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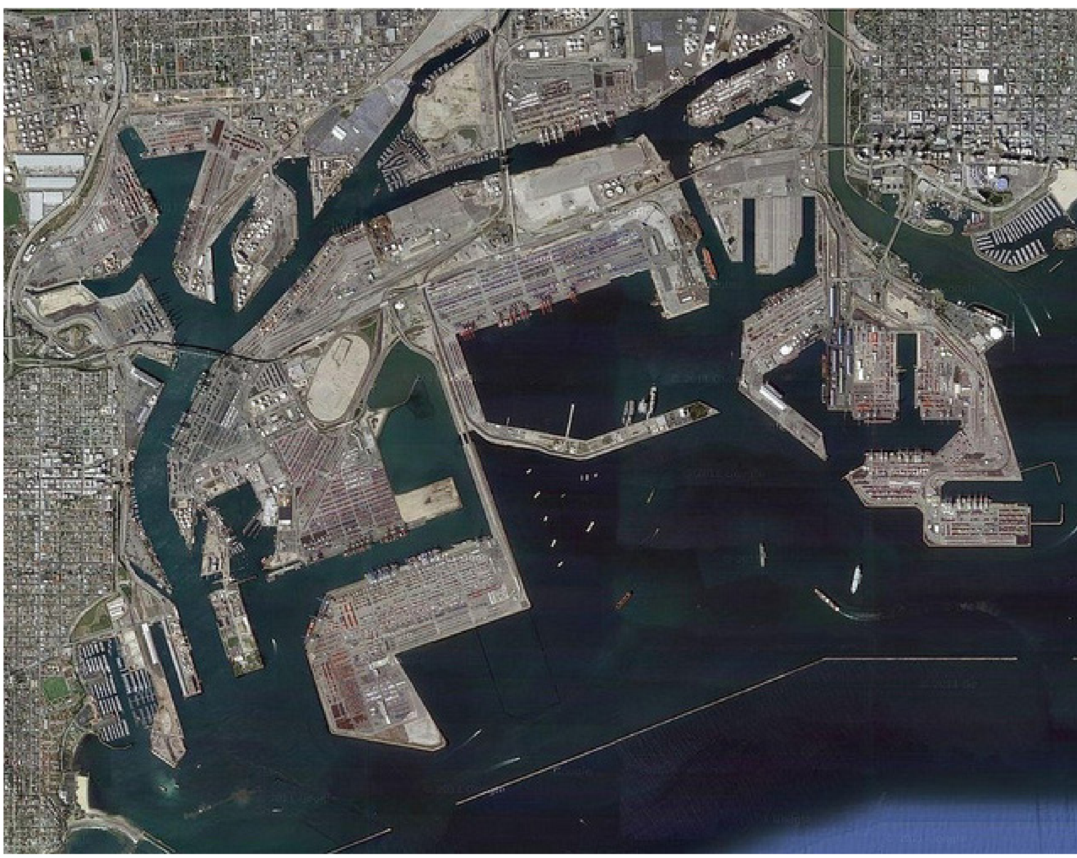
Moving Towards Resiliency:

An Assessment of the Costs and Benefits of Energy Security Investments for the San Pedro Bay Ports



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2013

Moving Towards Resiliency

OVERVIEW

The Aquamarine Institute, with support from the Port of Los Angeles and the Port of Long Beach, commissioned the UCLA Luskin Center for Innovation to create a framework to (1) study electricity consumption and (2) evaluate energy management strategies at the San Pedro Bay Ports. The resulting framework serves as a decision support tool to assess specific energy efficiency and local energy generation options. This framework could inform and serve as a foundation for comprehensive and collaborative energy management planning.

ABOUT

UCLA Luskin Center for Innovation

The UCLA Luskin Center for Innovation translates world-class research into real-world policy and planning solutions. Based in the UCLA Luskin School of Public Affairs and organized around initiatives, the Luskin Center addresses pressing issues of energy, transportation and sustainability in collaboration with civic partners.

The following people from UCLA worked on this project:

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ACKNOWLEDGEMENTS

The aforementioned authors appreciate collaborating with Sean Arian, Mark Vargas, Peter Peyton and others from the Aquamarine Institute. We also thank the staff of the Port of Los Angeles and the Port of Long Beach for providing information and other support necessary for this study. This includes Rick Cameron, Christine Houston, Captain John Holmes, Michael Christenson, David Libatique, Tim DeMoss, Kevin Maggay and Vahik Haddadian.

In Collaboration with Aquamarine Institute

AQUA MARINE INSTITUTE

The Aquamarine Institute is dedicated to providing the expertise, trust, and validation necessary to catalyze the development of a comprehensive Ports-wide strategy and implementation of energy self-sufficiency at the Port of Los Angeles and the Port of Long Beach.

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DISCLAIMER

The Luskin Center appreciates the contributions of the aforementioned individuals and their agencies and organizations. This document, however, does not necessarily reflect their views or anyone else involved. Port staff and others listed make no claims regarding the accuracy or completeness of the information in this report. Any errors are the responsibility of the primary authors.

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1. Introduction and Objectives

The Port of Los Angeles and the Port of Long Beach, collectively the San Pedro Bay Ports (Ports), are important transportation nodes that play a critical role in the national economy. As our national and regional economies have become more reliant on the Ports to facilitate commerce, the Ports are becoming more reliant on electricity to operate. This is due to multiple economic, technological, environmental and regulatory factors increasingly affecting the San Pedro Bay Ports.

The Ports face significant energy related challenges that impact competitiveness, national security, job creation and environmental goals. These challenges can be effectively addressed by developing and implementing an integrated energy management plan.[1] Integrated energy management planning can result in:

1) Increased Port competitiveness, through reduction of operating costs and increased reliability;
2) Increased energy resiliency in the Ports, thereby increasing supply chain resiliency and national security;
3) Regional job creation through the installation and maintenance of new energy technologies; and
4) Improved ability to most cost-effectively comply with environmental mandates and goals that will result in reduced greenhouse gas emissions and local air pollutants.

The size of these benefits will increase as regulations, environmental health concerns, and technological advancements drive future electrification of the Ports. The resulting upward pressure on electricity bills could be controlled through strategic investments in cost saving energy efficiency measures. Concerns over grid reliability and heightened security planning underscore that planning now for integrated energy management is timely and important.

A comprehensive energy management plan could complement and help to cost effectively implement the landmark San Pedro Bay Ports Clean Air Action Plan (CAAP). The CAAP creates a framework for reducing emissions, a key component of which involves serving the electricity needs of yard equipment, ships at berth (cold ironing), and other applications.

To maximize the aforementioned benefits, port officials will make critical programmatic decisions involving:

1) Energy efficiency investment options; and
2) Local, distributed energy generation investment options.

In order to make these decisions, port officials need to understand current and future patterns

1 The terms 'energy management' and 'electricity management' are used interchangeably within this report given the report's focus on electricity rather than other forms of energy.

of electricity consumption as well as how specific energy technology investments will influence those patterns. This report provides an initial framework that provides preliminary answers to these questions for each port.

While the Port of Long Beach and the Port of Los Angeles are different in important ways, they share the need to better understand how to adapt new energy technologies in order to achieve the aforementioned benefits. By sharing their experiences and analyses with one another, each port can reduce its costs of developing an integrated management plans and increase its likelihood of success.

1.1 Executive Summary

The Aquamarine Institute, with support from the Port of Los Angeles (POLA) and the Port of Long Beach (POLB), commissioned the UCLA Luskin Center for Innovation to create a framework with the following objectives.

Our first objective is to provide detailed descriptions of electricity usage and costs: 1) for the POLA and POLB, both port-wide and by terminal types, 2) in the present and in the near future planning horizon, 3) by types of technology within a typical terminal and 4) for important facets of electricity consumption like average, seasonal and peak demand. Our second objective is to undertake a preliminary scoping of the proto-typical energy investment opportunities that might comprise energy management strategies at the San Pedro Bay Ports (the Ports). Our third objective is to identify how collaboration between the Ports can expand the learning benefits while also reducing the financial costs of energy audits, field studies of promising energy technologies and joint solutions to energy resilience challenges. The resulting framework has the capacity to reveal the costs and benefits of engaging in specific efficiency and local energy generation options. The framework is a first step to inform and serve as a foundation for comprehensive and collaborative energy management planning.

1.1.1 Baseline and Future Electricity Consumption

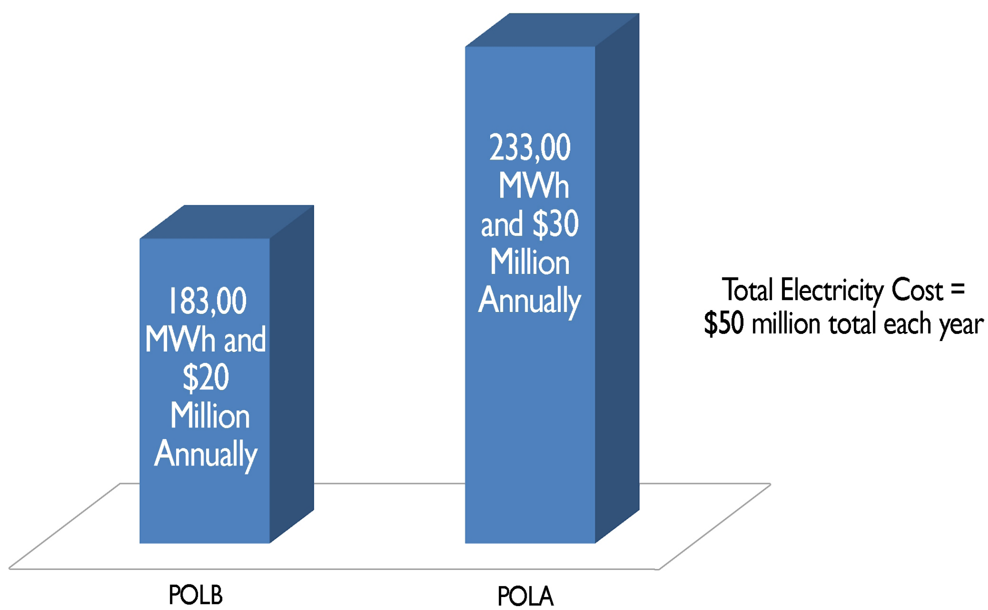
This study is the first of its kind to present an accessible description of electricity consumption at the Ports, looking beyond the numerous organizational boundaries, to facilitate a comprehensive understanding of how electricity is used throughout the Ports. This is not a straightforward task. There is not one centrally managed electrical system within the Harbor Districts. Instead it is many interconnected systems with hundreds of electricity billing meters, managed by multiple stakeholders with overlapping responsibilities. By taking a Ports-wide perspective, this report conceptualizes broader patterns and trends in electricity that may not be apparent from any single stakeholder's perspective. This is important because one can only understand the scope of the benefits of energy investment options by placing these options in the context of current and expected electricity consumption and cost patterns.

The following are some of the key findings from this report.

Energy Costs Likely Total More than $50 million a Year Currently

The activities that take place within the Ports consume significant amounts of electricity. If the Ports were single entities, they would each be among a small group of the very largest electric utility customers in Southern California. We calculated that the various users of electricity at the Port of Los Angeles (POLA) collectively consumed 200,000 to 250,000 mega-watt hours in fiscal year 2012, costing approximately 30 million. We also estimate that the Port of Long Beach (POLB) consumed 150,000 to 200,000 MWh in calendar year 2011, with a price tag of about $20 million.

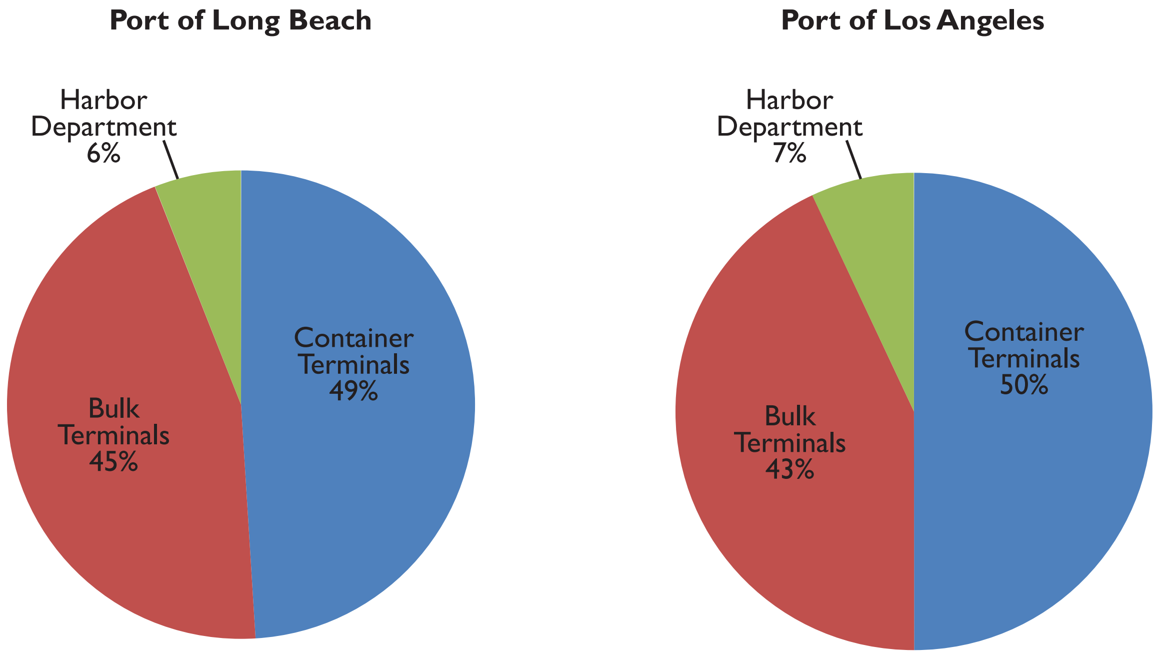
Figure 1: Current Estimated Total Electricity Usage and Cost



Container Terminals Use Roughly Half of the Electricity Consumed at the Ports and Terminal Operators Pay about $3 Million a Year on Electricity Charge

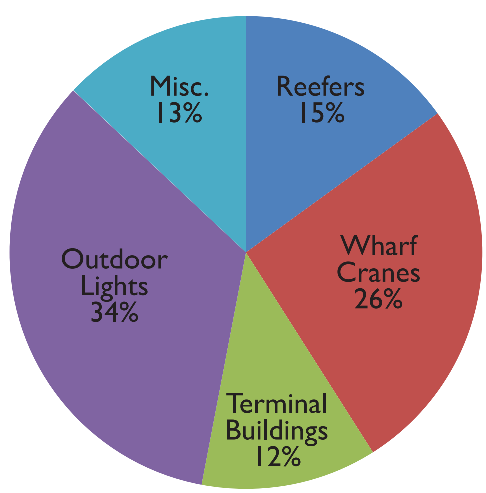
Container terminal tenants use roughly half of the electricity consumed by each Port during a year. Container terminals are the logistical anchors of our regional and national supply chains. POLA has eight major container terminals while POLB has five.

Figure 2: Share of Annual Electricity Consumption by Users in the Ports



With an understanding of the main drivers of electricity consumption at a terminal, terminal operators are better equipped to make strategic investments in energy efficiency. The investment schedule can also be aligned with that terminal's existing schedule for equipment replacement and upgrades. Figure 3 presents a breakdown of electricity consumption by technology for a protypical container terminal.

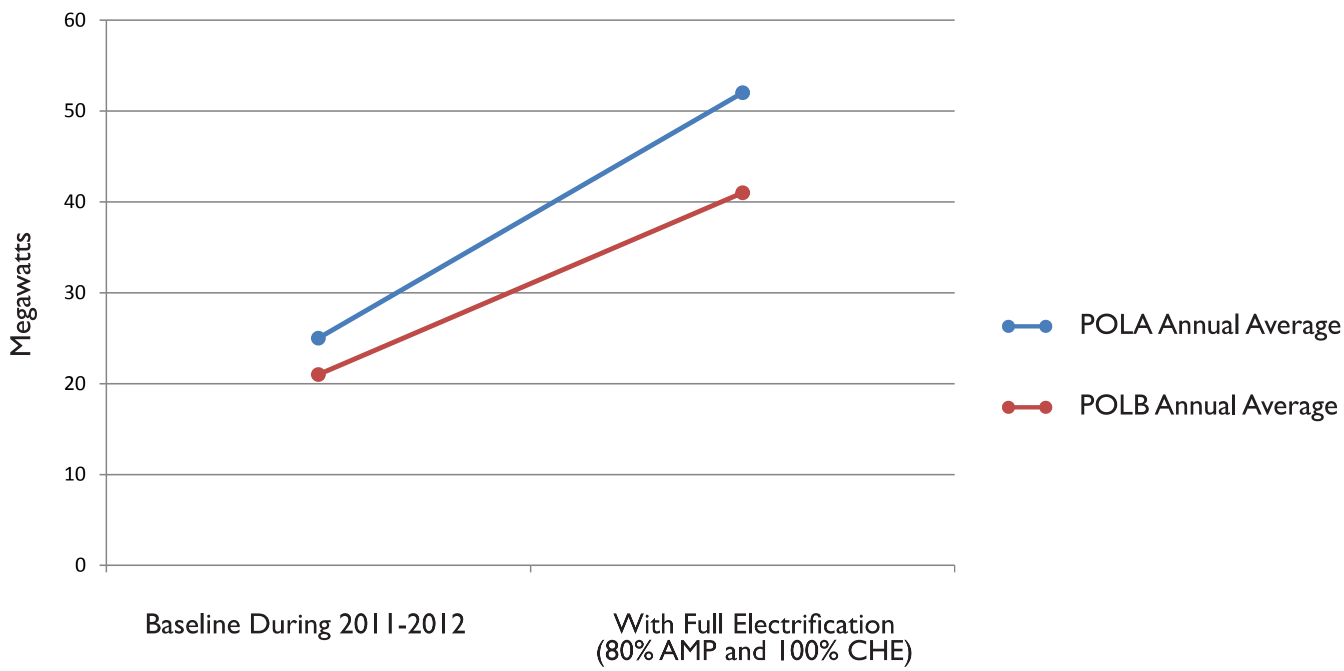
Figure 3: Share of Annual Electricity Consumption by Source in a Typical Container Terminal



Energy Consumption Could Double by 2020

Operational, regulatory, and environmental factors are leading to increased electrification of the Ports. Electricity usage and total cost will rise significantly in the next decade. We estimate that electricity consumption could approximately double within the next decade. We used conservative assumptions for our calculation. Actual energy usage will depend on many uncertain variables. Regardless of the exact amount, demand for electricity will increase dramatically in the near future.

Figure 4: Estimated Electricity Consumption Increases



Port tenants may not only require more electricity, but also are exposed to the risk of rising prices. The combination of increased energy demand and volatile prices will increase existing electricity related vulnerabilities.

Electrical Reliability Concerns Will Be Magnified by Increasing Consumption

Electrical supply disruptions already routinely impact container terminals. Instantaneous frequency or voltage variations that are not observable by typical commercial or residential customers can, for instance, stop an array of wharf cranes as they unload a container ship. The cranes have to be restarted and double checked for safe operations by a trained mechanic, while costing about $75,000 in damages for the first hour of delay.[2] Complete outages are more costly with economic impacts increasing dramatically based on the duration and geographic

2 These cost assumptions are representative of the planning figures shared during interviews with terminal representatives in POLA.

scope of the disruptions.[3] New equipment is increasingly controlled using solid state electronics, so it will certainly be more sensitive to power quality and supply disruptions. These types of technology shifts will make baseline electricity use, even without any consideration for further electrification, more challenging to manage, but increasingly important to do so.

Increasing Costs and Energy Reliability Concerns Can be Addressed with Energy Planning

Fortunately, costs can be controlled and reliably increased with integrated energy management. This includes evaluating options for 1) energy efficiency, 2) renewable energy generation and 3) dispatchable energy generation, as the following sections highlight. Evaluating and strategically prioritizing energy investment options requires understanding the context of current and expected electricity consumption and cost trends, as just described. Thus, the first half of our study facilitates the second half.

1.1.2 Energy Management Strategy Assessment

The UCLA Luskin Center qualitatively reviewed energy management options in the following three categories:

1) Energy efficiency
2) Renewable energy, focusing on solar
3) Dispatchable generation options, focused on:
    - o Reciprocating engines
    - o Combustion turbines and microturbines

We then quantitatively evaluated specific project options within those three technology classes using parameters described in the Report's Appendix. The criteria to evaluate projects included:

1) Competitiveness: economic costs and benefits at the Port and terminal levels
2) Jobs: regional employment impact
3) Environment: air pollution reduction impact
4) Security, Operational & Other Concerns: energy security and other key considerations

The following is a summary of these scenario assessments.

Energy Efficiency is a Clear Win that Could Save More Than $8 Million per Year

Conservation and energy efficiency measures are integral to realizing the benefits of energy management. Based on our calculations of the benefits of using existing technology, energy efficiency measures have a clear economic value proposition. There are myriad small

3 Estimates of the economic harm caused by disruptions in the Ports vary in magnitude but are all significant. A Congressional Budget Office report from 2006 cites previous studies which estimate a one-week shutdown of container shipments in the Ports of Los Angeles and Long beach could cost the U.S. economy up to $150 million per day. Other estimates provided higher figures.

opportunities that cumulatively can have a large impact. Many of these have been overlooked historically, and thus present opportunities for attractive cost savings.

An optimistic, but achievable target could be to save $4 million, per year per Port, in electricity charges by the end of 2015 from the baseline years. The reduction of demand not only saves money on monthly electricity bills, but also can reduce the need for up-front investment in supply alternatives. And fortunately, energy efficiency projects typically do not require external development permits and can achieve results with a relatively quick turnaround. For these reasons, energy efficiency should be prioritized first in any Port program to manage energy.

Scenario: A reduction in demand intensity of 60% for all high-mast terminal lighting

- Competitiveness: A 60% reduction in demand intensity of high-mast terminal lighting could save 33,000 MWh and $2.4 million per year in POLA and 20,000 MWh and $2.1 million per year in POLB.
- Jobs: This investment at either Port would create 17 local full-time and part-time jobs in the region.
- Environment: It would also reduce carbon dioxide emissions by up to 17,000 metric tons per year in Los Angeles, and 11,000 in Long Beach.

A challenge is that energy efficiency opportunities are distributed throughout the Ports and cross organizational boundaries. Capturing these opportunities would require a coordinated effort to evaluate and prioritize the highest payoff projects. Energy efficiency measures are necessary, but alone are not sufficient to fully address reliability and continuity concerns. Energy efficiency can facilitate more comprehensive energy planning efforts.

On-site Renewable Energy is an Economic and Operational Challenge

On-site generation with renewable resources, such as solar and wind energy, is a visible statement with environmental benefits. Cost-effective, environmentally-focused projects can occur where space is not a constraint and incentives can be monetized. However, because these types of resources are space-intensive, they are not likely to be cost-effective when accounting for the high opportunity cost of space within the Ports. The energy produced, aligned with available spaces in the Ports, would make only a small contribution to total electricity consumption.

Another challenge is that these technologies produce electricity intermittently, not necessarily when the Port is using electricity. Standard configurations of on-site solar and wind energy devices are not designed to produce emergency backup power due to electrical interconnection and safety standards.

Scenario: One megawatt solar parking canopy

- Competitiveness: A one MW solar parking canopy is not likely to be cost-effective for either Port. It would produce up to 1,478 MWh per year, only about 5% of total consumption of a large terminal, and make no contribution to continuity or security with a standard grid-connection.

- Jobs: The regional impact on employment of this project would be about 28 full-time and part-time jobs created during construction period. After construction, it would support less than one job for the remaining operations and maintenance phase of the project.
- Environment: This project could reduce carbon dioxide emissions by 486 metric tons per year and thus would support Port climate action goals.
- Key Considerations: Although the system could be net-metered and grid-connected, it could not provide electricity during grid outages. It could be designed to offset the on-site consumption of a terminal operator and provide some co-benefits through shaded parking spots for employee-owned vehicles. It would make a highly visible environmental statement.

On-site Generation with Dispatchable Resources can be Cost Effective and Offer Other Primary Benefits but Would Require Additional Resources to Manage

For instance, Reciprocating Engines could Provide Continuity Benefits via Flexible Backup Power to Avoid Work Shutdown Costs in Case of Grid Outage

Reciprocating engines are internal combustion engines used in power generation applications. They are most often used for backup power or in specific applications where flexibility is an important concern. Reciprocating engines can be configured to burn a variety of fuels including natural gas or renewable biogas. They are relatively low cost to install but not particularly efficient and not designed to operate continuously for long periods of time. The primary advantage of this type of generator is operational flexibility. They can be started and stopped rapidly, with the output adjusted easily, especially if multiple engines operate in a coordinated fashion.

The extent of cost-effectiveness is dependent upon the utilization rate of the asset, the escalation of utility rates and long-term fuel costs. If the resources are primarily idle, used for infrequent backup emergency power, they have less opportunity to recovery their capital costs.

Scenario: 10 MW of reciprocating engines in a larger terminal to occasionally shave peak demand during routine operations or power critical loads in an emergency

- Competitiveness: This project could reduce operational expenses but because they would operate relatively infrequently, it does not provide enough savings to recoup the up-front investment on this measure alone. However, if 10 hours of delay are avoided per year and the avoided delay is worth $100,000 per hour, the continuity benefits might be valued at up to $8.5 million over the life of the project. This additional value might justify investment.
- Jobs: The project would support up to 84 full and part-time jobs during the construction period and 2 long-term jobs over the life of the project.
- Environment: The total carbon dioxide emissions impacts would be negligible because the engines would operate somewhat infrequently. During operation, the engines' carbon

dioxide emissions would be comparable or slightly greater than that of purchased power in Los Angeles. This type of project can be installed with Selective Catalytic Reduction (SCR) technology to reduce harmful local criteria pollutants, particularly nitrogen oxides.

- Security, Operations and Other Considerations: This type of generator can provide continuity benefits and flexibility for a terminal if the plant is designed to provide backup power in the event of a grid outage. It could be started and stopped rapidly, and the output can be adjusted easily, especially with multiple engines operating in a coordinated fashion.

Combustion Turbines could Support Energy Independence Objectives

Combustion turbines are the workhorses of modern power generation. They are powerful, efficient, flexible, and can be fired with a variety of fuels. Small and medium sized turbines can be sited on just a few acres with a relatively low profile. Larger plants could provide most of the energy needed at the Port of Los Angeles, and thus have a very significant effect on avoided electricity purchases from the utility. In the event of an outage, the generator would continue to supply power only to the most critical Port loads. The system controls and demand management system would shed non-essential load to keep the Port operating at a pre-defined level of service.

Challenges with this and other types of on-site, dispatchable generation could include external environmental permits, fuel cost and availability, optimal plant siting and the complexity of load balancing. When operated independent from the utility grid, the volatile load of most Port terminals presents a system balancing problem. Therefore, any dispatchable resources used in this manner must be able to match and follow dynamic Port loads. Designing a plant and the electrical system to operate in this manner would increase cost and complexity.

Scenario: An on-site 40 MW natural gas-fired combustion turbine with an enhanced local distribution and control system designed to operate at high capacity factors and sized only to the most critical loads

- Competitiveness: A large combustion turbine facility could save at least $200 million in avoided electricity purchases over the service life of the plant.
- Jobs: The regional employment impacts would be meaningful, supporting up to 226 job-years during the construction phase and up to 44 jobs per year during the operations phase.
- Environment: Relative to power purchased from the grid in Los Angeles, the carbon dioxide impacts would be a moderate reduction of up to 9,968 metric tons per year. The addition of SCR technology would minimize local criteria emissions.
- Security, Operations and Other Consideration: Reliability and security benefits could be realized by providing backup power in case of an outage or emergency, but this would require load balancing automation. These additional capabilities would add cost and complexity, but are feasible and likely cost-effective over the life of the facility.

1.1.3 Next Steps

This report is a high-level and foundational assessment of different approaches to electricity management. The conceptual framework offered is intended as a first step; it should be built upon as assumptions are validated, more data is obtained and further research is conducted involving electricity audits, engineering studies and technology analyses. At its core, this framework is designed to support informed policy and organizational decision making on electricity management projects, programs and planning. We offer the following recommendations for next steps:

1) Facilitate further research on relevant Port energy topics. This would involve further validating the model of this study with field data. We recommend conducting energy audits at the terminal level and other units at each Port. The energy audits would go beyond the scope of this baseline, high-level study to include more granular, detailed data. Other research could involve a port-wide security case study to: 1) determine how much energy it would take to maintain critical levels of port operations in event of a disaster or grid outage, 2) assess available space for energy generation, and 3) analyze what it would take for self-generation to maintain critical levels of port operations during a disaster or grid outage.
2) Measure and verify to identify best practices and technologies. Learn from pilot demonstrations at interested terminals. The pilots would allow for testing technologies in real-world settings to reveal a nuanced picture about promising technologies and their actual potential. The results could be compiled into a comprehensive assessment of technologies that includes cost benefit analysis and best practices. Then, scale the lessons learned to other terminals.
3) Conduct comprehensive and coordinated energy management planning. With these recommended studies, the Ports would be well positioned to engage in integrated energy management planning, and go after federal and state funding (such as California's cap-and-trade revenues) to achieve the benefits of energy management planning.

1.2 Context: The Ports as Unique and Diversified Electricity Consumers

The Ports and their tenants purchase electricity from regulated electric utilities like any other utility customer. It is important for all energy-intensive industries, including the San Pedro Bay Ports, to manage energy usage and find opportunities to become more efficient and reliable. But the Ports deserve special consideration in terms of planning for electricity supply and consumption for several reasons.

First, the Port stakeholders are not typical utility customers. They operate a diverse mix of energy-intensive industrial machinery with highly variable electrical loads. Electricity consumption in the Ports is driven primarily by the continuous operations of global supply chains, not by the predictable schedules and seasonal weather patterns that govern local residential and commercial consumption. Not only are the loads variable and difficult to forecast, but also the Port machines are increasingly automated. They are controlled with solid-state electronics and information technology, making them more sensitive to reliability and power quality issues than typical industrial customers. Small electrical disruptions can have a big economic impact. For instance, a momentary disruption in power that most other utility customers may not notice, can disable an entire row of wharf cranes for an hour or more, causing delay and economic harm.

Second, as a group, the entities that constitute the Ports have strong linkages with more sectors of the regional and national economies than nearly any other type of electricity customer. As a major transportation network hub, this agglomeration of stakeholders facilitates a major share of the nation's shipping and international trade. These energy-intensive stakeholders are geographically concentrated. Furthermore, they rely exclusively on the existing utility distribution system for a major share of their energy use and consequently, any grid disruption in the Port area can cause disproportionately widespread impacts throughout supply chains.

Third, multiple regulatory, economic and environmental factors are driving the Ports to find ways to substitute the on-site combustion of fossil fuel with electricity. While most utility customers are seeking to reduce consumption, the Ports are actively seeking to switch fossil fuel use with electricity, increasing total usage as a result and putting more demands on the exiting electrical infrastructure. Amid multiple, competing requirements, long-term planning for electricity at the Ports requires accounting for massive uncertainty. The electrification of the Ports could increase variability and potentially double total consumption within the next decade, magnifying the existing vulnerabilities to electricity grid disruptions.

Finally, there is unique complexity associated with managing energy due to the various Port stakeholders and the decentralized way in which electrical service within the Harbor Districts is managed. The following section describes this structure and its impact on energy management.

1.2.1 Port Stakeholders and Issues for Energy Management

There is not one interconnected electrical system within the Harbor Districts. Rather, several systems and sub-systems exist within each of the two Port environments. Management responsibility for these systems is not centralized. Different aspects of the system are overseen by different stakeholders. Electricity usage is paid for by all Port tenants through hundreds of different utility accounts. Supply is provided by two different electric utilities. The distribution infrastructure at the terminals is owned, operated and planned for by the Ports, while the day to day activities which consume energy are managed by the terminal operators. Each stakeholder has somewhat different interests and different governance. The result of this diversity is that coordinated energy management planning has not been done before, but the challenges in doing so are worth overcoming.

The following section provides an overview of the Harbor Departments and other key stakeholders.

Harbor Departments

The Harbor Departments are the City agencies that manage the Harbor Districts in trust for the State of California. These public agencies lease the Harbor facilities to private terminal operators and other tenants. The Harbor Departments conduct the long-term planning and management of the coastal resources in their trust, but have little direct control over the operations and commercial activities of the tenants. Both Ports are "landlord" Ports.

Terminal Operators

Terminal operators are the businesses that conduct the day-to-day operations of moving cargo through the San Pedro Bay Ports. Some are subsidiaries of shipping companies. Their primary activities are scheduling cargo flow between transportation modes, utilizing organized labor resources and operating the cargo handling systems. Because of the competitive dynamics and capital-intensity of the industry, there is a strong incentive for efficiency in the cargo handling process. Reliability can be a differentiating factor when cost considerations are equal, which underscores the importance of a resilient electrical system.[4]

An increasing share of cargo handling equipment (CHE) is electrified. The terminal operators purchase electricity to run this equipment from the utility. As tenants of the space in which they operate, the terminal operators do not directly conduct long-term infrastructure planning and development, such as that required to provide electrical distribution systems. The economic life of many electricity-related upgrades and investments may be longer than the term of the typical lease, creating barriers for investments that might otherwise help the terminal operators become more efficient and reliable.

Electric Utilities

Electric utilities provide service to the Harbor Departments and the terminal operators. Each separate entity within the Ports maintains its own electrical account. Although the two Ports share a boundary, they are serviced by two distinct electrical utilities. The entities within the Port of Los Angeles are serviced by the Los Angeles Department of Water and Power (LADWP) while the Port of Long Beach entities are serviced by Southern California Edison (SCE). The utilities charge customers based on standardized rate schedules approved by regulatory bodies.

Summary

The number of electrical customers and diversity of interests within the Port environments create some organizational barriers to systemic, port-wide management of electrical service. The Harbor Departments and Commissions that govern the landlord Ports conduct long-term resource and infrastructure planning to support terminal operations, including planning for electric distribution infrastructure. They can enter into long-term lease agreements with tenants, create incentives to align terminal operations with Port objectives, and influence how tariffs are imposed throughout the Port. But the Ports as landlords do not have direct influence

4 IBISWorld (2012). 18.

over how much or how fast tenants consume electricity. As a result, day to day management of electricity use is decentralized to the tenants. The terminal operators, along with the Harbor Districts, could benefit from decision support tools to help prioritize energy efficiency investment options and plan for longer term energy management in coordination with the electric utilities.

1.3 Report Organization

Section 2 of this report introduces the purpose, methodology and findings of the electricity consumption baseline study. It also introduces trends that are impacting Port energy costs and predicts future increases in electricity costs that can be mitigated with energy management strategies. Section 3 then assesses specific energy management options. The hypothetical scenarios fall into three categories: 1) energy efficiency, 2) on-site generation with renewable resources, and 3) on-site dispatchable generation. Evaluation criteria include economic competitiveness, job creation, environmental benefits, port security and other key considerations. Section 4 concludes the study and suggests next steps in support of a comprehensive and collaborative energy management planning initiative.

2. Baseline Electricity Consumption in the Ports

The activities that take place within the Ports consume large amounts of electricity. If the Ports were single entities, they would each be among a small group of the very largest electric utility customers in Southern California. They are not single entities. The Ports are diversified clusters of transportation, maritime and recreational activities spread out over 7,500 acres of land area.[5]

Obtaining an accurate picture of Port-wide electricity consumption is among the first steps towards assessing the opportunities for management of electricity as a strategic resource. Yet this is not a straightforward task. Electric billing meters typically record detailed information but comprehensive, Port-wide data are not accessible for analysis, even by Port staff. Each tenant of each Port is a distinct utility customer and the Ports are serviced by two different electric utilities. Furthermore, most tenants have several electrical billing meters. Billing and consumption data is considered confidential customer information by the utilities. Without top down data available, UCLA researchers estimated the annual Port electric load profile from the bottom up. Section 2.2 describes our methodology for doing so.

A more collaborative approach to sharing high-resolution electricity meter and billing data would benefit any future Port-wide management programs. To protect the confidentiality of Port tenants, the results could be aggregated and stripped of identifying information. In the short-term, a bottom up, high-level estimate of electricity consumption is appropriate and necessary.

2.1 Purpose of Baseline Analysis

An objective of this baseline analysis is to offer a comprehensive representation of electric consumption for all cargo-related and administrative Port facilities. Total electric energy consumption is estimated in megawatt-hours (MWh) and the rates of power consumption are estimated in megawatts (MW).[6]

The results suggest how much power is required by all Port facilities over the course of a year. The results can be disaggregated by major use or by each container terminal. By disaggregating into major uses of power, it is possible to understand the impact of each type of equipment or facility on the total amount and cost of electricity. Not only does the analysis estimate the amount and rate of consumption, but it also gives an approximation of when the electricity

5 Both Ports cover large geographic areas. POLB covers 3,200 acres of land (http://www.polb.com/about/facts.asp) while the POLA covers 4,300 acres of land (http://www.portoflosangeles.org/about/facts.asp).

6 The report focuses on estimates of real power consumption. Real power is a measure of the instantaneous flow of electrical energy at a specific point on a circuit. It consists of apparent power and reactive power, both of which have important economic and technical implications in the management of interconnected power systems. Real power is typically the most important component of electrical utility charges. For an informative description of these concepts, see Blume (2007).

might be consumed, including seasonal variations. This is a baseline representation of a complex, dynamic and evolving system. It can be used as a starting point to assess the Port-wide impacts of new technology, utility-side upgrades, operational changes, on-site energy generation and conservation efforts.

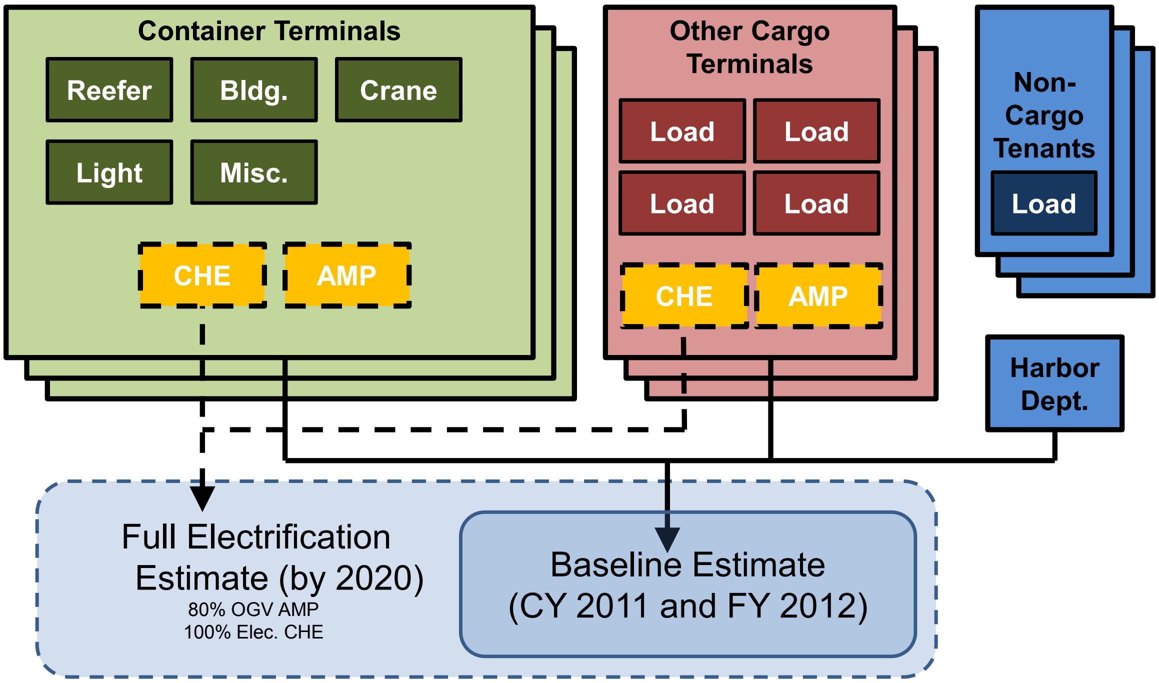
The bottom-up results should be used in a manner consistent with their intended use. It is intended to paint a high-level picture of electricity use within the geographic area of the Ports and to assess opportunities for electricity management at a Port-wide scale or within a single terminal. The framework created by UCLA could be later used to conduct higher-resolution analysis, should additional data become available.

We note a few other issues. While actual Port statistics were used to estimate machine and facility activity, the data were originally designed for various purposes that were not necessarily related to energy management. We verified our estimated results with actual utility data as it was available, but for the aforementioned reason, there may be some inaccuracies because the various data used to estimate activity levels may not perfectly correlate with actual activity. Furthermore, presenting the results as a single load profile implies that all Port facilities are powered by one interconnected distribution circuit where all consumption can be measured at a single point. Instead, the energy load profile represents the aggregation of many electrical distribution systems spread over a wide geographic area. Yet an aggregation is important to begin thinking comprehensively about Port energy management.

2.2 Methodology

The approach we took to aggregating electricity consumption for the baseline analysis is illustrated in the following figure.

Figure 5: Components of Port Electricity Estimates



Our method to represent annual Port electricity consumption consisted of three steps. Each step used the available data sources as inputs. These data came from the Ports, existing literature, government information sources, or the applicable utility. The outputs of each step were aggregate Port-wide estimates of the relevant information. The outputs were estimated for each hour of the baseline year. The same method was replicated for each Port and for both the baseline years and for the electrification scenarios.

Table 1: Methodology for Port Electricity Estimates

	Input Data	Estimated Outputs
Step One: Estimate Current and Future Port Activity	Indicator statistics of activity for major load sources: • Annual and monthly cargo throughput (TEU and tonnage) • Vessel types, cargo capacities, time and date of arrivals, shifts, and departures • Climate data for the Port area • Gate Moves • Regulatory mandates and Program guidelines • Electrification (AMP OGV, CHE) • Load factors from existing emissions inventories	Machine activity and load factors by hour of the baseline year: • Estimated cargo flow rates • Total machine activity required to move cargo at estimated flow rate
Step Two: Estimate Demand & Consumption	Electrical specifications, engine Characteristics, and demand/load planning factors for load sources: • Utility Billing information from several Port entities • Equipment specifications • Electrical planning factors • Engine characteristics from existing emissions inventories	Aggregate Port demand and consumption by hour of the baseline year: • Hourly average demand in megawatts (MW) • Hourly consumption in megawatt-hours (MWh) • Aggregated port and container terminal • Aggregated by load source • Estimates of bulk cargo terminals
Step Three: Estimate Total Costs of Energy and Demand	Utility rate schedules: • Energy charges per kilowatt-hour (kWh) • Demand charges per kilowatt (kW) • Time-of-use differentiation of charges • Eligibility and service voltage	Total annual costs: • Energy costs • Demand costs • Total aggregate electricity cost for all Port entities or by certain tenants

The baseline estimates consist of load sources in the Ports during the baseline years. The future electrification estimate consists of the additional load from 80% implementation of the Alternative Marine Power (AMP) program and 100% implementation of electrifying CHE.

Step One: Estimate Port Current and Future Port Activity

The first step of the analysis was to identify the primary users of electricity (load sources). Container terminals have five primary categories of demand: buildings, wharf cranes, refrigerated container outlets, high-mast terminal lighting, and miscellaneous sources. Miscellaneous sources include all other sources that do not fall within another category and cannot be easily categorized at a Port-wide or terminal-wide scale. Examples of miscellaneous sources include but are not limited to container washing activity, low-mast security and street lighting, rail and gate operations, parasitic load from electrical distribution equipment, or charging of electric passenger vehicles.

These five primary categories of demand are particularly relevant to the highly-automated, capital-intensive container terminals. There are also other types of terminals such as bulk cargo and those with recreational and various commercial uses. The Harbor Departments themselves are major consumers as they operate many buildings and facilities with administrative, security, and maintenance functions. The demand and consumption from the container terminals, the other bulk cargo terminals, and the Harbor Departments, make up the baseline estimates.

Both Ports have mandates and programs to electrify the auxiliary engines of vessels while at berth and convert fossil-fueled cargo handling equipment to electricity. These two activities will be significant new sources of electric demand in the future. These new demand sources were also estimated as potential future demand that would be additional to the baseline.

Demand is driven by Port activities and influenced by climate factors. Activity levels for each load source were estimated from existing Port statistics and location-specific environmental data.[7] Port statistics include vessel activities, vessel categories, TEU and tonnage flow, and various equipment and vessel characteristics used in the Port's emissions inventories. Environmental data include hourly climate information in the Port area. Activity levels were estimated for each hour of the year. Where hourly distributions were not possible, average annual activity levels were estimated from available data.

Step Two: Estimate Demand & Consumption

The second step in the analysis was to estimate average hourly electrical demand based on the activity levels. The primary information used in this step is the specifications of the equipment itself. Representatives from the terminal operators and Port staff offered general planning factors. This information was supplemented with publicly available information and figures taken from each Port's emissions inventories.[8] The result of the second step was an hourly

7 The staff from each Port provided their available internal information regarding utility purchases, energy analysis, and Port operations. Publicly available statistics from the Port's websites such as monthly TEU and tonnage volume was used to develop the estimates in this report (http://www.polb.com/economics/stats/5_yr.asp and http://www.portoflosangeles.org/maritime/stats.asp). Climate data from NOAA and the U.S. Navy Observatory supplemented the estimates of lighting and building demand intensity.

8 Each Port publishes an annual inventory of air emissions. The inventories provide extensive data about the number, type, and characteristics of equipment, vessels, vehicles, and machines operating in the Ports. These data were used to make realistic assumptions about baseline and full electrification demand and consumption.

demand (measured in MW) for each hour of the year, leading to a representative, aggregated load profile. The advantage of an hourly approach is that the data can be easily managed and it is more representative of how electricity is actually sold by the utilities to Port customers. The disadvantage of using an hourly approach is it is fairly low-resolution approximation of a highly dynamic system. Because the system is so dynamic, there might be significant inter-hour variations that are not effectively represented by this approach.

Step Three: Estimate Total Annual Costs

With the representative load profile from step two, the third step was to estimate the total costs for electricity charges based on actual utility rate schedules. This involved both energy costs, charged per kilowatt-hour, and demand charges, based on peak kilowatt. Most rate schedules for industrial customers differentiate charges based on when the user consumes electricity. Often, the charges are highest when the utility's demand is highest. This creates an incentive to shift activity from high-cost periods to lower-cost periods.

The rate schedules helped researchers estimate total energy and demand charges based on the representative load profile, but this analysis cannot account for other factors that impact total cost of electrical services. The methodology does not incorporate service fees, late payment charges, or any account-specific costs that are not charged on a per kilowatt-hour or per kilowatt basis. Also, any management decisions made at the operator level, such as scheduling activity to avoid the highest time-of-use charges, will not be accounted for in the estimated total costs of energy and demand.[9]

2.3 Results

A summary of the estimated results of our baseline electricity consumption model are illustrated in the below table. These represent aggregated results.[10] We then provide a more nuanced discussion organized by individual Port and types of energy users within the Port environments.

9 A manager of one Port terminal offered an example of the importance of aligning operations with utility rates schedules. A machine was scheduled to shut down every day before 10 a.m. when time-of-use demand charges increase. Once by mistake, the machine was shut down a few minutes past the hour. The maximum demand for the period on the customer's monthly bill increased, costing the customer an additional $150,000 in utility charges that month.

10 These results suggest the total electricity required by the cargo related activities in each Port, given the actual number of vessel, TEU, and tonnage throughput in each baseline year. To the extent that this representation of electricity is accurate, the total utility purchases for all Port entities could be more or less than estimated for several reasons. First, we did not include non-cargo tenants, such as recreational or other commercial tenants, in our estimates. Second, Port managers can schedule activities to avoid the peak hours and minimize utility costs. Third, this baseline analysis did not assume any offset of utility expenses through on-site back-up generators, existing solar, or industrial combined heat and power (CHP) facilities. If these capabilities exist now in the terminals, actual utility purchases could be less estimated, while total electrical requirements would remain unchanged.

Table 2: Summary of Port Electricity Consumption Estimates in Baseline Years

	Port of Los Angeles	Port of Long Beach
Period	FY 2012	CY 2011
Total Annual Energy Consumption	200,000 to 250,000 MWh	150,000 to 200,000 MWh
Peak Hourly Average Demand	50 to 60 MW	40 to 50 MW
Minimum Hourly Average Demand	17 MW	15 MW
Annual Average Demand	27 MW	21 MW
Total Annual Cost of Demand and Energy	$28 to 32 MM	$18 to 22 MM

2.3.1 Results and Context for the Port of Los Angeles

Electricity Usage at POLA Totals About 233,000 MWh Annually

The Port of Los Angeles and all its tenants and facilities likely consumed between 200,000 and 250,000 MWh (200-250 million kilowatt hours) of electricity during its fiscal year 2012. To put these numbers in context, this is about 1% of Los Angeles Department of Water and Power's forecasted Retail Sales for the same period.[11] It is also the amount of electricity consumed by about 35,000 to 44,000 typical Los Angeles residential utility customers during one year.[12]

Energy usage at the Port of Los Angeles is equivalent to that consumed by more than 35,000 typical homes in Los Angeles.

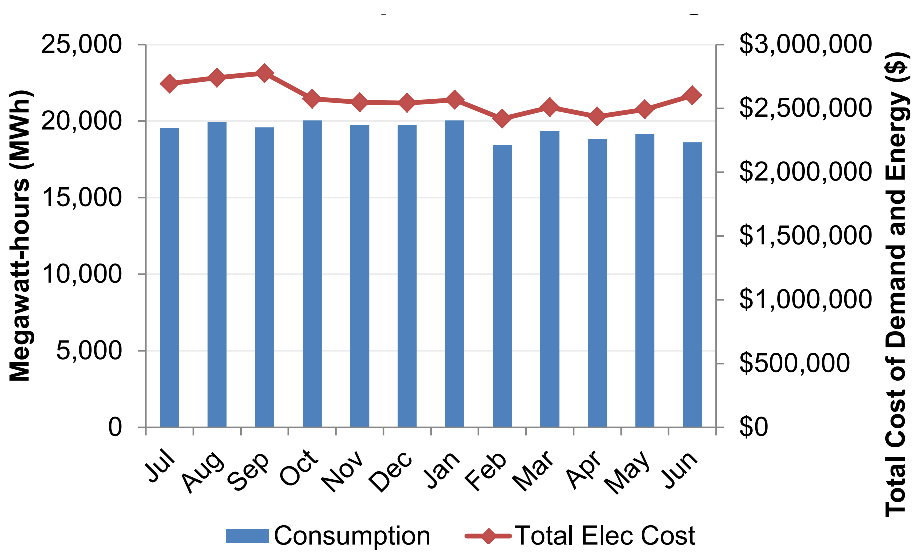
These consumption figures put the Port of Los Angeles' facilities in a comparable category with other large institutional customers in the City such as USC and UCLA.[13] These institutions might be considered single utility customers, but consumption in the Port area occurs through hundreds of billing meters for dozens of separate utility customers.

11 LADWP (2011), 2-4.

12 This estimate is based on an average annual residential consumption per customer of 5,725 kWh, referenced from the LADWP Facts and Figures webpage.

13 Both USC and UCLA are large institutions that consume roughly comparable amounts of electricity each year as each Port does, in aggregate. The key differences between these large, institutional users and the Ports are 1) their electrical load profiles are smoother and more predictable, and 2) as single entities, they can more easily conduct coordinated, centralized energy planning to manage electricity.

Figure 6: Estimated Consumption in POLA During FY2012



The total rate of consumption in POLA is highly variable and less predictable than that of most other electricity customers. The variability is primarily driven by the intermittent activity of an array of industrial machinery such as belt conveyors, cranes, metal shredders, high output lights and refrigerated containers. The lowest periods are likely to have aggregate demand of about 15 to 20 MW with a peak hourly average demand between 50 and 60 MW.[14] The 60 MW peak would be equal to about 1% of the 2010 summer peak demand experienced by the City of Los Angeles.[15] Momentary peaks in demand could be significantly higher than 60 MW. This baseline estimate is based on 2012 Port statistics and current equipment specifications at the Ports. While POLA might be comparable in total annual consumption to other large institutions, its users collectively draw electricity from the grid much more erratically and rapidly, at times, than other institutional utility customers with smoother load profiles.

Electricity Costs at POLA Total About $30 Million Annually

The Port of Los Angeles and all its tenants likely spent between $28 and $32 million during fiscal year 2012 for electricity charges. About two-thirds of this cost can be attributed to energy charges while the other third is demand and related charges.[16]

14 The baseline analysis used hourly average demand figures. Because demand is highly variable, peak instantaneous demand for the Port area could be much higher for very short periods of time. The Port of Long Beach Electrical Master Plan estimated that by 2015 peak coincident demand might reach 96.2 MW.

15 LADWP (2011), 2-7.

16 Energy costs are charged per kilowatt-hour used in the billing period and demand charges are based on the peak kilowatt used.

2.3.2 Results and Context for POLB

Electricity Usage at POLB Totals About 183,000 MWh Annually

The POLB consumed an estimated 150,000 to 200,000 MWh during calendar year 2011 (CY 2011). To put this number in perspective, this might be approximately 6% of the electricity consumption of the City of Long Beach based on high level estimates from 2007.[17] Yet because Southern California Edison (SCE), the electric utility that serves POLB, also serves a huge territory, this amount of energy is only a small fraction of the retail sales of SCE.[18]

The annual electricity consumption at the Port of Long Beach accounts for around 6% of all energy consumed in the City of Long Beach.

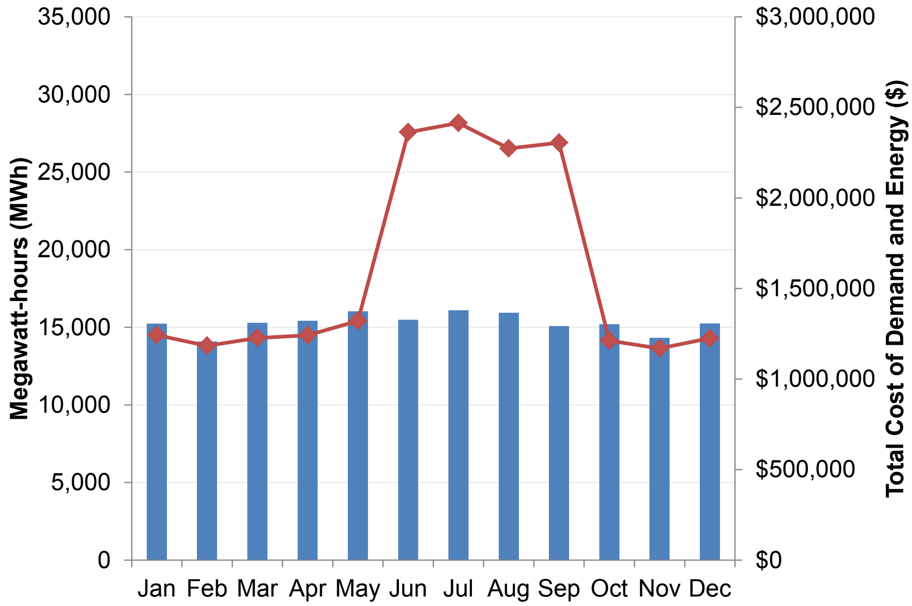
The rate of consumption varies from hour to hour based on Port activities driven by cargo throughput, berthing ships and truck moves around the Port area. Climate also plays a smaller role in lighting and air conditioning load. POLB peak hourly average demand is about 40 to 50 MW with a minimum demand of about 10 to 15 MW. As in POLA, momentary demand peaks are likely to be higher than these hourly averages of 50 MW. As the following graph illustrates, POLB is affected significantly by demand charges (and more so than the POLA).

Electricity Costs at POLB Total About $20 Million Annually

The Port of Long Beach and all of its tenants likely spent between $18 and 22 million during calendar year 2011. In total, the San Pedro Bay Ports in total spend about $50 million per year on electricity. The following figures breaks down energy consumption by month and by main users for the Port of Long Beach.

17 The City of Long Beach estimated that the City used 2.9 kilowatt-hours in 2007 (http://www.longbeach.gov/citymanager/sustainability/energy.asp). This is equivalent to 2.9 million megawatt-hours. The baseline estimate for POLA would be about 6% of the total if the City were to use this same amount during CY 2011.
18 EIA Form 861, Data for 2011.

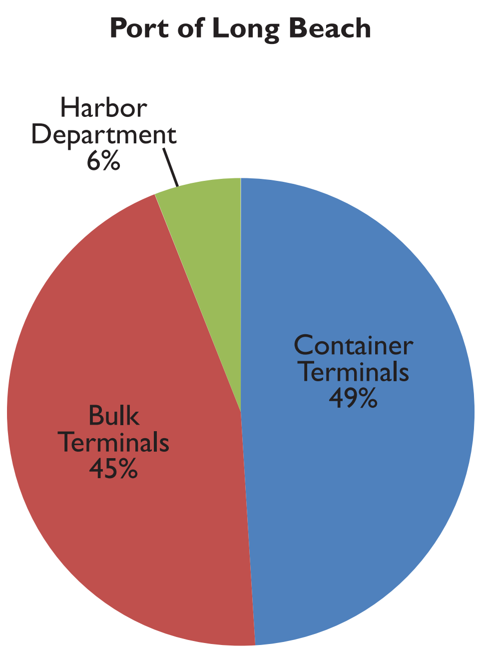
Figure 7: Estimated Consumption in POLB during CY 2011

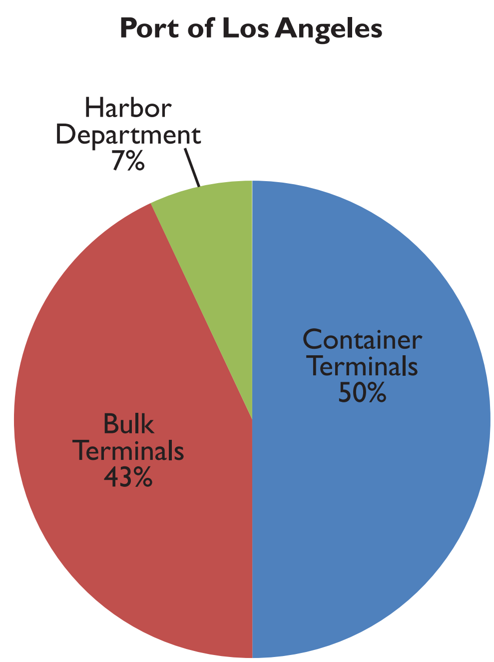


2.3.3 Disaggregating Consumption

Figure 8 presents a break-down of the major sources of electricity consumption at the Port of Long Beach and the Port of Los Angeles.

Figure 8: Share of Annual Electricity Consumption by Users in the Ports





2.3.4 Results of a Typical Container Terminal

Container Terminals Use Roughly Half of the Electricity Consumed at the Ports

Container terminal tenants use roughly half of the electricity consumed by each Port during a year. Container terminals are the logistical anchors of our regional and national supply chains. POLA has eight major container terminals and POLB has five.

Container operations are not only highly automated, but also energy intensive. The terminals are designed to rapidly move high volumes of containerized cargo between modes of shipping. They accomplish this through the use of CHE such as cranes, yard hostlers, and other technology that has over time increased overall throughput. Annual TEU throughput has risen in POLB and POLA 5% and 7% respectively from 1995 to 2011.[19]

Terminal Operators Pay an Average of About $2 to $3 Million in Electricity Charges each Year

The electricity consumption of a typical container terminal is roughly equal to that consumed by 6,000 households.

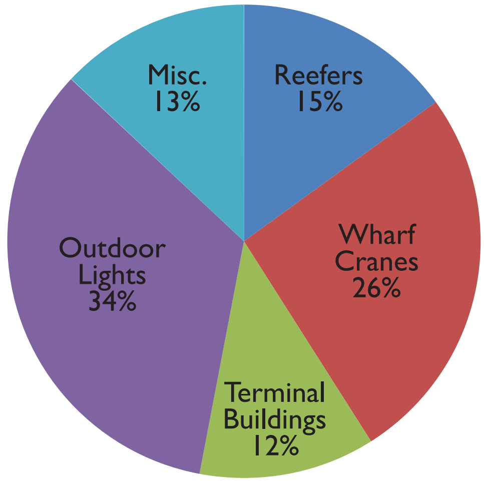
A representative container terminal at either Port might consist of 10 ship-to-shore cranes, 3 berths, 300 refrigerated container outlets, 100,000 square feet of space for administrative, operations and maintenance functions, and 200 total acres of terminal area. At the handling rates of about a million TEUs per year, the terminal might consume between 13,000 and 16,000 MWh with a peak hourly average demand of 6 to 8 MW.[20] This level of usage would cost the terminal operator about $2.0 to $3.0 million in electricity charges for the year. The total consumption will vary on the amount of available equipment and its utilization rate, primarily driven by cargo flow and terminal activities.

The largest and busiest container terminals in the Ports might consume more and pay more. They likely consume as much as 30,000 to 40,000 MWh per year, with a peak hourly average demand of up 10 to 15 MW and somewhat higher momentary peaks. This total consumption is comparable to the total annual consumption of about 6,000 southern California households.

The below figure breaks down where electricity demand is coming from at a typical container terminal.

19 POLA, TEU (Container) Statistics, (http://www.portoflosangeles.org/maritime/stats.asp), and POLB, TEUs Archive Since 1995, (http://www.polb.com/economics/stats/yearly_teus.asp).
20 Peak hourly average demand will be less than peak coincident demand.

Figure 9: Share of Annual Electricity Consumption by Source in a Typical Container Terminal



Importance of Energy Management Planning for Container Terminals

> ***A momentary power disruption can stop terminal operations and cost $75,000 or more for each hour of delay.***

As container terminals adapt to the demands of global commerce, several trends are driving up overall energy use and making the container terminals more reliant on electricity, thus increasing vulnerability to grid disruptions. Container terminals have become more automated over time. The terminals still depend upon the availability of a qualified labor force to oversee this array of machinery, but they are handling higher cargo volumes with more constrained timelines, thus increasing reliance on electrically-powered information systems and automation to maximize efficiency. Mandatory switching from fossil fuel combustion to electrical power increases the systemic vulnerability to electrical supply disruptions, which can be managed with energy planning.

Electrical supply disruptions already routinely impact container operations. Instantaneous frequency or voltage variations that are not observable by typical commercial or residential customers can stop an array of wharf cranes as they unload a container ship. The cranes have to be restarted and double checked for safe operation by a trained mechanic. The first hour of delay might cost $75,000 in damages.[21] Complete outages are more costly with economic impacts increasing dramatically based on the duration and geographic scope of the disruption.

21 This assumption is representative of planning figures shared by terminal representatives.

2.3.5 Results of a Typical Bulk/Break Bulk Cargo Terminal

Bulk Cargo Terminals Use About 45 Percent of Electricity Consumed at the Ports

POLA has 23 bulk cargo terminals, while POLB has 19. Collectively, these bulk cargo tenants use from about 45% of each Port's total annual consumption.

Bulk cargo terminals specialize in moving non-containerized cargo between transportation modes. Liquids, break bulk, dry bulk commodities, automobiles, metal scrap, and other goods are handled in the bulk terminals. Because of the cargo diversity, there are many different types of operations and handling processes. Electricity requirements vary by design and purpose of the terminal, so demand and consumption patterns are difficult to generalize.

There is no representative bulk cargo terminal in terms of electricity consumption and demand. The major sources of demand in bulk terminals are cranes, conveyors, hoppers, pipelines, tank farms, pumps, sorters, compressors, shredders and other mechanized handling equipment. These terminals, while smaller in area than container terminals, are similarly reliant on conditioned buildings and high output area lighting.

Annual consumption could range from 1,000 MWh for smaller or more labor intensive terminals to 10,000 MWh for a highly mechanized and highly utilized terminal. The largest or most energy intensive of the bulk terminals could use even much more. A scrap metal processing facility could have an on-site demand as high as 10 MW for short periods, although the load is likely to be intermittent and highly dynamic. A liquid bulk facility with high utilization might have a lower peak demand of one to two MW, but if it uses electricity smoothly and continuously, the terminal may reach very high levels of annual consumption.

Importance of Energy Management Planning for Bulk/Break Bulk Terminals

Break bulk cargo terminals typically use more labor inputs per unit of output than container terminals, and consequently a grid-related disruption that shuts down operations can cause a disproportionate escalation of labor costs. There is a degree of inherent flexibility and resilience in most aspects of break bulk operations, except where shore-powered electrical equipment is concerned. Reliance on cranes and other electrically powered equipment make them equally vulnerable to power quality events and outages as container terminals. While break bulk terminals are more labor intensive than other types of terminals, they can also benefit significantly from energy planning.

2.4 Future Scenarios

Energy Consumption and Costs at the Ports May Double by 2020

Electricity usage will rise in the next decade as technology advances and regulatory and environmental factors cause the shift to electricity from on-site combustion of fossil fuels. We estimate that electricity consumption will approximately double within the next decade, if cargo throughput and terminal operation remain consistent with the baseline years, and if the electrification schedule discussed below is achieved.[22]

As the following table and graphs illustrate, electrification is planned in two primary areas: Alternative Marine Power (AMP) for vessels at berth and to power the Cargo Handling Equipment (CHE) used throughout the terminals. The California Air Resources Board has mandated that the Ports achieve 80% electrification of Ocean Going Vessels at berth by 2020.[23] The ultimate share of electrified equipment is uncertain and will be based on Port programs and myriad operational factors. Complete electrification of CHE would be an even larger share of electricity demand than AMP.

If 100% of the CHE in the Ports were electrified and the AMP program requirements were fully implemented to 80% by 2020, each Port's electricity consumption would approximately double relative to the baseline years. If CHE were electrified at about 50%, the total consumption would be about 60% more than the 2011 and 2012 baselines estimates.

We used conservative assumptions for our calculation. Future energy usage will depend on many uncertain factors. The results in this analysis are a representative estimate. Implementation of policies and programs may lead to different results than suggested here, but this analysis is designed to highlight the range of possible outcomes. Regardless of the exact amount, demand for electricity will increase dramatically in the near future as electrification occurs, and this will magnify the existing vulnerabilities to electricity grid disruption and affect port competitiveness.

Port tenants not only may require more electricity, but also are exposed to the risk of rising prices. The combination of increased energy demand and volatile prices will magnify existing vulnerabilities to electricity grid disruption.

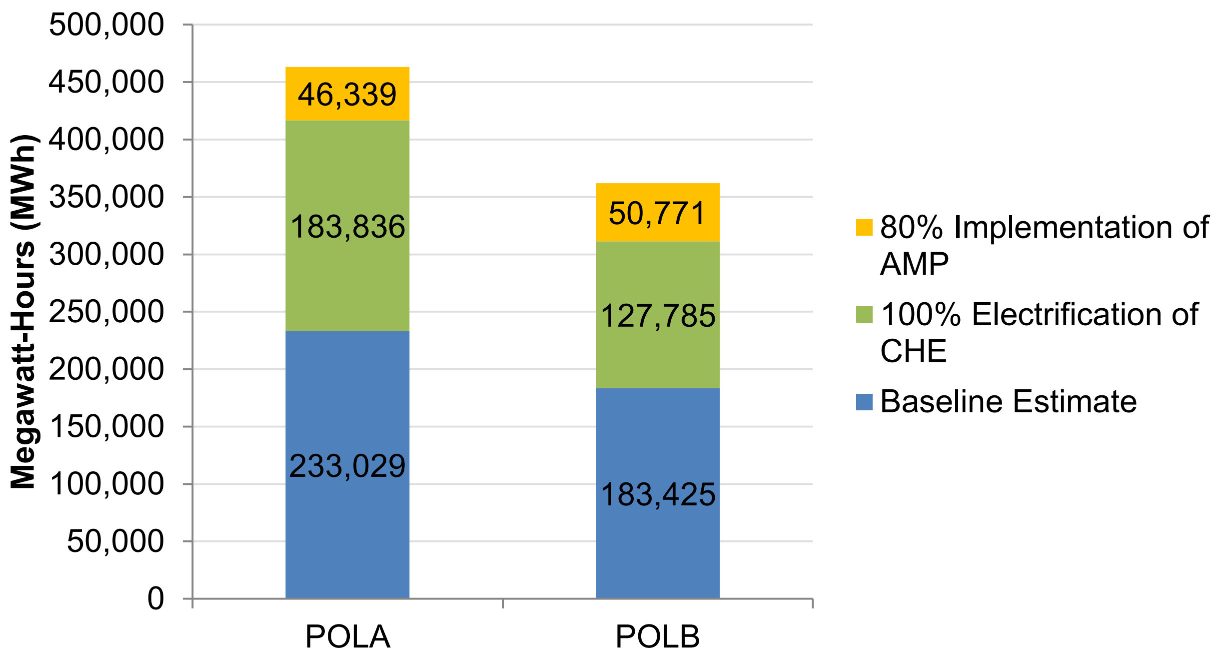
22 The doubling of consumption and cost by 2020 will occur given today's terminal design plus full electrification. New terminal design guidelines could increase the overall electricity requirements from what they are today. If the upgraded terminals in 2020 demand more electricity than today's terminals, this consumption will be additional to these estimates of total consumption in 2020.

23 The California Air Resource Board enacted a regulation in 2007 which requires vessel operators to shut down their auxiliary engines while at berth for 50% of visits by 2014 and up to 80% of visits by 2020 (http://www.portoflosangeles.org/environment/alt_maritime_power.asp). In order to serve the load of critical on-board processes, some vessels are equipped with connections to shore electrical power, otherwise known as Alternative Marine Power (AMP). AMP creates significant additional electrical demand and is estimated in the full electrification analysis.

Table 3: Summary of Electricity Consumption Estimates with Full Electrification (80% AMP and 100% CHE)

	Port of Los Angeles by 2020	Port of Long Beach by 2020
Energy	400,000 to 500,000 MWh	300,000 to 400,000 MWh
Peak Hourly Avg. Demand	80 to 100 MW	50 to 70 MW
Minimum Hourly Average Demand	39 MW	29 MW
Annual Avg. Demand	53 MW	41 MW
Total Cost of Electricity	$60 MM	$45 MM

Figure 10: Estimated Impact of Electrification on Total Annual Energy Consumption



Electrical Reliability Concerns Will also Increase in the Future

Electrical supply disruptions already routinely impact terminal operations. Instantaneous frequency or voltage variations that are not observable by typical utility customers can, for instance, stop an array of wharf cranes as they unload a container ship. The cranes have to be restarted and double checked for safe operations by a trained mechanic, while costing $75,000 in damages for the first hour of delay. Complete outages are more costly with economic impacts increasing dramatically based on the duration and geographic scope of the disruptions.

Reliability will become an increasing concern as technology shifts. New equipment is increasingly controlled using solid state electronics, so it will certainly be more sensitive to power quality and to supply disruptions. These types of technology shifts will make baseline electricity use, even without any consideration for electrification, more challenging to manage, but increasingly important to do so.

2.5 Section Summary and Conclusion

Energy management at the Ports deserves special attention. Electricity use in the Ports is essential for the continuity of major transportation systems, but management of this critical resource is distributed among many parties. The UCLA study for the first time aggregated the various electricity systems and sub-systems to create a shared understanding from which to create a foundation for comprehensive and coordinated energy management planning.

Increasing Energy Costs and Reliability Concerns Can be Mitigated with Energy Management Planning

While a doubling of electricity usage will affect utility bills and energy reliability, costs can be controlled and reliability increased with energy management planning. A first step is to use the baseline evaluation described in Section 2 to assess energy management options, such as those presented in Section 3.

3. Assessment of Customer-Side Options for Electricity Management in the Ports

The Ports have unique energy challenges. Concerns over cost and reliability will only become more acute in the future and thus it will become increasingly important for Port stakeholders to critically examine approaches that would allow Port entities to manage consumption and supply. This Section assesses the costs and benefits of pursing greater efficiency and generating electricity on-site, at the Ports.

Energy investments for improved reliability and efficiency could have immediate and direct effects on budgets and financial positions. Wise investments may yield ongoing savings and create competitive advantages while risky investments may expose Port stakeholders to unnecessary or unanticipated costs.

3.1 Approach

The comprehensive picture of electricity usage—the baseline analysis of Section 2—facilitates the assessment of potential approaches to managing electricity at the Ports. UCLA researchers first qualitatively reviewed a range of energy strategies and then narrowed down specific feasible project options in the following categories:

1) Energy efficiency
2) Renewable energy, focusing on solar
3) Dispatchable generation options, focused on:
    - Reciprocating engines
    - Combustion turbines and microturbines

The parameters of the conceptual project options were based on available data and realistic assumptions. Researchers used the following criteria to evaluate project options:

1) Competitiveness: economic costs and benefits at the Port and terminal levels
2) Jobs: regional employment impact
3) Environment: air pollution reduction impact
4) Security and operational: energy security and other key considerations

The most direct impacts captured by our analysis are savings from avoided utility purchases for terminal operators and other utility customers at the Ports, regional employment impacts, and changes in carbon dioxide emissions.

See the Appendix for our methodology used to estimate these impacts.

The long-term security, reliability and operational impacts of large investments can be difficult to quantify. But given the importance of the Port transportation hub to the larger economy, these impacts must not be overlooked. For the scenarios assessment summary, we include a Security, Operational and Other Considerations criteria. In this component, we highlight the key advantages or disadvantages that should be considered (even if they are not quantified). Different energy options have differing sets of advantages and disadvantages. A comprehensive, diversified strategy can provide balance. There could be operational conflicts or efficiencies created by energy projects that must be fully investigated and accounted for in any evaluation. For instance, if the project were designed to enable a reliable, even if partial, supply of electricity during a grid outage, then the avoided disruption will be a significant benefit. Yet within the Ports, space is a valuable commodity, so the opportunity cost of using space for energy-related projects must be accounted for and balanced against the reliability and security benefits that also have economic implications. Site-specific environmental impacts must be addressed in the planning process. At the regional and national level, potential impacts of these types of projects might include continuity for supply chains, improved disaster recovery capability and impacts on fuel and electricity supply networks.

Because of the scale and scope of the Ports' energy supply systems, any electricity-related project in the Ports could have a broad range of impacts. The following table lists the various Port stakeholders and how they could be affected by energy management approaches. This framework could be used for more detailed assessments of energy management options than what we provide in this first step, proof of concept report.

Table 4: Potential Cost/Benefit Impacts from Port Electricity Projects

Category of Project Impacts	Scale of Project Impacts		
	Port-wide	Regional	Supra-Regional
Competitiveness and Jobs	Savings from Avoided Utility Purchases Cost of Environmental Mitigation Benefits of Power Quality Mitigation	Employment Economic Output Earnings Benefits of Supply Chain Continuity for Regional Industries	Benefits of Supply Chain Continuity for U.S. Industries
Operational	Conflicts or Efficiencies with Other Port or Terminal Operations	Impact on Gas and/or Electric Distribution Systems	Impact on Gas and/or Electric Utility Transmission Networks
Security	Benefits of Improved Business Continuity during Major Outages	Improved Disaster Recovery Capacity	Improved Disaster Recovery Capacity
Environmental	Opportunity Cost of Energy-related Land Uses	Net Changes in Emissions of Criteria Pollutants Additional Visual or Noise Impacts based on Site-specific Concerns	Net Changes in GHG Emissions

3.2 Scenario Assessments

The scenarios in this section are not mutually exclusive, nor do they include the complete set of alternatives either for efficiency or self-generation that could be pursued by the Port. They are representative of Port demand-side approaches (customer-side) rather than utility supply-side approaches to address the important issues related to electricity in the Ports. This section offers a framework to begin to evaluate and compare different approaches to energy management. These scenarios illustrate potential costs and benefits, primarily those that directly impact Port stakeholders and the regional economy. These scenarios are not intended to recommend project design criteria. This is a first, if incomplete, step to actively managing electricity as a critical resource.

3.2.1 Energy Efficiency and Conservation Scenarios

Energy Efficiency and Conservation Offer Clear Benefits and are Integral to Energy Management

Conservation and efficiency measures are integral to realizing the benefits of energy management. The conservation approach is characterized by realizing energy savings through building awareness of waste, streamlining operations, or modifying individual behaviors. The efficiency approach is characterized by upgrading equipment or making capital investments to produce the same output with less energy input.

The reduction of demand not only saves money on avoided electricity costs, but also can reduce the need for up-front investment in supply alternatives. And the reduction of demand through efficiency or conservation is typically a lower cost approach than increasing supply, and unlike energy generation projects, energy efficiency projects typically do not require external development permits and can achieve results with a relatively quick turnaround. For these reasons, conservation and energy efficiency should be prioritized in any Port energy action plan.

Ports Could Save $4 Million with Lighting Retrofits

Lighting should be among the first areas to examine for demand reduction. Existing lighting is energy-intensive, highly utilized, and relatively straightforward to upgrade. Based on our calculations of off-the-shelf technology, energy efficiency measures have a clear economic value proposition. There are myriad small opportunities that cumulatively can have a large impact. Many of the opportunities have been overlooked historically. An optimistic, but achievable target could be to save $4 million, per year per Port, in electricity charges by the end of 2015 from the baseline years.

The following scenario demonstrates the impacts of retrofitting existing high-mast lighting, currently utilizing high-intensity discharge (HID) lamps, with 400 watt LED fixtures. The scenario assessed impacts of this retrofit project at both the terminal scale and at the Port-wide scale.

Scenario: A reduction in demand intensity of 60% for all high-mast terminal lighting

- Competitiveness: A 60% reduction in demand intensity of high-mast terminal lighting could save 33,000 MWh and $2.4 million per year in POLA and 20,000 MWh and $2.1 million per year in POLB.
- Jobs: This investment in either Port would create 17 local full-time and part-time jobs in the region.
- Environment: It would also reduce carbon dioxide emissions by up to 17,000 metric tons per year in Los Angeles, and 11,000 in Long Beach.

- Security, Operations, and Other Considerations: Reducing the demand from lighting will decrease the required up-front investment in supply alternatives. New lighting solutions will have different operational and maintenance requirements that must be fully understood and planned for. One example of an operational benefit is that LED lights can reduce or eliminate the warm-up times associated with other lighting alternatives.[24]

The following table summarizes the project economic benefits.

Table 5: Estimated Savings from Lighting Retrofits in Ports

	Large Terminal		Port	
	Partial	Full	Partial	Full
Investment Cost ($ MM)	$1.0-2.0	$2.0-4.0	$5.0-7.5	$10.0-15.0
Annual Energy Savings (MWh)	1,250	2,500	16,500	33,000
Electric Cost Savings ($ MM)	$0.150	$0.300	$1.2	$2.4

Our analysis suggests that LED lighting retrofits would be cost-effective for the Ports. Depending on the specific LED technology solution, demonstration projects suggest that LED lamps can achieve payback in fewer than ten years, within the life of the equipment.[25]

It is clear that LED lamps use less electricity than the alternatives and are a highly promising technology, but the total impacts of implementation in the Ports must be fully considered. Their cost and performance attributes are not widely known. So their ultimate cost-effectiveness for use in the Ports cannot be determined through this analysis alone. The Ports can be harsh environments for technology, necessitating special performance requirements. The marine conditions might deteriorate the performance of lamps and fixtures. For occupational safety reasons, lighting must have certain color and intensity attributes and must meet strict quality requirements. We recommend conducting pilot demonstrations of specific lighting technologies at cooperating terminals.

Other Efficiency Opportunities Should be Further Examined

The large scale and industrial nature of the Ports' facilities suggest that many other opportunities exist for beneficial efficiency and conservation measures. We provide a quick overview of the cost savings potential of a few examples. A more comprehensive evaluation could occur as a next step.

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24 Hertel, R. (2012) "LED lighting delivers cost savings to terminal operators." Port Technology International, Technical Papers. Retrieved from (http://www.porttechnology.org) on August 12, 2012.
25 DOE (2012), 43.

A 25% Efficiency Increase for Port Buildings would Yield Annual Savings of $800,000

A Port-wide reduction in the energy-intensity of all buildings in the POLB area by 25% would yield annual savings of up to $400,000 and 2,600 MWh. Similar reductions are possible in POLA, for a total of approximately $800,000 in cost savings per year.

Reducing Electricity Demand by Just 5% from Wharf Cranes would Yield Annual Savings of $350,000 at the POLA

Reducing the demand intensity of the fleet of POLA wharf cranes simply by 5% through various efficiency measures such would yield annual savings of $350,000 and 2,000 MWh. This is comparable to the total electricity used annually by a medium-sized commercial building park. These reductions are each only a small fraction of total Port consumption. A focused program to identify and capture these numerous, but otherwise unnoticed energy reduction opportunities can yield a high payoff through immediate cost savings and environmental benefits. This concerted effort requires up-front resources, but can have a large cumulative impact.[26]

A coordinated energy management initiative could facilitate the synchronization of energy efficiency investments with planned equipment replacement schedules, yielding further savings. But not all energy savings opportunities will originate from the replacement or upgrade of equipment. The following example underscores this possibility, by exploring measures to improve the efficiency of refrigerated containers without upgrading the containers themselves.

Reducing Electricity Demand by 50% from Refrigerated Containers would Save $1.2 Million at the POLB

Shading parked refrigerated containers from the warming effects of direct sunlight, perhaps with solar photovoltaic canopies, might be one way to reduce overall electrical demand and yield considerable savings.[27] Refrigerated containers stay in the Ports only a short time on their way to their final destination, but continuously draw electricity to maintain temperature-sensitive cargo. Energy usage from the containers may account for about 20% of the consumption in a large container terminal and about 8% of total Port consumption. Upgrading the containers with more efficient containers is typically not feasible. Finding ways to conserve energy used by these load sources would require a different approach beyond simply upgrading equipment, but the benefits could be significant. If there were an operationally viable way to reduce total electric demand from refrigerated containers by 50%, this measure would save up to 9,000 MWh and $1.7 million annually throughout POLA and up to 7,500 MWh and $1.2 million in POLB.

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26 Gaffney, M., (2010). "Improving energy and emission efficiency in port terminals." Port Technology International, Edition 46. Retrieved from (http://www.porttechnology.org) on August 12, 2012.
27 Sisson, M., & Gauthier, D. (2011). "Solar power for marine terminals: generating energy and public acceptance." Port Technology International, Technical Papers. Retrieved from (http://www.porttechnology.org) August 15, 2012.

3.2.2 Local Generation from Renewable Resources Scenario

It is increasingly common for energy-intensive organizations to operate on-site renewable generation to offset energy costs and achieve long-terms savings. The benefits of distributed renewable generation can be cost savings, avoided emissions, support for emerging industries, and visibility for environmentally beneficial actions. Typically, on-site renewables are supported by tax-based incentives offered by the government and rate-based incentives offered through local utility programs. Through a combination of incentives or third-party financing structures, the users of these systems are usually able to achieve a lower cost of energy from this source than their other alternatives. This is a strong enough value proposition for many users. The total costs and benefits of on-site renewable generation for the Ports must be carefully considered.

On-site Renewable Energy is a Financial and Logistical Challenge but Technologies are Quickly Evolving

The following scenario demonstrates the impacts of installing a one mega-watt (MW) solar photovoltaic system in the Port area. The hypothetical system evaluated in this scenario is installed over a large employee parking lot in one of the large POLB terminals. This system would generate about 1,478 MWh per year, approximately 5% of the annual consumption of a single large terminal. The coverage area would require about 5 acres for a one MW system, thus the parking lot must be acceptably large. The system could be designed to use less area, but would also produce less energy.

Scenario: One megawatt solar parking canopy

- Competitiveness: A one MW solar parking canopy is not likely to be cost-effective for either Port. It would produce up to 1,478 MWh per year, only about 5% of total consumption of a large terminal.
- Jobs: The regional impact on employment of this project would be about 28 full-time and part-time jobs created during construction period. After construction, it would support less than one job for the remaining operations and maintenance phase of project.
- Environment: This project could reduce carbon dioxide emissions by 486 metric tons per year and thus would support Port climate action goals.
- Security, Operations, and Other Considerations: This system would make no contribution to continuity or security with a standard grid-connection. Although the system could be net-metered and grid-connected, it could not provide electricity during grid outages given existing rules of interconnection. Rather, the project is designed to offset the on-site consumption of a terminal operator and provide some co-benefits through shaded parking spots for employee-owned vehicles, which could be valued significantly. Additionally, it would make a highly visible environmental statement.

The following table summarizes the project economic impact to competitiveness.

Table 6: 20 Year Net Present Value of Avoided Utility Purchases for a 1 MW Solar System ($ millions)

		Real Electricity Rate Annual Escalation				
		-2.0%	0.0%	2.0%	4.0%	6.0%
Capital Cost of Project ($/kilowatt)	$4,000	-$1.1	-$1.1	-$0.9	-$0.7	-$0.4
	$5,000	-$1.7	-$1.6	-$1.4	-$1.2	-$0.9
	$6,000	-$2.3	-$2.1	-$2.0	-$1.7	-$1.5
	$7,000	-$2.8	-$2.7	-$2.5	-$2.3	-$2.0
	$8,000	-$3.4	-$3.2	-$3.0	-$2.8	-$2.6

In this scenario, the capital costs of the system are relatively high because it is designed as a parking canopy. If there were an acceptable location in the Ports, the capital cost of an equally large rooftop system would likely be less than a parking canopy configuration. This scenario is one representative example that demonstrates economic drivers and integration challenges for local, intermittent power generation in the Ports.

Beyond cost, major barriers to integration of on-site renewable resources in Ports are space consumption and intermittency. If operationally viable co-use solutions are found or space constraints can be overcome, then on-site generation with intermittent renewables might be a cost-effective, supplementary approach to reduce demand.

The opportunity cost of using land for energy generation is high, so this must be properly accounted for. Most renewable resources are space intensive. There are no obvious areas available within the Ports large enough to generate meaningful amounts of electricity in this way. There are small-scale opportunities for rooftop solar or similar applications, but the energy generation potential is not enough to make major contributions to the Ports goals.

The intermittency of solar energy (producing energy only when the sun is shining) can be mitigated though net-metering for small renewable projects, which essentially provides a way to store the economic value of the energy generation. This is not a realistic option for large scale renewables, however. Operating the Ports independent of the utility grid using large-scale renewable projects, would be a significant challenge. The output would have to be instantaneously balanced with the Port's load, both of which are highly variable and difficult to schedule at a Port-wide scale. If the total contribution of local renewable generation increased to be a major proportion of Port electricity, integration would become a significant challenge without the ability to deliver the excess to the utility grid.

For example, an offshore wind energy project consisting of 8 to 12 offshore turbines and 20 MW of generating capacity could deliver between 40,000 to 60,000 MWh in a typical year to the Port, but the system output would not be coincident with Port electricity loads. It may not be possible to deliver any excess to the utility grid during moments of oversupply, and consequently it would become more critical to exactly balance the on-site generation with on-site load at all times.

Bulk electricity storage may be viable in the future as technologies are rapidly evolving. Right now, there are no commercially viable electricity storage solutions for the Port that could store and deliver hundreds of MWhs of renewable electricity at the rates needed, especially given the dynamic loads that exist with the Ports.

While wind, solar, and marine energy resources are intermittent, renewable biogas and biofuel resources are typically more flexible. However, there would need to be a long-term, local bioenergy fuel source, and the appropriate storage and distribution systems. Reciprocating engines, microturbines, fuel cells, or gas turbines are potential generating alternatives that could convert this type of renewable fuel into dispatchable power for the Port and its tenants.

Renewable technologies are evolving rapidly along with market conditions. The potential contributions of on-site renewables in the Port environment are fairly limited right now, but will improve in the future. The Port and its stakeholders should continue to evaluate opportunities for local generation with renewables and integration with energy storage.

3.2.3 Local Generation from Dispatchable Resources Scenarios

On-site Generation with Dispatchable Resources can be Cost Effective and Offer Other Primary Benefits but Would Require Additional Resources to Manage

Reciprocating Engines could Provide Continuity Benefits via Flexible Backup Power to Avoid Work Shutdown Costs in Case of Grid Outage

Reciprocating engines are internal combustion engines used in power generation applications. They are most often used for backup power or in specific applications where flexibility is an important concern. They can be configured to burn a variety of fuels including natural gas or renewable biogas. They are relatively low cost to install, not particularly efficient, and have relatively high fixed annual maintenance costs. The primary advantage of this type of generator is operational flexibility. They can be started and stopped rapidly, and the output can be adjusted easily, especially with multiple engines operating in a coordinated fashion. These types of generators are not designed to operate continuously for long-periods of time.

The following scenario demonstrates the potential impacts associated with a reciprocating engine array with 10 MW of capacity located on a large container terminal within POLA. The terminal operator owns and operates the units to provide emergency backup power to the terminal. The units are fueled from the local natural gas distribution system, run at low annual capacity factors, and are designed to occasionally shave peak demand or power critical loads within the terminal during utility system outages.

Scenario: 10 MW of reciprocating engines in a large terminal to occasionally shave peak demand during routine operations or power critical loads in an emergency

- Competitiveness: This project could reduce operational expenses but because they would operate relatively infrequently, it does not provide enough savings to recoup the up-front investment on this measure alone. However, if 10 hours of delay are avoided per year and the avoided delay is worth $100,000 per hour, the continuity benefits might be valued at up to $8.5 million over the life of the project. This additional value might justify investment.

- Jobs: The project would produce 84 full and part-time jobs during the construction period and 2 long-term jobs over the life of the project.
- Environment: The total carbon dioxide emissions impacts would be negligible because the engines would operate somewhat infrequently. During operation, the engines' carbon dioxide emissions would be comparable or slightly greater than that of purchased power in Los Angeles. This type of project can be installed with Selective Catalytic Reduction (SCR) technology to reduce harmful local criteria pollutants, particularly nitrogen oxides.[28]
- Security, Operations, and Other Considerations: This type of generator can provide continuity benefits and flexibility if the plant is designed to provide backup power in the event of a grid outage a terminal. They can be started and stopped rapidly, and the output can be adjusted easily, especially with multiple engines operating in a coordinated fashion.[29]

The cost-effectiveness is dependent upon the utilization rate of the asset, the escalation of utility rates, and long-term fuel costs. If the resources are primarily idle, used infrequently for backup emergency power, they have less opportunity to recovery their capital costs.

Table 7: 20 Year Net Present Value of Avoided Utility Purchases for 10 MW of Reciprocating Engines ($ Millions)

		Real Electricity Rate Annual Escalation				
		-2.0%	0.0%	2.0%	4.0%	6.0%
Capital Cost of Project ($/kilowatt)	$1,000	-$8.4	-$7.9	-$7.3	-$6.5	-$5.5
	$1,250	-$10.5	-$10.0	-$9.3	-$8.5	-$7.6
	$1,500	-$12.6	-$12.1	-$11.4	-$10.6	-$9.7
	$1,750	-$14.7	-$14.1	-$13.5	-$12.7	-$11.7
	$2,000	-$16.7	-$16.2	-$15.6	-$14.8	-$13.8

The primary driver of value to the terminal in this table is avoided utility purchases. Another measure of value would originate from improved business continuity. If the engines were able to keep the terminal operating with at least partial capacity during grid outages, significant value may result.

28 U.S. EPA (2008). 11.

29 If these engines operated isolated from the grid, their output would have to be balanced with the electrical load. The dynamic load of many Port terminals presents a system balancing concern. Therefore any dispatchable resources used in this manner must be able to match and follow dynamic Ports loads. Designing a plant and the electrical system to operate in this manner will increase the cost and complexity.

Microturbines could be an Option for Port Headquarters

Microturbines are another technology to generate reliable, dispatchable, distributed energy. They are small machines that can be easily sited near critical energy loads. They can operate more reliably with less maintenance than reciprocating engines at constant loads, but their output can decrease noticeably with environmental conditions such as heat and humidity. They can be fueled with renewable biogas or natural gas.

The following scenario demonstrates the potential impacts of a 250 kW natural gas microturbine array sited at a key administrative building in the POLB. These turbines would be owned and operated by the Harbor Department. This system would operate more continuously to offset the majority of site consumption. The microturbines require less periodic maintenance, but consequently have not demonstrated as long of an operating life as other distributed energy technologies.

Scenario: 250 kW natural gas microturbine array at a key POLB administrative building

- Competitiveness: As with the engines, the primary driver of value for the microturbine project is the avoided utility purchases. Depending on the electricity cost rate escalation, the project could be cost effective
- Jobs: The microturbines would only create up to 8 jobs over the project life.
- Environment: The project could increase carbon dioxide emissions by about 630 metric tons per year relative to purchased power from the grid in Long Beach.
- Security, Operations, and Other Considerations: The electric output would reduce peak demand and provide backup power to the building during outages, providing business continuity benefits.

Table 8: Eight Year Net Present Value of Avoided Utility Purchases for a 250 kW Microturbine Project ($ Millions)

		Real Electricity Rate Annual Escalation				
		-2.0%	0.0%	2.0%	4.0%	6.0%
Capital Cost of Project ($/kilowatt)	$2,000	-$0.207	-$0.107	$0.002	$0.119	$0.245
	$2,250	-$0.274	-$0.173	-$0.065	$0.052	$0.178
	$2,500	-$0.341	-$0.240	-$0.132	-$0.015	$0.111
	$2,750	-$0.408	-$0.307	-$0.199	-$0.082	$0.044
	$3,000	-$0.475	-$0.374	-$0.266	-$0.149	-$0.023

Combustion Turbines could Support Energy Independence Objectives

Combustion turbines are the workhorses of modern power generation. They are powerful, efficient, flexible and can be fired with a variety of fuels. Small and medium sized turbines can be sited on just a few acres with a relatively low profile. Selective Catalytic Reduction technology can minimize local criteria emissions. It is possible for the generator to be configured with cogeneration capability, serving any nearby thermal loads with useful thermal output. Cogeneration would require additional investment, but this configuration can bring the overall plant efficiency above 60%.[30]

The following scenario demonstrates the potential impacts of a locally sited natural gas-fired combustion turbine with an enhanced local distribution and control system. The facility would be designed to operate at high capacity factors and sized only to the most critical loads in the Port.[31] During routine operations, the turbine would provide a significant portion of the energy and capacity demanded by the Port users, while purchasing standby energy and capacity from the utilities' existing electrical service based on the appropriate rate structure. In the event of an outage, the generator would continue to supply power only to the most critical Port loads, while shedding the load of non-essential functions. The system controls and demand management system would shed non-essential load to keep the Port operating at a pre-defined service level. The terms of this arrangement to provide continuity of operations could be differentiated by terminal based on each Port's strategic priorities. Load shedding capability could keep the size of the plant small, operating at high capacity factors, thus maximizing efficiency and minimizing cycling costs.

Scenario: An on-site 40 MW natural gas-fired combustion turbine with an enhanced local distribution and control system designed to operate a high capacity factors and sized only to the most critical loads in the Port

- Competitiveness: A large combustion turbine facility could provide most of the energy needed at the Port of Los Angeles, saving at least $200 million in avoided electricity purchases alone over its life.
- Jobs: The regional employment impacts would be meaningful, with up to 226 job-years created during the construction phase and up to 44 jobs per year during the operations phase.
- Environment: Relative to power purchased from the grid in Los Angeles, the carbon dioxide impacts would be a reduction of up to 9,968 metric tons per year.
- Security, Operations, and Other Considerations: The challenges with on-site, dispatchable

30 Generators that burn fuel to produce electricity can be configured for "cogeneration" or combined heat and power applications (CHP). The waste heat from the generator can be captured and used to serve industrial processes or for district heating. The advantage is greater overall efficiency and avoided combustion of heating fuel. The disadvantage is reduced operational flexibility of the generator because the thermal loads and electrical loads are not necessarily coincident. The opportunity for CHP was not evaluated for the Ports in this report. If there is a significant thermal requirement in or near the Ports, CHP would be worth investigating in future analysis. See EPA (2008) for more details.

31 Sizing the turbine only to the critical loads instead of the peak loads is the most capital-efficient approach to this investment. Furthermore, a small plant is easier to site, obtain permits to operate, and requires less resources to maintain.

generation are external environmental permits, fuel cost and availability, optimal plant siting, and the complexity of loading balancing.

Table 9: 30 Year Net Present Value of Avoided Utility Purchases for a 40 MW Simple Cycle Combustion Turbine Project ($ millions)

		Real Electricity Rate Annual Escalation				
		-2.0%	0.0%	2.0%	4.0%	6.0%
Capital Cost of Project ($/kilowatt)	$1,000	-$20.8	$81.2	$224.8	$429.2	$723.4
	$1,250	-$32.9	$69.1	$212.7	$417.1	$711.3
	$1,500	-$45.0	$57.0	$200.6	$405.0	$699.2
	$1,750	-$57.1	$44.9	$188.4	$392.9	$687.1
	$2,000	-$69.2	$32.8	$176.3	$380.8	$675.0

This on-site combustion turbine alternative could be cost-effective on the basis of avoided utility purchases over the life of project. Other important drivers to the economics are the availability and long-term cost of natural gas, the cost of utility distribution upgrades related to electric interconnection, and any required upgrades to the Port-owned distribution and control system. The cost of criteria pollutant reduction technology would be additional costs that would fall within the ranges suggested in the Table. These generators are most frequently powered with natural gas, but if a high-quality renewable biogas fuel was available in large quantities from a local source, it is feasible that at least some of fuel could be renewable.

As previously described, the potential continuity benefits of a turbine could be significant. Yet other operational factors should also be weighted. While the turbine would be a relatively compact installation, any operational or siting conflicts must be considered. Finally, the development and permitting of this type of installation would require a significant period of time, involve many external stakeholders, and the ultimate outcome would be uncertain.

4. Conclusions

Energy Security and Energy Management Investments Can Provide Clear Benefits to the San Pedro Bay Ports and Their Stakeholders

The objective of this study was three-fold. First, we provided detailed descriptions of electricity usage and costs: 1) for the POLA and POLB, both port-wide and by terminal types, 2) in the present and in the near future planning horizon, 3) by types of technology within a typical terminal and 4) for important facets of electricity consumption like average, seasonal and peak demand. This allowed for us to then undertake a preliminary scoping of the proto-typical energy investment opportunities that might comprise energy management strategies at the San Pedro Bay Ports (the Ports). Third, we have begun to identify how collaboration between the Ports can expand the learning benefits while also reducing the financial costs of energy audits, field studies of promising energy technologies and joint solutions to energy resilience challenges.

By looking across organizational boundaries and developing a comprehensive picture, this report creates a representative, baseline profile of electricity usage that is otherwise difficult to conceptualize. This Port-wide perspective facilitated the realistic evaluation of several approaches to energy management investments specifically tailored for the Port environment. It is also the first step towards aligning the stakeholders and managing the Ports' electricity requirements in a more unified manner to better support its public purpose. The resulting framework has the capacity to reveal the costs and benefits of engaging in specific efficiency and local energy generation options. The framework is a first step to inform and serve as a foundation for comprehensive and collaborative energy management planning.

The individual energy management strategies in this report evaluate commercially-available solutions that are proven to be beneficial in many applications. Other large users such as commercial buildings, military bases, hospitals and campuses have demonstrated the use of these technologies for similar purposes. Without exception, energy management programs include efficiency investments and conservation efforts. Renewable energy can be a cost-effective option under some circumstances and self-generation with conventional resources is also commonly used to mitigate utility costs or provide backup power. All of these solutions are technically feasible for the Ports and can provide a range of benefits as described in this report.

The findings demonstrated throughout this report show how these different aspects of integrated energy management can make specific contributions to goals of the San Pedro Bay Ports. These benefits include:

1) Increased Port competitiveness, through reduction of operating costs and increased reliability.
2) Increased energy resiliency in the Ports, thereby increasing supply chain resiliency and national security.
3) Regional job creation through the installation and maintenance of new energy

management systems.

4) Improved ability to cost-efficiently comply with environmental mandates and goals that will result in reduced greenhouse gas emissions and local air pollutants.

To the extent that these benefits of integrated energy management are realized in the Ports, other local, regional and national stakeholders may experience co-benefits. Increased Port competitiveness may lead to greater market share and increased local investments, benefiting the regional economy. As the Ports become more resilient in the face of natural disasters, utility outages or terrorist actions, supply chains throughout the U.S. are less vulnerable to potential disruptions. If the Ports can operate at a reduced capacity after a major earthquake, commerce can still flow and critical supplies can be delivered more easily, facilitating the recovery. Any significant energy project will bring construction jobs and long-term operations jobs to Southern California. If the projects evaluated in this report are well-designed and incorporate the best available technologies they can reduce the total regional impact of emissions associated with the Port operations.

Integrated Energy Management at the Ports Will Require Additional Resources But Also Will Yield Significant Long-term Benefits

Because the Ports are unique and diversified electricity consumers, there are special considerations associated with comprehensive electricity planning to support energy security, economic competitiveness and environmental mitigation. The challenges include but are not limited to space constraints, dynamic electrical loads and numerous organizational boundaries. While the individual technologies evaluated in this report are commonplace, any electrical system with the capability to coordinate multiple resources, balance supply and demand, or operate independently from the grid must be specially-designed for the Port's unique constraints. Increasingly, microgrids can incorporate some or all of the types of resources evaluated in this report into a unified system in order to provide the highest amount of control and flexibility.[32] Achieving this independence and flexibility does not solely result from any single technological solution. It also requires significant organizational resources.

Next Steps

The conceptual framework offered within this body of work is intended as a first step; it should be built upon as assumptions are validated, more data is obtained and further research is conducted involving electricity audits, engineering studies and technology analyses. At its core, this framework is designed to support informed policy and organizational decision making on electricity management projects, programs, and planning.

We offer the following recommendations for next steps:

32 Microgrids are integrated systems which combine information technology, electrical control systems, renewable, and/or dispatchable generation in order to maximize independence from the grid or to minimize costs or environmental impact. Microgrids are usually designed to continue to provide electricity if they become isolated from the utility grid or during grid outages, also known as "islanding."

1) Facilitate further research on relevant Port energy topics. This would involve further validating the model of this study with field data. We recommend conducting energy audits at the terminal level and other units at each Port. The energy audits would go beyond the scope of this baseline, high-level study to include more granular, detailed data. Other research could involve a port-wide security case study to: 1) determine how much energy it would take to maintain critical levels of port operations in event of a disaster or grid outage, 2) assess available space for energy generation, and 3) analyze what it would take for self-generation to maintain critical levels of port operations during a disaster or grid outage.
2) Measure and verify to identify best practices and technologies. Learn from pilot demonstrations at interested terminals. The pilots would allow for testing technologies in real-world settings to reveal a nuanced picture about promising technologies and their actual potential. The results could be compiled into a comprehensive assessment of technologies that includes cost benefit analysis and best practices. Then, scale the lessons learned to other terminals.
3) Conduct comprehensive and coordinated energy management planning. Based on the recommended studies and associated projects, the Ports would be well positioned to create a plan and associated programs for synchronized, comprehensive energy management.

A dedicated program at the Ports would elevate energy management issues and potential solutions to a level commensurate with their strategic importance. Such an integrated energy management program could support goals of energy security and achieve other benefits for all of the Ports' stakeholders.

5. Appendices

5.1 Appendix A: Port Economic Impact Assessment

This Appendix describes how the direct project costs and benefits of the scenarios were evaluated.

Economic aspects were evaluated using the System Advisor Model (SAM). The SAM, developed by the National Renewable Energy Laboratory (NREL), is a publicly-available financial and performance model designed to assist public stakeholders with decision making related to energy generation projects. This tool is a downloadable software program which estimates the economic viability of an energy generation project based on user-defined inputs and publicly available data sources. The measures of worth estimated by the model are from the perspective of the project owner, lender, investor, or other party with a direct economic interest in the project. The social and environmental costs and benefits associated with the scenarios were not explicitly evaluated in the SAM model. Other evaluation techniques were used to address these aspects and are described in Appendices B and C.

The advantage of using SAM as a starting point to assess self-generation opportunities for the Ports is that it is transparent, consistent, and accessible. For example, SAM uses publicly-available NREL data to assess the local solar energy resources available in the Port area. The model uses the actual hour-specific utility rate schedule data to evaluate the benefits of avoided electricity purchases. The alternative to using SAM would be the use of proprietary software or spreadsheet analysis to conduct the assessments. Proprietary software programs are not necessarily transparent and accessible and spreadsheet analysis would not be consistent across each of the scenarios. The disadvantage of using SAM is that it is designed to be flexible and incorporate a broad range of technologies under numerous, highly customizable scenarios. Because of this, SAM may not perfectly capture some of the technical and operating characteristics of the conceptual energy projects in the scenarios. Future planning and decision making will necessitate more precise investigation and modeling of the technical and operating characteristics of these conceptual scenarios. However, the SAM is an appropriate tool for a high-level economic feasibility analysis.

The SAM uses a discounted cash flow methodology to evaluate the economic feasibility of a project. The user defines numerous model inputs that accurately and realistically describe the conceptual energy projects. Examples of performance inputs include technology type, system availability, expected annual operational profile (expected hourly energy output for a year), heat rates, and production factors. Other important information such as location-specific climate and solar irradiance data by hour of the year and expected annual variations can be downloaded and applied to the evaluation. The user defines basic economic attributes such as capital costs, fixed and variable operating costs, fuel costs, annual inflation rates, utility rate schedules, utility rate escalation, and owner discount rates. The user can also define common ownership and financing structures for the project, such as third-party Power Purchase Agreements (PPAs), debt financing, and tax equity partnership structures. A simple cash investment with commercial ownership and a behind-the-meter structure was assumed for each scenario in this analysis. Future investigation of these opportunities should include the availability and impact of all potential financing methods, but to keep the focus on basic economic viability, this assessment did not evaluate the impact of third-party financing. Even though each of the scenarios are defined within one of the two Ports, all are generally applicable to both Ports. The primary differences will be in the avoided electricity rates since the Ports are serviced by two different utilities.

SAM simulates the performance of the project during each annual period of the analysis to arrive at an energy production profile and avoided utility purchases. Annual cash flow from the project is estimated from the summation of the fixed and variable operating costs and avoided utility purchases. These figures are adjusted for the impact of inflation and the time-value of money. These annual cash flows are compared to the initial investment to arrive at a Net Present Value (NPV) for the investment, the primary benefit stream being derived from avoided electricity purchases.

Table 10: Primary Inputs to System Advisor Model by Scenario

SAM Input	Intermittent – Solar PV in POLB	Dispatchable (Low) – Reciprocating Engines in POLA	Dispatchable (Low) – Microturbines in POLB	Dispatchable (High) – Combustion Turbine in POLA
Economic Life	20 years	20 years	8 years	30 years
Generation Capacity	1.0 MW DC	10.0 MW	250 kW	40.0 MW
Year 1 Net Avoided Energy Purchases	1,478 MWh	6,612 MWh	1,664 MWh	221,635 MWh
Capital Investment Costs; Incentives	$4,000 - $8,000 per kW; SCE PBI ($0.03/kWh for 5 years)	$1,000 to $2,000 per kW; none	$2,000 to $3,000 per kW; none	$1,000 to $2,000 per kW; none
Annual Operating Costs	Fixed: $20/kW-year Variable: $0 Insurance: 1% of project cost	Fixed: $17/kW-year Variable: $7/MWh Insurance: 1% of project cost	Fixed: $0/kW-year Variable: $30/MWh Insurance: 1% of project cost	Fixed: $5.0 MM per year; $10/kW-year Variable: $3.50/MWh Insurance: 1% of project cost

SAM Input	Intermittent – Solar PV in POLB	Dispatchable (Low) – Reciprocating Engines in POLA	Dispatchable (Low) – Microturbines in POLB	Dispatchable (High) – Combustion Turbine in POLA
Fuel Type & Cost; Annual escalation	Solar Irradiance; None	Natural gas; $5.00 per MMBtu; with inflation	Natural gas; $5.00 per MMBtu; with inflation	Natural gas; $5.00 per MMBtu; with inflation
Generation Profile; Capacity Factor; Availability	Intermittent; 16.9% capacity factor; 99.0% availability	Low capacity factor, operating only for peak shaving and during outages; 7.5% capacity factor; 95% availability	High capacity factor, reduces demand, provides emergency backup; 76% capacity factor; 95% availability	High capacity factor, sized to critical port loads for emergency power; 63% capacity factor; 95% availability
Utility Rate Schedule	SCE TOU-8-B or self-gen. equivalent	LADWP A-3A or self-gen. equivalent	SCE TOU-GS-3 General Service Demand Metered	Multiple, primarily LADWP A-3A
Average Annual Inflation over Life; Real Discount Rate	2.75%; 7.0%	2.75%; 7.0%	2.75%; 2.25%	2.75%; 2.25%
Real Retail Electricity Annual Escalation Rate	-2.0% to 6.0%	-2.0% to 6.0%	-2.0% to 6.0%	-2.0% to 6.0%
Effective Heat Rate/ Production Factor	1,478 kWh per kW per year	8.8 MMBtu/MWh	13.0 MMBtu/ MWh	9.0 MMBtu/ MWh
Annual Performance Degradation; Capacity Derate	0.5% annually; 0% derate	0% annually; 5% derate	0% annually; 0% derate	0% annually; 5% derate

The project NPV measures the relative value of two distinct alternatives: continuing to buy electricity from the utility or investing in local generating equipment to make some of it on-site and purchasing the balance from the utility. The most important variables that impact the NPV are the up-front investment costs, the avoided electricity charges, and the annual escalation of the charges over the life of the project. The current retail electricity charges are taken directly from the utility rate schedules and are known with certainty. Total installed costs based on the necessary design features and how electricity rates will change in the future are more uncertain. This is why the NPV is displayed in table format over a realistic range of values for the two uncertain variables.

5.2 Appendix B: Regional Employment Impact Assessment

This Appendix describes the method for assessing the regional employment impacts associated with each of the scenarios.

The regional employment impacts are one measure of the social benefits associated with the scenarios. The equipment would be owned and operated by the Ports or their designated third-party representatives, so the direct economic benefits from avoided electricity purchases (described in Appendix A) would accrue directly to the Ports. But the local community and other regional stakeholders would benefit from additional employment opportunities and increased economic activity.

As the following map illustrates, the applicable geographic region is the Los Angeles-Long Beach-Santa Ana Metropolitan Statistical Area (CBSA Code 31100), inclusive of Los Angeles and Orange Counties. This regional boundary was used for modeling regional employment impacts. Local energy projects will not replace the existing centralized supply system, so they are additional and will create regional economic development benefits such as employment and growth economic output.

Figure 11: Map of Los Angeles-Long Beach-Santa Ana Metropolitan Statistical Area (Source: U.S. Census)

Impacts were estimated using regional employment multipliers, derived by the U.S. Bureau of

Economic Analysis Regional Impact Modeling System II (RIMS).[33] These multipliers express estimated annual changes in jobs within a defined geographic region based on annual changes in economic activity. In this case, Port investments in energy efficiency or power generation equipment and the long-term operation of the facilities will cause a change in full time and part time jobs within the local area.

The multipliers used for the impact estimates are derived by the U.S. BEA RIMS II model. This input-output model estimates the multipliers from the structure and relationships between industries with a local region.[34] The multipliers are specific to the region for which they are created. It is not valid to apply the multipliers created for this region to other regions or to use multipliers created for other purposes in this context. The multipliers are expressed as a ratio of annual jobs per $ million (2008 USD) of change in annual regional economic activity from production, transportation, wholesale, and retail trade. Port investments in local power generation facilities are typically net increases in local economic activity and therefore lead to positive local employment impacts. It is possible that self-generation and energy efficiency investments are a direct substitute for other economic activity, such as distribution of electricity by utilities. However, because the Port investments would be relatively small in size and scope compared to a utility network, they are not considered substitutes and do not replace any other economic activities.

While the multipliers are a useful tool to compare the impacts of a variety of energy efficiency and distributed generation opportunities, it is important to keep in mind the limitations of the input-output method. These considerations have been previously identified by others. Ambargis and Bess give an excellent overview of the technical considerations of applying multipliers derived from input-output models.[35] For the purposes of this study, decision makers should consider these results only as upper-bound estimates of annual employment changes contingent upon the embedded assumptions within the input-output methodology and this analysis. From a practical perspective, this means that the units of analysis are "job-years," or one person employed for one year. Furthermore, the multipliers do not distinguish between a part time job and a full-time job. The annual purchases associated with the scenarios only impact local employment to the extent that purchases are made to local suppliers. Fifty percent local share has been used consistently throughout this analysis, except where purchases naturally require local vendors. This could be significantly lower or higher in practice, thereby producing different levels of benefits. The data used in the input-output models to create the multipliers is based on 2002 information. Industry structures may have changed since the data were originally produced. Another consideration is that only Type I multipliers were considered. These multipliers estimate job impacts only for direct and indirect economic activity, but not for induced activity. Any jobs created from induced impacts are not included in these estimates. Finally, the timing of the job impacts roughly follow the timing of the investment-related purchases. For this reason, the assessment used the "Bill of Goods" approach, breaking down

33 BEA (2012).
34 BEA (1997), 1.
35 Ambargis, Z., & Bess, R. (2011).

purchases not only by industry but also by project phase. This methodology provides realistic and comparable estimates of job impacts between the different scenarios.

Table 11: Bill of Goods by Industries and Project Phase for Dispatchable-High Scenario[36]

2002 NAICS Code	Impacted Industry	Final Demand Employment Multiplier (Type I)	Local Purchase Share	Annual Purchases by Project Phase (Purchaser Prices, current $ in millions)		
				Design, Development, & Engineering	Construction	Operations & Maintenance
541300	Architectural, engineering, and related services	8.5	50%	$0.5		
5416A0	Environmental and other technical consulting services	12.9	50%	$0.5		
333611	Turbine and turbine generator set units manufacturing	3.9	50%	$25.0		
333618	Other engine equipment manufacturing	5.3	50%	$2.0		
213112	Support activities for oil and gas operations	7.3	50%	$2.0		
333912	Air and gas compressor manufacturing	7.7	50%	$2.0		

36 Decommissioning and salvage operations can have a one-time impact on regional employment similar to construction activities. The employment impacts of this phase of operations were not evaluated for two reasons. First, the impacts occur far into the future at the end of the economic life of the project, anywhere between 8 and 30 years past the initial operation and commissioning. Also, any number of outcomes or variations of outcomes are possible. The projects could be decommissioned and the material salvaged, the project could continue to operate in a degraded condition, the generator could be repowered with updated technology, or the assets could be reconfigured for other useful purposes. Because of this uncertainty, no value was given to purchases during this phase or residual project value, thus there are no employment impacts during this project phase.

2002 NAICS Code	Impacted Industry	Final Demand Employment Multiplier (Type I)	Local Purchase Share	Annual Purchases by Project Phase (Purchaser Prices, current $ in millions)		
				Design, Development, & Engineering	Construction	Operations & Maintenance
334220	Broadcast and wireless communications equipment	6.1	50%	$2.0		
334290	Other communications equipment manufacturing	6.1	50%	$2.0		
335311	Power, distribution, and specialty transformer manufacturing	6.3	50%	$2.0		
335313	Switchgear and switchboard apparatus manufacturing	6.4	50%	$2.0		
335314	Relay and industrial control manufacturing	6.8	50%	$2.0		
335999	All other miscellaneous electrical equipment and component manufacturing	7.8	50%	$1.0		
230000	Construction	9.6	100%		$15.0	
811300	Commercial and industrial machinery and equipment repair and maintenance	6.9	100%			$0.8

2002 NAICS Code	Impacted Industry	Final Demand Employment Multiplier (Type I)	Local Purchase Share	Annual Purchases by Project Phase (Purchaser Prices, current $ in millions)		
				Design, Development, & Engineering	Construction	Operations & Maintenance
811200	Electronic and precision equipment repair and maintenance	8.6	100%			$0.8
221200	Natural gas distribution	2.8	100%			$12.6

Table 12: Employment Impacts for Dispatchable-High Scenario

Project Phase	Design, Development, & Engineering	Construction	Operations & Maintenance	Decommission & Salvage
Length of Phase	3 years	1 year	30 years	N/A
Direct Hiring by Project Owner	2 jobs	2 jobs	2 jobs	N/A
Subtotal Annual Project Purchases	$1.0 MM	$57.0 MM	$14.1 MM	N/A
Total Project Purchases	$3.0 MM	$57.0 MM	$423.0 MM	N/A
Total Purchases over Economic Life of Project	$483.0 MM			
Subtotal Regional Employment Impacts (full and part time)	5.1 jobs	226.2 jobs	44.5 jobs	N/A
Total Regional Employment Impacts (full and part time)	15.3 jobs	226.2 jobs	1,336.0 jobs	N/A
Total Impact over Economic Life of the Project (full and part time)	Up to 1,577.5 full and part time jobs (direct and indirect economic activity)			

5.3 Appendix C: Greenhouse Gas Emissions Impact Assessment

The purpose of this Appendix is to describe the methodology used to estimate the GHG impacts from each of the scenarios.

The methodology and basic assumptions were derived from the U.S. EPA website.[37] Electricity that is either not used or generated on site displaces utility electricity. The net CO2 emissions were estimated and with purchasing the same amount of energy from the utility provider. Because of the increasing penetration over time of renewables in the utility's portfolios, the utility emissions factors will decrease relative to the on-site generation with dispatchable resources.

Table 13: Emissions Impact Assessment for Dispatchable-High Scenario

Electricity Generated and Displaced	221,365.2	MWh
Effective Heat Rate	9.0	MMBtu/MWh
Average Carbon Coefficient of Natural Gas	14.47	Kilograms of Carbon/ MMBtu
Carbon Combusted	28,828,390	Kilograms
Fraction of Carbon Oxidized to CO2 during Combustion	100%	Percent
Ratio of CO2 to Carbon by Molecular Weight	44/12	Grams
CO2 Emitted	105,704	Metric Tons
CO2 Emitted	233,037,366	lbs
Generator Emissions Factor	1,053	lbs/MWh
Utility Emissions Factor	1,152	lbs/MWh
Net Avoided CO2 Emissions	9,968	Metric Tons CO2

5.4 Appendix D: Key Terminology

AMP: Stands for Alternative Marine Power. For air quality reasons, this program requires ocean going vessels to shut down their fossil fuel auxiliary engines at berth and replace the energy with electricity drawn from large, shore-based grid connections. Also known as "cold ironing."

Annual Average Demand: This means the average of all hourly average demand estimates (in MW) within the baseline year for a Port.

37 EPA (2012).

Capacity Factor: Capacity Factor is a measure of utilization of a generating facility over the course of a year. It is typically expressed as a percentage (total amount of energy actually produced over one year / total amount of energy the facility could have produced if it operated at maximum capacity in all hours of the year).

CHE: Stands for Cargo Handling Equipment. The Ports use a variety of diesel, gasoline, propane, and compressed natural gas powered CHE to handle containers and move cargo within the Ports. CHE consists of light duty trucks, yard hostlers, side loaders, forklifts, rubber-tired gantry cranes, etc. The Ports are evaluating options for electrification of CHE.

Consumption: Consumption is the total quantity of electric energy used by a machine, a utility customer, or in a geographic area over a specific period of time. The unit of consumption used in the analysis is megawatt-hours (MWh).

Demand: Demand is the instantaneous measure of power required by a machine or electrical device. Aggregate demand is the total rate of energy consumption by all electrical load sources on a circuit or within a geographic area. The unit of demand used in this analysis is megawatts (MW).

Dispatchability: Dispatchability refers to the ability of an electric generator to be controlled in real time by a power system operator. That is, the plant can be turned on or off, or the output can be adjusted up or down. Many generators that use fuel to produce electricity have some dispatchability available to the operator. The degree of dispatchability is dependent on many technical and operational factors (type of prime mover, co-use of thermal output, design criteria, etc.).

Energy: Energy is a quantity of electricity. It is quantified by measuring the power delivered over a period of time [power (watts) x time (hours) = watt-hours]. Electricity customers are charged based on the amount of electrical energy they used during the billing period. The unit of electric energy used in this analysis is megawatt-hours (MWh).

Intermittency: Intermittency means the variability of output associated with some renewable energy technologies. This type of output may or may not be predictable, but cannot be controlled at the request of a power system operator. Typical wind and solar facilities produce intermittent output.

Kilowatt: A kilowatt (kW) is a measure of power equal to 1,000 watts (W).

Kilowatt-hour: A kilowatt-hour (kWh) is a measure of energy equal to 1,000 watt-hours (Wh).

Megawatt: A megawatt (MW) is a measure of power equal to 1,000,000 watts (W).

Megawatt-hour: A megawatt-hour (MWh) is a measure of energy equal to 1,000,000 watt-hours (Wh).

Minimum Hourly Average Demand: This means the lowest demand (MW) estimated in a Port over all hourly measurement intervals within the baseline year. This represents an average over that hour. Actual demand is variable and could be significantly higher or lower in any given instant during that hour.

Power: Power is the ability to do work. Power is an instantaneous measure of electricity flowing in a circuit measured in watts (W). Industrial electricity customers are often charged based on the maximum power they required at any time during the billing period. The unit of electric power used in this analysis is megawatts (MW).

Peak Hourly Average Demand: This means the highest demand (MW) estimated in a Port over all hourly measurement intervals within the baseline year. This represents an average over that hour. Actual demand is variable and could be significantly higher or lower in any given instant during that hour.

TEU: Twenty-foot Equivalent Unit (TEU) is a measure of cargo roughly equivalent to that which is loaded in a twenty foot long shipping container. Shipping containers come in various sizes, but cargo volumes are often normalized to TEUs for consistency.

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