

Electric Ship to Shore Cranes: Costs and Benefits

EXECUTIVE SUMMARY

Pressure on ports to comply with air quality controls has caused them to look at cleaner technologies, including electric, for their diesel equipment needs. Equipment manufacturers have responded to this market demand by creating a wider variety and greater number of cleaner equipment that can be used at ports. As a result, more and more electric equipment is available to ports, including ship to shore (STS) cranes, historically sold only as diesel equipment.

Electric STS cranes are now so commonly available that they can be purchased at a comparable cost per unit compared to diesel models, which, combined with lower operating costs, can make these critically important pieces of equipment a great economic asset to ports.

Although many ports have made new electric STS crane purchases the standard, they may be left with older diesel models still operational at their facilities. Converting these older models to electric, as Georgia Ports Authority (GPA) has done at its Savannah facility, can be done and may allow ports to realize substantial economic and environmental benefits.

This case study describes not only the costs and benefits of electric STS cranes but also details GPA's experience with its electric STS cranes, both new purchases and diesel to electric conversions.

Introduction

A Ship to Shore (STS) crane, also known as a quay crane, is a large dockside crane that moves containers to and from ships at container ports (Photo 1). 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 containers on ships they can load and unload. 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.

These cranes, which are commonly available in either diesel or electric mode, stay in a well-defined area of the dock and typically work and idle constantly while a container ship is at port. An average crane diesel engine with a 1,500 horsepower (HP) engine running 3,800 hours per year uses approximately 69,000 gallons of diesel fuel; the calculated electric equivalent uses 890,000 kilowatt hours (kWh) of electricity.[1] These averages will be used throughout this study for our analysis.

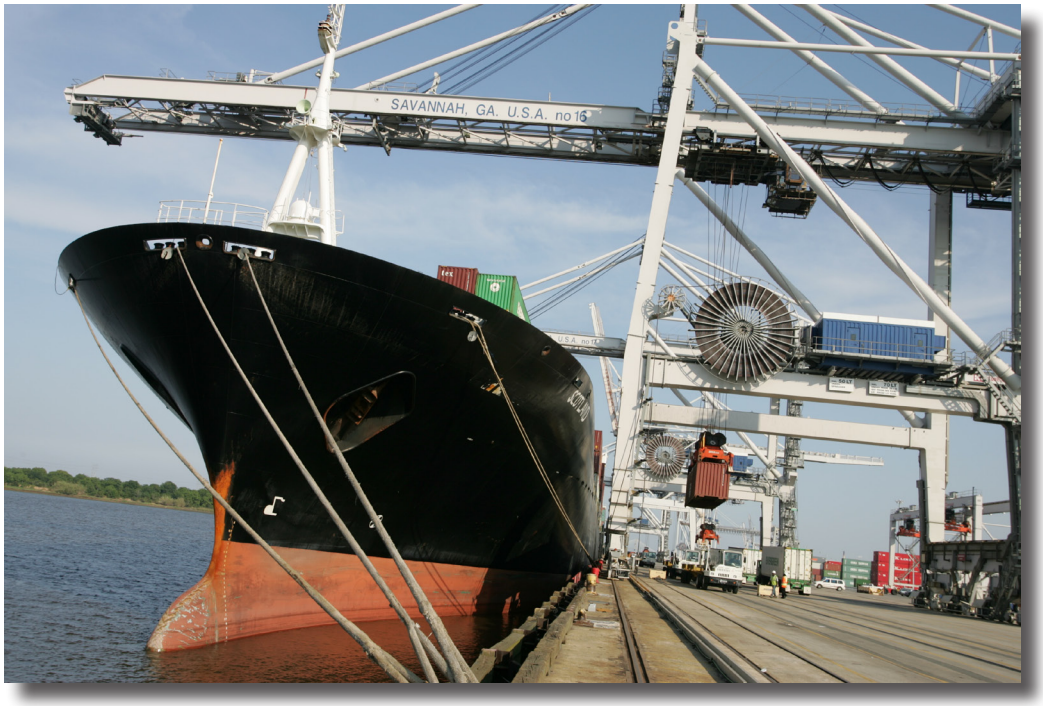
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1 Based on modeling using EPA's NONROAD model. EPA's NONROAD model uses load factors for diesel engines such as light,medium, and heavy use duty cycles. There are, respectively, 21%, 43%, and 59%. After careful consideration, the light-duty load cycle was adopted for this analysis, similar to what is used for the Diesel Industrial Material Handling equipment category. This load factor is, we believe, more in line with this stationary crane's usage and profile, where there are not the heavier hydraulic pump loads for travel, moving, booming, and winching that can be found on mobile cranes.

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Photo 1: Electric STS Cranes at Georgia Ports' Savannah Facility



(Photo courtesy of Russ Bryant and the Georgia Ports Authority)

Although in the past, STS cranes were largely powered by diesel engines, they are now often found as electric models (photo 2). These electric models typically use electric power from the dock with an electrical service requirement ranging from 4,160 to 13,800 volts depending on use. The power cord used for electric delivery may restrict the motion of these relatively stationary pieces of equipment.

Photo 2: Cable Reel and Electric Equipment on a Port of Houston Electric STS Crane



(Photo courtesy of Bryan Coley, Southern Company)

The impetus for this move toward electric STS cranes has been three-fold: 1) the recognition of economic, energy, and operational efficiencies of electric compared to diesel; 2) rising fuel prices; and 3) emission reduction pressures at ports.

Many new STS cranes are electric, but older diesel models can still be found at container ports. Several vendors offer services that effectively remove the diesel engine and components from the STS crane and install an electric motor to power the equipment. The conversion allows equipment owners to realize many long term benefits despite the initial investment in conversion costs and potential electrical infrastructure upgrades needed.

Benefits of STS Crane Electrification

STS cranes are workhorses for container ports, sometimes being used around the clock; therefore any efficiencies in the operation of the crane can be associated with benefits. Although available at a comparable price to its diesel counterpart, the electric STS crane can have:

- Greater energy efficiency resulting in reduced operating costs
- Reliability
- Lower maintenance costs
- Longer equipment life
- Emission reductions
- Safety

Economic Benefits

STS cranes, whether diesel or electric, typically cost the same - approximately $10-12 million. Any operating efficiencies realized through electric power will result in a lower life cycle cost for the equipment. The fuel source – electricity – for the electric STS crane is, in most parts of the U.S., less expensive than the fluctuating cost of diesel. Using an average industrial rate of $0.08 per kWh[2] compared to off road diesel at an average of $2.30 per gallon,[3] running these powerful cranes on electricity often works out to be a more economical fuel choice. For example, a diesel STS crane will use 69,000 gallons of diesel fuel in an average 3,800 hour year, while the electric STS crane will use the equivalent energy of 890,000 kWh of electricity – the economic benefit is almost $87,000 in fuel savings, as shown in Table 1.

Table 1: Fuel Comparison for an Average STS Crane*

Fuel	Diesel	Electricity
Rate	$2.30 per gallon	$0.08 per kilowatt hour
Amount Consumed/year	69,000 gallons	890,000 kWh
Costs/year	$158,206	$71,400

*Operating 3,800 hrs per year.

2 http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

3 http://tonto.eia.doe.gov/oog/info/wohdp/diesel.asp Average on road diesel price is $2.80, assuming reduction of $0.50 for taxes equals off road price.

Maintenance on electric cranes is reduced due to electric transformers versus diesel equipment requiring oil changes, belt changes and other needs of a diesel engine. Little data exists on what these maintenance cost savings are, but the Georgia Ports Authority (GPA) estimates that equipment down time on their electric cranes has been cut by approximately 25% compared to their diesel cranes, at an average maintenance cost of $20.80 per hour of operation for a diesel crane compared to $1.97 for an electric. GPA estimates this annual savings to be as much as $7,200 per crane.[4]

Another economic consideration is electrical upgrades and other infrastructure that may be required to run electric cranes from dock-side power. Every port will have their own needs and it would be misleading to estimate the dollar investment required for such infrastructure. Newer ports or terminals that have ample electric capacity and infrastructure in place may have no infrastructure upgrade needs, while other ports may need to make an initial investment in order to have the cranes effectively serviced. For example, the Port of Houston – at its newest terminal, Bayport, anticipated electrical needs and constructed the terminal with ample electric capacity to serve its many electric STS cranes. As a result, no initial additional investment in electric infrastructure was needed when the port installed its first electric cranes at this location. Other ports – like Savannah - have required electrical infrastructure upgrades to serve new and converted electric STS cranes.

Emissions from port operations are being scrutinized more and more because of environmental and regulatory pressures. As a result, diesel emission reduction programs have been established across the nation. These programs often include efforts to reduce diesel equipment emissions through the use of alternative fuels, including electricity. Equipment that run on electricity produces no operating, or tailpipe, emissions. The only emissions associated with electric equipment are those emitted through the generation at the power plant. This compares very favorably to emissions from diesel equipment, which in the case of an STS crane can mean several tons per year of many major pollutants.

Table 2 below illustrates what an average pre-1990 STS diesel crane emissions profile looks like.[5] Average carbon dioxide (CO_2) emissions of 776 tons per year for one STS crane is equivalent to emissions from approximately 150 average passenger cars.[6]

Table 2: Annual Emissions from an Average Diesel STS Crane[7]

Emissions (tons/yr)[8]				
NO_X	HC	CO	PM	CO_2
12.8	0.9	3.6	0.5	776

4 Communicated by Rich Cox, GPA on October 27, 2009.

5 Emission modeling occurred using EPA's NONROAD model. EPA's NONROAD model uses load factors for diesel engines such as light, medium, and heavy use duty cycles. There are, respectively, 21%, 43%, and 59%. After careful consideration, the light-duty load cycle was adopted for this analysis, similar to what is used for the Diesel Industrial Material Handling equipment category. This load factor is, we believe, more in line with this stationary crane's usage and profile, where there are not the heavier hydraulic pump loads for travel, moving, booming, and winching that can be found on mobile cranes.

6 *Assuming vehicle emits 25 lbs per year of NO_X and 5-6 tons per year CO_2. Environmental Defense Fund, Tailpipe Tally.

7 Based on 3,800 operation hours per year. Assumptions include: a 1,500 horsepower pre-1990 engine, equipment usage of 3,800 hrs per year, and CO_2 was based on the carbon content of the fuel using the following equation: CO_2 EF = (BSFC * 453.6 – HC) * 0.87 * (44/12) Where BSFC is from the NONROAD model and is expressed in terms of pounds per HP-hour.

8 NO_X: nitrogen oxide; HC: hydrocarben; CO: carbon monoxide; PM: particulate matter; CO_2: carbon dioxide. Modeling is based on EPA's NONROAD model.

As stated above, although an electric crane has no tailpipe emissions, there are emissions associated with the generation of electricity used to power the electric crane. Depending on the source of electricity, these emissions can range widely. A national average for carbon dioxide emissions from power plants of 1.35 lbs/kWh will be assumed for this analysis.[9]

Using the national average for CO_2 generation emissions discussed above, an STS crane is estimated to use 890,000 kWh per year, the generation of which is associated with 603 tons per year CO_2 emissions, a decrease of 22% compared to a diesel crane (Table 3). For the electric crane itself, there are zero tailpipe emissions at the port.

Table 3: Annual Total CO_2 Emissions Associated with Diesel vs Electric STS Crane

	Associated CO_2 Emissions (tons per yr)
Diesel Crane using 69,000 gallons per year	776
Electric Crane using 890,000 kWh per year	603

*Operating 3,800 hours per year.

Electric STS Cranes at Georgia Ports Authority: A Savannah Case Study

In the late 1990's, the Georgia Ports Authority (GPA) - the sixth largest container port in the United States in 2008 - made the decision to go electric. Their decision was motivated by environmental and equipment reliability considerations. In 1997, the port purchased two new electric STS cranes, like those shown in Photo 3 below, from KoneCranes for its Savannah, Georgia facility. The electric cranes were so impressive that the port decided to convert seven of its existing diesel STS cranes to electric over the course of the next few years.

The scope of GPA's electric crane project has continued to expand, first to a total of 17 electric STS cranes operating at Savannah's Garden City Terminal. Four new recent additions to the family – super post-Panamax electric cranes from KoneCranes - have just gone online in the fall of 2009, bringing the total number of cranes at the terminal to 23. Today, Savannah's STS terminal has one of the largest fleet of electric STS cranes in the country. Many of these cranes, like other modern electric STS cranes around the world, are capable of regeneration, or the generation of a portion (30% in the case of GPA's cranes) of their energy requirements through their own operations.

GPA's STS electrification project at the Port of Savannah was in reality a multi-phased project, consisting of:

- Diesel crane conversion to electric
- New crane purchases
- Electrical infrastructure upgrades

Electric Crane Conversion and Purchase

GPA's own staff conducted the STS crane conversion project design and project management. Construction packages were then put out to bid for component supply and installation work.

9 http://www.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/e-supdoc.pdf

Crane conversion work included removing the diesel generator system from the diesel STS crane, and installing on each crane:

- A new 13,800 volt main power cable reel,
- A new 13,800 high voltage disconnect,
- A 13,800 to 480 volt transformer,
- Structural support structures,
- Interconnecting cabling,
- Software program modifications (GPA uses Program Logic Controller).

The estimated cost for this conversion done in 2002 was $350,000 per crane. Although this seems like a big number, in fact it is less than 5% of the total purchase price of the crane and, perhaps more importantly, can be recouped over a matter of about 2 years in fuel savings.

New crane purchases for GPA were equivalent to diesel crane prices, at about $10-12 million per crane. There was no incremental cost associated with the purchase of electric equipment.

Operating Costs

The conversion and purchase of the Port's first 17 electric STS cranes was estimated to save approximately 1.2 million gallons per year of diesel from being used at the port. Now, at 21 electric cranes, even more diesel and its associated emissions have been avoided. Altogether, these cranes save the port approximately $3.3 million dollars per year in diesel costs at a diesel price of $2.30 per gallon. Compared to the purchase of electricity to power these cranes at $0.075/kWh, estimated to cost approximately $1.26 million for the 21 cranes using an average of 800,000 kWh per year each, electric is much easier on the port's bottom line.

Maintenance Costs

The Port is realizing not only operating expense savings but also maintenance expense savings. Georgia Ports estimates that each of their diesel STS cranes experienced about 34 hours per year of down time for maintenance; about 20% of this downtime was directly attributed to diesel-related issues. Equipment down time translates into lost revenue for a port. The electric cranes at the port, by comparison, spend about 19 hours per year in down time, a near 50% decrease in maintenance time. In addition, the Port expects significant increases in equipment life span compared to diesel – from an estimated 25 years for a diesel crane to an estimated 40 years for an electric crane - further tipping the economic scales toward electric. GPA experiences further savings on maintenance with electric STS cranes when it comes time to replace the cranes' electric transformers. At a cost of $75,000 compared to a diesel engine replacement at an average of $200,000, plus savings in the time it takes to complete these tasks, overall maintenance savings on a fleet of electric cranes has been substantial for GPA.

Infrastructure Requirements and Costs

In addition to the crane purchases and conversion work, electric infrastructure improvements to the terminal were required to insure that the cranes would be properly served electrically. GPA made an initial $2.5 million investment in electrical upgrades to accommodate the electric STS cranes, including:

- electrical power infrastructure to get power from Georgia Power's substation to the new crane switchgear building
- cabling from switchgear building to the crane vaults/pits

- new substation to serve the cranes
- transformers: 20+ mBA in order to insure redundancy.

In addition to the $2.5 million described above, an additional investment of $900,000 was required later to insure equipment redundancy and maintainability. The larger transformer size allowed for the equipment redundancy and maintainability demanded by the port, leaving additional capacity for GPA's future electricity needs at this terminal. GPA is also considering installation of some electric rubber tired gantry cranes (RTGs) at another of its terminals; these RTGs will be served by a separate substation.

From the port's utility (Georgia Power) perspective, the electric cranes are very easily served in part because of the ample capacity and because they are close to a transmission line.

Once the required electrical infrastructure was in place early on in the project, the incremental cost to add additional cranes at the terminal has been zero for GPA.

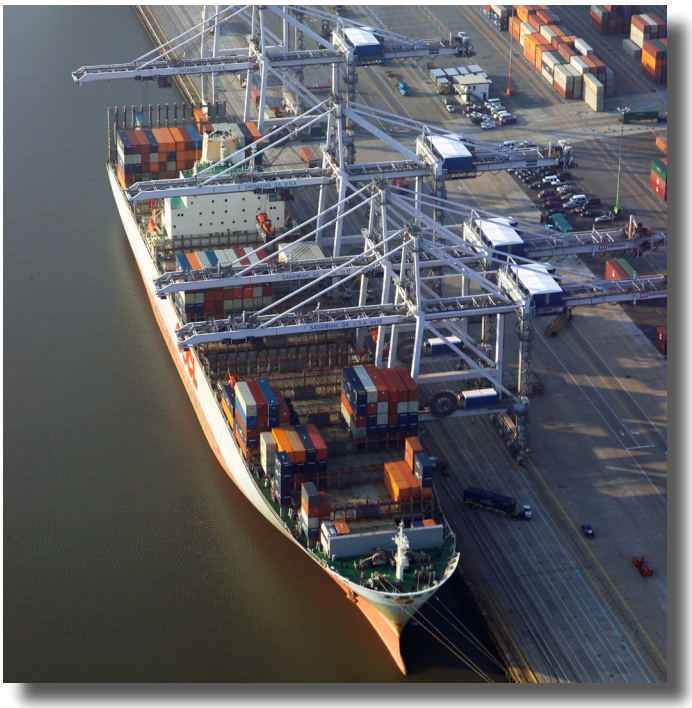
Environmental Considerations

In addition to cost benefits of Savannah's electric cranes, environmental benefits are also realized through emissions savings. Emissions from a diesel crane similar to those used by the Port of Savannah are approximately 776 tons of CO_2 and 13 tons of NOx per year. These localized tailpipe emissions are entirely avoided when replaced with an electric crane, which is associated with zero operating emissions. This environmental benefit is an important consideration for ports, many which face increasing pressure to decrease their contribution to regional air quality problems.

Conclusions

The electric cranes at GPA's Savannah facility (photo 3) have positively impacted not only the port's air emissions but also its financial bottom line. With approximately 1.5 million gallons of diesel fuel no longer being purchased to power the cranes, and electricity pricing in the area far more economical than the price of diesel, the port saves millions of dollars every year. Over the 25-40 year average life of an STS crane, the cost savings in the case of GPA are tens of millions of dollars (Table 4).

Photo 3: Electric STS Cranes in Operation at the Port of Savannah



(Photo courtesy of David Smalls and the Georgia Ports Authority)

Table 4: Cost and Emission Comparison to Diesel for GPA's 21 Electric STS Cranes		
	21 Diesel STS Cranes	**21 Electric STS Cranes (14 new 7 converted)**
Equipment Costs @ $10M ea	$210 million	$142.5 million*
Infrastructure Costs	$0	$3.4 million
Cost to Operate/yr	$3.3 million	$1.26 million
Fuel Cost over 25 yrs^	$83 million	$31.5 million
Annual CO_2 Emissions	776 tpy tailpipe emissions within the port	603 tpy generation emissions outside of the GPA
Lifetime** CO_2 Emissions (tons)	19,400 tons	15,075 tons

*includes $350,000 conversion cost x 7; ** based on average 25 year life. ^Not including maintenance costs. tpy: tons per year.

As it moves into the future, Georgia Ports – one of the fastest growing ports in the U.S. – plans to make even greater use of electric equipment at its facilities given the success of its electric STS crane project. Not only will additional electric STS cranes be purchased as growth demands it, at another terminal in Savannah, the Port will conduct a pilot program to test an electric Rubber Tired Gantry (RTG), the first of its kind in the U.S. If successful, the port will consider installing these cranes on a broader basis.

Conclusions

Electric STS cranes, currently the norm at ports across the globe, can offer vast reductions in operating costs. New electric cranes are available at a comparable price point compared to diesel, making operating cost efficiencies an important benefit. Existing, older model diesel STS cranes can also be converted to electric, with potentially millions of dollars saved and hundreds of tons of CO_2 emissions negated every year.

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