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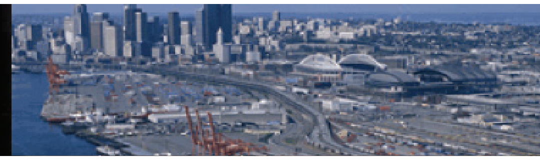

Environmental and Electric Strategies at Seaports: A Port of Seattle, Washington Case Study

Electrification of equipment used in port operations is one strategy used by seaports to achieve air emission reductions. This strategy, and specifically the use of electric cranes and shore power for cruise ships at berth, has been used successfully by the Port of Seattle.

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Emission Reductions at Seaports

Like many industries across the U.S., seaports have been intensifying their search of ways to reduce air emissions associated with their operations. The impetus to reduce emissions associated with port operations is often multi-faceted, ranging from governmental regulations and mandates, to environmental objectives, to mitigation measures associated with port expansion plans.

Electricity As a Means to Emission Reductions

Port-related equipment, ranging from small forklifts to cranes and even the ships themselves, has traditionally been fueled by diesel at ports around the world. Increasingly though, alternatives to this relatively dirty fuel have been utilized. Electricity is one diesel alternative that can often be cost effectively incorporated into port equipment with the result being substantial emissions benefits.

Electrification of port equipment, including cargo handling equipment and ships, is a strategy that has been employed by several ports, including the Port of Seattle, as one of many means to reduce emissions. Electric power can be utilized in a variety of ways at ports, including:

- *Replacement of diesel cargo handling equipment with electric equipment.* Cargo handling equipment, such as cranes and forklifts, used to load goods on and off of ships and around terminal yards may be electric.
- *Ship to Shore Power, or the use of shore-side electricity rather than ships' auxiliary engines for ships at berth.* 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. Substantial emission reductions can be achieved through cold ironing, with estimates of oxides of nitrogen (NO_X) reductions of over one ton per ship per day, in addition to particulate matter reductions.[1]
- *Electric and hybrid electric on-road vehicles.* On-road vehicles that operate at the port may also be electric and/or hybrid electric.

1 Environ International Corp, Cold Ironing Cost Effectiveness Study. Port of Long Beach., March 2004.

- *Truck stop electrification and truck refrigeration unit electrification.* 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.
- *Electrification of rail activities.* 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™).[2]
- *Electrification of construction and dredging equipment.* Finally, equipment used for port facility construction and maintenance, like that associated with dredging for example, can also be electric.

Environmental Stewardship at the Port of Seattle

As part of its strategy, the Port of Seattle has initiated a variety of emission reduction programs and projects across many port sectors, including operations, cargo handling equipment, and vessels.

The Port of Seattle is considered by many to be ahead of the curve on environmental efforts. The City of Seattle itself is geared toward maintaining attainment of the U.S. Environmental Protection Agency (EPA)'s National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants designated by EPA. Although the region is in attainment for all six of these criteria pollutants, the health of the region's air quality—and in particular sulfur oxides (SO_X), greenhouse gases (GHG), particulate matter (PM) and oxides of nitrogen (NO_X)—is carefully monitored.[3]

In its 2003-07 Plan, the Port of Seattle identified the demonstration of environmental stewardship as one of seven key strategies during this 5-year period. Improving air quality was one of the objectives identified in this plan that will help the port achieve success in environmental stewardship.[4] The Port cites many reasons for its commitment, including:[5]

- air pollution prevention,
- concerns about air toxics,
- commitment to maintaining air compliance status,
- environmental justice,
- climate protection,
- public and agency support,
- employee health,
- regional haze, and
- competitive business environment.

2 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
3 EPA Port Case Studies: *Port of Seattle.* http://www.epa.gov/cleandiesel/ports/casestudies.htm#seat
4 http://www.portseattle.org/about/organization/strategies.shtml
5 Addressing Air Emissions at the Port of Seattle: An Attainment Area Approach. Presentation by Barbara Cole, Port of Seattle. Montreal, Canada. October 7, 2007.

Table 1 Port of Seattle and Tenant Emission Reduction Projects

Operations	Cargo Handling Equipment	Vessels
• 99% biodiesel in seaport diesel • Plug in hybrid electric pilot project • Natural gas vehicles at airport • Equipment retrofit project • Gasoline vapor recovery • Green Fleet – hybrid vehicles • Biodiesel at Shilshole Bay Marina • Employee trip reduction and hybrid vehicles • Bike and pedestrian paths	• Equipment replacements • Retrofits with advanced pollution controls • Biodiesel and ultra low sulfur diesel use • Terminal electrification pilot • Electric cranes and reefers	• Cleaner engines • Cleaner fuels and additives • Sea water scrubbing • Shore power • Efficiencies

As part of its strategy, the Port of Seattle has initiated a variety of emission reduction programs and projects across many port sectors, including operations, cargo handling equipment, and vessels. Some of these projects include those listed in Table 1.[6]

Among those projects listed above, several—including electric plug-in refrigerated containers (reefers), electric cargo cranes, and shore power—are associated with electrification. It is these Port of Seattle activities that will be the focus of this case study.

Equipment Electrification at the Port of Seattle

At the Port of Seattle, electrification of equipment is used as one strategy employed to achieve its emission reduction goals. The following electric equipment, owned by either the Port or its tenants, is operated at the Port of Seattle:[7]

- 26 Electric Cranes
- 13 Electric Forklifts
- 21 Electric Pallet Jacks

These 60 pieces of equipment, representing 12% of the port's total cargo handling fleet, are fueled by electricity from the grid.

Shore Power at the Port of Seattle

Shore power is currently being utilized at the Port of Seattle's cruise ship Terminal #30 (Figure 1) by two cruise ship tenants, Princess Cruises and Holland America. This arrangement, a partnership between the Port, the two cruise lines, the U.S. EPA, Seattle City Light and the Puget Sound Clean Air Agency, involves passenger ships plugging into the city grid and turning off their engines while at berth, a process that results in substantial emission reductions from these giant ships.

6 Ibid.
7 The Puget Sound Maritime Air Emissions Inventory. Starcrest Consulting Group LLC. April 2007. http://www.maritimeairforum.org/emissions.shtml

Figure 1. Cruise Ships at the Port of Seattle (photo courtesy of the Port of Seattle)

Traditionally, both passenger and cargo ships have used diesel engines to maintain a minimum level of electricity while at berth. These engines generate emissions that can be avoided with the use of dock-side electricity from the grid.

Background

The Port of Seattle's cruise ship season lasts approximately five months, spanning May 1 through the end of September. During this period, cruise line companies including Holland America and Princess Cruises operate ships carrying between 1,600 and 2,600 passengers. Each cruise ship comes into port carrying passengers, pulls up alongside the dock at Terminal 30, disembarks passengers and typically loads another ship full of passengers for another voyage within 8–10 hours. This process is usually accomplished with one diesel generator engine kept running to maintain certain ship functions, including lighting and air conditioning. Princess Cruises and Holland America have voluntarily retrofitted several of their ships and the dock so that ships can turn off this diesel generator engine and instead plug into power offered dockside. A more detailed description of these projects follows.

The Port of Seattle is one of a very few ports that offers this "shore power" to some ships at berth. At its Terminal 30 Cruise Ship Terminal, two cruise ships can be hooked up to shore power at one time, making Seattle the only port in the U.S. with this capability.[8] In addition to the Terminal 30 shore power operation, the Port of Seattle also offers shore power facilities to other vessels, including large fishing vessels, docked at its Terminal 91.[9]

Traditionally, both passenger and cargo ships have used diesel engines to maintain a minimum level of electricity for the ship while at berth. These engines generate emissions that can be avoided with the use of dockside electricity from the grid. However, ships and the terminals at which they berth need to be retrofitted in order to employ this strategy, often proving to be very costly. As a result, few ports currently offer shore power as an option. The few that do, such as Seattle, do so on a voluntary basis. However, a proposed regulation mandating cold ironing at some ports in

8 http://www.portseattle.org/news/press/2006/08_18_2006_52.shtml
9 Port of Seattle Memorandum, August 22, 2007. http://www.portseattle.org/downloads/about/commission/RM_20070828_7b_memo.pdf

California[10] may change that. In addition to California's proposal, the U.S. EPA has requested that the International Maritime Organization implement more stringent ocean going vessel emission limits,[11] which may also increase pressure on some ports and their tenants to offer shore power, one way in which achieving more stringent emissions standards can be met.

Princess Cruises and Holland America Shore Power Projects

In 2005, Princess Cruises (operated by Carnival Corporation) was the first port tenant at Seattle to invest in the cold ironing technology, after having used shore power successfully in Juneau, Alaska. At the Port of Seattle, this cruise line company initially upgraded two of its ships so that they were shore power compatible, spending about $1.5 million including terminal upgrades. Currently, Princess Cruises has retrofitted seven of its cruise ships that call at the Ports of Seattle and Juneau with the necessary equipment to utilize shore power while at berth. They have helped to create what may be a standard for shore power cable, connectors and transformers that allows it, as well as their sister company Holland America and others, to utilize shore power at any cruise port that offers it.

Holland America, also owned by Carnival Corporation, operates cruise ships out of Seattle, and has also embraced shore power. They recently converted three Vista Class cruise ships and paid to install the associated dockside infrastructure so that shore power can be utilized while their ships are docked.

Project and Operating Costs

The cost was partially offset by the U.S. EPA and Puget Sound Clean Air Agency which provided grant funding to assist with the cost of the project.

Princess Cruises' shore power project at Port of Seattle cost $2.7 million, including $1.7 million for landside infrastructure and $1 million ($500,000 per vessel) for shipside retrofit costs. During the 2007 cruise season, Princess Cruises expected to spend $216,000 to operate shore power at Terminal 30; $106,000 of this expense is for electricity and $110,000 is for set-up, testing, and electrician labor to connect the vessels.[12] It should be noted that this estimate is a 2007 estimate only and will change in future years according to the price of electricity.

Holland America's shore power project at the Port of Seattle cost $4.8 million, including landside infrastructure costs of $1.5 million, and ship retrofit costs of $1.1 million per vessel. Two of Holland America's passenger ships, the ms Noordam and the ms Oosterdam, consume about 63 megawatt-hours of electricity while hotelling during their 8-hour port calls. In 2006, the average cost of a megawatt-hour of electricity in the northwest region was $53.50, for a total cost of $3,371 per call to use shore power. [13] The alternative—running a diesel engine that consumes 12.5 tons of fuel at a cost of $365 per ton while hotelling—cost approximately $4,563 per call.

10 http://www.arb.ca.gov/ports/shorepower/septdraftreg.pdf
11 US EPA Press Release. *U.S. Proposal to Cut International Ship Emissions Finds Key Support.* June 28, 2007. http://www.epa.gov/otaq/oceanvessels.htm#imo
12 Ibid.
13 This does not include labor costs associated with shore power.

Table 2 Shore Power Project Costs

Project/No. of Ships	Project Cost per Ship	Project Infrastructure Costs	Total Project Cost
Princess Cruises 2 ships	$500,000	$1.7 million	$2.7 million
Holland America 3 ships	$1.1 million	$1.5 million	$4.8 million

Together, the Holland America and Princess Cruises shore power projects have cost approximately $7.5 million (Table 2). This cost was partially offset by the U.S. EPA and Puget Sound Clean Air Agency which provided $75,000 in grant funding to assist with the costs of the project ($50,000 for Princess Cruises and $25,000 for Holland America Line).[14]

Utility Perspective at Seattle

The local Seattle utility, Seattle City Light, was a partner in both of the shore power projects described above. They assisted the cruise line companies with electrical requirements and setup. Seattle City Light offers typical interruptible peak rates of 5.33 cents per kilowatt hour on Saturdays and off peak rates of 3.56 cents per kilowatt hour on Sundays; cruise ships come into port only seasonally and during the weekends.[15] These rates may also be subject to demand charges.

Seattle City Light purchases $10,000 in greenhouse gas (GHG) offsets annually from each cruise line. About 1500–2000 GHG offsets are created as a result of the cruise ships plugging into the grid instead of using their diesel engines while docked.[16]

Shore Power Requirements

Investment in electrical infrastructure is most often necessary in order to utilize shore power at a port. Most ships and cruise liners are not currently equipped to plug into shore side power, necessitating onboard modifications in order to cold iron. In most cases, the terminals that these ships berth at will also need to be modified with electric infrastructure. Electrical transformers are also necessary at the terminal or on board the ship.

14 *Port of Seattle Cuts Vessel Emissions by 29% Annually and Saves 26% on Energy Costs Per Call.* Sarah Rapp, Port of Seattle. Clinton Climate Initiative, 2007. http://www.c40cities.org/bestpractices/ports/seattle_vessels.jsp

15 Correspondence with Corrine Grande and Lynn Best, Seattle City Light, 9/07, 10/07.

16 Ibid.

At the Port of Seattle, both the terminal and the cruise ships underwent upgrades. Landside at the Port, power is transmitted from an onshore substation for each cruise line equipped with a dual voltage 16.25 megawatt capacity transformer (Figure 2) that supplies power to the ship, which is typically a 6.6kV or 11kV class. Shoreside monitoring and protection is achieved with a relay system. Power is carried to each ship through five cables that are routed through a grounding switch (Figure 3).[17]

17 *Shore Power Projects.* Presentation by: Mike Watts, Cochran Electric; Dean Brown, Princess Cruises; Per Thunem, Callenberg Engineering. Alternative Maritime Power (AMP) Conference Los Angeles Harbor Hotel, San Pedro, CA April 24–25, 2006.

Figure 2. Shore Power Transformer and Metering Equipment at Port of Seattle (photo courtesy of Mike Watts, Cochran Electric)

Figure 3. Shore Power Cables (photo courtesy of Mike Watts, Cochran Electric)

Onboard, each ship has a custom electrical connection cabinet that automatically connects its electrical network to the on-shore utilities. Electricity is transmitted from the transformer ashore to the vessel via five 3-inch diameter flexible cables that hang festooning-style on a special gantry system on the docks. The actual cable connection on the vessel is a traditional, very large male/female plug and socket (Figure 4). The gantry and festooning equipment are designed to accommodate the rise and fall of the tide.[18]

Shore power offers substantial environmental benefits as well as overall fuel use reductions.

Shore Power Benefits

Shore power offers substantial environmental benefits as well as overall fuel use reductions. Emissions, including carbon dioxide (CO_2), NO_X and particulate matter, are effectively reduced to zero for ships that cold iron at port as a result of not using the engines to generate power. For example, an estimated annual reduction for the 2006 season of 3,525 tons of CO_2 emissions has been attributed to the Princess and Holland America shore power operations. [19]

Conclusions

In general, the costs associated with shore power vary depending on several factors, including electricity rates. Use of interruptible and off-peak weekend power at shore power terminals may make a project more economically feasible depending on the regional costs of electricity. Currently, electricity in the Pacific Northwest costs less than marine fuel per hours of use.

18 Ibid.
19 *Port of Seattle Cuts Vessel Emissions by 29% Annually and Saves 26% on Energy Costs Per Call.* Sarah Rapp, Port of Seattle. Clinton Climate Initiative, 2007.

Figure 4. Cable Connection on Board Holland America Ship (photo courtesy of Brian Sisco, Southern California Edison)

In addition to electricity rates, recent studies have determined that the cost-effectiveness of cold ironing is also dependent on:

- how frequently a ship calls at a particular port
- how long that ship is at port
- energy demand required while at port.[20]

Furthermore, the type of ship at berth is also a factor in determining the cost of shore power. A recent California Air Resources Board study has estimated that shore power is most economically effective for container, passenger and reefer cargo ships.[21]

But, given these limitations, shore power can be an economically and environmentally viable alternative for some ships as they dock at port. The Port of Seattle, along with Princess Cruises and Holland America its tenants, has shown that shore power can be successful.

20 http://www.arb.ca.gov/msprog/offroad/marinevess/presentations/110904/scaqmd.pdf.

21 Evaluation of Cold Ironing Oceangoing Vessels at California Ports. California Air Resources Board. March 6, 2006. http://www.arb.ca.gov/ports/shorepower/executivesummary.pdf

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