ELECTRIC POWER RESEARCH INSTITUTE

Electrification at Ports: A Port of Houston, Texas Electrification Case Study and Options for Electric Cranes

Environmental strategies can be effective in achieving emissions reductions at seaports. Practices ranging from electrification of equipment used in port operations to development of emissions inventories and the use of shore power to provide electricity to ships at berth are among many successful strategies used at ports. For ports that are facing operations expansion and the construction of new terminals, there is even greater opportunity to incorporate "green" or environmental strategies into new building design. At the Port of Houston, for example, a new terminal called Bayport has been called a Green Terminal by many because of the environmental components that have been incorporated into its design. One Bayport component is its use of electric ship to shore cranes. The use of these cranes at Bayport, as well as general information about them in a set-aside text box, will be highlighted in this case study.

Emission Reductions at Seaports

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

Using Electricity to Achieve 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 be cost effectively incorporated into port equipment with the result being substantial emissions benefits.

Electrification of port equipment, from cargo handling equipment to ships themselves, is a strategy that has been employed by several ports, including the Port of Houston, as one of many means to reduced 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 to the ship. A ship equipped for shore power

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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 (NOx) 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.
- ***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 electric, although the most popular alternative to date is the hybrid battery locomotive which has 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.

One way to implement some of the above strategies, perhaps maximizing not only emissions reductions but also potential economic efficiencies, is to incorporate environmental components into the design of new construction at ports, something that many ports with expansion in mind will go through in the next decade.

The Port of Houston is one such port that, when faced with expansion and a new terminal, took advantage of the opportunity to incorporate features such as additional electric capacity to make its new Bayport facility a state of the art terminal.

A Port of Houston, Texas Case Study

The Port of Houston Authority (PHA), the sixth largest port in the world, is committed to environmental stewardship. When the Port's commission and executive office gave a directive to staff to find clean air emission technologies for port operations, they did just that.[3] To accomplish this, goals were set and projects identified, including targeting clean technologies for cargo handling equipment and off road diesel engines. To this end, the PHA has:

- Conducted an emissions inventory
- Repowered its fire boat engine using cleaner diesel engines meeting International Maritime Organization standards
- Purchased on road and off road equipment with cleaner engines
- Developed an Environmental Management System
- Purchased electric cranes

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

[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] Clean Air Initiatives through TERP Funding. Presentation by Dana Blume, PHA. February 9, 2006.

In addition to these activities, the port committed to building a new "green" container terminal, Bayport, which opened its first phase for business in 2007.

Bayport – The New Green Terminal

[Bayport] will have a maximum capacity of about 2.3 million twenty foot equivalents (TEUs), a 200% increase over the Port's current container handling capacity.

The Bayport Container and Cruise Terminal, a $1.4 billion project, is being constructed over a period of about 20 years. Although Phase 1 of Bayport, which opened in early 2007, includes just one container berth and 65 acres (Photo 1), the full facility, which will be built in phases will include 1,043 acres with enough space for seven ships and a 378 acre container storage yard. It will have a maximum capacity of about 2.3 million twenty foot equivalents (TEUs), a 200% increase over the Port's current container handling capacity.[4]

Photo 1: Port of Houston's Bayport Facility (*Compliments of Port of Houston Authority*)

In designing Bayport, the PHA was determined to use the highest environmental standards and procedures. The terminal's design includes the following environmental components:[5]

- Preservation of coastal prairie habitat plan with Texas Parks and Wildlife
- Use of clean fuels and clean engine technologies in equipment
- Construction specifications
- ISO 14001 certified
- 3-mile long buffer zone around the facility with 20' sight and sound berm
- Lighting specifications to limit night-time impacts
- Wetland replacement plan with 3:1 ratio

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[4] Port of Houston press release. "Port of Houston Authority Tests Operations at Bayport." December 8, 2006.

[5] Port of Houston press release. "Environmental Agencies give Bayport Green Light". Oct 1, 2003.

- Creation of 200 acres of inter-tidal marsh using dredged material
- Procurement of 4 electric ship to shore cranes from manufacturer ZPMC; 2 additional cranes were added in late 2007 and a total of 21 electric ship to shore cranes are expected at full build-out
- Infrastructure to support shore power

These features, some voluntary and some designed as mitigation measures for the construction and operation of the terminal, were developed with input from the public as well as government agencies looking to reduce the impact of the project.

Environmental impacts were considered not just in the design of Bayport but also in the construction of Bayport. The PHA considered environmental factors such as air pollution in the pre-construction phase of the Bayport construction project. In order to minimize the environmental footprint of the project, contractors were educated on emission reduction technologies, and a NOx emissions calculator was developed in order to estimate project emissions. Potential Bayport construction contractors were required to demonstrate that emissions from their construction equipment would be less than 25 tons in any rolling 12-month period.[6]

Among the many environmental components integrated into... Bayport...is the use of electric power for the facility's ship to shore cranes.

Among the many environmental components integrated into the design and operation of Bayport is the use of electric power for the facility's ship to shore cranes and, perhaps in the future, for the ships that call there. Cranes and ships that come to call at the dock are significant sources of emissions at the Port of Houston; cranes comprise 10% of all cargo handling equipment emissions at the Port and ocean going vessel (OGV) hotelling[7] comprises 44% of all OGV emissions.[8]

Bayport's Ship to Shore Cranes

Bayport's ship to shore cranes (Photo 2 below) are all electric $7.5 million pieces of equipment purchased from Shanghai Zenhua Port Machinery (ZPMC), a Chinese crane manufacturer. The cranes have been set back from the face of the wharf 20 feet for safety and operational flexibility to meet industry standards. The cranes can reach out 178 feet and can pick up a container weighing as much as 65 tons. Even though they are heftier, the new cranes are 15 percent faster than anything in PHA's existing inventory.[9]

Specifications for the crane include:[10]

- Maximum Noise – 85 decibels
- Service Required – 12,470 volts
- 1,600 tons weight (static) with a 100 foot lifting height
- 65 long tons under spreader
- 80 long tons under cargo hook
- Trolley speed is 800 feet-per-minute and they can hoist a rated load 250 feet-per-minute

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[6] EPA Port Case Studies. Port of Houston Authority Terminal Construction. http://www.epa.gov/cleandiesel/ports/casestudies.htm#pha

[7] Hotelling is the term used to describe the practice of maintaining ship power while at berth.

[8] "Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level. Final Report." April 2005. ICF Consulting for the Federal Highway Administration.

[9] http://www.portofhouston.com/pdf/pubaffairs/PortReport-May06.pdf

[10] Port of Houston Authority Fact Sheet: Bayport Ship to Shore Cranes. May 2006.

Photo 2: Bayport's Ship to Shore Cranes (*Compliments of Port of Houston Authority*)

Electric cranes [can serve] as a "platform for future technologies" to enhance efficiencies.

Roger Guenther, Bayport General Manager, states that most ports these days use electric ship-to-shore cranes instead of diesel, particularly when there are no mobility constraints such as extended operating area with a reach beyond what a power cord can offer. The capital costs associated with these electric cranes are comparable to diesel models and they offer operating and maintenance cost efficiencies. Electric cranes have the added advantage of serving as a "platform for future technologies" to enhance efficiencies. Instead of replacing old, obsolete equipment, the cranes allow for easier upgrading. At ports, more efficiency means more cargo.[11]

There may also be efficiencies associated with ship to shore crane conversions for ports with older diesel equipment who wish to convert to electric. Costs for these conversions can be offset by incentive programs that some states offer – the Texas Emission Reduction Program in Texas[12] and the Carl Moyer Program in California[13] for example – for cleaning up diesel equipment. Once converted, these now electric cranes may offer the emissions and maintenance benefits associated with an original equipment manufacturer electric crane.

For example, the Georgia Ports Authority converted its ship to shore cranes to electricity in 2003. The $4.7 million project reduces environmental emissions from the high sulfur diesel fuel by 415,658 pounds per year. It also reduces the risk of environmental hazards caused by diesel and coolant spills. Additional benefits of electrification will come in the form of safety, operations and maintenance cost-savings. The crane conversion process included installing a medium voltage diesel disconnect, a low-voltage breaker stack, associated wiring and a new cable reel that is eight meters in diameter. Infrastructure preparation included building a switchgear room at the dock and installation of cabling for the conversion under the dock.[14]

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[11] Roger Guenther, PHA. EPRI Non Road Transportation Group Meeting, Houston, Texas. October 2007.

[12] http://www.tceq.state.tx.us/implementation/air/terp/

[13] http://www.arb.ca.gov/msprog/moyer/moyer.htm

[14] *Georgia Ports Authority Goes Electric*. Marine Link World Maritime News. July 18, 2003.

In order to power its new cranes, Bayport was constructed with its own electrical substation, something that other PHA terminals do not individually have. The PHA spent $3.4 million to build this substation, which was specifically designed to power the new cranes, in addition to terminal buildings, equipment, and in the future ships at berth. Bayport has two parallel 138 kV feeder lines coming into this substation, with a loop switch for each electric crane.

Shore Power Possibilities

In addition to the electric cranes described above, the Port of Houston has also paved the way for the possibility of utilizing shore power at its new Bayport facility by installing the infrastructure necessary to do so at its new cruise ship terminal. Both electrical power supply and the conduits necessary for shore power if and when it is offered at the Port of Houston were put into place during construction of Bayport.

When a new terminal or facility is constructed with shore power capabilities, cost and design efficiencies may be achieved when compared to retrofitting an existing facility.

Traditionally, 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 shore power. Because shore power requires specific dockside electric infrastructure, many ports looking to implement this strategy are faced with costly electric retrofits at the terminals where shore power would be implemented. When a new terminal or facility is constructed with shore power capabilities, cost and design efficiencies may be achieved when compared to retrofitting an existing facility. Although the Port of Houston Authority has no specific plans to offer shore power at Bayport, by including these electrical features in the design of the new Bayport facility, the PHA will be able to increase the cost effectiveness of shore power if it is implemented in the future.

The ABCs of Port Cranes

All-electric cranes, including rubber-tired gantry cranes, rail-mounted gantry cranes, and ship to shore cranes, are becoming more widely used at port authorities today. Traditionally powered by diesel, these substantially cleaner electric cranes can offer many advantages, including reduced air emissions, operational efficiencies, and cost benefits.

Ship to Shore Cranes

A ship to shore (STS) crane, also known as a quay crane among other names, is a large dockside crane that moves containers to and from ships (see Photo 3 below). STS cranes have a lifting device attached to them called a spreader that picks up and moves containers.

Container Cranes are generally classified by their lifting capacity, and the size of the container ships they can load and unload containers. A modern container crane capable of lifting two 20 foot long containers at one time will typically have a rated lifting capacity of 65 tons from under the spreader, although there are cranes that can lift much more than this.

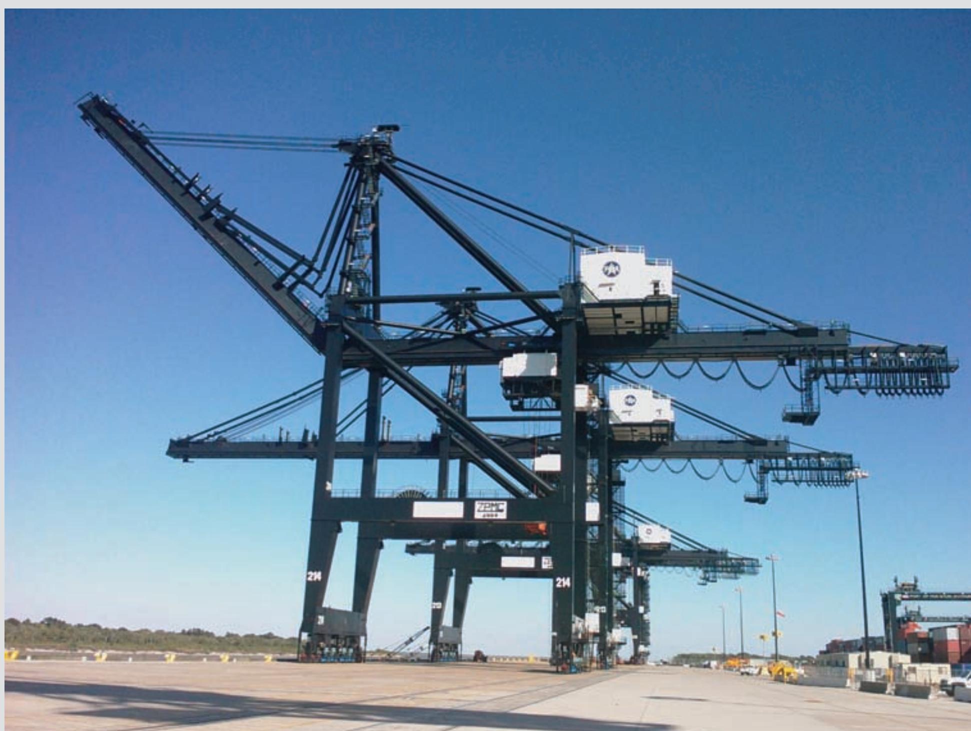

Photo 3: Ship to Shore Cranes at the Port of Houston's Bayport Facility (*Photo courtesy of Bryan Coley, Southern Co.*)

Although in the past, STS cranes were largely powered by diesel engines, they are now often found as electric models. These electric models which can cost upwards of $7.5 million, typically use electric power from the dock, with an electrical service requirement of about 12,000 volts. These cranes stay in a relatively small, well-defined area of the dock and as such electric power via power cord poses few if any mobility constraints.

Although most new crane purchases these days are electric, many older cranes operating at ports today are diesel. Many ports, such as the Port of Georgia, have seen the merits of converting these older diesel cranes to electricity. Such conversions may offer operating and maintenance cost efficiencies in addition to the environmental benefits associated with electric power compared to diesel.

Rail-Mounted Gantry Cranes

RMGs have the advantages of being driven by electrical power, cleaner, bigger lifting capacity, and higher gantry traveling speed with cargo.

A rail mounted gantry (RMG) crane, like that shown below in Photo 4 below, is a mobile gantry crane similar to the STS crane described above. Although its function is the same as the STS crane, the RMG crane runs along the dock on two rails, able to move along the wharf or dock to position containers at any point along the length of the ship. It is often used to transfer cargo containers from barges and ships to train cars. Like with the STS crane, containers are lifted by a spreader attached to cables. Rail mounted cranes come in a variety of models with different spans and overhangs and are, like STS cranes, widely available as electric models.

Photo 4: Rail Mounted Gantry Crane (*Courtesy of Melissa Silva, Starcrest Consulting Group, LLC*)

RMGs have the advantages of being driven by electrical power, cleaner, bigger lifting capacity, and higher gantry traveling speed with cargo. RMG cranes are particularly effective for rail/road transhipments of large quantities of containers. RMG systems can cost up to three times as much as the more commonly used rubber-tired gantry crane, but has the advantage of greater efficiency.[15]

[15] "Intermodal Trends: What Should we Expect in the International Supply Chain System?" Curtis Spencer. *Area Development Online*. Aug/Sept 2007. "http://www.areadevelopment.com/specialPub/aug07/ldwIntermodal.shtml" http://www.areadevelopment.com/specialPub/aug07/ldwIntermodal.shtml

Electric RMGs appear to be increasing their presence in US markets recently, and are seen more and more in port and even intermodal applications. Recently, BNSF announced that they will become the first American intermodal operator to order Konecranes wide-span electric RMG.[16] Konecranes RMG is all-electric and uses regenerative network braking units that enable energy released during lowering the load or during braking to be fed back to the local electric power grid instead of being wasted.

Rubber-Tired Gantry Cranes

Kalmar's Zero Emission Electric RTG…runs entirely on a plug in electric feed system, reducing NOx, CO and PM emissions to zero.

The rubber-tired gantry (RTG) crane moves containers to and from container stacks at ports. The RTG, shown in Photo 5 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 as containers are added and removed from the terminal.

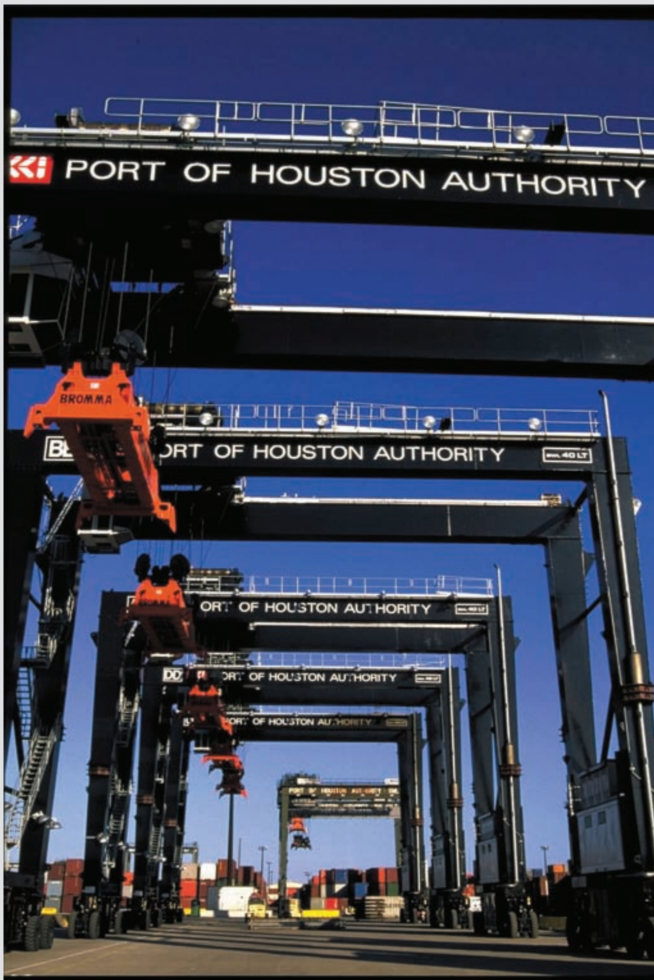

Photo 5: Rubber Tired Gantry Crane (*Compliments of Port of Houston Authority*)

These approximately $1.5–2 million pieces of equipment are a commonly seen at container ports such as the Port of Houston and can be found in either diesel or, to a more limited extent, electric models.

[16] BNSF the First American Intermodal Operator to Order Wide-Span Rail-Mounted Gantry Cranes 2007-08-02.

Standard diesel RTG manufacturers include Kalmar, Konecranes, Paceco and ZPMC from China. Some, including Kalmar and Paceco,[17] have recently begun to offer an electric, cable powered RTG. Kalmar's Zero Emission Electric RTG (photo 6), for example, runs entirely on a plug in electric feed system, reducing NOx, CO and PM emissions to zero. In addition to the environmental benefits of such a crane, lower maintenance costs may also be realized.[18] The Zero Emission RTG requires the following infrastructure on the ground:

- 3.3 kV connection box
- tension relief reel
- cable guide

Kalmar's Zero Emission RTGs are available at an incremental cost of approximately $200,000 above the cost of Kalmar's standard RTG, and are currently in use in Oslo, Norway, but not in the U.S. yet.[19] Although electric RTGs are not in use in the U.S. at this time, several manufacturers have expressed a willingness to offer this equipment in that market.

Photo 6: Power cord on a Kalmar Zero Emission RTG (*Credit: Kalmar*)

[17] Correspondence with Philip Tam, Paceco Corp; November 2007.

[18] Kalmar Zero Emission RTG marketing document.

[19] Correspondence with Dan House, Kalmar; November 2007.

In addition to traditional diesel and full electric RTGs, several crane manufacturers offer a lower emission combination diesel engine and electric RTG. Chinese manufacturer ZPMC, for example, offers a cable powered RTG that has only a small diesel generator that can be utilized when the crane is being moved.[20] Additionally, a prototype for a hybrid electric RTG has been developed by Terminal Systems Inc. and Railpower Inc. The two have recently completed a prototype of ECO Crane, a diesel hybrid system that is installed on a diesel RTG. The Railpower hybrid replaces the RTG's conventional diesel generator set with a smaller diesel engine/alternator and lead-acid battery. The system is in initial testing phase but is showing a preliminary 74% fuel savings compared to a traditional diesel RTG.[21]

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[20] http://www.zpmc.com/Newtech_detail.asp?Article_ID=577&Column_ID=18

[21] "Diesel Hybrid Rubber Tired Gantry Crane in Service in Canada". Green Car Congress, June 2007. "http://www.greencarcongress.com/2007/06/diesel_hybrid_r.html"

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