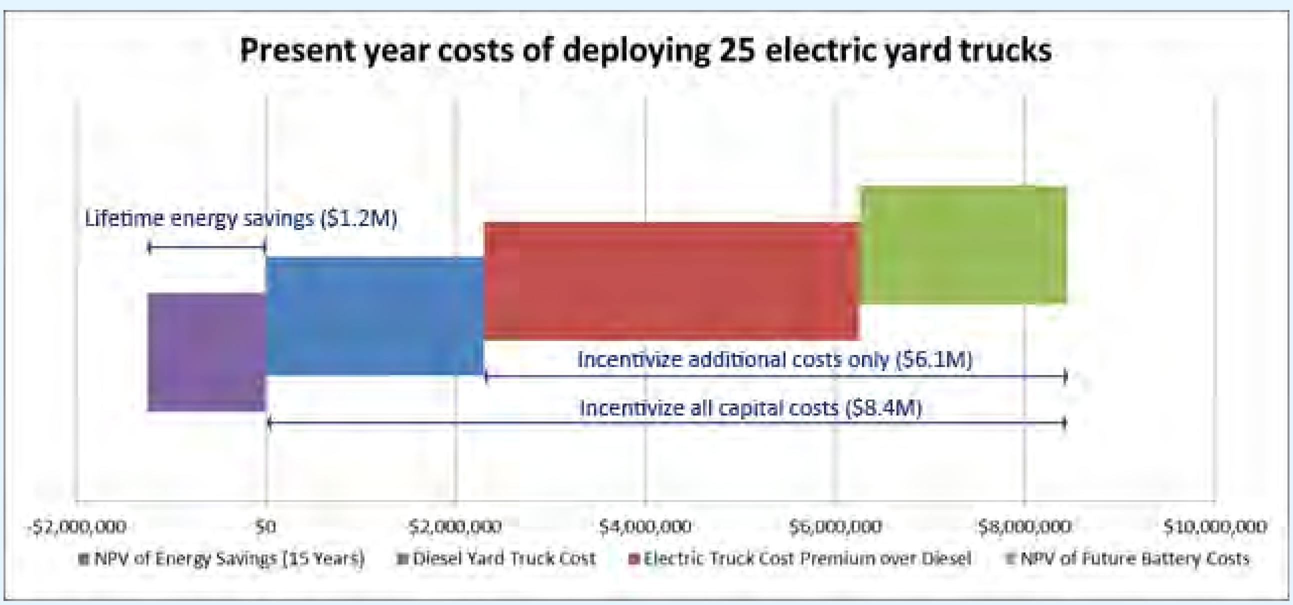
7.5 Cost Conclusions and the Role of Subsidies

The long-term promise of electrified equipment for operators is increased reliability since there are far less powertrain components, less maintenance-related downtime, and a lower overall impact on operator time. Even though it may need additional care during the prototype stage, the reliability of electrified equipment has been demonstrated by successful electrification of other commercial equipment such as large forklifts and airport ground support equipment – notably in a controlled environment like a terminal or warehouse or airport. For these reasons, some may argue that the market will eventually, with time and experience, come to favor battery-electric technologies as fuel prices rise and capital costs fall.

In the short term, capital costs are likely to remain very high for both manufacturers and operators. This highlights a problem: how best to encourage an environment in which manufacturers want to build electrified equipment and operators may start to gain sufficient experience to be fully comfortable with them by the time the market balances? In the short term, federal, state and regional government incentives are likely to be needed to help offset costs where production of this equipment is low due to the presence of less expensive alternatives and the resulting lack of widespread demand. An incentive program would have to be based on government funding, such as from federal, state, and regional air districts or state bond issues such as the Proposition 1B Goods Movement funds, or incentives from other available sources, such as the Greenhouse Gas Reduction Fund. An incentive program should only be considered a short-term "interim" solution to help transition this technology to a market-based model.

Options to Incentivize Electric Trucks

When looking at the costs associated with purchase and operation of zero emission trucks, there are three main options to incentivize trucks which include: 1) pay all costs, 2) pay capital cost difference between new diesel and electric trucks, and 3) pay capital cost differences and deduct energy savings. The following figure illustrates these potential costs associated with a scenario of deploying 25 electric yard tractors.



8.0 Next Steps

Given the Harbor Department's air quality improvement goals, regional goals under the CAAP, and the goal to reduce greenhouse gas emissions, the Harbor Department must continue to advance the industry's reduction of air pollutant and greenhouse gas emissions associated with container movement. This will require a steady movement toward use of zero emission technologies. However, as discussed in the preceding sections, the current technical and economic challenges are real – the transition to zero emission operations is not likely to happen very quickly – at least not within the near-term. For these reasons, the Harbor Department must continue to facilitate the development of zero emission technologies for use in maritime goods movement related activities.

Successful development of this technology will not occur from Harbor Department efforts alone. A comprehensive program in collaboration with key partners such as the Port of Long Beach, regional and state agencies, and industry partners will be required for zero emission technologies to become a reality in Southern California and elsewhere. The Ports of Los Angeles and Long Beach have recently agreed to update the CAAP, and a zero emissions plan could be included in that effort, though the CAAP update will take many months to be developed. Consequently, in the near term Harbor Department staff believes the following recommended course of action will result in substantive progress towards a zero emissions port. This proposed **Five Year Action Plan** consists of three primary focus areas: zero emission vehicle testing, infrastructure planning, and continued support of regional near-zero technology implementation in the near term.

Zero Emission Vehicles – Under staff's proposed Five Year Action Plan, the Harbor Department would use its leadership to advance the industry's transition of cargo handling equipment to zero emissions, beginning with a coordinated effort with marine terminals for voluntary demonstration of zero emission tractors, as well as a similar coordinated effort for voluntary demonstrations with a small number of short-haul drayage vehicles, both facilitated by federal, state, and regional government incentive funding. This segment of the action plan would be implemented as follows:

- Secure Funding: The Harbor Department will make all reasonable efforts to secure necessary funding sources to support the purchase of electric vehicles currently manufactured and offered as pre-commercialized products. The Harbor Department will seek up to $20 million annually through federal, state, and regional funding programs. For example, in 2015, up to $75 million in funding from two state programs[19] will support low-carbon transportation technologies and accelerate the implementation of advanced technology vehicles and equipment. The Harbor Department will seek to partner with state agencies to secure a minimum of up to $20 million annually to implement projects that directly address these state objectives. Over a five-year period, if successful, this equates to a planned funding of zero-emission heavy-duty vehicles on the order of $100 million.

[19] Refer to Appendix 2 for additional information on funding opportunities for electric vehicle and equipment technologies.

- <u>Purchase Zero Emission Heavy-Duty Vehicles:</u> Up to $20 million in annual funding would allow the Harbor Department to purchase up to 40 heavy-duty zero emission vehicles each year, together with supporting infrastructure. As appropriate, the Harbor Department will engage in a selection process for zero emission vehicle manufacturers, as well as seeking marine terminal volunteers to demonstrate and operate these vehicles in daily, real-world container movement operations. Similarly, the Harbor Department will engage in a selection process for trucking companies that would volunteer to operate and test short-haul drayage trucks. For this effort, the Harbor Department will not ask for an upfront cash contribution from the operators towards this equipment – the operators would instead provide an in-kind contribution as described below. The Harbor Department would work with each participating operator to install appropriate electric vehicle charging infrastructure. The terminal or trucking company would also have to agree to be responsible for the cost of the grid electricity.

  Harbor Department staff will oversee management of federal and/or state funds as well as the projects being implemented by participating marine terminal or trucking companies. Participating operators will be required to agree to terms of use pertaining to this equipment, including agreeing to allow the Harbor Department monitor, document, and report on vehicle performance, reliability, hours of operation, and downtime.

  Following successful completion of a predetermined test and demonstration period, the operator would be allowed to retain title to the vehicle for continued container movement operations.

Harbor Department Budget Commitment – Staff is currently evaluating anticipated budget requirements to support this effort and funding scenarios and recommendations will be provided to the Board.

Infrastructure Plan Development – Under staff's proposed Five Year Action Plan, the Harbor Department would work with industry partners and stakeholders to concurrently develop a comprehensive Infrastructure Plan to prepare the Port for the future deployment of hundreds – if not thousands – of zero emission trucks. This infrastructure plan would consider the charging or fueling needs of both on-road drayage and on-terminal electric yard tractors. Special consideration would be given to infrastructure standardization and the potential impact on California's electrical grid; as such, smart charging and system optimization will be key components of the Infrastructure Plan.

This effort is proposed to begin in the fourth quarter of 2015 and take two years or more to complete. This effort will be designed to eventually be integrated with the Port of Los Angeles Capital Improvement Program.

Continued Support of Stakeholder Efforts to Test and Operate Zero and Near-Zero Emission Drayage Trucks – The SCAQMD and other regional stakeholders have played key roles in the region by managing the development and planned demonstration of zero and near-zero emission heavy-duty trucks applicable to container drayage. As mentioned in preceding sections, near-zero technologies are expected to be commercially available over the next few years and serve as the transitional pathway to 100% zero emission vehicles. Near-zero emission vehicles will be applicable to short haul container drayage as well as medium and long distance container hauling; the first fully zero emission drayage trucks are expected to predominately support short haul drayage due to anticipated limited range.

The Harbor Department will continue to monitor and, where appropriate, support regional technology advancement efforts for on-road zero and near-zero drayage trucks, emphasizing uniform vehicle testing in accordance with the *Zero/Near-Zero Emission Truck Testing & Demonstration Guidelines* currently under development.

In summary, staff's proposed Five Year Action Plan would yield the following tangible benefits:

- At the end of five years, up to 200 zero emission, heavy-duty vehicles would be operating at the Port of Los Angeles.
- By offering participating operators zero emission vehicles and recharging infrastructure at no upfront cost eliminates any perceived barriers to participation – this approach eliminates the programmatic risk associated with new technology. The funds to cover these upfront costs would come from federal, state, and regional government incentives designed to support the implementation of zero emission maritime goods movement operation; and
- An operator agreement to operate, test, document, and report on zero emission vehicle performance represents a meaningful in-kind cost share contribution that can be quantified and used as match funding when seeking State incentive funding; and
- Up to $20 million per year program is manageable at a reasonable administrative cost to the Harbor Department, estimated to require approximately one (1) full time person (could be Harbor Department staff or outsourced) – this level of effort will likely be an acceptable cost under the state incentive programs and thus reimbursable to the Harbor Department.

At the end of this five-year effort, the Harbor Department will have a much better understanding of the ease of operation, costs, vehicle durability and reliability, marine terminal acceptance, as well as a wealth of real world data to contribute to the transition of zero emission vehicles into maritime goods movement related activities at the Port of Los Angeles.


ZPMC

9.0 Findings and Recommendations

The fastest scenario for widespread implementation of zero emission technologies to occur is if a national or statewide regulatory requirement for their use is imposed. At a minimum, a statewide requirement would attract OEM participation by signaling a strong and reliable market, presumably large scale, and thereby (hopefully) drive down costs closer to conventional truck costs, while not imposing a competitive disadvantage to particular region, industry or facility. However, a regulation will only be imposed once there is a strong, successful operating history with zero-emission heavy–duty vehicle technology, and only when today's operational and cost uncertainties are fully addressed. As such, Harbor Department staff proposes to contribute to the development of this needed operating history by establishing a collaborative effort with regional stakeholders, including the Port of Long Beach, industry and agency partners, to further development of these technologies. In addition, staff recommends a Port of Los Angeles Five Year Action Plan as a path toward the acceleration of zero emission technology implementation.

The Harbor Department staff believes that short-haul drayage and on-terminal container handling equipment are the two areas of maritime goods movement operations where zero and near-zero emission solutions are most likely to develop in the near-term. While short-haul drayage remains a key pursuit, staff recommends that increased emphasis be placed on the development and demonstration of zero and hybrid near-zero on-terminal yard tractors and container handling equipment. This is because staff expects this to be the first area where a market for these vehicles could develop. Further, yard tractors provide a simpler and more stable platform for demonstration, and staff believes that increased expenditures focused on developing off-road zero emission yard tractors would help to ***accelerate*** the commercialization of on-road short haul drayage trucks by providing for technology transfer at the component level and a proving ground for zero emission technology in a more controlled environment. The Five Year Action Plan laid out in Section 8 provides the path forward in support of zero emission implementation. Specific recommendations are summarized below:

- Complete a stakeholder-developed zero emission in-use testing and demonstration plan that incorporates independent third-party testing and reporting conducted by a certified dynamometer testing laboratory, in order to ensure an objective and consistent vehicle performance evaluation.
- Secure adequate grant funding to purchase up to 40 new zero emission vehicles each year for a five-year period starting in 2016. Anticipated funding opportunities from the State of California may include more than $75 million each year to freight technologies, including zero emission drayage trucks and multi-source facility projects at warehouse, distribution center and intermodal facilities. As described in preceding sections, increased focus in testing would be toward off-road vehicles and equipment, though some short haul drayage would also continue to be purchased and tested.
- Evaluate and recommend appropriate Harbor Department budget, staff, and resources needed to support this program.

- Develop a comprehensive Infrastructure Plan to prepare for the future deployment of hundreds – if not thousands – of zero emission trucks. This plan will consider the charging or fueling needs of both on-road drayage and on-terminal electric yard tractors. Special consideration will be given to infrastructure standardization and the potential impact on the California electrical grid; as such, smart charging and system optimization will be key components of the Infrastructure Plan.
- Continue to support regional efforts to test and develop and encourage use of zero and near-zero emission technologies. Near-zero emission vehicles are anticipated to help with short haul container drayage as well as medium and long distance container hauling until zero emission technologies are fully tested and demonstrated.
- As part of CAAP 3.0, consider the benefits of near-term incentivizing using federal and state grant funding for the following:
    - ZE yard equipment;
    - ZE Peel Off (and possibly short haul drayage) equipment;
    - Near ZE (0.02 NOx) short, medium and long haul drayage equipment until technology and infrastructure are developed for more widespread deployment.

APPENDIX 1 – Ongoing and Completed Demonstration Projects

The Harbor Department is co-funding five key technology projects that are currently underway. These are summarized, as of May 31, 2015, below:

- **Balqon -** Since 2008, the Harbor Department has been working together with Balqon Corporation (Balqon) on the development and demonstration of electric terminal tractors (i.e., yard tractors) and short-haul on-road electric drayage trucks. The Harbor Department owns a total of fourteen Balqon yard tractors and one on-road drayage truck. The yard tractors consist of first and second generation designs that are equipped with lead-acid and lithium-ion battery chemistries, respectively. These early designs were tested at a marine terminal and found to fall short of terminal operator requirements, since the units would not last an entire shift on a single charge. Due to the operating range concerns, none of the first or second generation units were deployed at marine terminals, and Balqon focused their efforts on the development of a third generation design that optimized the battery management system utilizing the units equipped with the lithium-ion batteries. Under this project, six third generation units will be deployed at the terminals for a one-year demonstration. The Harbor Department spent approximately $200,000 to construct charging infrastructure in support of this project. The on-road drayage truck utilized the optimized battery systems designed for the yard tractors and also operated on lithium-ion batteries. The on-road truck demonstrated an approximate 80-mile range when fully loaded. In 2012, Balqon completed a preliminary demonstration that included several round-trips from a near-dock rail yard to port terminals. The Harbor Department and Balqon plan to work with a Clean Truck Program drayage operator to test the truck in short-haul drayage operations.

- **International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion -** Beginning in July 2013, International Rectifier (IR) began a project to convert, or retrofit, a conventional diesel-fueled Class 8 drayage truck into a plug-in hybrid electric vehicle (PHEV). The project includes development and demonstration of the PHEV in drayage operation. The PHEV will have three main sub-systems that include: a) an all-electric drive, b) a combined diesel-electric drive (hybrid mode) and c) an electrified accessory drive (zero emission idling system). The current design utilizes lithium-titanate batteries to improve battery performance. The total project cost is $731,972 with $350,000 provided by the TAP ($175,000 from the Harbor Department) and the balance of funding provided by IR. Emissions and performance testing of the baseline truck is complete and the truck conversion is underway. Post conversion emission testing is expected to take place prior to in-service demonstration, which is slated for mid-2015. It is noteworthy that this project vehicle will also be part of the Zero Emission Cargo Transport (ZECT) II program, discussed further below.

- **Zero Emission Cargo Transport I Program (2012) –** SCAQMD is leading the ZECT I program with major co-funding from the California Energy Commission and US Department of Energy, and additional co-funding from SCAQMD, Transportation Power, Inc. (TransPower) and the Harbor Department via the TAP. In this project, TransPower is developing for evaluation and demonstration a zero emission battery-electric drive system for heavy-duty trucks for drayage service. TransPower's ElecTruck™ electric propulsion system is being integrated into seven Navistar International ProStar trucks. As each truck is integrated with the TransPower's ElecTruck™ drive systems, it will operate in drayage service at SA Recycling or Total Transportation

Services, Inc. (TTSI) for at least two years, with operating data collected and analyzed during this period.

Two of the seven Electric Drayage Demonstration (EDD) trucks were completely integrated by the end of 2014. Trucks EDD1 and EDD2 are currently being demonstrated in-service and have accumulated a combined 7,234 miles to date. The main difference between these first two units is the design of the battery subsystem that supplies all of the stored electrical energy required for truck operation. The batteries in EDD1 are installed into 18 different modules (or enclosures), while the newer EDD2 design utilizes just five battery enclosures, reducing wiring and maintenance complexity. In addition, EDD2 uses smaller battery cells and a newer, more advanced battery management system, which are expected to improve overall truck performance and reliability while reducing battery subsystem weight by more than 1,000 pounds. Both trucks have shown the ability to travel approximately 120 to 130 miles on a single charge (empty load) at a top speed of at least 65 miles per hour. With a full load of 80,000 lb., the trucks use about 2.5 kWh per mile and can travel approximately 70 miles on a single charge.

Integration of all subsystems in EDD3 and EDD4 was completed in early 2015, and these trucks successfully passed initial validation and drive testing. To date, these two trucks accumulated a combined 1,700 miles of operation. The remaining three trucks are expected to be completed by September 2015. The Harbor Department is contributing $150,000 to this project, which has a total budget of $5,087,921.

Figure A1-1: EDD1 at SA Recycling

Figure A1-2: EDD2 Carrying Metal Load

- **TransPower Electric Yard Tractor Demonstration -** Since 2013, the TransPower Electric Yard Tractor Demonstration (EYTD) Project has been implemented by the Harbor Department under CARB's AB 118 Air Quality Improvement Program (AQIP): "Advanced Technology Demonstration Project: Zero Emission Off-Road Equipment." For this project, TransPower integrated their electric drive technology into two off-road yard tractors, which will ultimately be demonstrated at POLA's APL terminal/Eagle Marine. The two electric yard tractors completed the system integration stage as well as initial validation and drive testing, and are both operating on a limited basis until adequate charging infrastructure is installed at the APL terminal/Eagle Marine. The first tractor is currently operating at TTSI with no major problems, and the second tractor is operating at the Port of San Diego's Dole facility on a temporary basis. The planned completion date of this charging infrastructure project is mid-2015. The Harbor Department is contributing $40,000 for charging infrastructure to support this project, which has a total budget of $1,053,000.

- **Zero Emission Cargo Transport II Program (2014) -** At its December 10, 2014 meeting, the TAP Advisory Committee approved a recommendation to Harbor Department staff to co-fund the SCAQMD's ZECT II Program. Harbor Department support of this project is subject to final Board of Harbor Commissioners consideration. This project consists of two components: 1) development and demonstration of five zero emission fuel cell range extended electric drayage trucks, including hydrogen fuel cell and compressed natural gas, and 2) development and demonstration of two hybrid electric drayage trucks for goods movement operations between the Ports of Los Angeles and Long Beach near dock rail yards and warehouses. The Harbor Department is contributing $566,990 to this project, which has a total budget of nearly $20 million. It should be noted that the same truck being developed by International Rectifier in the TAP project described above is also being used in ZECT II as a means to collect additional operational data.

Table A1-1 provides a summary of these POLA-sponsored projects currently underway[20].

Table A1-1: Ongoing Technology Development Projects Co-Sponsored by the Harbor Department

Project Title	Partners	Objective	Total Project Cost	POLA Share
Balqon On-Terminal Demonstration of six yard tractors	Balqon Corporation POLA	Construction of charging infrastructure for the demonstration of six (6) zero emission electric yard tractors for one year of regular service at two port terminals. These trucks will use the 3rd generation lithium-ion battery system.	$200,000	$200,000
International Rectifier (IR) Plug-In Hybrid Electric Class 8 On-Road Truck Conversion	International Rectifier, POLA, POLB	Retrofit a used Class 8 drayage truck into a plug-in hybrid electric vehicle (PHEV), including demonstration of the PHEV in drayage operation. The PHEV will allow for all-electric drive, combined diesel-electric drive (hybrid mode) and an electrified accessory drive (zero emission idling system).	$731,972	$175,000

[20] The Zero Emission Cargo Transportation II Program is underway with partner funding, but POLA co-funding is pending Board of Harbor Commissioner review.

Project Title	Partners	Objective	Total Project Cost	POLA Share
Zero Emission Cargo Transportation I Program (2012)	US DOE, TransPower, CEC, SCAQMD, POLA, POLB	Develop and demonstrate a zero emission electric-battery drive system for heavy-duty drayage trucks. TransPower's ElecTruck™ electric propulsion system is being integrated into seven (7) Navistar International ProStar trucks.	$5,087,921	$150,000
TransPower Electric Yard Tractor Demonstration (EYTD)	POLA, CARB	Integrate TransPower's electric drive technology into two off-road yard tractors for port terminal demonstration and develop charging infrastructure. (AB 118 funding)	$1,053,000	$40,000
Zero Emission Cargo Transportation II Program (2014)	US DOE, US Hybrid, TransPower, BAE, International Rectifier, CEC, SCAQMD, LADWP, SoCalGas, POLA, POLB	Development and demonstration of five zero emission drayage trucks with fuel cell range extenders and two hybrid electric drayage trucks.	$19,984,820	$566,990

Note that detailed summaries of all Harbor Department-sponsored projects are provided in the TAP Annual Reports, available on the TAP website[21].

[21] *www.cleanairactionplan.org/programs/tap/techdemos.asp*

Table A1-2: Completed Projects that Support Zero and Near-Zero Truck Technologies

Project Title	Partners	Objective	Total Project Cost	POLA Share	Key Findings
Balqon E-30 Electric Terminal Tractor Development & Demonstration Project (2009)	Balqon Corporation POLA SCAQMD	To prove performance capabilities, commercial feasibility and practicality of using two zero emission electric terminal (yard) tractors.	$527,000	$263,500	• 1st generation range of only 2-4 hours/charge • Charge times did not meet terminal requirements
Capacity Plug-In Hybrid Electric Terminal Tractor (2010)	Capacity of Texas, Inc., POLB, POLA, Ports America, Total Terminals, Inc., and Yusen Terminals, Inc.	Trial to evaluate one Capacity Pluggable Hybrid Electric Terminal Tractor (PHETT™).	$61,500	$32,000	• Achieved 34% reduction in fuel consumption • PHETT not good candidate for ports since it does not meet CARB CHE regulation (i.e., not Tier 4-interim compliant)
Hybrid Yard Tractor Development & Demonstration (2010)	US Hybrid, POLA, POLB, CALSTART, US EPA, Kalmar Industries, Long Beach Container Terminal (LBCT)	To design, develop and demonstrate three hybrid yard tractors.	$1,200,000	$300,000	• Three hybrid yard tractor underwent six months of operation and in-use testing at LBCT and were able to perform all the tasks required of yard tractor in real-world maritime goods movement operations, and were well accepted by drivers and maintenance staff • The hybrid system was estimated to provide a 12 - 18% improvement in fuel economy • Differences in the mechanical specifications of the vehicles were discovered that limited comparability, so the Beta Test (2011) was conducted to assess benefits

Project Title	Partners	Objective	Total Project Cost	POLA Share	Key Findings
Hybrid Yard Tractor Development & Demonstration – Beta Test (2011)	US Hybrid, POLA, POLB, LBCT	Assessment of design improvements made to first generation technology.	$26,000	$13,000	• The Generation 1.1 yard tractor did not demonstrate significantly different fuel economy compared to either the baseline yard tractor or the Generation 1.0 hybrid yard tractor tested during the previous demonstration (above) • The Generation 2.0 yard tractor demonstration tests were inconclusive.
Balqon Lithium-Ion Battery Demonstration (2011)	Balqon Corporation POLA	To evaluate and demonstrate a lithium-ion battery as a technological upgrade to the lead-acid battery pack used in the original demonstration with goal to significantly increase range. (one unit)	$940,000	$400,000	• 2nd generation range of only 6 hours/charge, due to BMS issues. • This led to a new design that achieved 12 hours/charge with the addition of battery capacity. • The lead-acid battery system provided 30 to 50 mile range under comparable test conditions.
Characterization of Drayage Truck Duty-Cycles (2011)	TIAX, LLC, POLB, POLA	To provide information on typical duty cycles associated with drayage service, in order to support design specification.	$25,681	$12,841	• Vehicle operational (in-use) data for multiple trucks were collected during a period of several weeks, over three areas: near-dock, local, and regional operation.

Project Title	Partners	Objective	Total Project Cost	POLA Share	Key Findings
Development of a Drayage Truck Chassis Dynamometer Test Cycle (2011)	TIAX, LLC, POLB, POLA	To develop a detailed test cycle for use when testing HDVs on a chassis dynamometer that is based on the modes of operation and trip data previously identified in the above study; facilitates repeatable and comparable evaluation.	$23,466	$11,466	• Development of a detailed driving schedule suitable for use when testing heavy-duty vehicles on a chassis dynamometer that is based on the modes of operation and trip data previously identified in the earlier above study. • This test cycle reflects typical port drayage truck operation and is a tool to compare the emissions performance from various drayage truck technologies.
Vision Motor Corp. Hydrogen Fuel Cell Hybrid Electric Trucks (Zero-TT and Tyrano) (2012)	Vision Motor Corp., POLA, POLB	To demonstrate the zero emission hydrogen fuel cell/hybrid-electric drive system in two units: a short-haul drayage truck and a yard tractor.	$191,250 (Note: Original budget was $1 million, but project was not completed)	$95,625	• Experienced significant design and software integration issues • Vision was unable to begin the demonstrations before the contract expired due to significant schedule delays; thus, there were no results to report from the TAP testing period. • Vision subsequently filed Chapter 7 and is no longer in business.

APPENDIX 2 - Funding Opportunities

To support the Five Year Action Plan, near term opportunities exist for continued Harbor Department participation in technology development and demonstration projects for both on- and off-road port trucks. These opportunities provide ability to leverage Harbor Department investment to accelerate commercialization of zero and near-zero emission technologies and, more importantly, to provide input and guidance to the technology implementation and commercialization process to maximize success.

Three major California initiatives are scheduled to allocate significant funding to support zero emission vehicle technology implementation. These include the Proposition 1B Goods Movement Emission Reduction Program, AB-118 Air Quality Improvement Program and the Low Carbon Transportation Greenhouse Gas Reduction Fund. In addition, the federal government continues to support criteria and greenhouse gas emission reduction projects throughout the country via the US EPA Diesel Emission Reduction Act's Ports Initiative and the US DOE Clean Cities Program. Harbor Department staff will continue to work with stakeholders to maximize port access to these funds to support the accelerated demonstration of zero and near-zero technologies in the goods movement sector. Table A2-1 summarizes upcoming funding programs that are expected to be available in the near term to support zero emission technology implementation in on- and off-road vehicles that operate in or near the port.

Table A2-1: Near Term Funding Sources for Zero Emission Technology Programs

Program Title	Funding Source	Funding Agency	Eligible Projects	Timeline	Funding Target
Advanced technology Freight Demonstration Projects: Zero Emission Drayage Trucks	Proposition 1B Goods Movement Emissions Reduction Program (GMERP), Air Quality Investment Program (AQIP) and the Greenhouse Gas Reduction Fund (GGRF)	CARB, CEC	Larger fleet demonstration of pre-commercial truck technologies that completely eliminate tailpipe emissions.	Released: June 23, 2015 Due: September 24, 2015	$20-$25 million
Advanced technology Freight Demonstration Projects: Multi-Source Facility Projects	Air Quality Investment Program (AQIP) and the Greenhouse Gas Reduction Fund (GGRF)	CARB, CEC	Concurrently demonstrate in a single facility multiple zero emission yard and regional haul trucks, fueling /charging infrastructure, and other equipment used in distribution and warehouse centers.	Released: June 23, 2015 Due: September 24, 2015	$20-$25 million

Program Title	Funding Source	Funding Agency	Eligible Projects	Timeline	Funding Target
Advanced technology Freight Demonstration Projects: Other Freight Projects	Air Quality Investment Program (AQIP) and the Greenhouse Gas Reduction Fund (GGRF)	CARB, CEC	Broader category that includes zero and near-zero CHE technology, line-haul and regional-haul truck demonstrations, etc.	Mid-2015	Up to $10 million
Diesel Emission Reduction Act (DERA)	Ports Initiative	US EPA	Annual program to reduce port emissions.	Anticipated mid-2016 if appropriated	Up to $10 million

Harbor Department staff will continue working with technology developers, regulatory agency partners, port marine terminal tenants, and licensed motor carriers to successfully complete current on-road and on-terminal zero emission demonstration projects. As discussed above, new opportunities to demonstrate zero emission port-related equipment are expected mid-2015. Accordingly, staff will pursue, in coordination with agency partners, near-term funding opportunities to continue development and refinement of zero and near-zero technologies, especially near term opportunities promoting, zero emission, short-haul drayage trucks.

In addition to currently identified opportunities, the Harbor Department, in cooperation with stakeholder partners, will continue to actively pursue opportunities related to development and demonstration of zero and near-zero emission container movement trucks and equipment. This intensified level of effort on the off-road sector has many beneficial features, as discussed below.

Please email comments on the
DRAFT Zero Emission White Paper to:
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Please provide comments by August 7, 2015


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