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Seaport Land-Side Equipment Electrification Opportunities

At the Port of Houston, Texas, the Port of Long Beach, California and the Port of Toledo, Ohio

Technical Report

Seaport Land-Side Equipment Electrification Opportunities

At the Port of Houston, Texas,
the Port of Long Beach, California
and the Port of Toledo, Ohio

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REPORT SUMMARY

Like many industries across the United States, seaports have begun investigating ways to reduce air emissions associated with their operations. As ports consider their emission reduction options, they must first consider the control strategy opportunities available to them to reduce emissions. Equipment electrification—the subject of this report—is one control strategy option available to them. This report investigated the potential effects of electric equipment options at three different U.S. seaports: Houston, Texas; Long Beach, California; and Toledo, Ohio.

Background

The air quality problems associated at the Ports have become a widely discussed issue facing cargo handling in recent years. While growth is necessary for economic health, the pollution emitted is growing as well. This study gives an overview of the many aspects of the port that can be considered for electrification. The emphasis of the work is a complete review of land-side equipment including terminal tractors, forklifts, top loaders, empty container handlers, non-road vehicles, rubbery tired gantry cranes, and wharf cranes. The report estimates emissions of key pollutants such as oxides of nitrogen (NO_x), carbon monoxide, hydrocarbons, and particulate matter in terms of tons per year. In addition to emissions by equipment type in aggregate, emissions per single piece of equipment are also estimated.

Objectives

To determine the feasibility of replacing cargo-handling equipment at three selected ports with electric equipment, with the ultimate aim of decreasing port-wide emissions and improving operational efficiencies.

Approach

The project team assessed the feasibility of retrofitting or replacing with electric some of the diesel land-side equipment operated at three U.S. ports: The Port of Houston, located on the Gulf of Mexico; The Port of Long Beach, located on the Pacific; and the Port of Toledo, located on the Great Lakes. The team based their assessment on information on equipment and emissions from previous inventory studies of land-side equipment at the Port of Houston and the Port of Long Beach. For the Port of Toledo, an estimation of the inventory of land-side equipment was used for the assessment. The team used the Environmental Protection Agency's NONROAD2 Model to estimate the output of emissions at Houston and Toledo and the California Air Resources Board OFFROAD model to estimate emissions at Long Beach. The project team summarized the benefits and costs associated with electrification and discussed the possibility of future electric projects associated with ships, rail, and trucks.

Results

The introduction of electric land-side equipment is a potentially effective and cost effective strategy for reducing emissions while also serving other key objectives such as the use of alternate fuels and improving operational efficiencies. The capital, operating, and infrastructure costs associated with electrification may be offset by one of several financial incentives that exist at the local, state, and federal levels.

The Port of Houston and its tenants and the Port of Long Beach and its tenants operate a variety of equipment types within the Port. Forklifts, yard trucks, container handlers and rubber-tired gantry (RTG) cranes are among the most prevalent equipment types. Forklifts, particularly those small in size, and RTG cranes are the focus of this report due to the general commercial availability of forklifts and relative emissions contribution of diesel forklifts and cranes. An estimated 106 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of 100 of the Port of Houston small forklifts and ten RTGs. An estimated 134 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of 100 of the Port of Long Beach's small forklifts and 20 rubber-tired gantry cranes.

The Port of Toledo and its tenants operate a variety of equipment types within the Port. Forklifts, front end loaders and cranes are among the most prevalent equipment types. Forklifts, particularly those small in size, and large cranes are the focus of this report due to their general commercial availability and relative emissions contribution. An estimated 15 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of the Port's two large cranes (Big and Little Lucas) and ten small forklifts.

EPRI Perspective

Although land-side equipment is the major focus of this report, ship shore power, truck stop electrification, and electric rail are also potential effective strategies to reduce emissions that may be cost effective for ports.

Keywords

Electric transportation
Ports
NO_x
Particulate matter
Air quality

ABSTRACT

The air quality problems associated at the Ports, have become a widely discussed issue facing cargo handling in recent years. While growth is necessary for economic health, the pollution emitted is growing as well.

This study gives an overview of the many aspects of the port that can be considered for electrification. The emphasis of the work is a complete review of the land side equipment. Primary equipment includes: terminal tractors, forklifts, top loaders, empty container handlers, non-road vehicles, rubbery tired gantry cranes, wharf cranes, and more.

EXECUTIVE SUMMARY

The purpose of this study has been to investigate land-side equipment electrification options. This report is part of a three part study which investigated electric equipment options at three different U.S. seaports: Houston, Texas (POH), Long Beach, California (POLB), and Toledo, Ohio. The three ports reflect vastly different maritime shipping concerns:

- The Port of Houston, located on the Gulf of Mexico, is principally a petroleum refining port, with a large presence of bulk carriers and containerships. It is one of the largest U.S. ports in terms of tonnage.
- The Port of Long Beach, located on the Pacific Ocean, is mainly a containership and secondly a petroleum processing port. It is one of the largest U.S. ports in terms of dollar revenue and container throughput.
- The Port of Toledo, located on the Great Lakes, is mainly a break-bulk cargo port known for large shipments of coal, grain, taconite, petroleum products, and foods. Responsible for the Port is the Toledo-Lucas County Port Authority, one of only a handful of port authorities that is responsible not only for a seaport but also an airport, regional economic development, and surface transportation. Compared to Houston and Long Beach, the Port of Toledo is relatively small in size of operations.

The differences among ports, highlighted briefly above for the Ports of Houston, Long Beach, and Toledo, are important as one considers the opportunities to which land-side equipment can be electrified, whether it be by dedicated electric service, rechargeable batteries, or diesel/battery hybrid configurations.

The term “land-side equipment” is used to describe cargo handling equipment associated with loading and unloading ships at a marine terminal, and moving the cargo around the terminal before or after its ship-borne transport. Throughout this report, the terms land-side equipment and cargo handling equipment will be used interchangeably. Highway trucks and railroad locomotives are distinct and separate mobile source categories. There are some land-side equipment categories, including certain forklifts and cranes, that may be effective as electric rather than diesel. The availability of these types of equipment, as electric, varies. Some equipment may be purchased directly from the manufacturer as electric, while other equipment may be retrofitted by the equipment owners. Depending on the age of existing equipment, retrofit/replacement of diesel equipment with electric power could be a cost-effective strategy to introduce into a seaport’s land-side equipment fleet.

The Port of Houston and its tenants and the Port of Long Beach and its tenants operate a variety of equipment types within the Port. Forklifts, yard trucks, container handlers and rubber-tired gantry (RTG) cranes are among the most prevalent equipment types. Forklifts, particularly those small in size, and RTG cranes are the focus of this report due to their general commercial availability and relative emissions contribution. An estimated 106 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of 100 of the Port of Houstons small forklifts and ten RTGs. An estimated 134 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of 100 of the Port of Long Beachs small forklifts and 20 rubber-tired gantry cranes.

The Port of Toledo and its tenants operate a variety of equipment types within the Port. Forklifts, front end loaders and cranes are among the most prevalent equipment types. Forklifts, particularly those small in size, and large cranes are the focus of this report due to their general commercial availability and relative emissions contribution. An estimated 15 tons of oxides of nitrogen (NO_x) savings would be achieved with the electrification of the Port's two large cranes (Big and Little Lucas) and ten small forklifts.

This potential electrification is associated with costs – capital, operating, and infrastructure expenditures – that may be offset by one of several financial incentives that exist at the local, state and federal level.

Although land-side equipment is the major focus of this report, ship shore power, truck stop electrification, and electric rail are also potential effective strategies to reduce emissions that may be cost effective for ports.

The introduction of electric land-side equipment at the PHA serves the Port's key objectives of its environmental management system, namely air emissions reduction, solid waste recycling, and storm water quality improvement.[1]

The introduction of additional electric land-side equipment at the POLB would serve the POLB's commitment to reducing emissions from vehicles and other equipment used to handle its cargo containers.

The introduction of electric land-side equipment at the Port of Toledo may serve the Port's environmental objectives of tenant equipment upgrades and the use of alternative fuels. It may also be an effective strategy to reduce port-wide emissions while maintaining operational efficiencies.

[1] "Port of Houston 2003 Environmental Report: At the Helm of Environmental Leadership", Port of Houston, 2003. See also: www.portofhouston.com

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1
INTRODUCTION

This study is to investigate electrification possibilities that may exist for land-side equipment at seaports. Three locations, Houston, Long Beach and Toledo, were selected as representative of the various types of ports in the continental United States.

Scope and Objectives

The three ports studied reflect vastly different maritime shipping concerns:

- The Port of Houston, located on the Gulf of Mexico, is principally a petroleum refining port, with a large presence of bulk carriers and containerships. It is one of the largest U.S. ports in terms of tonnage.
- The Port of Long Beach, located on the Pacific Ocean, is mainly a containership and secondly a petroleum processing port. It is one of the largest U.S. ports in terms of dollar revenue and container throughput.
- The Port of Toledo, located on the Great Lakes, is mainly a break-bulk cargo port known for large shipments of coal, grain, taconite, petroleum products, and foods. Responsible for the Port is the Toledo-Lucas County Port Authority, one of only a handful of port authorities that is responsible not only for a seaport but also an airport, regional economic development, and surface transportation. Compared to Houston and Long Beach, the Port of Toledo is relatively small in size of operations.

The objective of this report is to determine the feasibility of replacing targeted land-side equipment (also called cargo handling equipment) at the selected ports with electric equipment, with the ultimate aim of decreasing port-wide emissions, and improving operational efficiencies at the Port.

Equipment and emissions information from the *2001 Port of Houston Stevedore Equipment Emissions Inventory*, developed by Starcrest Consulting Group, LLC and released in July 2002[2] was utilized to assess the feasibility of retrofitting or replacing with electric some of the diesel land-side equipment operated at the PHA.

Equipment and emissions information from the *2002 Port of Long Beach Baseline Emissions Inventory*, developed by Starcrest Consulting Group, LLC, and released in March 2004[3] was utilized to assess the feasibility of retrofitting or replacing with electric some of the diesel land-side equipment operated at the POLB.

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[2] *Port of Houston 2001 Stevedore Equipment Emissions Inventory. Starcrest Consulting Group. July 2002.*

[3] *Port of Long Beach 2002 Baseline Emissions Inventory. Starcrest Consulting Group. March 2004.*

An equipment emissions inventory has not been previously done at the Port of Toledo, Ohio. An assessment of existing land-side equipment was conducted, and emissions for major equipment types were estimated.

Also discussed in this report is an overview of the benefits and costs associated with this strategy. Finally, a discussion of future studies and other issues – including the possibility of electric projects associated with ships, rail and trucks – is included.

Methodology

This report is structured to provide information on the feasibility of establishing electric equipment within port terminal operations. As stated above, information contained in this report regarding land-side equipment and its associated emissions is largely based on data collected by Starcrest Consulting Group, LLC as part of the *Port of Houston 2001 Stevedore Equipment Emissions Inventory* (for brevity, this report will be referred to as *PHA Stevedore Inventory* throughout the remainder of this report) and the *Port of Long Beach 2002 Baseline Emissions Inventory* (for brevity, this report will be referred to as *POLB Inventory)*. In addition to this literature review, interviews via email and telephone were conducted as part of the information collection process. Specific individuals contacted are listed below:

- Alan Ahrens, CenterPoint Energy
- Gary Shadwell, CenterPoint Energy
- Dana Blume, Port of Houston Authority
- Jerry Rhame, Port of Houston Authority
- Steve Sun, Texas Commission on Environmental Quality
- Coleen Tessema, Southern California Edison
- Brian Sisco, Southern California Edison
- Byran Pham, Southern California Edison
- Jeff Lowry, California Air Resources Board
- Paul LaCompte, CSX
- Steve Briggs, FirstEnergy Corp.
- Richard Kovacs, FirstEnergy Corp.
- Hans Rosebrock, FirstEnergy Corp.
- Dave Myers, Toledo Edison, FirstEnergy Company
- Steve Smegelski, Kuhlman
- Jim Lynch, Manitowac
- Doug Strubel, Midwest Terminals
- Justin Olman, Midwest Terminals

- John Murphy, Midwest Terminals
- Lee Burkleca, Ohio EPA
- Warren McCrimmon, Toledo-Lucas County Port Authority
- Joe Cappel, Toledo-Lucas County Port Authority

For the Port of Houston and the Port of Long Beach, equipment data was utilized from the Starcrest report cited above and categorized according to feasibility of electrification. For the Port of Toledo, data gathered in the equipment survey was first screened as to being off-road, cargo handling equipment; second, it was assigned average horsepower and hour levels based on modeling defaults and information received from tenants to characterize it; and finally emission were estimated using U.S. Environmental Protection Agency (EPA) emission factors.[4]

Emissions Estimating Methodology

Port of Houston

Like the equipment inventory, emissions modeling outputs were also utilized from the Starcrest report cited above for consistency.

The reported numbers were utilized from the *PHA Stevedore Inventory* which were calculated using the U.S. EPA's NONROAD2 Model. For this model, emissions estimates are the product of annual hours of use, average horsepower, an emission factor that expresses mass of emissions in terms of horsepower-hours, and a load factor; this factor represents an engine's average load, taking into consideration idling and periodic bursts of power. This information was collected for the *PHA Stevedore Inventory* conducted in 2002 and was utilized for this report on electrification of equipment at the PHA. The source for load factors and emission factors are the NONROAD model developed by the U.S. EPA.

Unlike the Port of Toledo Equipment Electrification study, this report focusing on the PHA utilizes not modeling defaults but actual equipment and usage information collected as part of the *PHA Stevedore Inventory*. As a result, emissions estimates are more precise for the PHA report.

In this report, emissions of key pollutants such as oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM) are expressed in terms of tons per year. In addition to emissions by equipment type in aggregate, emissions per single piece of equipment are also estimated.

[4] EPA 2004, 'NONROAD2004', Office of Transportation Air Quality, April 2004. See also www.epa.gov

Port of Long Beach

Like the equipment inventory, emissions modeling outputs were also utilized from the Starcrest report cited above for consistency. The California Air Resources Board (ARB) modeled emissions with their OFFROAD model, which estimates emissions from off-road equipment fleets in the State of California, including industrial equipment like that found at seaports.[5] Because ARB does not have a publicly available version of the OFFROAD model, the agency ran the model using the data collected as part of the *POLB Inventory* and provided emissions information based on model output. This information was utilized for this report on electrification of equipment at the POLB.

Whereas the reports for the Port of Toledo and the Port of Houston use EPA's NONROAD model to estimate emissions, the POLB report utilizes ARB's OFFROAD model. The models are similar, but do differ in one respect: whereas EPA's NONROAD model is designed to cap increases in emissions due to deterioration after an engine reaches its median age, ARB's OFFROAD model continues to deteriorate, or increase, emissions for a longer period of time. This difference has the net result of slightly higher emissions estimates using ARB's model. Because of these model differences, it will be difficult to compare POLB's cargo handling equipment emission estimates with those of the other two ports in this study, or in general any port in a state other than California, which has used the EPA model for estimating emissions. However, the emission estimates will be comparable with other California ports that have used the OFFROAD model.

Port of Toldeo

Emissions of key pollutants such as oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM) are expressed in terms of tons per year. The reported numbers are calculated as the product of annual hours of use, average horsepower, an emission factor that expresses mass of emissions in terms of horsepower-hours, and a load factor; this factor represents an engine's average load, taking into consideration idling and periodic bursts of power. The source for load factors and emission factors are the NONROAD2005 model developed by the U.S. EPA.[6] Because the ages (model years) of Port of Toledo equipment and engines are not known, except for the two Lucas cranes, emission factors reflective of older, pre-1996 diesel engines were used as the modeling default. Should newer engines be documented, emissions would be lower because 1996 and newer engines are subject to lower emission standards.

[5] http://www.arb.ca.gov/html/soft.htm#modeling

[6] *Ibid.*

2
BACKGROUND

Like many industries across the U.S., seaports have begun investigating ways to reduce air emissions associated with their operations. As ports consider their emission reduction options, they must first consider the control strategy opportunities available to them to reduce emissions. Equipment electrification – the subject of this report – is one control strategy option available to them.

Ports and Air Quality

The impetus for ports to reduce emissions is not always the same and comes from a variety of different drivers, including:

- An effort to be good neighbors and good corporate citizens.
- A response to local and state plans to decrease state-wide emissions in compliance with state implementation plans and other programs. The states of California, Oregon, and Washington, for example, have signed a compact to work together to reduce emissions specifically at marine ports.[7]
- An effort to comply with the relatively new federal non-road vehicle standards.
- An effort to retain commercially competitive by being allowed to expand operations.

There are several different control strategies available to reduce emissions depending on the area of port operations and which pollutants the port wishes to target. In considering control strategies for land-side equipment, for example, options include:

- Equipment retrofit devices
- Repowering with cleaner engines
- Replacing equipment
- Alternative fuels including electric power

Among the variety of options available to ports, electrification is something that can achieve not only substantial emission reductions, but can also be operationally sound.

[7] West Coast Collaborative Fact Sheet, August 2005. See also: http://www.westcoastdiesel.org/

Electrification at U.S. Ports

As stated above, there are several emission source categories within a seaport that can potentially utilize electric power to reduce emissions; these include:

- Electric land-side equipment, including cranes and forklifts
- Electric and hybrid electric on-road vehicles operating within ports
- Truck-stop electrification
- Cold ironing on ships
- Electric locomotives

Cargo handling equipment, such as cranes and forklifts, used to load goods on and off of ships and around terminal yards may be electric. On-road vehicles that operate at the port may also be electric and/or hybrid electric. Trucks used for cargo transport may have an electric component that allows them to switch off their diesel engines during longer layovers at the port and still keep power to the truck for heat, and refrigeration. Some ships and terminals have the infrastructure that allows them the ability to "cold iron", or plug into shore power, while in port instead of using diesel power generators to supply power for the ship. A ship equipped for shore power can turn off its diesel auxiliary engines while at a berth that is equipped to provide shore power. Finally, switching locomotives that move cargo in and around ports can also be modified to be electrified, although the most popular alternative to date is the hybrid battery locomotive having a small diesel auxiliary engine (i.e., Green Goat™).[8]

Table 2-1 below highlights various electrification projects that have been implemented, or are currently being implemented, at several ports across the county. The PHA itself has implemented some electric equipment programs, including hybrid electric vehicles and electric cranes.[9]
In addition those projects identified in Table 2-1 there are many ports around the country that utilize electric wharf gantry cranes.

Two important objectives that ports consider and achieve when evaluating and implementing emission control strategies is that operational integrity must be maintained and cost effectiveness targets are met. Electrification of land-side diesel powered equipment within seaports is one of several emission reduction strategies that ports may evaluate as they look at options to decrease port-wide emissions.

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[8] BNSF Rail Company Press Release: BNSF to Expand Use of Environmentally Friendly "Green Goat®" Switch Engines in Los Angeles Area and Texas. 23 May 2005. See also: http://www.railpower.com/dl/news/news_2005_05_23.pdf

[9] www.portofhouston.com

Table 2-1
Electrification Projects at U.S. Seaports

Port	Project	Status
Miami	Seven electric gantry cranes[10]	Underway
Houston	Ten OEM electric wharf cranes Hybrid electric on-road vehicles[11]	In place; two additional in early 2006
Long Beach	Hybrid diesel battery locomotive Hybrid electric on-road vehicles[12] Electric cranes	Scheduled
Los Angeles	Cold ironing or alternative marine power (AMP) at China Shipping Terminal[13] Yusen Terminals and P&O Nedlloyd terminals being equipped for AMP Millennium assist tugs fleeting operations using AMP	Terminal Open
Seattle	Shore power for cruise ships[14]	Terminal Open
Savannah	Ship cranes converted from diesel to electric in 2003[15]	Terminal Open
Oakland	Thirty electric vehicles[16]	Donated by Ford Motor Company

[10] http://www.cranemgt.com/

[11] Jerry Rhame, PHA correspondence with Starcrest in August 2005. See also: www.portofhouston.com

[12] http://www.polb.com/html/4_environment/airquality/Improvements.html

[13] http://www.portoflosangeles.org/environment_aqp.htm

[14] http://www.portseattle.org/news/press/2004/09_30_2004_13.shtml

[15] http://www.savannahnow.com/exchange/stories/072203/EXCCRANES.shtml

[16] http://www.portofoakland.com/newsroom/pressrel/pressrel_99.asp

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PORT OF HOUSTON

The Port of Houston, shown in Figure 3-1[17] below, is a 25-mile-long complex of diversified public and private facilities located along the Houston Ship Channel just a few hours' sailing time from the Gulf of Mexico.

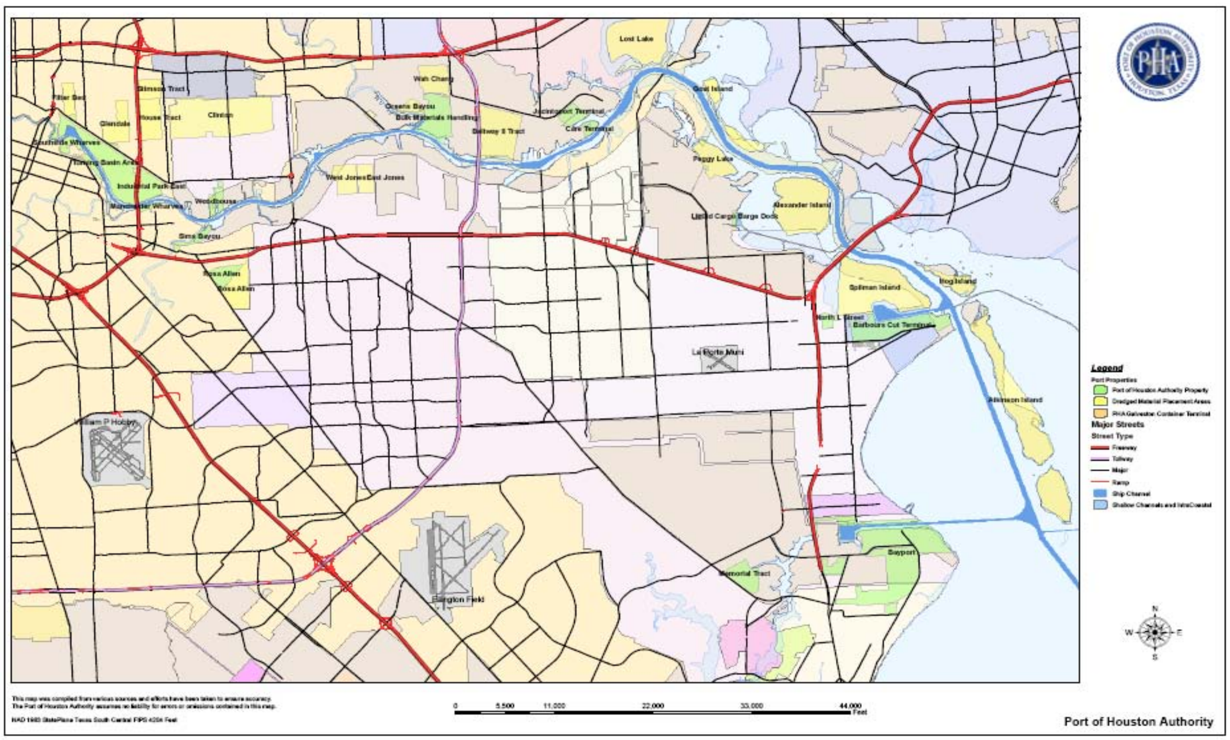

Figure 3-1
Port of Houston Map

General Description of Port of Houston Operations

The Port of Houston is ranked first in the United States in foreign waterborne commerce, second in total tonnage, and sixth in the world. About 200 million tons of cargo moved through the Port of Houston in 2004. A total of 6,539 vessel calls were recorded at the Port of Houston during the year 2004.[18]

[17] Courtesy of Dana Blume, PHA.

[18] www.portofhouston.com

The Port of Houston Authority owns and operates the public facilities located on the Houston Ship Channel and is the ship channel's official sponsor. The Port's facilities were designed for handling general cargo, containers, grain and other dry bulk materials, project and heavy-lift cargo.

Public facilities which are owned and operated by the Port Authority include 43 general cargo wharves available for public hire and two liquid-cargo wharves. The Port Authority's facilities handle approximately 15% of the cargo moving through the Port; the Port's tenants handle the remainder at various other terminals within the Port.

To relieve growth pressure at the port's current terminals, the Port Authority is building the Bayport Container and Cruise Terminal. The project broke ground in June 2004 and is on course for completion of the first phase in mid-2006. This $1.2 billion project will create more than $1 billion in new business revenues and more than $40 million in new tax revenues every year.[19]

The PHA has undertaken several environmental initiatives including:[20]

- Establishing an Air Quality Improvement Program for the Houston-Galveston area, because of its high levels of ozone, nitrogen oxides and VOCs. The port has coordinated the program with various air quality committees at the local, state, and federal level. Research has focused on offroad mobile sources and emission inventories, and steps have been taken to reduce vessel emissions as well.
- Committing to the International Standards (ISO). In 2002, the Port of Houston became the first U.S. port to achieve compliance with ISO 14001. The PHA received that designation based on voluntary environmental management systems implemented at Barbours Cut and the Central Maintenance Facility. The new facility at Bayport will be ISO 14001 compliant.
- Use of alternative fuels, including diesel emulsions, in some cargo handling equipment.

Port of Houston Cargo

The Port of Houston is home to a $15 billion petrochemical complex, the largest in the nation and second largest worldwide. As such, although PHA cargoes are diverse, they are dominated by petroleum and petroleum products. Top import commodities include petroleum and petroleum products; iron and steel; and crude fertilizers and minerals, among others. Top export commodities, other than petroleum and petroleum products, include organic chemicals; cereals and cereal products; and plastics, among others.[21]

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[19] *Ibid*.

[20] *Ibid*.

[21] *Ibid*.

Port Tenants and Equipment Operators

Cargo coming in and out of the port is handled both by the PHA and by its tenants and as such the Port owns and operates its own fleet of cargo handling equipment. The remainder of the cargo is handled by the port's tenants, listed below, who own and operate their own fleets of equipment.[22]

- A & L Trucking
- All Transport Services
- Arrow Steel Processors
- Arrow Trucking
- BCIS
- Burrus Contractors Supply
- Calcorp Resources, Inc.
- Calvin Hearne
- Cenex Harvest States Milling (Horizon Milling, LLC)
- Ceres Gulf
- Coastal Cargo of Texas
- Coastal Liquids
- Davis Petroleum
- Devon LA Corporations
- Dockside Tire Service, Inc.
- DuPont Logistics
- Dynamic Warehouse & Trucking
- Empire Stevedoring
- EOTT Energy Liquids, L.P.
- Frontier Logistics, L.L.C.
- Hansen-Mueller
- Houston Regional Monitoring
- Houston Tubulars, Inc.
- Inbesa America, Inc.
- Independent Truckers (WDF Trucking)

[22] Dana Blume, PHA email correspondence with Starcrest in October 2005.

- Irvin Schoeneman
- Jacob Stern & Sons
- James J. Flanagan Shipping Corporation
- KinderMorgan
- Louis Dreyfus Corporation
- Maersk Sealand (APM)
- Maritime Services, Inc.
- Megafleet Towing Company
- Michael Jackson
- Oxid
- P & O Ports Texas, Inc.
- Port Container Industrial Services, Inc.
- Port Cooper T. Smith Stevedoring
- Port Rail Services
- Quick Catch Trucking, Inc.
- Richardson Steel Yard, Inc.
- Richway Cartage, Inc.
- Seaboard
- Seafarers Center (TBT)
- Seafarers Center (BCT)
- Seaman’s Church Institute
- Shipper Stevedoring Company
- Southcoast Terminals
- Southern Stevedoring
- Southport Agencies, Inc.
- Storage & Processors, Inc.
- Sundown Metals
- Superior Supply and Steel
- Texas Brine, Inc.
- Texas Petro Chemical
- The Point Restaurant

- The Seabrook Association
- Tim Brock
- Tom Godwin
- Transco Shipping (USA), Inc.
- Trans-Global Solutions
- U.S. Customs
- Valero Marketing and Refining
- Volkswagen
- Westway Terminal Company, Inc.

PHA Terminals and Operational Characteristics

Seaport terminals vary widely in operational characteristics depending on the type of terminal and the material handled at each. As discussed above, the equipment used at each of the PHA's primary terminal types is different due to the handling needs of the material being transported. A general discussion of PHA terminals and equipment found at each follows. A detailed description of equipment found at each terminal is included later in this chapter.

Turning Basin

The Turning Basin Terminal is a multipurpose complex located eight miles from downtown Houston and serves as the navigational head of the Houston Ship Channel, just 50 miles from the Gulf of Mexico. The banks along this section of the channel are lined for 2.5 miles downstream with an alternating arrangement of open wharves and docks backed by transit sheds and warehouses. Each year, some 2,800 ship and barge calls are recorded at the Turning Basin Terminal's 37 docks. These docks are equipped to handle break bulk, containerized, project or heavy-lift cargoes. This terminal also is equipped for handling large, odd-shaped cargoes, long-term project cargo and vehicles.[23]

Barbours Cut

The most modern intermodal facility on the U.S. Gulf, Barbours Cut Container Terminal was designed with one priority in mind: vessel productivity. It accomplishes this by providing a fast turnaround for container and roll on/roll off (RO/RO) vessels and project cargo. The terminal is located at the mouth of Galveston Bay and is 3.5 hours' sailing time from the Gulf of Mexico.

[23] http://www.portofhouston.com/geninfo/facilities.html

The terminal's six berths provide 6,000 feet of continuous quay. Twelve wharf cranes ensure efficient and reliable handling of containers. The facility also includes a roll-on/roll-off platform, a LASH dock, a cruise terminal, 230 acres of paved marshaling area and 255,000 square foot of warehouse space and acres of open marshaling and storage area. A computerized inventory control system tracks the status and location of individual containers. The terminal also features electronic data interchange capabilities.[24]

Port of Galveston

The Port of Houston Authority leases and operates the Port of Galveston's East End Container Terminal. The 45-acre terminal includes two berths, three cranes and various other equipment. This terminal is located 9.3 miles from the open sea, less than 40 minutes sailing time from the Gulf of Mexico. It contains a 1,346-foot container berth and 45 acres of paved storage area. On site at this terminal are three rail-mounted container wharf cranes; one rubber-tired gantry crane; 31 terminal tractors; and other associated equipment.[25]

Grain Elevator

The Houston Public Elevator was acquired by the Port Authority in December 1992 and commenced operations in June 1993. The elevator is located within the Woodhouse Terminal in Galena Park, Texas. Construction of this facility was completed in 1979, making it one of the newest and more modern export elevators in the country. Continuing mechanical and technological upgrading will keep this facility at the forefront of the industry's export elevators.

The elevator is used by shippers who export large volumes of grain. It has a rated storage capacity of 6.2 million bushels and a maximum rated loading capability of 120,000 bushels per hour. Trucks are received on two pits at a maximum rate of 30 trucks per hour while rail receipts from three pits reach 20 cars per hour.[26]

Woodhouse Terminal

Woodhouse Terminal is located on a 100-acre tract on the north side of the Houston Ship Channel near the Sims Bayou juncture, a short distance downstream from the Turning Basin Terminal. The terminal includes approximately 235,000 square foot of warehouse space, 10 acres of open storage, RO/RO ramps and three general cargo wharves ranging from 600 feet to 660 feet long.[27]

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[24] *Ibid.*

[25] *Ibid.*

[26] *Ibid.*

[27] *Ibid.*

Wharf 32

Wharf 32, located within the Turning Basin Terminal, was specially designed for handling project and heavy-lift cargoes and is a $10.8 million state-of-the-art freight handling facility. It has a 1000 pound per square foot load capacity. Its 806 linear feet of berthing space and 20 acres of paved marshaling area offer sufficient space for heavy-lift or project cargo of all types.[28]

Jacintoport

Jacintoport Terminal is situated on a 125-acre tract on the north side of the Houston Ship Channel near Channelview, Texas. The terminal features three berths providing 1,836 feet of continuous quay, 7.5 acres of paved cargo marshaling area and an 82,500-square-foot transit shed located adjacent to Berth 3. The terminal also features a 437,000-square-foot transit shed. A "Spiralveyor" bagged cargo handling system is capable of loading ships at a very high rate of speed. In addition, the Jacintoport property includes a waterfront refrigerated and frozen storage facility. The warehouse offers 200,000 square feet of temperature and humidity-controlled storage, as well as enclosed truck and rail bays.[29]

Care

Care Terminal is a 32-acre facility located on the Houston Ship Channel near Channelview, Texas. Care offers onsite rail siding with switching services provided by the Port Terminal Railroad. Approximately $14 million in recent improvements include a new state-of-the-art wharf and dock which was designed for handling project and heavy lift cargo. Care Terminal has over 1,100 feet of berthing space directly adjacent to 15 acres of paved open storage area and over 45,000 square foot of warehouse space.[30]

Bulk Materials Handling Plant

The Bulk Materials Handling Plant is located nine miles downstream from the Turning Basin Terminal. The terminal is a dry bulk export/import facility. The plant's modern and well-maintained ship-loading system can handle dry bulk commodities, ranging from particles as fine as sand to eight-inch lumps weighing as much as 200 pounds per cubic foot. The plant is equipped with a high-speed loading system and a sophisticated dust collection system that permits the handling of extremely dusty commodities. The plant is operated by Econo-Rail Corporation as a public facility.[31]

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[28] *Ibid*.

[29] *Ibid*.

[30] *Ibid*.

[31] *Ibid*.

Bayport

As discussed above, the Bayport Container and Cruise Terminal construction is underway. The project broke ground in June 2004 and is on course for completion of the first phase in mid-2006. Bayport will be built out in phases over approximately 20 years and will eventually have enough space for seven ships and a 378-acre container storage yard. It will have a maximum capacity of 1.4 million containers, a 200% increase over the Port Authority's current container handling capacity.[32] Bayport is being built with state-of-the art equipment, including several new electric cranes due to be delivered in early 2006.[33]

Equipment Types at PHA

Because of the diversity of cargo at each of these terminals, there are wide ranging types of equipment. The majority of the equipment found at the PHA terminals can be classified into one of the following equipment types:

- Cranes
- Dozers
- Excavators
- Forklifts
- Rubber tired gantry (RTG) cranes
- Container handlers
- Sweepers
- Yard tractors
- Rubber tired loaders

In addition, diesel-powered refrigeration units (commonly used on trucks and containers during transit) are also common at the PHA. These units are on grid-supplied power when parked at the terminal and the diesel powered generators are only used during transit. This equipment was not included in the *PHA Stevedore Inventory* survey.

Specific land-side equipment surveyed at the Port of Houston is discussed in the next section.

Land-Side Equipment Inventory

The cargo handling inventory list, which lists all equipment operating at the above PHA terminals, as compiled by Starcrest Consulting Group for the *PHA Stevedore Inventory*[34] has been aggregated by equipment type and is presented below in Table 3-1.

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[32] Bayport Economic Impact Fact Sheet. Port of Houston Authority.

[33] Jerry Rhame, PHA correspondence with Starcrest in September 2005.

[34] *PHA Stevedore Inventory*.

Table 3-1
PHA Land-Side Equipment Inventory

Equipment	Quantity
Forklift	394
Yard Truck	287
Crane	53
Container Handler	41
RTG	30
Aerial Lift/Lift Truck	25
Other	37
Total	**867**

Among the 30 RTG cranes currently operating at the PHA, 10 are electric. Two additional electric cranes are due to be delivered to PHA in early 2006.[35] As can be seen in the table above, the most predominant equipment types found at the PHA are:

- Forklifts
- Yard Trucks
- Cranes
- Container Handlers
- RTGs

Together, these equipment types represent 93% of the cargo handling equipment at the PHA. This equipment is generally described below.

Forklifts

Forklifts, representing 32% of all cargo handling equipment at the PHA, are typically found throughout the port as they may be used for both cargo and non-cargo handling activities. Forklifts are technically called counterbalanced lift trucks, which may be equipped with cushion tires (inside or flat surfaces) or pneumatic (rough terrain or outside; heavy loads require pneumatic tires). At the PHA, they ranged in size from 80 horsepower to 250 horsepower. Figure 3-2[36] below shows a typical forklift.

[35] Jerry Rhame, PHA correspondence with Starcrest in September 2005.

[36] http://www.mit-lift.com

Figure 3-2
Forklift

Yard Trucks

The equipment inventory shows that diesel-powered yard tractors, also known as terminal tractors, yard trucks and yard hustlers, account for 43% of the cargo handling equipment used PHA terminals. A common use of yard tractors, shown below in Figure 3-3[37], is to move containers to and from the ship, move containers within the terminal, and move containers to and from RTGs for placement on or removal from stacks. As such, they are very commonly found at container terminals, but are also used in other terminal types.

Figure 3-3
Yard Truck

[37] http://www.ottawatruck.com

Cranes (RTG and Other)

For this report, rubber-tired gantry (RTG) cranes and other cranes have been grouped together. The diesel-powered RTG crane, shown in Figure 3-4[38], moves containers to and from the container stacks in a grounded operation. The RTG straddles the stacks of containers and has room for a heavy-duty truck/yard tractor to pull under and move containers between the stacks and vehicles. It is also used to consolidate the stacks weekly as containers are added and removed from the terminal. Other cranes include hydraulic cranes and boom crawler cranes, which tend to be smaller in horsepower than gantry cranes used at the wharf. Cranes represent 10% of the cargo handling equipment at the PHA.

Figure 3-4
Rubber Tired Gantry Crane

Container Handlers

Container handlers consist largely of top and side loaders. Approximately 5% of the equipment inventoried at the PHA are container handlers, including top and side handlers. Top loaders, shown below in Figure 3-5[39], are commonly used at container terminals as they move, stack and load containers using an overhead telescopic boom to accomplish this. Side handlers typically move and stack empty containers and as such have less power than top loaders. Top handlers can be used in place of or in conjunction with RTG cranes to lift heavy containers within a terminal.

[38] http://www.pacecocorp.com

[39] http://www.taylorbigred.com

Figure 3-5
Top Loader

Current Emissions Associated with Land-Side Equipment

Based on *PHA Stevedore Inventory* surveys of equipment, average power, and hours of annual use, emissions were estimated for the equipment described above. Table 3-2 below summarizes this equipment and its associated NO_x and PM emissions in terms of tons per year (tpy) for each equipment type in aggregate.

Table 3-2
Emission Estimates by Equipment Category

Equipment	NO_x (tpy)	PM (tpy)	Quantity
Yard Trucks	478.6	25	287
Forklifts	254	33.7	394
RTGs	125.5	6.7	30
Cranes	105.7	6.`	53
Container Handlers	43.6	2.1	41

As seen in the table above, among the most abundant equipment types at the PHA, the largest equipment category NO_x emitters are the yard trucks, followed by forklifts, RTGs and cranes. Electric gantry cranes currently in use at the PHA are associated with no NO_x or PM emissions. The relatively larger NO_x emissions associated with yard trucks are largely a result of the frequency of usage.

4
PORT OF LONG BEACH

The POLB, a map of which is shown in Figure 4-1 below is a 3,000-acre major marine port located in Southern California. The POLB boundaries are delineated by the Port of Los Angeles (POLA) to the west, Anaheim Street to the north, the Los Angeles River to the east, and the breakwater to the south.

Figure 4-1
Port of Long Beach Map

General Description of Port of Long Beach Operations

The POLB is one of the world's busiest seaports. Although diverse in capabilities, container traffic is a major component of the POLB operations; container traffic has increased by 175% since 1990. It is the 12th busiest container cargo port in the world, and is the second busiest port in general in the U.S.[40]

At the POLB, several terminal reconfigurations and relocations took place in 2002; these are significant to this study because of the associated equipment location changes that took place. The relocation of marine terminals in 2002 opened space for terminal expansions and reconfigurations of existing terminals that increased capacity at the POLB. Most important are the PCT expansion to the larger Pier J area and ITS expansion to the former Maersk Sealand Pier G area. However, those changes did not change the cargo throughput in 2002, except for Maersk Sealand's relocation to the POLA. Container throughput dropped in October 2002 due to a labor dispute that resulted in port operations shutting down for 11 days. However, the overall container throughput caught up again due to higher than usual volumes in November and December.[41]

In addition to these reconfigurations, in order to handle projected cargo growth in the future, the POLB is planning a $1.9 billion program to redevelop seven of eight existing container terminals, and to build at least two new terminals. The following projects are planned for the next decade:[42]

- Complete a 375-acre Pier T container terminal on Terminal Island
- Construct a 160-acre Pier S terminal on a former Terminal Island oil field
- Build a deepwater, liquid bulk terminal on Pier T to serve larger tankers
- Replace five-lane Gerald Desmond Bridge with a taller bridge with at least six lanes

As the POLB and other seaports respond to growth in international trade, and expand to accommodate this growth, they must be mindful of the net effect on local and regional air quality. The Long Beach area is classified as nonattainment for ozone, PM_{10} and CO.[43] As such, any increase in emissions – such as those associated with port growth – by industry in the area is looked at closely by air quality planners. The California Air Resources Board (ARB) has issued a draft regulatory proposal for the proposed regulations for mobile cargo handling equipment at ports and intermodal rail yards.[44] The newly proposed Title 12, Section 2479 of the California Code of Regulations, which is scheduled for ARB Board consideration in December 2005, will mandate that all newly purchased cargo handling equipment at ports and intermodal rail yards after January 1, 2007 meet either on-road emission standards or Tier 4 off-road emissions standards. These new regulations will substantially decrease the emissions from cargo handling equipment.

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[40] http://www.polb.com

[41] *POLB Inventory,* Starcrest.

[42] http://www.polb.com

[43] http://www.epa.gov/region9/air/maps/maps_top.html

[44] http://www.arb.ca.gov/msprog/offroad/cargo/cargo.htm

In light of these air quality limitations, the POLB has undertaken several operational initiatives aimed at improving air quality at the port, including:[45]

- Completed an Emissions Inventory for Cargo Handling Equipment in order to identify the contribution of various port-related sources. By identifying the relative contributions from different sources, the Port can direct emission reduction programs to those areas that will provide the most benefit.
- Established a program to convert port-owned vehicles to cleaner burning engines such as compressed natural gas and hybrid/electric and to install pollution control devices such as diesel oxidation catalysts on heavy-duty maintenance equipment operated by the Port.
- Developing a tariff requiring tenants to prepare plans to significantly reduce emissions of particulates and nitrogen oxide by 2008. The provision will give tenants flexibility on how to achieve the required reductions.
- Will work with the Pacific Harbor Line and regulatory agencies to refit railroad locomotives with cleaner-burning diesel engines or replace the engines with cleaner models. For every new engine, emissions of nitrogen oxides are reduced by an estimated 20 tons per year.
- Is a founding partner in the Gateway Cities Clean Air Program, together with the Gateway Cities Council of Governments and the California Air Resources Board. The program provides financial incentives to independent truckers and trucking companies to trade in their diesel trucks for newer used models with cleaner-burning engines. The program has taken a number of 1983 and older model diesel trucks off the road and replaced them with less-polluting models.

Port of Long Beach Cargo

Cargo moving in and out of the POLB is diverse, ranging from exports of petroleum coke, petroleum, hay, fruits and nuts to imports of machinery, steel products, plastics and vehicles. The total value of all cargo through the port in 2003 was $95.9 billion.[46] This cargo is handled primarily by POLB tenants, each of which operates equipment at their terminals specific to the cargo they handle.

Port Tenants and Equipment Operators

The Port of Long Beach is largely a landlord port, which means that virtually all cargo handling equipment is owned and operated by tenants at the port's various terminals. The tenants listed below were included in the study.

- AIMCOR
- Long Beach Container Terminal (LBCT)
- Baker Commodities

[45] http://www.polb.com/html/4_environment/airquality/Improvements.html

[46] http://www.polb.com

- Maersk Sealand (APM)
- BP/ARCO
- Metropolitan Stevedore
- Cal United
- Morton Salt
- Cemex
- Mitsubishi Cement
- Chemoil Marine
- National Gypsum
- Cooper & Smith
- Pacific Coast Recycling
- Equillon
- Petro Diamond
- Forest Terminal
- SSA - Pacific Container Terminal
- Fremont Forest
- SSA – Pier C
- Hanjin (Total Terminals, Inc.)
- SSA Bulk – Pier F
- Horizon Lines
- Sulex
- ITS
- Toyota
- Koch Carbon

Terminal and Equipment Types

The POLB has four primary terminal types: container, break bulk and dry bulk, liquid bulk, and auto terminals. Container terminals have the most extensive use of cargo handling equipment, followed by break bulk and dry bulk, which were found as part of the *POLB Inventory* to have roughly a tenth of the emissions of the container terminals.[47] Some equipment, such as yard tractors, side handlers, top handlers, and rubber tired gantry cranes are mostly found in container terminals, while some construction type equipment, such as skid steer loaders, dozers, excavators, and rubber tired loaders, are found at the liquid, dry bulk, and break bulk facilities.

[47] *POLB Inventory,* Starcrest.

Because of the diversity of cargo, there are wide ranging types of equipment. The majority of the equipment found at the POLB terminals can be classified into one of the following equipment types:

- Cranes
- Dozers
- Excavators
- Forklifts
- Reach stackers
- Rubber tired gantry (RTG) cranes
- Skid steer loaders
- Side handlers
- Sweepers
- Top handlers
- Yard tractors
- Rubber tired loaders

Terminal Types and Operational Characteristics

Seaport terminals vary widely in operational characteristics depending on the type of terminal and the material handled at each. As stated above, the equipment used at each of the POLB's primary terminal types is different due to the handling needs of the material being transported. A general discussion of POLB terminal types and equipment found at each follows. A detailed description of equipment found at each terminal is included in the *Land-side Equipment Inventory* section below.

Container Terminals

The POLB and other West Coast ports are major ports of entry for containerized cargo shipped by ocean-going vessels (OGVs) into the United States. In 2002, POLB ranked second in container throughput for all U.S. ports, behind Los Angeles and ahead of New York/New Jersey and Oakland.[48] Together with the Port of Los Angeles, the Port of Long Beach serves the Los Angeles Basin, southern California, and other destinations in the continental U.S.

The operation of a container terminal is dependent on the amount of land available for the terminal to use. There are three basic types of configurations that can be found in the POLB container terminals: wheeled, grounded, and combination. These types represent how the containers are physically stored and kept on a terminal. Wheeled operations are generally the most efficient operations as all the containers are kept on a chassis and can be moved anywhere

[48] http://www.polb.com

on or off the terminal by the use of a yard tractor or heavy-duty truck. Grounded operations are where containers are stored on-site in "stacks" that can be several containers wide by two to four containers high, thus requiring the use of RTG cranes, side and top loaders to move the containers to/from and within the stacks. Combination terminals employ a mix of wheeled and grounded operations as land permits. Most of the POLB container terminals use a combination of grounded and wheeled operations. Wheeled operations have low container-per-acre densities and thus require significantly more land than grounded operations, which have high container densities. However, wheeled operations are more efficient and require less CHE than grounded operations. Grounded operations use a mixture of RTG cranes, top loaders, side loaders and yard tractors while wheeled operations mostly use yard tractors; therefore, grounded operations generally have higher emissions per container moved. The type of operation at any specific terminal is generally dictated by the amount of land available and the number of containers that the terminal processes per year. In 2002, container terminals on seven POLB pier areas served the sea-to-land link for container transport. Approximately 850 pieces of land-side equipment is operated at these terminals.

The off-road equipment used directly in handling cargo at container terminals consists mainly of yard tractors, forklifts, top handlers, side handlers, and RTG cranes. Most of the equipment inventoried at the container terminals use diesel fuel, except for 31 of the 77 forklifts, which use liquefied petroleum gas (LPG).

Break Bulk and Dry Bulk Terminals

Break bulk terminals receive cargo that is not shipped in containers, such as steel, lumber, large machinery and other large product cargo, so the cargo has to be unloaded from a ship's hold and then loaded onto trucks on the dock for distribution. Steel products, such as plates or rolls, are placed in a ship's hold and must be removed individually. Large machinery may also be carried with special "RoRo" (roll-on/roll-of) vessels equipped with large ramps for driving vehicles and portable or mobile wheeled equipment on and off the ship. Lumber and lumber products are often carried by dedicated vessels and barges that are designed to carry their specific cargo. Some vessels that call on break bulk terminals may mix containerized cargo and break bulk cargo and are called "combination" ships, where the break bulk cargo is stored in the below deck holds and containers are stacked on the hatch covers that cover the cargo holds during sailings. In general, the ships that call at break bulk terminals are smaller than the specialized container ships that call at the container terminals.

Due to their weight and characteristics, heavy lift machines are used for handling bulk cargo on the terminal and for loading rail or truck. Cargo is discharged either by the vessel's own ship-to-shore cranes, or by large boom cranes that operate on the dock and are highly mobile so that they can move into position based on the ship's configuration. Hydraulic and boom crawler cranes were inventoried at POLB facilities. Most break bulk cargo leaves the terminals by truck.

Dry bulk cargoes include materials that can be processed by bucket loaders, screw loaders, conveyors or suction and that are stored in piles or silos on the terminals. The most common dry bulk cargoes at POLB include cement and salt for import, and scrap metal, sulfur and petroleum coke for export.

Seven break bulk and seven dry bulk terminals at the POLB operated diesel-powered land-side equipment in 2002 and were included in the *POLB Inventor*y.

The equipment operating at the dry bulk and break bulk terminals consists of forklifts, rubber tired loaders, yard tractors, cranes, sweepers, dozers and excavators. Approximately 200 pieces of equipment in total are used at the dry bulk and break bulk terminals.

Liquid Bulk Terminals

Liquid bulk terminals predominantly import petroleum products. Some terminals export refined petroleum to other U.S. West Coast destinations and one small facility imports and exports vegetable oils.

Compared to other types of terminals, liquid bulk cargo operations use little fuel-powered terminal equipment. Most liquid cargo is transported in pipelines to or from the refineries. The pump stations at the terminals operate on electricity that is supplied by the utility grid. Emissions from the vessel unloading pumps are not within the scope of this inventory. Only six forklifts were found at the liquid terminals.

Auto Terminals

The U.S. is a major importer of vehicles and California is a significant market. West Coast ports are a port of entry for many automobiles manufactured in Asia, and for the local market. The POLB has one 143.7-acre auto-marine terminal, which serves mostly the local California market. In the year 2002, approximately 340,000 automobiles, mostly passenger cars and sport utility vehicles, were imported through the POLB auto-marine terminal.

Loading and unloading of automobiles does not require the use of a large amount of cargo handling equipment. Being self-propelled, the vehicles are discharged (or loaded) by driving them off (or onto) the vessel. The terminal workers drive the cars to a “first point of rest,” from where they are driven to an area where accessories may be installed as needed. After accessorizing, the automobiles are driven to dedicated parking areas on the terminal. Shipment out of the terminal is by truck or rail.

Land-Side Equipment Inventory

The cargo handling inventory list, which lists all equipment operating at the above POLB terminals, as compiled for the *POLB Inventory* has been aggregated by equipment type and is presented below in Table 4-1.

Table 4-1
POLB Land-Side Equipment Inventory

Equipment	Quantity
Crane	1
Crane, cable	2
Crane, hydraulic	3
Dozer	2
Excavator	3
Forklift	236
Lift	1
Lift Truck	1
Reach Stacker	3
Rubber-tired Loader	19
Rubber-tired Gantry Crane	80
Side Pick	41
Skid Steer Loader	3
Sweeper	9
Top Handler	89
Yard Truck	566
Total	**1,060**

The most predominant equipment types found at the POLB were:

- Forklifts
- Yard Truck
- Top/Side Handlers/Loaders
- RTGs

Top and side handlers were grouped together for two reasons: 1) ARB categorized these equipment types thus for modeling purposes as part of the *POLB Inventory*. As such, it is difficult to separate them without remodeling. 2) These equipment types have similar specifications and emissions profiles, although top handlers do typically have higher horsepower ratings. This report focuses on these most commonly found equipment types at POLB terminals. In addition to the four equipment types listed above, this report will also include cranes – which are grouped with RTG cranes - due to their relatively high emissions profile and because ARB grouped other cranes with RTG cranes in its modeling for the *POLB Inventory.* Together, these five equipment types represent 92% of the cargo handling equipment at the POLB. This equipment is generally described below.

Forklifts

Forklifts, representing 22% of all pieces of cargo handling equipment at the POLB, are typically found throughout the port as they may be used for both cargo and non-cargo handling activities. Forklifts are technically called counterbalanced lift trucks, which may be equipped with cushion tires (for inside use or on flat surfaces) or pneumatic tires (for use on rough terrain or outside; heavy loads require pneumatic tires). Forklifts are associated with 6% of the cargo handling equipment-related NO_x emissions at the POLB. Figure 4-2 below shows a typical forklift.[49]

Figure 4-2
Forklift

Yard Trucks

The equipment inventory shows that diesel-powered yard tractors, also known as terminal tractors, yard trucks and yard hustlers, account for 53% of the pieces of cargo handling equipment used on POLB terminals. A common use of yard tractors is to move containers to and from the ship, move containers within the terminal, and move containers to and from RTGs for placement on or removal from stacks. As such, they are very commonly found at container terminals, but are also used in other terminal types. Yard trucks, an example of which is shown in Figure 4-3[50] below, account for almost 60% of the cargo handling equipment related NO_x emissions at the POLB.

[49] http://www.mit-lift.com

[50] http://www.ottawatruck.com

Figure 4-3
Yard Truck

Rubber Tired Gantry (RTG) Cranes

The diesel-powered RTG cranes move containers to and from the container stacks in a grounded operation. The RTG, shown in Figure 4-4[51] below, straddles the stacks of containers and has room for a heavy-duty truck/yard tractor to pull under and move containers between the stacks and vehicles. It is also used to consolidate the stacks weekly as containers are added and removed from the terminal. RTGs at the POLB represent 8% of the pieces of cargo handling equipment at the POLB. Together with general cranes, they represent 15% of the associated NO_x emissions at the port.

Figure 4-4
Rubber Tired Gantry Crane

[51] http://www.pacecocorp.com

Other Cranes

Approximately 3%, or six units, of the equipment at the POLB are diesel-powered cranes. Three of the cranes were listed as hydraulic cranes. Figure 4-5 below shows an American 797C boom crawler crane,[52] a crane model inventoried at POLB. Although cranes represent only a small percentage of all equipment at the POLB, they have been included in this report because of their relatively high emissions profile; together with RTGs, they emit 15% of all cargo handling equipment related NO_x at the port.

Figure 4-5
Crane

Top/Side Loaders

Approximately 12% of the equipment inventoried at the POLB was diesel-powered top and side handlers, also known as top and side loaders or top and side picks and reach stackers by the terminal operators. Top loaders, shown below in Figure 4-6,[53] are commonly used at container terminals as they move, stack and load containers using an overhead telescopic boom to accomplish this. Side handlers, shown in Figure 4-7[54] below, typically move and stack empty containers and as such have less power than top loaders. Top handlers can be used in place of or in conjunction with RTG cranes to lift heavy containers within a terminal. Top and side loaders combined emit 15% of the cargo handling equipment-related NO_x emissions at the POLB.

[52] http://www.accranes.com/amer797c

[53] http://www.taylorbigred.com

[54] http://www.cal-lift.com

Figure 4-6
Top Loader

Figure 4-7
Side Loader

Current Emissions Associated with Land-Side Equipment

Based on *POLB Inventory* surveys of equipment, average power, and hours of annual use, emissions were estimated by ARB for the equipment described above. Table 4-2 below summarizes this equipment and its associated NO_x and PM emissions in terms of tons per year (tpy) for each equipment type in aggregate.

Table 4-2
Emission Estimates by Equipment Category

Equipment	NO_x (tpy)	PM (tpy)	Quantity
Yard Trucks	1,567	104	566
Cranes (RTG, other)	378	20	88
Top/Side Loaders	398	21	131
Forklifts	115	8	239

As seen in the table above, among the most abundant equipment types at the POLB, the largest equipment category NO_x emitters are the yard trucks, followed by RTGs/cranes, top/side loaders, and forklifts. The relatively higher NO_x emissions associated with yard trucks are a result of the quantity of equipment in use and the frequency of usage.

5
PORT OF TOLEDO

The Port of Toledo, Ohio services St. Lawrence Seaway draft vessels at the confluence of the Maumee River and Lake Erie. The Port is 611 miles, or approximately 68 sailing hours, from the Atlantic Ocean. The Port is operated by the Toledo-Lucas County Port Authority, which also operates the Toledo Express Airport.

General Description of Port of Toledo Operations

The Port of Toledo, shown in Figure 5-1 below,[55] is one of the busiest ports on the Great Lakes. Within the Port of Toledo, bulk shipments of coal, petrochemicals, aggregates, grain, and food products are typically handled with auto-loading equipment that is either electrically operated or is part of a ship's physical plant. General cargo loading and unloading is mainly conducted at the Midwest General Cargo Terminal, which has two large diesel-powered wharf cranes called "Big Lucas" and "Little Lucas."

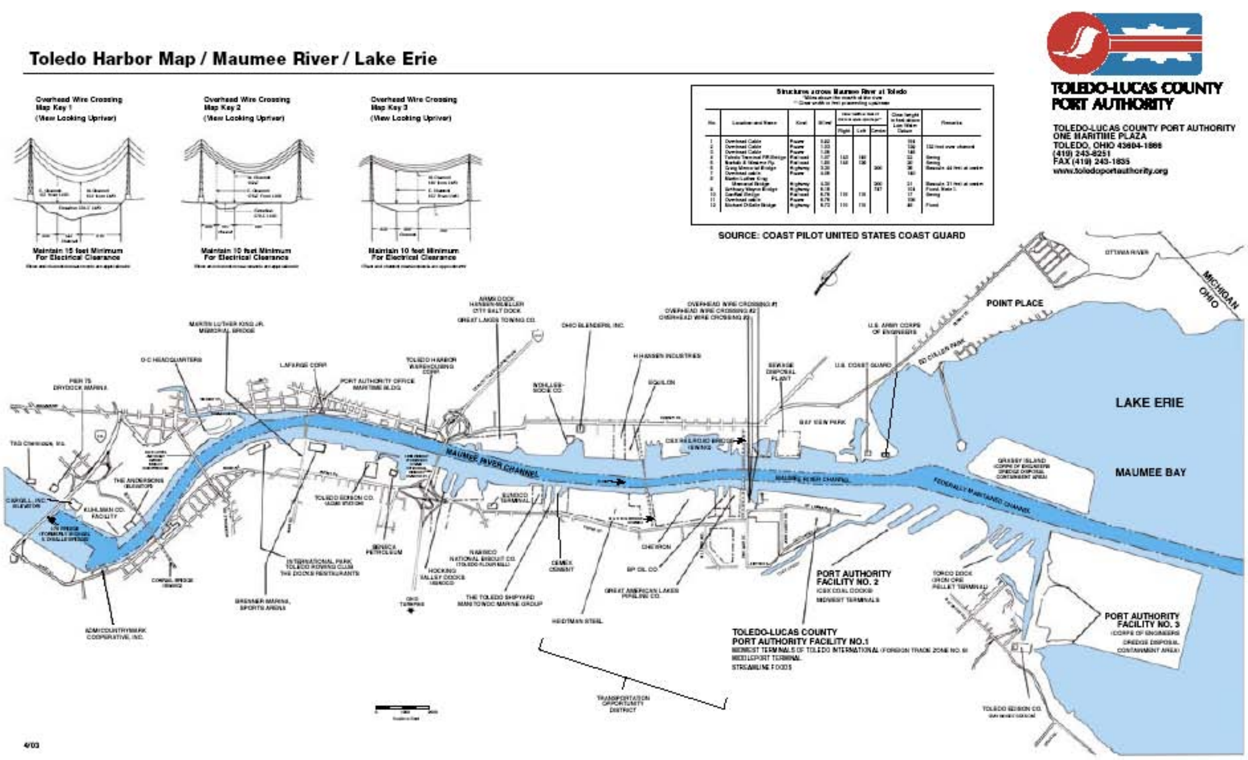

Figure 5-1
Port of Toledo Map

[55] http://www.toledoportauthority.org/services/Portmap.pdf.

Because of severe temperatures in winter, the Port has very limited operations during approximately four months of the year (December through March). The first international ship making passage this year, for example, was on 1 April 2005.[56]

Port of Toledo Cargo

The Port contains seven berths and handles dry and liquid bulk cargos as well as some containers. Cargos ranging from corn and soybeans to iron ore and metal products, in addition to a variety of other dry and liquid bulk products, are handled regularly. General cargo includes bulk, non-containerized goods on pallets, bundles, coils, and bags, although some containers may be included on the decks of some of the ships.

Rail cargo plays a major part of the Port of Toledo operations. Four major freight railroads move freight through the region. With several rail yards loading petroleum products, automotive parts, completed automobiles, bulk and break-bulk cargo, and food products, Toledo ranks as one of the top five rail hubs in the U.S.

Port Tenants and Equipment Operators

The Port of Toledo is largely a landlord port, which means that cargo handling equipment is owned and operated by tenants at the Port's various terminals. The Port's primary cargo handling operator, with a vast majority of the equipment, is Midwest Terminals of Toledo. Port of Toledo tenant terminals are listed below.

- Midwest Terminals of Toledo International
- Kuhlman
- The Andersons, Kuhlman Drive and Edwin Drive (Cargill) Facilities
- Archer Daniels Midland (ADM)
- Hansen Mueller - Toledo
- BP Products North America
- Center Terminal Company of Toledo
- Middleport Terminal Incorporated
- Seneca Petroleum Company
- Sunoco Mid-America M&R
- St. Mary's Cement Incorporated
- La Farge Cement
- Arms Dock

[56] *First Foreign Ship of 2005 Arrives in Toledo*. Toledo Blade, April 1, 2005. See also: http://toledoblade.com/apps/pbcs.dll/article?AID=/20050401/NEWS11/504010370.

- City of Toledo Dock
- Toledo Ship Repair Company (Manitowac)
- H. Hansen Industries

In addition to the above tenants, the rail company CSX operates two of the busiest terminals at the Port of Toledo. The CSX coal dock transfers coal from rail cars onto vessels for shipment to industries and public utilities scattered throughout the Great Lakes region and overseas. In addition, the TORCO iron ore dock is also operated by CSX. This dock transfers taconite pellets from vessels onto rail cars for delivery via rail to Ohio steel mills.

Although each of the above tenants has its own fleet of cargo handling equipment, the majority of equipment operated at the Port is owned by either Midwest Terminals or Kuhlman. Manitowac, owned by Toledo Ship Repair, has handled shipyard repair and as such owns and operates some equipment at the Port of Toledo shipyard. However, this equipment is not included in this study as the company will be ceasing operations at the shipyard soon.[57] Thus, the equipment assessment conducted as part of this report (see Section 3.5) was limited to the Port's two primary equipment operators: Midwest Terminals and Kuhlman.

Terminal Types and Operational Characteristics

Seaport terminals vary widely in operational characteristics depending on the type of terminal and the material handled at each. As stated above, the Port of Toledo handles some container traffic, as well as dry and liquid bulk. The equipment used at each terminal is different due to the handling needs of the material being transported. A general discussion of terminal types and equipment found at each follows.

Liquid Bulk Cargo Terminals

Compared to other types of terminals, liquid bulk cargo operations use little fuel-powered terminal equipment. All liquid cargo is transported in pipelines to or from the refineries. The pump stations at the terminals operate on electricity that is supplied by the utility grid. Liquid bulk cargoes at the Port of Toledo include petroleum products.

Dry Bulk Cargo Terminals

Dry bulk cargoes include materials that can be processed by bucket loaders, screw loaders, conveyors or suction and that are stored in piles or silos on the terminals. Many ships have auto-loading capabilities. Typical equipment found at this type of terminal includes forklifts, rubber tired loaders, cranes, yard tractors, sweepers, dozers, and excavators. Dry bulk cargoes at the Port of Toledo include grains, aggregates, coal and taconite.

[57] Jim Lynch, Manitowac; phone conversation with Starcrest in September 2005.

General Cargo and Container Terminals

Much of the activity involving land-side cargo handling equipment is related to general cargo, which may include bundles, coils, rolls, pallets, and some marine containers. Depending on configuration, container terminals at ports use a combination of cranes, forklifts, loaders and yard tractors to move containers to and from ships. In general, the land-side equipment used at container terminals consists of yard tractors, forklifts, top and side handlers, front loaders, and gantry cranes. Typically, this equipment is run on diesel.

Port of Toledo Terminals and Equipment Types

The Port of Toledo contains four primary terminals:

- Grains and Aggregates Complex
- Coal and Iron Ore Center
- Overseas Cargo Center
- General Cargo Facility

The tenants that operate at each of these terminals were listed above. As discussed above, the commodities handled at each terminal vary, as does the equipment used. Typical commodities found at each terminal are shown in Table 5-1.[58] While some tenants, such as Midwest Terminals of Toledo, operate in more than one terminal, others focus solely on one commodity type and as such are limited to one terminal.

Table 5-1
Port of Toledo Capabilities

Terminal/Complex	Commodity	Primary Port Tenant
Grain and Aggregates Complex	Corn, soybeans, wheat	The Andersons, ADM, Andersons – E
Coal and Iron Ore Center	Coal, iron ore	CSX
Overseas Cargo Center	Various	Midwest Terminals
General Cargo Facility	General cargo, including grain, petroleum products	ADM

As discussed above, equipment used at each terminal is specific to the cargo that is handled. At the CSX iron ore and coal terminals, the port tenant operates bulk handling materials equipment primarily consisting of ship loaders, locomotives, and conveyor belts. According to CSX, much of this equipment is currently electric.[59] The terminals in which Midwest Terminals operates contain the majority of the Port of Toledo's operating equipment, consisting primarily of forklifts, cranes, and loaders. The grain and aggregates complex contains some forklifts, front end loaders, and forklifts. The majority of equipment at this location is on-road vehicles, as shown in Table 5-2.

[58] www.toledoseaport.org.

[59] Paul LaCompte, CSX; phone conversation with Starcrest in September 2005.

Table 5-2
Major Diesel Equipment Operating at the Port of Toledo

Terminal/Area	Primary Equipment on Site
Disposal Area	Not currently active
CSX Iron Ore Dock	Import facility, conveyor belts
CSX Coal Terminal	Export facility, locomotives; mules; electric rotary dumper, conveyor belts
Midwest Terminals Aggregate Facility	Front end loaders
General Cargo	Gantry and mobile cranes, front end loaders; forklifts
Cement Silo	No equipment on site
Shipyard	Gantry cranes, forklifts

Land-Side Equipment Assessment

The two major equipment operators (Midwest Terminals and Kuhlman) were interviewed regarding the type and quantity of land-side diesel equipment operated at the Port. Information obtained during these interviews was consolidated and major equipment was grouped by type as shown in Table 5-3. This list does not represent a total inventory of port-wide equipment, but rather is an assessment of major equipment types and quantities among the Port's two primary tenants.

Table 5-3
Port of Toledo Land-Side Equipment Assessment

Equipment	Quantity
Forklifts	40
Front End Loaders	10
Cranes	5
Conveyors	3
Locomotives	2
Other	7

The most commonly seen types of equipment at the Port of Toledo are forklifts, cranes (small gantry cranes and wharf cranes) and front end loaders. This equipment is generally described below.

Rubber Tired Gantry (RTG) Cranes

The diesel-powered RTG crane moves containers and other cargo to and from the container stacks in a grounded operation. The RTG straddles the stacks of containers and has room for a heavy-duty truck/yard tractor to pull under and move containers between the stacks and vehicles. It is also used to consolidate the stacks weekly as containers are added and removed from the terminal. Figure 5-2 shows an RTG operating at the Port of Toledo[60].

Figure 5-2
Rubber Tired Gantry Crane

Forklifts

Forklifts are typically found throughout the Port as they may be used for both cargo and non-cargo handling activities. Forklifts are technically called counterbalanced lift trucks, which may be equipped with cushion tires (inside or flat surfaces) or pneumatic (rough terrain or outside; heavy loads require pneumatic tires). Forklifts at the Port of Toledo were by far the most numerous piece of diesel equipment in use. At the Port of Toledo, forklifts typically run eight hours a day, five days a week. Some of the larger forklifts run fewer hours per day. Figure 5-3 shows a typical forklift operating at the Port of Toledo.[61]

[60] *Photo courtesy of Steve Briggs, FirstEnergy with permission.*

[61] *Photo courtesy of Steve Briggs, FirstEnergy with permission.*

Figure 5-3
Forklift

Rubber Tired Front Loaders

Rubber tired loaders are loaders with large rubber tires that make it useful for work in construction sites and rough terrain. A rubber tired front end loader operating at the Port of Toledo is shown in Figure 5-4.[62]

Figure 5-4
Rubber Tired Front Loader

Wharf Cranes

Wharf cranes are used to load and unload cargo from ships. Wharf cranes are in use at the Port of Toledo any time a general cargo ship needs to be loaded or unloaded. This kind of wharf crane is mounted on rails and can move along the wharf; a boom extends out over the ship at an angle, which is different from how containership gantry cranes work, since they use a horizontal "bridge" boom. Figure 5-5 below shows Big Lucas, the Port of Toledo's largest crane. Big Lucas was an electric crane, but was long ago converted to run on diesel.[63]

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[62] *Photo courtesy of Steve Briggs, FirstEnergy with permission.*

[63] *Photo courtesy of Steve Briggs, FirstEnergy with permission.*

Figure 5-5
Wharf Crane – Big Lucas

Table 5-4 below shows only those pieces of equipment that were most commonly found at the Port of Toledo, and how many are operated by the two major port tenants. This equipment summary was developed from the equipment list presented above, and consolidated to show which equipment types were most abundant at the Port of Toledo.

Table 5-4
Summary of Major Land-Side Equipment Types – Port of Toledo

Equipment Type	Size	Count
Forklift – small	1 – 4 tons	21
Forklift – medium	5 – 14 tons	11
Forklift – large	> 15 tons	6
Front end loader	2 – 10 cubic yards	10
Small mobile cranes	Varies	4
Wharf cranes	70 – 110 tons	2

As can be seen in Figure 5-6 below, forklifts followed by front loaders were the most commonly found pieces of land-side equipment at the Port. Although cranes – wharf and small mobile or gantry – are less numerous, they have been included in this equipment assessment because of their size and relatively large emissions.

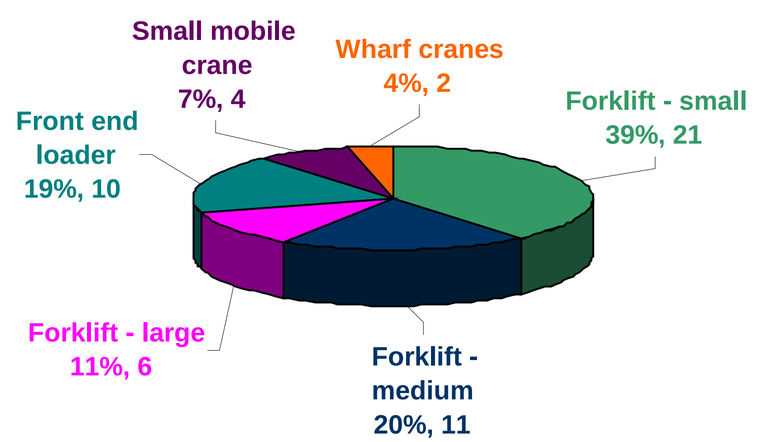

Figure 5-6
Port of Toledo Equipment Distribution

Current Emissions Associated with Land-Side Equipment

Based on initial surveys of equipment, average power, and hours of annual use, emissions were estimated for the equipment presented in Table 5-4 above. Table 5-5 below summarizes this equipment and estimates equipment capacity and usage by type. While estimated hours of operation data were available for the forklifts and loaders, it was not available for the cranes surveyed. As such, the modeling default of approximately 3 hours per day (990 hours per year) was estimated for both the small mobile cranes and the larger wharf cranes.

Table 5-5
Equipment Summary – Size and Usage

Equipment	Lift Capacity	Quantity	Average Horsepower	Hours	Load	Horsepower-Hours
Forklift – small	1 – 4 tons	21	61	2,000	59%	1,511,580
Forklift – medium	5 – 14 tons	11	150	500	59%	486,750
Forklift – large	> 15 tons	6	225	500	59%	398,250
Front end loader	2 – 10 cubic yards	10	125	2,000	59%	1,475,000
Small mobile cranes	Varies	4	200	990	43%	340,560
Wharf cranes	70 – 110 tons	2	700	990	43%	595,980

Estimating emissions requires the use of emission factors. Emission factors used in this analysis are presented in Table 5-6 below and are from the U.S. EPA's NONROAD2005 model.[64]

Table 5-6
Emission Factors

Pollutant	NO_x	CO	HC	PM
Emission factor, g/Hp-h	10.3	4.6	0.9	0.9

Emissions in terms of tons per year for each equipment type and quantity operated at the Port of Toledo were then estimated and are presented in Table 5-7.

Table 5-7
Emission Estimates

Equipment Type	NO_x	CO	HC	PM
Forklifts – small	17.16	7.66	1.50	1.50
Forklifts – medium	5.53	2.47	0.48	0.48
Forklifts – large	4.52	2.02	0.40	0.40
Front end loaders	16.75	7.48	1.46	1.46
Small mobile cranes	3.87	1.73	0.34	0.34
Wharf cranes	6.77	3.02	0.59	0.59
Total	54.59	24.38	4.77	4.77

As seen in Table 5-7 above, the largest equipment category NO_X emitters at the Port of Toledo are the small forklifts, followed by the front end loaders. These relatively larger NO_X emissions are a result of the quantity of equipment in use and the frequency of usage. The small forklifts and front end loaders are used approximately 2,000 hours per year each.

[64] *NONROAD2004'*, U.S. EPA, Office of Transportation Air Quality, April 2004.

6

ELECTRIFICATION OPPORTUNITIES

Seaport land-side equipment is largely run on diesel fuel. However, some equipment manufacturers do produce electric equipment for some equipment types and models. This section discusses electrification options for port land-side equipment.

Electricity Options for Land-Side Equipment

There are several ways to convert internal combustion industrial equipment to electric use.

- *Direct hookup to the power grid.* Use transformers, alternating current/direct current (AC/DC) converters, and other switchgear. A power cord is usually run to large motors such as on a wharf crane.
- *Battery power.* Internal combustion engines are replaced with electric motors which are powered exclusively by batteries. Smaller forklifts are ideal for this technology, since they have relatively slow discharge rates. When not in use, the batteries must be recharged, usually within 8-10 hours or overnight.
- *Fuel cells.* Various fuels such as methane and hydrogen are used to generate power which can then be used in stationary or portable industrial equipment. Fuel cells are still in development and are not thought to be tested-out for the industrial equipment market except as commercial generators.
- *Hybrid.* Small diesel engines are used for boost power and to recharge on-board batteries. The Green Goat™ [65] switch locomotive is an example of hybrid technology. Another example would be battery-powered industrial equipment having a micro-turbine to continuously recharge the batteries, as is marketed by Capstone Turbines, Incorporated[66]. Note that many turbine technologies have extremely low emissions but are not common in mobile source equipment used at ports. Such assistive technology reduces the need for lengthy recharging.

The first two options, direct electric and battery power for replacing equipment that formerly was diesel powered, is particularly attractive because the non-road emissions, especially for oxides of nitrogen and particulate matter, are eliminated. It is true that the power used to supply this equipment, measured in kilowatt-hours, is attributed to the power source, which could be fueled by coal, oil, or natural gas, and as such have associated emissions, but estimates of those emissions are beyond the scope of this report. It should be noted, however, that through night-time charging, the utility supplier will supply the most efficient and least polluting generation available.[67]

[65] http://www.railpower.com/

[66] http://www.capstoneturbine.com/

[67] Toledo Edison correspondence with EPRI 21 December 2005.

Hybrid systems usually involve some use of an auxiliary diesel engine that has some associated emissions, but there can still be significant savings. For example, a 2,000 horsepower locomotive engine could be replaced by a 270 horsepower auxiliary engine, as seen in the Green Goat, and thus emissions are reduced by over 75%.

Some cargo handling machinery is described as "diesel-electric". This means that a diesel engine is used to drive a generator, which in turn creates power for electric drive motors. Machinery of this kind is still considered as a diesel engine with its associated emissions.

General Options for Electric Equipment

There are several types of electric equipment that are generally commercially available which ports may consider, either as a retrofit of an existing piece of equipment, or as a new original equipment manufacturer (OEM), including:

- Wharf gantry cranes
- Railcar movers
- Forklifts
- Man-lift
- Railcar/container loading gantry crane
- Light duty vehicles
- Lighting (much of the lighting used for night work at seaports is diesel powered)
- Refrigerated containers (reefers)

In addition to electric equipment that is currently commercially available, there seem to be two equipment trends with regard to container operations at seaports: the automation of gantry cranes and the automation of terminal tractors or yard trucks. Companies such as Kalmar Industries[68] and Kone Cranes[69] as well as others are working on electrical systems for RTGs and rail-mounted gantries (RMG). Kalmar currently has one of the first hybrid and all-electric RTGs on the market (see *commercial availability*). Some work is being done on fixed rail and automated guided vehicles (AGV) for terminal tractors.[70] AGVs, unmanned vehicles that transport cargo from one location to another, are currently being used at the Sea-Land terminal in Rotterdam.[71] Automation of some components of container operations, including gantry cranes and yard tractors, seems to hold some promise for the future.

[68] www.kalmarind.com

[69] www.konecranes.com

[70] Spasovic, Lazar. 'Study to Determine the Need for Innovative Technologies for Container Transportation Systems, Final Report. Prepared by the New Jersey Institute of Technology for the New Jersey Department of Transportation, December 2004. See also: http://www.transportation.njit.edu/nctip/final_report/InnovativeContainer.htm#_Toc77996529

[71] *Ibid*.

Equipment Possibilities for Electrification

The Port of Houston

It is suggested that the small-to-medium sized forklifts be considered for electrification. Large cranes, including gantry cranes, are another good candidate for electrification. Although the PHA currently has several electric RTG cranes, any remaining diesel-powered cranes may be considered eligible for electric conversion. This recommendation is based on several selection criteria, including commercial availability, cost, emissions benefit, operational effects, and impacts to electric infrastructure. Each of these factors is discussed below.

Although yard trucks seem a good choice for electrification because of their relative aggregate NO_x emissions, they are not suggested at this point. In addition to being commercially unavailable as an electric option, yard trucks, in addition RTGs, are the focus of an EPA grant-funded project at the PHA to investigate the emissions impacts of the combination of $PuriNO_x$ and PuriMuffler, both products from The Lubrizol Corporation.[72]

Yard trucks may be the focus of some technology shifts currently underway in the marine equipment industry.[73] As described above, yard trucks and gantries may be moving toward automated systems within port container terminal operations. As this technology is still in developmental stages, it is not known whether these automated systems would use diesel, battery, hybrid or dedicated electric power. There are, however, some current applications of automated systems in use today, namely at the Sea-Land Terminal in Rotterdam,[74] in The Netherlands and at Hamburg Germany's Altenwerder Terminal.[75]

Like yard trucks, container handlers such as top and side loaders currently also have limited potential as electric primarily because of a lack of commercial availability. However, there is no operational reason why this type of equipment – the side loader in particular - would not be suitable in battery powered, direct electric power, or hybrid configurations. Equipment manufacturers may respond to a significant demand for such equipment should it be selected as a potential electric candidate.

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[72] http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

[73] Yong-Leong Cheng, Hock-Chan Sen, Karthik Natarajan, Singapore-MIT Alliance Program; Chung-Piaw Teo, National University of Singapore; and Kok-Choon Tan, PSA Corporation. *Dispatching Automated Guided Vehicles in a Container Terminal*. 23 May 2003. see http://www.bschool.nus.edu.sg/Staff/bizteocp/agv3.pdf

[74] Spasovic, Lazar. 'Study to Determine the Need for Innovative Technologies for Container Transportation Systems, Final Report. Prepared by the New Jersey Institute of Technology for the New Jersey Department of Transportation, December 2004. http://www.transportation.njit.edu/nctip/final_report/InnovativeContainer.htm#_Toc77996529

[75] *RALFH News Brief. "New Containter Terminal Altenwerder at the Port of Hamburg." July 2002. See also:* http://europa.eu.int/comm/taxation_customs/resources/documents/ralfh3_en.pdf

The Port of Long Beach

In light of the equipment that currently operates at the port, and considering electric equipment availability, it is suggested that the small-to-medium sized forklifts – including those that currently run on LPG – be considered for electrification. In addition, the gantry cranes may also be good candidates for electrification.

Although yard trucks seem a good choice for electrification because of their relative aggregate NO_x emissions, they are not suggested at this point. In addition to being commercially unavailable as an electric option, yard trucks are one focus for the POLB's Diesel Emission Reduction Program. This program, described in more detail in *Offsetting Costs: Incentives, Grants and Programs* section below, focuses on retrofitting diesel terminal equipment with diesel oxidation catalysts, a device that can reduce PM emissions by as much as 25%. Hundreds of diesel oxidation catalysts (DOCs) have been installed on various equipment at several terminals within the POLB. Yard trucks have been good candidates for this technology. As part of this program, in addition to the DOCs, the Port is encouraging and providing financial support for the use of emulsified diesel in terminal equipment. The yard trucks are another good choice for this alternative fuel, which yields significant reductions in both PM and NO_x emissions.

It should also be noted that yard trucks may be the focus of some technology shifts currently underway in the marine equipment industry.[76] As described above, yard trucks and gantries may be moving toward automated systems within port container terminal operations. As this technology is still in developmental stages, it is not known whether these automated systems would use diesel, battery, hybrid or dedicated electric power. There are, however, some current applications of automated systems in use today, namely at the Sea-Land Terminal in Rotterdam,[77] in The Netherlands and at Hamburg Germany's Altenwerder Terminal.[78]

Like yard trucks, top and side loaders currently also have limited potential as electric primarily because of a lack of commercial availability. However, there is no operational reason why this type of equipment – the side loader in particular - would not be suitable in battery powered, direct electric power, or hybrid configurations. Equipment manufacturers may respond to a significant demand for such equipment should this type of equipment be selected as a potential electric candidate.

The electric equipment options identified above were selected using several criteria, including commercial availability, cost, emissions benefit, operational effects, and impacts to electric infrastructure. Each of these factors is discussed below.

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[76] Yong-Leong Cheng, Hock-Chan Sen, Karthik Natarajan, Singapore-MIT Alliance Program; Chung-Piaw Teo, National University of Singapore; and Kok-Choon Tan, PSA Corporation. *Dispatching Automated Guided Vehicles in a Container Terminal.* 23 May 2003. see http://www.bschool.nus.edu.sg/Staff/bizteocp/agv3.pdf

[77] Spasovic, Lazar. '*Study to Determine the Need for Innovative Technologies for Container Transportation Systems, Final Report. Prepared by the New Jersey Institute of Technology for the New Jersey Department of Transportation*, December 2004. http://www.transportation.njit.edu/nctip/final_report/InnovativeContainer.htm#_Toc77996529

[78] *RALFH News Brief. "New Containter Terminal Altenwerder at the Port of Hamburg." July 2002. See also:* http://europa.eu.int/comm/taxation_customs/resources/documents/ralfh3_en.pdf

The Port of Toldeo

It is suggested that small forklifts and the large wharf cranes be considered for electrification. This recommendation is based on several selection criteria, including commercial availability, cost, emissions benefit, operational effects, and impacts to electric infrastructure. Each of these factors is discussed below.

Front loaders were also considered for possible electrification, but were rejected because of their relatively great need for tractive and breakout force (see discussion below in Equipment and Maintenance Impacts). A preliminary search revealed no commercial options for the rubber-tire front end loaders as battery powered, direct electric power, or hybrid configurations.

Yard trucks may be the focus of some technology shifts currently underway in the marine equipment industry.[79] As described above, yard trucks and gantries may be moving toward automated systems within port container terminal operations. As this technology is still in developmental stages, it is not known whether these automated systems would use diesel, battery, hybrid or dedicated electric power. There are, however, some current applications of automated systems in use today, namely at the Sea-Land Terminal in Rotterdam[80], in The Netherlands and at Hamburg Germany's Altenwerder Terminal.[81]

Commercial Availability

Forklifts and cranes, including gantry cranes, are among the electric equipment that is generally commercially available, depending on equipment specifications desired. A discussion of the commercial availability of each of these equipment types follows.

Forklifts

There are several classes of electric lift trucks or forklifts, including sit-down rider trucks; narrow idle trucks and hand trucks, with variations among each class as to size and lift capacity. Many companies, including Toyota, Yale, Caterpillar and Hyster, manufacture electric forklifts, but most are small forklifts suitable for warehouse work and truck loading. Larger forklift manufacturers such as Kalmar, Sisu, Ottawa, and others do not currently produce a battery-electric version. There are electric counterbalanced lift trucks available for general cargo, break-bulk, and palletized marine terminal operations. Many currently available models have 12,000-pound lift capacities, although a few models have much higher lift capacities.

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[79] Yong-Leong Cheng, Hock-Chan Sen, Karthik Natarajan, Singapore-MIT Alliance Program; Chung-Piaw Teo, National University of Singapore; and Kok-Choon Tan, PSA Corporation. *Dispatching Automated Guided Vehicles in a Container Terminal.* 23 May 2003. see *http://www.bschool.nus.edu.sg/Staff/bizteocp/agv3.pdf*.

[80] Spasovic, Lazar. '*Study to Determine the Need for Innovative Technologies for Container Transportation Systems, Final Report. Prepared by the New Jersey Institute of Technology for the New Jersey Department of Transportation*, December 2004. *http://www.transportation.njit.edu/nctip/final_report/InnovativeContainer.htm#_Toc77996529*.

[81] *RALFH News Brief. "New Containter Terminal Altenwerder at the Port of Hamburg." July 2002. See also: http://europa.eu.int/comm/taxation_customs/resources/documents/ralfh3_en.pdf*.

Gantry and Other Cranes

Kalmar is one of the few manufacturers of rubber-tired gantry cranes. Kalmar's E-One all-electric RMG crane reduces fuel consumption by at least 30 percent.[82] The E-One does involve several patented systems such as its Smartrail™ and remote machine interface (RMI). Rail guided gantries also benefit from not having pneumatic tire deformities, which are a definite problem with loads up to 90,000 pounds; however, constructing a rail system can become expensive. Large electric wharf cranes are available and are manufactured by companies such as Samsung, Kone, and Paceco.

As discussed briefly above, the use of gantry cranes, as well as yard tractors, may undergo an overhaul in the future due to the apparent trend toward automated guided vehicles (AGVs) in container terminal operations. Such overhauls in design are not uncommon in the equipment industry.[83] Future systems mentioned in the Spasovic report cited above include magnetic induction (Noell Corporation), large secondary overhead gantry cranes which are stationary (Auto-GO system), and other systems that could also be fully electrified, requiring no mobile RTG or RMG at all.[84]

Costs

In considering the costs associated with land-side equipment electrification, one must consider three cost categories: capital costs, operating costs, and infrastructure development costs. Although a detailed analysis of each of these three costs is beyond the scope of this report, the factors associated with each are described briefly below.

Capital Costs

In considering electric equipment options at a port, three opportunities – each with their own cost differentials depending on equipment type – are available to equipment operators:

- Retrofit older diesel equipment with electric motors and instrumentation
- Purchase new equipment that is original equipment manufacturer (OEM) electric
- Purchase used equipment elsewhere and rebuild the electric motors for longevity

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[82] http://www.kalmarind.com/show.php?id=29538

[83] Early RTG models such as by Travelift were diesel-powered and used hydraulic pump motors for lifting, steering, and driving. Over the last 25 years there has been an increased use of electrical components in RTGs. Today, the average RTG or RMG has a diesel engine in the 300-750 HP range, with hydraulic pumps, a large alternator, and perhaps even a generator or inductor depending on whether the drive and winch motors are AC or DC. Thus, current RTGs utilize a type of diesel electric configuration as opposed to earlier models that used a diesel hydraulic combination.

[84] Spasovic, Lazar. 'Study to Determine the Need for Innovative Technologies for Container Transportation Systems, Final Report. Prepared by the New Jersey Institute of Technology for the New Jersey Department of Transportation, December 2004.

Retrofit and the purchase of used equipment is recommended only for very large equipment such as large cranes, locomotives and marine vessels due to the relative ease in overcoming retrofit constraints, including engine compartment size, and engine mounts.[85] The following cost discussion focuses on new OEM purchases.

Detailed cost information was not available from equipment manufacturers, who provide cost estimates based on detailed equipment specifications. However, in general, it can be said that the purchase price of electric equipment is often slightly higher than their diesel counterparts.[86] Like their diesel counterparts, electric equipment comes with full manufacturer warranties. Although there may be a slightly higher purchase price for electric equipment, operational costs are offset by decreased diesel usage.

Initial costs for a battery electric model, for example, may include:

- Battery charger and battery charger station
- Battery crane hoist to install the battery
- Electric and other construction costs (e.g., for ventilation)
- Training
- Delivery costs

Retrofitting older diesel equipment, particularly larger equipment, with electric components may be a cost-effective strategy for equipment that is not yet in need of replacement.

Operating Costs

As noted by Gross and Associates, electric power may have a higher initial investment – as described above - but the operating costs (costs per hour) are usually much lower.[87] These decreases are largely due to substantial savings in diesel purchases. There are, however, costs associated with maintenance, including the recharging and replacement of batteries. A battery charging station would need to be installed for battery powered equipment; these batteries need infrequent, but regular replacement. Depending on what type of battery is installed, this replacement may need to occur every few years. Electric equipment, like its diesel counterparts, does need to be serviced regularly. Additional training may also be required for operators to understand optimal battery discharging and recharging rates, so as to protect the life of the batteries.

Although diesel costs – which vary drastically according to many factors – would be eliminated with electric equipment, there are additional electricity costs that are not associated with diesel equipment. Electricity costs represent the large majority of operating costs associated with

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[85] For any retrofit, the equipment owner must reconcile recommendations in the equipment warranty that suggest that only OEM equipment be utilized.

[86] Schneider, A., 'Vistavia Warehousing, Inc.,' J. of Global Perspectives on Accounting Education, Vol. 1, 2004.

[87] Gross & Associates, 2001, 'How to Choose the Right Lift Truck that's Right for You,' www.grossassociates.com.

electric equipment. The price of electricity varies, but ranges from 6 to 20 cents per kilowatt hour. As an illustration, the cost per year of operating a small forklift on diesel (at an average price of $3/gallon) compared to electricity (at an average price of $0.10/kw-hr) is estimated in Table 6-1 below. Of course, as the price of both diesel and electricity fluctuates, this operating cost differential will change.

Table 6-1
Estimated Annual Operating Costs for Small Forklift

	Diesel Forklift	Electric Forklift
Hours of operation/year	2000	2000
Dollars/unit to operate	$3.00/gallon	$0.10/kw-hr
Cost ($) to operate annually	$13,000	$5,300

Infrastructure Costs

Although not long-term, the costs associated with the infrastructure necessary for land-side equipment may be significant depending on what infrastructure is already in existence at a port. Infrastructure costs vary depending on which electric strategy is selected for equipment, including direct electric hookup or battery power. For direct electric hookup to the power grid, a power cord is typically run to the equipment motor, plugging directly into the power supply for the port. This strategy necessitates an appropriate level of electric capacity. If that is not available, then adding electric capacity (discussed below within *Electrical Infrastructure Impacts*) must be factored into potential infrastructure costs. Additional infrastructure costs for direct electric hookup include the power cords and associated equipment needed for "plugging in" the equipment. In addition, upgraded electric circuits and wiring may be necessitated. Battery power may involve fewer infrastructure costs because each piece of electric equipment in effect powers itself. Infrastructure costs associated with this option may include battery change out stations, upgraded electric circuits and wiring.

Emissions Benefits

Although there are an unlimited number of equipment scenarios that could have been modeled, this report contains emission reductions associated with a piece by piece replacement and/or retrofit of the equipment recommended above for electrification, namely cranes and forklifts. Using the same methods and procedures discussed above, emissions were estimated in tons per year (tpy) for an average single piece of equipment in each of the categories described above and presented in Table 6-2.

Table 6-2
Emission Estimates by Single Piece of Equipment

Equipment	NO_x (tpy)	PM (tpy)
1 Forklift	0.64	0.09
1 Yard Truck	1.67	0.09
1 Crane	1.99	0.11
1 Container Handler	1.06	0.05
1 RTG	4.18	0.22

As seen in Table 7-2 above, a typical RTG operating at the PHA emits approximately 4.2 tons of NO_x per year. This emissions number is an estimate based the grouping of all RTGs operating at the PHA. Each of the 30 RTGs operating at the PHA – including 10 electric RTGs – have slightly different horsepower and operating characteristics and as such, the 4.2 tons per year (tpy) NO_x emissions indicated above should be viewed as an average.

Because of the unlimited number of equipment scenarios that include electric equipment at the PHA, the table above is used to illustrate what NO_x and PM reductions may be achieved if any one type, or any combination of types, of equipment are converted to electric. In effect, the emissions per year for that equipment would be subtracted in their entirety from the total emissions for that equipment type. In other words, if 100 forklifts were converted to electric, an emissions benefit of 64 tons of NO_x per year (100 x 0.64) would be achieved.

Equipment and Maintenance Impacts

One of the reasons for using diesel to power an engine is tractive force, a concept related to turning the drive wheels on industrial machinery such as lift trucks, gantry cranes, front-end loaders, and terminal tractors. When operating in rough terrain, the tractive force required to rotate the wheels is very high. Counterbalanced electric lift trucks (forklifts) usually have smaller solid or pneumatic tires than the off-road diesel models because tractive force losses can become a substantial battery draw; for this reason they work best on smooth surfaces such as concrete, asphalt, or steel rails.

Breakout force is related to the force required to lift something off the ground, such as scooping loose material into trucks with an excavator. It is measured slightly differently than “maximum lift capacity.” The diesel hydraulic system usually has an advantage over electric systems in terms of breakout force, especially with load-sensing hydraulic values that prevent engine stalling. For operators requiring large breakout forces in equipment, battery power is less ideal because batteries would discharge very quickly, and would produce excessive waste heat from the electric motors. However, with new electric power management systems, load sensors, and automated electric components, tractive and breakout force issues are not as important as in the past. Electrification is expected to become more prevalent in the future when port processes are automated, such as the use of remote-controlled gantry cranes for loading and unloading railcars.

Engineers are still developing "deep cycle" batteries that can handle large power output rates that would not discharge the battery too quickly, and thus reduce its operating time and service life. Batteries are expensive and, after several years of use, may need to be replaced. This may not be such an issue with the smaller electric forklifts, which basically use batteries similar to automotive or small engine marine designs, but could be critical with the larger equipment sizes. It should also be noted that in very cold climates such in Toledo during the winter, batteries may not function as well; however, if stored inside a heated area this should not be a major impediment.

Electrical Infrastructure Impacts

According to CenterPoint Energy – the electric utility in the Port of Houston area – there are currently no electric capacity constraints at the Port. In fact, a new electric substation is being constructed as part of the new Bayport terminal at the port; this addition will offer ample electric capacity. [88]

There are currently electric infrastructure constraints at the POLB that may result in electric capacity constraints should an increased load to the electric system at the POLB occur.[89] In light of the equipment recommended as electric as part of this study, it may be necessary for the POLB to investigate electric system upgrades prior to electrification of a large quantity of equipment. This is particularly relevant should the large gantry cranes become part of an electrification plan.

In the Port of Toledo proximity, Toledo Edison (a First Energy Company) has existing 7, 12, 69, 138, and 345kV electrical Distribution and Transmission infrastructure. Capacity is available for normal system electrical loads. Delivery voltage is typically determined from a number of different factors including, but not limited to, area and site specific geographics, amount of electrical load (both immediate and future), and the nature and characteristics of the proposed loads. Any potentially required system modifications (if any) and associated costs are part of the analysis done when an application of service is submitted. Typically these determinations are made upon receipt of service application details. Customers who qualify may provide and own their electrical substation.

Generally, loads anticipated in excess of 2500 kVA are served by voltage systems above 12kV. First Energy (FE) has a formal process for studying transmission (above 12kV) point requests. An application for this study is required for all load additions of 1 MW or more at existing or new customers connected to the FE transmission system.

Offsetting Costs: Incentives, Grants and Programs

There are many incentives, grants and programs throughout the U.S. that have been established to provide financial assistance to entities wishing to make cleaner equipment part of their fleet. Although grants are an obvious choice as an incentive, others incentives such as tax credits and emission credit trading, also should be considered. In addition to these monetary incentives, non-monetary incentives such as environmental stewardship are also important to consider.

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[88] Alan Ahrens and Gary Shadwell, CenterPoint Energy correspondence with Starcrest in August 2005.

[89] Bryan Pham, Southern California Edison correspondence with Starcrest in October 2005.

This section summarizes some of those opportunities that are directly related to seaport equipment. New opportunities arise regularly; the Internet references are intended to aid in monitoring those opportunities.

Federal Grants and Programs

There are several federally based programs and initiatives that may provide financial assistance to port authorities seeking to replace/retrofit diesel equipment with electric – or other cleaner – technologies.

EPA Voluntary Diesel Retrofit Program Demonstration Grants Awarded

On February 23, 2005, EPA announced the award of $1.6 million to 18 grantees for projects designed to demonstrate effective emissions reduction strategies for diesel fleets. The grantees are State and local governmental organizations, including air agencies and port authorities, and non-governmental organizations.[90] The Clean Ports USA Initiative (described below within *Partnerships and Collaboratives*), which provides assistance to ports authorities to help them overcome barriers that impede the adoption of cleaner diesel technologies and strategies, falls within this EPA program.[91] Additional information on the 2004 Voluntary Diesel Retrofit Program Demonstration Grants is at: http://www.epa.gov/otaq/retrofit/dieselgrants2004.htm

As part of the Voluntary Diesel Retrofit Program, EPA oversees the Environmental Technology Verification (ETV) process, which verifies the emission reductions that can be achieved using a particular technology in a particular application. The ETV process applies rigorous testing procedures to determine the amount of emission reduction that equipment owners will realize in real-word applications of the product and it also verifies that the performance of the technology is maintained over time. (In California, CARB performs a similar process called the Diesel Emissions Control Strategy Verification Procedure.)

EPA National Clean Diesel Campaign Demonstration Assistance Agreements

EPA regularly solicits proposals from eligible entities for partnership projects that demonstrate the applicability and feasibility of implementation of EPA and/or California Air Resources Board verified (or certified) pollution reduction retrofit technologies in non-road vehicles and equipment such as those used in construction or port-related activities. Eligible activities include the use of verified pollution control technologies or innovative uses of verified pollution control technologies in non-road diesel vehicles and equipment in public, tribal or privately owned fleets. Diesel engine/vehicle/equipment replacements or the application of cleaner fuels are also eligible.[92] Additional information on this program is available at: http://www.epa.gov/air/grants_funding.html

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[90] *http://www.epa.gov/otaq/retrofit/latestnews.htm*.

[91] *http://www.epa.gov/otaq/retrofit/ports.htm*.

[92] *http://www.epa.gov/cleandiesel/*.

Legislation

In June 2005, U.S. Senator George Voinovich (R-OH) proposed the Diesel Emissions Reduction Act of 2005, a five-year program to reduce harmful diesel emissions from older diesel engines in a wide range of public and private vehicles.[93] The bill was considered in committee and was recommended to be considered by the entire Senate. Although it has not yet been voted on, it has been put on the Senate's calendar of business. The Diesel Emissions Reduction Act of 2005 would provide $200 million annually in grants and loans to help states and organizations develop diesel equipment retrofit programs.[94]

Tax Incentives

A variety of tax incentives at both the state and federal level of government are in existence and may provide some incentive to fleets wishing to purchase alternatives to diesel equipment. However, in reality, these programs offer small incentives and thus have had minimal impact.[95]

State and Regional Programs

The State of Texas is a leader in state programs that specifically target diesel emission reductions. PHA is eligible to receive grant money through the state's Texas Emissions Reduction Plan (TERP) program, described below.

Texas Emissions Reduction Plan

TERP is designed to improve the air quality in the State through voluntary incentives programs. Eligible applicants include operators of on-road heavy-duty vehicles, non-road equipment, marine vessels, locomotives, and stationary engines in nonattainment areas or other eligible counties. Funding is potentially available for the incremental cost of a control measure with cost effectiveness of $13,000 per ton NO_x reduced, or less. More information is available at: http://www.tceq.state.tx.us/implementation/air/terp/

Emissions Credit Trading Program

Emissions trading is a regulatory tool that provides flexibility and cost savings in reducing emissions. It provides financial incentives for entities that reduce emissions, effectively allowing them to sell these emission "credits" to those who need emissions "offsets".

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[93] 109th Congress, Senate Bill 1265: Diesel Emissions Reduction Act of 2005. See also: http://www.govtrack.us/congress/bill.xpd?bill=s109-1265 and *http://energy.senate.gov/public/_files/DieselRetrofitFinal.pd.f*

[94] *Ibid*.

[95] ICF Consulting. "Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors", Final Report. 19 May 2005. See also: *http://www.epa.gov/sectors/pdf/emission_20050519.pd.f*

Some states, including Texas, offer mobile emissions credit trading. The state of Texas credit trading program allows mobile discrete emission credits (MDERCs) to be generated. The program has not had a great deal of activity, with no actual trading having been reported to date.[96]

In theory, MERCs can provide an incentive for construction companies or port terminal operators to voluntarily reduce emissions from off-road diesel equipment. MERCs. In practice, however, there have been very few examples of the generation of MERCs. These programs need further activity in order to be considered a viable incentive for ports as they seek cleaner alternatives to diesel equipment.

Congestion Mitigation and Air Quality Funds

State governments and regional metropolitan planning councils disperse congestion mitigation and Air Quality (CMAQ) funds from the federal government for projects that reduce criteria pollutants in metropolitan areas. The Port of Houston, for example, has recently received funding through this program for The Port of Houston Pilot Retrofit Project, a voluntary project to retrofit rubber-tired gantries at the port. The project involves retrofitting between 50 and 250 vehicles with oxidation catalysts, and/or fuel additives (PuriNO_x and SINO_x: both are low emission diesel fuel emulsions). These retrofits are expected to reduce emissions of NO_x and PM. [97]

Port Programs

A number of ports administer grant programs that provide diesel retrofit funding for the port's tenants. These programs may be funded entirely by the port or the program may be funded in whole or in part by state or federal agencies. Although funding for PHA projects would not be eligible for the programs described below, these programs are described briefly below for illustrative purposes. The Ports of Long Beach, Oakland and Los Angeles administer significant grant programs that encourage retrofits, repowering, and replacement of diesel-powered marine terminal equipment. These port-administered grant programs have received significant funding from the ports themselves, sometimes as a result of lawsuit settlement agreements.

Port of Long Beach Diesel Emission Reduction Program[98]

The Port of Long Beach recently initiated the Healthy Harbor Program, including an air quality component. Consistent with that program, the Port's Board of Harbor Commissioners approved an Air Quality Improvement Program with a component that addresses terminal equipment called the Diesel Emission Reduction Program (DERP). The DERP focuses on retrofitting diesel terminal equipment with diesel oxidation catalysts (DOCs) that can reduce particulate matter emissions by 25%. Through the Port's DERP, hundreds of DOCs have been installed at several terminals at the port. In addition to the DOCs, the Port is encouraging and providing financial

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[96] Steve Sun, Texas Commission on Environmental Quality correspondence with Starcrest in October 2005.

[97] http://www.epa.gov/otaq/retrofit/exporthouston.htm

[98] http://www.portoflosangeles.org/environment_air.htm

support for the use of emulsified diesel in terminal equipment. When used with a catalyst, emulsified diesel can reduce NO_x emissions by 20% and PM by more than 50%. For more information, see: http://www.gatewaycog.org/cleanairprogram

Port of Los Angeles Clean Air Program – Near-Term Measures Initiatives

The Port of Los Angeles has implemented several grant programs in recent years that promote diesel emission reductions. The Port's Air Quality Mitigation Program has offered $4.5 million in 2004 and will offer the remaining $15.5 million over the next three years. Among the eligible projects for funding are off road heavy duty equipment and engines including specialty port equipment. In addition to the Air Quality Mitigation Program, the Port has been funding the installation of DOCs since May 2003. The Port has also been pursuing use of emulsified fuels, which optimize the reduction in PM and NO_x when using a DOC. Finally, the Port approved in October 2002 a $2.8 million investment program for terminal and ship operations targeted at reducing diesel emissions. For more information, see:
http://www.portoflosangeles.org/business_rfp.htm

Port of Oakland Clean Air Program[99]

The Port of Oakland was the first in the nation to develop a major grant program focused on diesel emission reductions. The Port's Air Quality Mitigation Program includes grants to reduce both on-road and off-road diesel emissions at the Port. The terminal equipment component of the program offers grants to terminal operators to retrofit and repower cargo handling equipment. The Port has provided $4.5 million to fund the program.

Partnerships and Collaboratives

Cooperative partnerships and collaboratives among various entities interested in diesel emission reductions are being developed regularly. Among those that have been established to date are the following:

Clean Ports USA

As a part of EPA's Voluntary Diesel Retrofit Program, the Clean Ports USA will offer assistance to port authorities to help them overcome barriers that impede the adoption of cleaner diesel technologies and strategies. The initiative is encouraging port authorities to:

- Retrofit and replace older diesel engines with verified technologies
- Use cleaner fuels
- Increase operational efficiency, including environmental management systems, logistics, and appointment systems

[99] *http://www.portofoakland.com/environm/prog_04a.asp*

- Reduce engine idling
- Provide economic incentives for ports' contracts with tenants, contractors, and others
- Promote intermodal shifts

Additional information on EPA's ports retrofit program is at:
http://www.epa.gov/otaq/retrofit/ports.htm

EPA National Clean Diesel Campaign[100]

The National Clean Diesel Campaign (NCDC) works collaboratively with businesses, government and community organizations, industry, and others to provide an incentive-based approach to reducing diesel emissions. Members of these initiatives have agreed to collectively leverage additional funds and take a local approach to diesel mitigation. Benefiting from economies of scale while protecting against competitive disadvantages, these regional initiatives provide an ideal structure for significant reductions across a large geographic area. One of the collaboratives established under this program is the West Coast Diesel Emissions Reductions Collaborative.[101] This joint effort includes the EPA, U.S. Department of Agriculture Natural Resource Conservation Service, U.S. Department of Energy, U.S. Department of Transportation, Canada and Mexico, as well as state, local, non-profit and private sector partners from California, Alaska, Washington and Oregon to reduce air pollution emissions from diesel engines along the west coast.

The Collaborative provides funding for many industries, including shipping, railroad, construction, and agriculture, among others, to reduce their emissions. The Collaborative also provides additional incentives for early application of both Federal and state on-road and non-road diesel engine and fuel standards. Further information is available at:
http://www.epa.gov/cleandiesel/
http://www.westcoastcollaborative.org

Other Regional Collaboratives

Other regional collaboratives have formed around the country. The Midwest Diesel Initiative is a new cooperative, public-private effort to reduce diesel emissions along major transportation corridors and various sectors including, trucking, locomotive, construction, and ports, with emphasis on urban areas.[102]

In the Boston area, Greater Boston Breathes Better builds on a foundation of voluntary action and encourages participants to engage in projects that will reduce transportation related air pollution to help address the high asthma rates in the Northeast. See:
http://www.epa.gov/NE/eco/gb3/index.html

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[100] *http://www.epa.gov/cleandiesel/*.

[101] West Coast Collaborative Fact Sheet, August 2005. See also: *http://www.westcoastcollaborative.org*

[102] *http://www.epa.gov/cleandiesel/*.

The Philadelphia Diesel Difference Working Group was formed to help build a coalition of diverse partners with a mutual interest in reducing air pollution from diesel engines in the greater Philadelphia area (including the five surrounding counties) through voluntary programs and the use of innovative strategies including market-based approaches. See: http://www.cleanair.org/dieseldifference/index.html

EPA SmartWay Transport Partnership[103]

SmartWay Transport is a voluntary partnership between various freight industry sectors and EPA that establishes incentives for fuel efficiency improvements and greenhouse gas emissions reductions. There are three primary components of the program: creating partnerships, reducing all unnecessary engine idling, and increasing the efficiency and use of rail and intermodal operations.
http://www.epa.gov/sectors/pdf/emission_20050519.pdf

[103] ICF Consulting, "Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors", Final Report. 19 May 2005.

7
OPPORTUNITIES

Due to the scope of this report, investigations of electrification possibilities at ports were limited to land-side equipment. The possibility for the electrification of other equipment, including ships and vehicles, were not included in this analysis. These possibilities are discussed briefly below, but may warrant additional study to determine their feasibility. A limitation of this report is related to the discussion on the costs of electrification. The actual cost effectiveness of land-side equipment electrification cannot be fully assessed without a detailed cost-benefit analysis, including estimates for equipment, electricity costs, and infrastructure development. This type of analysis, discussed briefly below, is beyond the scope of this report, but may warrant additional investigation to better determine the feasibility of land-side equipment electrification.

Detailed Cost-Benefit Analysis for Land-Side Equipment Electrification

The cost information included in this report is a general cost assessment of equipment electrification. The actual cost effectiveness of land-side equipment electrification cannot be fully assessed without a detailed cost-benefit analysis, including estimates for equipment, electricity costs, and infrastructure development. This type of analysis is beyond the scope of this report, but may warrant additional investigation to better determine the feasibility of land-side equipment electrification.

In considering this future cost analysis, a site-specific matrix that evaluates capital, fixed, variable, and avoided costs associated with the proposed project may be warranted. An interesting study cited below compared cost and net present value for indoor/outdoor forklifts in the 4,000 to 5,000 pound capacity range.[104] The Schneider study conducted a life cycle cost-benefit model for these forklifts and found that initial capital costs were slightly higher with electric equipment, with the electric model being 15-30% higher ($21,451 electric versus $18,956 diesel). However, when labor, energy, and maintenance were included, such capital costs were insignificant (i.e., below 5% of the life-cycle costs).

This future cost-benefit analysis would also need to consider in depth the costs associated with electricity as compared to diesel. This discussion is difficult because of the ever-changing cost of both electricity and diesel. A cursory analysis, illustrated in Figure 7-1 below, using the assumptions listed below shows that – given the hypothetical prices of diesel at $3.00 per gallon and electricity at $0.12 per kW-hr – electricity has a substantial cost reduction that quickly offsets slightly higher capital costs.

[104] Schneider, A., 'Vistavia Warehousing, Inc.,' J. of Global Perspectives on Accounting Education, Vol. 1, 2004.

- A value of 0.371 pounds of diesel per horsepower-hour (hp-hr).
- When applied to horsepower (61 horsepower) and a load factor of 59% (both found in the NONROAD model), the result is 2.1 gallons per hour of diesel consumed.
- Electric forklift requires the same energy as the model diesel engine.

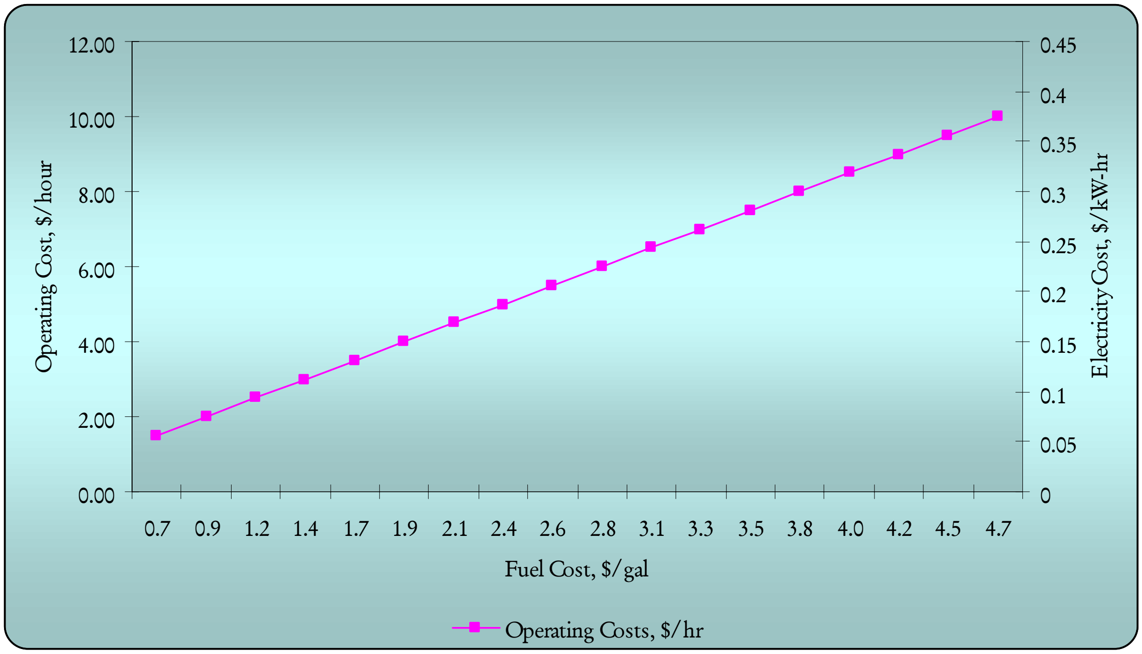

Figure 7-1
Operating Costs Associated with Diesel vs. Electric

Possibilities for Electrification of Other Equipment

The focus of this report has been electrification opportunities specifically for land-side equipment operating at seaports. Use of electric land-side equipment may be a cost-effective way to minimize emissions at seaports. In addition to electric land-side equipment, there is also the potential for electrification of other seaport components, including those related to ships, truck and other on-road vehicles, and rail. These options are briefly discussed below.

Electrification Projects Associated with Ships – Cold Ironing

Ships docked at port typically shut off their propulsion engines but still run their auxiliary diesel generators to power refrigeration, lights, and pumps. The emissions associated with this activity, commonly called "hotelling", are for the most part not subject to emission controls, although they can be substantial depending on the quantity of ships in port and the duration they are there.

One strategy to reduce the emissions associated with hotelling is to "cold iron", defined as the use of shore power by the ship instead of its own diesel generators for at dock needs. Substantial emission reductions can be achieved through cold ironing, with estimates of NO_x reductions of over one ton per ship per day, in addition to particulate matter reductions.[105] However, it is a comparatively expensive strategy and one that requires substantial infrastructure upgrades both on shore and aboard the vessel that cold irons.

There are currently no international requirements that mandate cold ironing of marine vessels. A recent worldwide emission control initiative – Annex VI of MARPOL – The International Convention for the Prevention of Pollution of Ships – does address hotelling emissions but does not specially mention cold ironing.[106] The EPA has developed emission standards for marine engines, but these apply only to U.S. flagged vessels, which comprise only a small percentage of ships that call to U.S. ports.

There are currently very few cargo ships that cold iron at U.S. ports. The Port of Los Angeles recently opened the world's first alternative maritime power container terminal.[107] The wharf at Berth 100, a China Shipping terminal at the Port of Los Angeles, was provided with the infrastructure to shore-power a compatible containership. The electricity is converted to a voltage compatible with the ship's electrical requirements; the ship is connected to the shore power while hotelling at the dock. China Shipping is the first of the Port of Los Angeles' customers to commit to the AMP technology, although others have signed memorandums of understanding to study its use and to implement cold ironing. China Shipping's container vessel, the Xin Yang Zhou, makes regular calls at the Port of Los Angeles, and additional China Shipping vessels are being fitted with the technology. The Port of Los Angeles hopes to incentivize other tenants by helping them underwrite the cost of building or retrofitting their first container ship to run on electric power when berthed at the Port. This incentive is capped at $810,000 per container steamship line or affiliated company.

In addition to Los Angeles, the Port of Long Beach is also currently assessing the possibility of cold ironing for vessels calling there. The Port of Long Beach recently commissioned a study on the cost effectiveness of cold ironing.[108] The report showed that some berths and vessels are cost effective to retrofit to cold ironing capability and some are not. The difference between cost effective and not are largely related to annual power consumption. When annual power consumption is 1,800,000 kW-hr or more, the cold ironing retrofit becomes cost effective. For a new vessel with cold ironing capability installed during construction of the terminal, cold ironing becomes more cost effective. The Port of Long Beach has taken further steps toward cold ironing by entering into a voluntary program with BP that involves the voluntary retrofit of at least two BP vessels with cold ironing capabilities. The Port will be responsible for the shore-side improvements necessary to accommodate these vessels.[109] In addition, the Port will require future terminal projects to accommodate cold ironing by vessels through lease agreements with operators.[110]

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[105] Environ International Corp*, Cold Ironing Cost Effectiveness Study.* Port of Long Beach., March 2004.

[106] Regulations for the Prevention of Air Pollution from Ships, Annex VI to MARPOL Convention, 1997. See also: *http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258#11*

[107] AAPA Advisory Online vol 38, no 22, 28 June 2004.

[108] Environ International Corp*, Cold Ironing Cost Effectiveness Study.* Port of Long Beach., March 2004.

[109] Robert Kanter, Ph.D, Presentation to the 2005 Air Innovations Conference. August 2005. "Port Projects Related to Air Quality Improvement."

[110] *Ibid*.

There has also been some effort by cruise line companies to utilize this strategy while calling into ports. Princess Cruise Line, for example, utilizes cold ironing in Alaska[111] and more recently Seattle.[112] Two of this lines cruise ships - The Diamond Princess and the Sapphire Princess – will use shore power at the Port of Seattle Terminal 30 cruise facility during the 2005 cruise season. The Port of Seattle estimates that air emissions will decrease by 30% this year as a result. Princess Cruises reportedly invested $1.8 million to equip the two vessels to run on shore power. The EPA has pledged $50,000 in grant money to the Seattle City Light to help cover the costs of infrastructure improvements related to providing power to ships.

In general, the cost-effectiveness of cold ironing is dependent on several factors, including how frequently a ship calls at a particular port, how long that ship is at port, and the energy demand required while at port.[113] It can be an effective way to substantially reduce emissions at seaports.

Electrification Projects Associated with On-Road Vehicles

Many ports across the country have incorporated hybrid vehicles into their light duty car fleets. Hybrid vehicles use the dual technologies of gas and electricity for power. The wheels of the hybrid car are driven by both a conventional engine that is fueled by gasoline or diesel as well as an electric motor. The two motors can be utilized in various ways, with a computer that is programmed to operate the car on either or both motors depending on the speed, the power required, and the amount of electricity left in the batteries.

Hybrid light duty vehicles such as those offered by Honda and Toyota and others have the advantages of increased fuel economy and decreased overall emissions of some pollutants. Hybrid vehicles meet the EPA's ultra low emission vehicle (ULEV) standards, and can be credited as such in many states' "Clean Fleet" programs.

Hybrid electric vehicles are cost-competitive with similar conventional vehicles, with sales prices from 0% to 25% higher. However, cost premiums can be offset by overall fuel savings and tax incentives.

Heavy Duty Vehicle Opportunities

There are fewer hybrid vehicle options for heavy trucks, which drive long distances at constant speed. Thus, for ports looking for electrification opportunities for heavy duty vehicles, hybrid technology is not currently a realistic strategy. There are, however, other electric strategies that involve heavy duty fleets at ports, including truck stop electrification and refrigeration units. The former, truck stop electrification, has some potential at ports The U.S. EPA has recently awarded through its SmartWay Program several million dollars in grant money to projects related to idle reduction technologies on trucks and at truck stops and ports across the country. One grant awarded was to the Texas Transportation Institute (TTI) for a truck engine idle reduction

[111] *Ibid.*

[112] http://www.portseattle.org/news/press/2004/09_30_2004_13.shtm.l

[113] http://www.arb.ca.gov/msprog/offroad/marinevess/presentations/110904/scaqmd.pdf.

technology demonstration program.[114] As part of their demonstration program, TTI will develop a design for, and demonstrate the benefits of, an advanced, no-idle truck stop prototype at the Port of Houston.[115]

Electrification of the refrigerated trucks, trailers and containers that are used by shippers to transport perishable items has significant electrification possibilities. EPRI has estimated that there may be as many as 300,000 of these refrigerated units, generally called transport refrigeration units (TRUs), in the U.S.[116] These TRUs may sit for hours, even days, at port terminals awaiting transfer to ship or truck. During this time, the refrigerated units are kept cold using an engine typically run on diesel fuel, although some are run on electricity. Because of the high emissions associated with this TRU activity, the California Air Resources Board has recently approved an air toxics control measure that specifically targets this equipment. This ARB control measure (Title 13, California Code of Regulations, Section 2477), which became effective in December 2004, will reduce PM emissions from TRUs operating in California through the use of in-use performance standards phased in over the next 15 years.[117]

Grid-supplied electric power of these TRU engines, a strategy that is already in use at some ports including Houston[118] and Long Beach,[119] is one strategy to reduce TRU emissions. This strategy involves the replacement of the diesel engine used to power the unit with an electric motor while the unit is idle at the port terminal.

For ports that have little container traffic, such as the Port of Toledo, this strategy will be of limited use because of the small number of refrigerated units operating at the port. However, for ports such as Long Beach and Houston which handle a large number of containers, many of them holding perishable goods, this may be a good strategy for substantial emissions reductions. The effectiveness of this strategy may be verified only through the investigation of actual operating practices, including hours and location spent idling, for these units. Little research in this area has been done to date. Future study of TRU electrification may be warranted given the number of units operating across the country and the apparent operating practices associated with these units.

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[114] U.S. EPA Press Release: "EPA Awards $3 Million Grant to Texas Transportation Institute", October 11, 2005. See also: http://yosemite.epa.gov/r6/press.nsf/name/SmartWayGrant

[115] Texas Transportation Institute. Research Team Information for Truck Engine Idle Reduction Technology Demonstration Program. See also: http://tti.tamu.edu/cfaqs/projects/truck_idling_reduction/

[116] EPRI Case Study: *Transport Refrigeration Equipment; Cost Effective Emissions Reductions.* 2004.

[117] California Air Resources Board, "Guidelines for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate". 20 April 2005.

[118] Starcrest Consulting Group. *Port of Houston Authority 2001 Stevedore Equipment Emissions Inventory*, July 2002.

[119] Starcrest Consulting Group. *Port of Long Beach 2002 Baseline Emissions Inventory,* March 2004.

Electrification Projects Associated with Rail

In addition to opportunities for the electrification of land-side equipment at ports, there may also be opportunities for electrification of the railway engines used by many ports to move cargo. In particular, switch engines – smaller locomotives used to move rail cars in a rail yard or similar area – may have electric potential due to their size and use specifications.

Many yard switch engines are older "unregulated" [120] diesel engines between 1,000 and 2,000 horsepower; some yard switchers may even be up to 4,400 horsepower. These engines operate in contained areas and spend as much as 60% of the time idling.

There are two leading possibilities for electrification of switch engines:

- The all-battery engine, which is commonly used for smaller train sets or groups of rail cars of less than seven. Railway Equipment Corporation's Enviro-Motive is an example of this type of unit. [121]
- The hybrid diesel-battery engine, which is capable of handling larger train sets of as many as 88-car mainline units. RailPower's "Green Goat™"[122] is an example of the hybrid diesel-battery technology.

Some smaller industrial facilities use rail movers, which are usually small rail-mounted vehicles powered by internal combustion engines to move single or small numbers of railcars; the leading providers are Trackmobile, Shuttle Wagon and Rail King. The Rail King developed by Stewart & Stevenson has a choice of diesel engines between 134 and 210 horsepower. Smaller battery-powered locomotives such as the Enviro-Motive are meant to replace these types of rail movers and be more efficient within the confines of a small switch yard.

Larger train sets required larger tractive power and thus hybrid technology is beneficial because idling is reduced and the diesel generator engines are much smaller than typical switch engines. For example, the RailPower Green Goat series "GG" has a 250 horsepower Tier 2 or Tier 3 EPA diesel engine; this generator recharges a large lead-acid battery pack. While these units can be used for small switch yards and spurs, these are typically used for rail switching which involves large strings of railcars and the equivalent of 500-2,000 horsepower demand. Larger models such as the "RP" series are also available in larger power configurations for road switching and short-line applications.

Both of the electric engine alternatives described above result in substantial emission reductions. The all-battery unit achieves mobile source emissions reductions of 100% because it relies entirely on electricity, while the hybrid diesel battery technology achieves mobile source emissions reductions – NO_x and PM in particular – of 80-90%. However, emissions must be compared to the conventional diesel engine that is being replaced, the use of which may be highly variable. Some switch engines are heavily used while others see only periodical service.

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[120] "Unregulated" refers to pre-1994 engines that have not been remanufactured; see discussion at 63 FR 18978 available at: http://www.epa.gov/otaq/locomotv.htm

[121] http://www.enviro-motive.com/

[122] http://www.railpower.com/index.html

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CONCLUSIONS

The Port of Houston

In light of the equipment that currently operates at the port, and considering electric equipment availability and cost, it is recommended that small-to-medium sized forklifts and cranes be converted to electric. Small-to-medium forklifts are an obvious choice for electrification because of the quantity in use, their relatively heavy use, and general commercial availability as electric. As discussed above, the large forklifts, yard trucks and container handlers are not currently as conducive to electrification.

An emissions analysis reveals that converting, for example, 100 forklifts and 10 RTG cranes to electric may result in NO_x emissions savings of 106 tons per year (a 10% decrease) and PM emissions savings of 11 tons per year (a 14% decrease).

With the help of funding through one or more of the means described above, the installation of this equipment as electric may be a cost-effective, operationally efficient strategy to reduce emissions at the Port of Houston.

The Port of Long Beach

In light of the equipment that currently operates at the POLB, and considering electric equipment availability and cost, it is recommended that small-to-medium sized forklifts and gantry cranes be converted to electric. Small/medium forklifts are an obvious choice for electrification because of the quantity in use, their relatively heavy use, and general commercial availability as electric. As discussed above, the large forklifts, yard trucks and front/side loaders are not currently as conducive to electrification.

An emissions analysis reveals that converting, for example, 100 forklifts and 20 gantry cranes to electric may result in NO_x emissions savings of 134 tons per year (a 6% decrease) and PM emissions savings of 24 tons per year (a 16% decrease).

With the help of funding through one or more of the means described above, the installation of this equipment as electric may be a cost-effective, operationally efficient strategy to reduce emissions at the Port of Long Beach.

The Port of Toledo

In light of the equipment that currently operates at the Port of Toledo, and considering electric equipment availability and cost, it is recommended that the small forklifts (1-4 tons) and the two large cranes – Big and Little Lucas – operating at the Port be converted to electric. Small forklifts are an obvious choice for electrification because of their relatively heavy use and general commercial availability as electric. As discussed above, the large forklifts and front-end loaders are not as conducive to electrification.

Although the large wharf gantry cranes operating at the Port of Toledo are not heavy NO_x emitters (due to their usage),[123] they have been included as potential conversions to electric because of their age and commercial availability. Should they need to be replaced in the near future, electric options for their replacements are available.

An emissions analysis reveals that converting 10 small forklifts and the two large wharf cranes to electric may result in a 15 ton decrease in port-wide NO_x emissions.

With the help of funding through one or more of the means described above, the installation of this equipment as electric may be a cost-effective, operationally efficient strategy to reduce emissions at the Port of Toledo.

[123] If these cranes operated 2,500 to 4,500 hours per year, their electrification would be more effective as emissions reduction strategy. At high intensity ports with a vast quantity of containers shipments, such as Miami, Savannah, Houston, and Long Beach, large cranes would normally operate several thousand hours per year. Electric cranes for these larger ports would be a cost-effective solution.

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