11-5-2017

Analytical assessment of port energy efficiency and management .: a case study of the Kenya Ports Authority

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ANALYTICAL ASSESSMENT OF PORT ENERGY EFFICIENCY AND MANAGEMENT: A CASE STUDY OF THE KENYA PORTS AUTHORITY.

By

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Kenya.

A Dissertation Submitted To World Maritime University in Partial Fulfilment of the Requirements for the Award of the Degree Of

MASTER OF SCIENCE

In

MARITIME AFFAIRS,

(MARITIME ENERGY MANAGEMENT)

2017.

Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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Acknowledgment

I wish to extend heartfelt appreciation to my family and friends for their support and encouragement. My immense gratitude goes to my thesis supervisor, Dr. F. Ballini for his insightful guidance, knowledge and support, especially in sourcing for research materials, and academic advice.

I am also most grateful to my WMU donors; The Germany Ministry of Transport who made it possible for me to embark on this academic journey. I also wish to extend my sincere gratitude to my employer; The Kenya Ports Authority (KPA) for granting me a 14-months study leave. I also want to say special thanks to WMU faculty and staffs, library assistance and the IT support team for their assistance. Without forgetting my MEM family headed by Professor O. Aykut and his capable team; Professor F. Ballin, Professor M. Kitada and my course mates. Finally I wish to express my gratitude and appreciation to my beloved family for supporting me throughout my study.

Abstract

Title of Dissertation	**Analytical Assessment of Port Energy Efficiency and Management: A Case Study of the Kenya Ports Authority**
Degree	**MSc**

With international shipping accounting for more than 80% of the global trade, Ports have evolved into very critical links in the supply chain and are no longer merely loading and offloading points. In order to meet the ever-expanding cargo volumes and throughput, ports have to invest more on infrastructural expansion, which includes more cargo handling facilities, more efficient conveyance systems etc.

A major handicap for the ports in Africa has been the insufficiency and unreliability of electrical power to drive the critical port operations. Although the sub-Saharan region nominally has electricity-generating capacity of 68 GW, this is largely unavailable due to ageing plants, poor maintenance and inadequate financing for the energy sector. This power shortage affects port operations across the African continents' 40,000 km coastline mainly because of heavy reliance on power from national grids (mainly sourced from Hydro).

Ports have to be equipped with standby diesel generators, with negative repercussions on operational cost and GHG emissions. This makes energy a high cost component for terminal operators. The growing international pressure, coupled with tighter emissions regulations and need to project competitiveness and corporate social responsibility with respect to environmental matters has positioned ports to take more proactive roles in relation to the environmental impact of their operations. Mombasa port is an energy hub, handling huge flow of fossil fuels (crude oil imports), and huge consumption of electricity accompanied by negative environmental impacts.

This thesis is motivated by the need to chart an energy efficiency path for Mombasa port that is consistent with growing regulatory pressure and sustainability needs. It will approach this subject by engaging in a technical and operational assessment of energy management and efficiency measures at the port of Mombasa.

KEYWORDS: Port Energy Efficiency, GHG Emissions, MARPOL, Renewable Energy, Benchmarking, ECOPORTs

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List of Abbreviations

AFDDT	Automated Fault Detection and Diagnostic Tools
BAS	Building Automation System
BPO	Baltic Port Organizations
BSR	Baltic Sea Region
CAPEX	Capital Expenditure
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DEA	Data Envelopment Analysis
DFID	Department of International Development
DWT	Dead Weight
EC	European Commission
ECA	Emission Control Area
EECA	Energy Efficiency & Conservation Agency
EIS	Energy Information Systems
E-MAP	Energy Management Action Plan
EnMS	Energy Management Systems
ESPO	European Sea Ports Organizations
ERC	Energy Regulatory Commission
EU	European Union
GHG	Green House Gases
GPA	Genoa Ports Authority
HELCOM	Helsinki Commission
IEA	International Energy Agency
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
ISO	International Standard of Organization
KENGEN	Kenya Electricity Generating Company
KPA	Kenya Ports Authority
KPLC	Kenya Power & Lighting Company
KVA	Kilo Volts Ampere
KV	Kilo Volts
LCOE	Levelized Cost of Electricity
MEPS	Minimum Energy Performance Standards
MoEP	Ministry of Energy & Petroleum
MP	Mombasa Port
MW	Mega Watt
MWh	Mega Watt Hour
NO_x	Nitrogen Oxides
MARPOL	International Convention for Prevention of Pollution from Ships
OPEX	Operating Expenditure
PAEP/PEEP	Port Energy Environmental Plan

PDCA	Plan-Do-Check-Act
pf	Power factor
PM	Particulate Matter
PV	Photovoltaic
RMG	Rail Mounted Gantry Cranes
ROI	Return on Investment
SECA	Sulphur Emission Control Area
SBM-DEA	Slakes-Based Measures Data Envelopment Analysis
SCADA	Supervisory Control and Data Acquisition
SO_x	Sulphur Oxides
Se4all	Sustainable Energy for All
STS	Ship-to-Shore Gantry Cranes
TEUs	Twenty Foot Equivalent Units
TMEA	Trademark East Africa
UNCTAD	United Nations Conference on Trade and Development
USD	US Dollar
U. S. EPA	United States Environmental Protection Agency

Chapter 1

1.0 Background.

With improvements in technology and world trade, the global energy demand has gradually swelled, with wide ranging impacts on the environment, and global greenhouse emissions. Along with this growth, there has been some negative effects of energy intensive applications, which complicate the quest for economic prosperity. “A tradeoff between economic growth and sustainable development emerges”. (Ismayilov, 2014) to achieve sustainability, Ports have to invest in solutions to the environmental impact of their operations.

There is a growing trend among ports to implement energy efficiency strategies including “green port policy”, Port Environmental Energy Plan (PAEP), ISO energy certification and environment friendly energy options. Apart from a few exceptional cases, most ports in Africa seem to be lagging behind in this quest.

Seaports are an integral component of the logistic chain, providing vital link between demand and supply. Port environments support business clusters which need significant sources of energy for their economic processes. Price volatility of energy resources, regulatory requirements and environmental concerns are major drivers for “the shift towards better management, improved efficiency and consumption of less energy in ports”. (Ilkka Hippinen, 2014).

The global push for energy efficiency in Ports is spearheaded by the International Maritime Organization (IMO) through (MARPOL Annex VI chapter 4). Generally, ports handle huge volumes of crude oil in the form of imports or exports. Due to this, port environments are susceptible to heavy pollution both from CO_2 and GHG emissions. In the case of the European Commission (EC), approximately 40% of all commodities handled are sources of energy making the European ports important industry clusters representing prominent energy users. (Boile, 2015)

The United Nations Conference on Trade and Development (UNCTAD) projects that, “Africa and Asia are expected to see the sharpest increase in emissions due to the strong port traffic growth and limited mitigation measures. However, legislation by governments in Africa and increasing global pressures on countries to espouse Green Port status could continue shaping investment decisions by port operators in the continent in the long term.” (Fairplay, 2016)

Whereas energy consumption in port terminals is a significant overhead for terminal operators, its cost and associated emissions are largely viewed as a fixed overhead, which the terminal manager has little control over. For instance in Mombasa Port, 100% of the energy supply is from the national grid. The current power demand stands at about 4.5 Mega Watts. This is inadequate, ineffective and subject to frequent power outages. The resulting stoppage of virtually all Port operations represents a cost which the Authority has no control over. A case in point was reported on 7th October 2013. The Kenya Ports Authority (KPA) once reported losses of over $800,000 after a three-day blackout, which rendered the cranes motionless for over 75 hours and no cargo, was loaded or off-loaded from container vessels. (Port Technology Organization, 2013).

With the implementation of Energy Management Programs, these costs and emissions can be minimized. According to various studies, “an initial reduction of 10 percent in energy cost and emissions is typical with minimal capital investment, plus payback in less than two years and more than 15 percent Return On Investment (ROI)”, (Boile, 2015). Such margin of reduction is consistent with the Port management aspirations.

KPA is finalizing a Green Port policy with the support of the United Kingdom’s Department of International Development (DFID) and Trademark East Africa (TMEA), at a budget estimated at USD34 million. Through this project, KPA targets the operationalization of measures that will lead to reductions in electricity and fuel consumption by vessels, trucks, and port equipment by 2020. The Green Port Policy will make it mandatory for all ships destined for the Mombasa Port to use clean energy and ensure only new technologies and equipment that are either electric-powered or use clean fuel operate at the port. Currently, the port uses diesel-powered generators for emergency power supply during temporary disruption of electricity from Kenya’s 2,177 MW national grids.

KPA is also keenly exploring measures that will improve efficiency and specifically lead to a reduction in its annual electricity budgets. This thesis explores the options available towards achieving this objective both from technical and operational perspectives.

1.1 Problem Statement

Electrical power to the Mombasa Port facility is supplied from two sub-stations connected to the National Power Grid. Typical port operations where the bulk of this power is utilized include: powering cranes, fixed equipment such as reefers, port lighting, office lighting and air conditioning. Despite measures undertaken to improve operational efficiency, the expected outcome in terms of reductions in energy consumption and electricity power bills has not been realized. The Port Management in Mombasa (KPA) monitors electricity consumed through the monthly bills with no sub-meters installed to enable verification and calculation of specific energy drawn by the various port sections. This makes it hard to focus energy efficiency efforts for maximum socio-economic benefits.

In 2013 total consumption as determined by the Utility Company was 12,750 MWh. These figures have remained high despite measures already instituted to improve energy efficiency and reduce consumption at the port. Therefore this thesis represents an attempt to find a solution to this opaque billing system, by benchmarking with other energy efficient ports, and recommending operational measures to improve efficiency and transparency in regard to energy demand and supply at the Mombasa Port.

1.2 Research Objectives.

KPA depends entirely on the national grid for electricity supply to the Mombasa Port, and other ports owned by the authority. The main area of the port's electricity consumption is ship-to-shore gantries, Rail Mounted Gantries operations and other port cargo handling equipment, lighting of yards and buildings.

The port conducted an analysis of the year of build of the vessels that visited the Port in 2013, and the findings were that more than 50% of the vessels were over 15 years old. Generally, most ships calling at the Mombasa Port are aged and have inefficient auxiliary engines. The consequence is more fuel consumption, additional GHG emission and higher than necessary noise levels within the port area. The situation therefore calls for urgent exploration of options for renewable energy sources. According to a consultant's report, "The initial focus can be providing green power to all workshops and the lighting of roads and yards. This will enhance visibility for 24/7 work, improve security, and reduce carbon emissions". (KPA Consultant's Report).

This thesis seeks to analyze energy consumption at Mombasa Port. The improved understanding of the port's energy consumption which results from this study, will assist the port's management in implementing measures and focusing resources on policies and energy efficiency procedures that guarantee positive results. To attain this overall goal, the following objectives will form the basis of this thesis:

1. Analysis of sectorial energy consumption at the Mombasa Port, with a view to identifying the scope for improvement of efficiency.

2. Comparison of energy consumption data with similar data obtained from energy efficient Ports, which will assist in charting the path towards a lean and efficient energy management strategy.

3. Analysis of policies, technologies and sustainability measures at the port of Mombasa, vis a vis measures pursued by some benchmarked energy efficient Ports with a view to making recommendations to the management of Mombasa Port.

1.3 Research Questions

The main aim of this research work is to carry out an analytical assessment on the Energy Profile of the Mombasa Port, identify gaps in energy efficiency and make recommendation for improvement. The following research questions will be addressed:

(1) What is the energy consumption profile of the port of Mombasa?

(2) Based on the current distribution and consumption patterns of this energy, are there measures that can improve energy efficiency?

(3) How can the Port Management incorporate "energy efficiency and management" into the Port's corporate Policy?

1.4 Methodology.

To respond to these research questions and set the stage for this research task, information and data was retrieved from a number of sources. Mombasa Port is the main subject of research, but for purposes of an objective appraisal, energy data of the ports of Genoa (Italy), Gothenburg (Sweden) and Durban (South Africa) were perused, to establish the correlation between the various port functions with regard to energy consumption. Information on cost data, technical and energy performance of each port considered in this thesis were obtained from journals, books, articles, periodicals and reports. Such sources include KPA's Annual Reports, World Energy Council Journals, International Maritime Organization (IMO), International Renewable Energy Association (IRENA), Lloyds List, European Seaports Organization (ESPO), reports, International Energy Agency (IEA) reports and European Commission (EC) directives on energy. For accuracy of analysis and projection of sectorial energy consumption, a complete sample of metered electricity bills was collected from the Mombasa Port over a period of two years.

This research task is tackled via a three-pronged approach. Firstly, the regulatory framework relating to energy efficiency in ports is carefully analyzed with a view to ascertaining the impact of emerging international, regional and national regulations on the short, mid, and long-term sustainability of the port. Secondly, the energy profile of the port is analyzed to establish gaps and potential areas for improvement. This is done through a benchmarking process with the ports of Genoa, Gothenburg and Durban (South Africa). This leads to a big picture overview with regard to energy management, helping the researcher to draw innovative recommendations on consumption, planning and management for consideration by Kenya Ports Authority.

1.5 Thesis outline

Chapter one of the dissertation will contain the highlights of the problem, objectives of the study, methods to address the problem, and research scope. Chapter two is an extensive literature review exploring on the energy efficiency, energy planning, energy management and environmental impacts in ports.

In chapter three, the Legal frameworks related to Energy Efficiency in maritime sector are discussed.at International, regional, national and local levels for energy efficiency in the Port. Chapter four explores the benefits of energy efficiency concept based on the benchmarked ports.

Chapter five is case study application on port energy efficiency and management at the Mombasa port.

Chapter six is the two main analysis- gap analysis and benchmarking analysis. Finally, chapter seven contains conclusions from the study and specific recommendations applicable to Mombasa Port.

1.6 Research Limitations.

This dissertation will encompass environmental, human factors, regulatory frameworks and technological concepts related energy efficiency. The system boundary in the context of the dissertation will be the port infrastructure, ships at berth as well as those within the port approach (awaiting berthing space/ instruction). The port cluster will be construed to extend to port induced, port related and port attracted business clusters. The human operational aspects with the regards to energy efficiency and management will constitute the major focus of this dissertation

CHAPTER 2

2.0 Literature Review.

This section reviews some previous studies undertaken in relation to energy management and efficiency improvement in ports. This thesis focuses more on measures necessary to improve energy efficiency, with attendant benefits in energy cost savings and GHG emissions reduction.

In recent times, *green* and *sustainability* issues have become "increasingly part of port agendas." (M. Adams, 2009). According to Burns & McDonnell Engineering Company, Inc. Brea, California, 2014: "Energy is a fundamental part of society. Some of the biggest challenges facing the nation, such as security and climate change, revolve around the efficient and innovative use of energy. Likewise, energy is critical to the current and future security and prosperity of the Port. With the gradual move away from fossil fuel-based terminal operations, the Port is going to increasingly rely on electricity to move goods." (Burns & McDonnell Engineering Company, Inc. Brea, California, 2014).

Studies undertaken on Port energy management have tended to mainly focus on Port energy efficiency, alternative fuels and environmental impact of port operations.

ESPO / EcoPorts surveys carried out in the last 15 years, identified the main environmental priorities of European ports as ;(1) air quality management, (2) waste management, (3) noise management, (4) water management (both consumption and quantity) and (5) energy conservation and climate change. These priorities issues have been continuously identified hence made the European ports to address them by demonstrating pro-activeness and self-regulation in practical terms. This is further demonstrated in Table 1 in chapter 4. (ESPO , 2012.)

Acciaro et al, 2014 examined energy management in seaports and presented new insights into the evolving roles for Port Authorities, as they position themselves for more direct and enabling roles in the supply chain. He also considered environmental sustainability in seaports as a basis for successful innovation in maritime policy and management. In their view: "Environmental sustainability in the port industry is of growing concern for port authorities, policy makers, port users and local communities. Innovation can provide a solution to the main environmental issues, but often meets resistance” (Acciaro et al, 2014).

Boile et al, 2015 extensively explored the issues and challenges surrounding the development of a port energy management plan and raised important prospects in relation to this goal. They concluded that energy consumption is a major overhead cost in ports, which can be reduced significantly in many cases with minimal capital investment. This finding underscores the fact that investment in energy efficiency involves a trade off in various competing resource end-uses.

Matulka et al, 2013 assessed key elements relating to the building of resilience centered on the benefits of energy security investment in San Pedro Bay Ports, and noted that: “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.” (R. Matulka, 2013)

Environmental impact is a major challenge resulting from port operations.

Adams et al, 2009, explored the environmental issues in ports’ competitiveness. In his assessment: “ports must comply with their applicable environmental laws and regulations in order to avoid enforcement actions by the responsible government agencies. Societal pressures act towards that direction as well motivating ‘greening’ initiatives further.” (M. Adams, 2009).

In another study conducted by Chang, 2013, labor, capital, and energy were deemed as inputs to the port sector, while cargo and vessel tonnage handled as desirable outputs. CO2 emission was deemed an undesirable output. It was collected and measured. The SBM-DEA model was able to yield a more effective trade-off between economic performance and environmental performance and was also able to capture slack values of input excess and undesirable output excess (CO2) as well as desirable output shortage. Based on this model, the study concluded that: “Korean ports were economically inefficient, but environmentally efficient when considering economic and environmental performances simultaneously.” (Chang, 2013). This emphasizes the fact that energy planning involves a trade-off between various competing end-uses.

The United States Environmental Protection Agency (U. S. EPA) in an information document for developing and implementing emission reduction program, 2011 proposed a resourceful guide for ensuring successful employment of strategies towards GHG reduction. All these insightful reports and publications provide practical gauge for the analysis of the energy consumption and management scenario at the port of Mombasa from operational, technical as well as the existing regulatory framework. Whereas energy sustainability and cost are key drivers for port energy efficiency initiatives, available studies and literature do not shed enough light, especially with ports in developing countries, where pollutants are becoming a key feature in port operations.

The subject of pollutants within the port environment continues to draw concern from various international, regional and national quarters. While considering the topic of energy efficiency in port environments; assessment of the pollutants resulting from port activities becomes imperative.

IMO has delivered a raft of recommendations through a series of GHG Studies. The IMO 2nd GHG Study identifies the following pollutants, deemed phenomenal to port environments, and directly associated with port operations: NO_x, SO_x, PM, VOC and to a lesser extent CO and CO_2. Controlling NO_x, PM and SO_x is a key objective for most national and regional regulatory agencies. Whereas most ports are becoming increasingly concerned over GHG emissions, health concerns are more prioritized. Not all CO_2 control measures deliver reductions in NO_x and PM and therefore for each port area, control strategies depend on individual Port Management's stated goals.

Oxides of Nitrogen (NOx) cause environmental effects, which include acid rain, nutrient overload in water bodies and visibility impairment when combined with atmospheric particles. Health effects associated with NO_x include inflammation in the respiratory system leading to coughing, chocking and reduced lung capacity over long period of exposure.

Particulate Matter (PM) cause acute respiratory stress and a range of chronic illnesses from long-term exposure. Several health authorities including the World Health Organization's (WHO) and International Agency for Research on Cancer (IARC) have listed PM that specifically comes from diesel engines (i.e. DPM) as a "toxic air contaminant" indicating it has specific and demonstrated carcinogenic effects.

On the other hand, Sulphur oxides (SO_x) describes the family of sulphur oxide gases that includes sulphur dioxide (SO_2), sulphur trioxide (SO_3) and sulphate (SO_4). When fuel-containing sulphur is burned, SO_x gases are produced. Despite regulations on fuel sulphur content around the world, SO_x emissions from ships and land-based equipment remain a significant challenge. Health effects include the resulting chain effect, when PM is generated in the combustion exhaust stream. PM generated from SO_x is harmful both as a physical lung irritant and for its chemical characteristics, making it particularly harmful to people with respiratory ailments such as asthma and chronic obstructive pulmonary disease. In addition to health effects, SO_x in the atmosphere can create significant aerosols that impair visibility and formation of acid rain.

Generally, port stakeholders are more concerned with pollutants that have immediate and localized impacts. NO_x, PM and SO_x are the most critical pollutants affecting air quality around port areas. Ozone and PM are the two most common drivers of air quality initiatives worldwide and stand at the core of Port Authorities' efforts to reduce emissions. Past studies show that, depending on geographic and meteorological conditions, emissions generated hundreds of miles out at sea can reach and affect shore-based populations. This translates to a very large footprint, rendering emissions a major concern in IMO's Pollution Prevention agenda (as outlined in MARPOL Annex VI, Chapter 4). Pollutants emitted near the shore within the port area, have an even higher potential for negative effects.

Another major area of focus at IMO, and among port operators has been the optimization of terminal operations with a view to reducing at berth time. Improved terminal efficiency leads to reductions in ship at-berth times and hence overall at-berth emissions. Efficiency improvements could include newer, more efficient quay cranes, streamlining administrative delays, elimination of terminal landside bottlenecks, improved ship positioning considerations, automated mooring systems, terminal automation, and overall efficiency improvements.

Automated Mooring Systems, (mooted in late 1990s) as efficiency improvement and emissions abatement measures, have been quite effective. Based on IMO's projections, ships employing automated mooring systems save up to 1.5 hours from the mooring process, thus reducing the resultant emission. The systems are remote-controlled vacuum pads, recessed or mounted to the quayside and attached to hydraulic actuated arms, which extend, attach and moor a ship under a minute. The systems can be designed to handle all ship sizes. They enable faster ship-turnaround times, speed up disembarking of passengers and crew, and reduce wear and tear on ship winches, hull and plating.

IMO has commissioned several studies that deal with a range of topics on ship-port interface. IMO Document MEPC 68/INF 16 (March, 2015) provides a broad summary of three areas in which measures applied at the ship-port interface can lead to good improvements: (1) equipment measures which incorporate engine technologies, (2) energy measures- which involve the application of alternative fuels and sources of power (for instance solar and wind). The third category involves operational measures, which aim to minimize ship’s idle time in ports by eliminating delays, The ship port time levels is important because typically, ships spend at least 25% of their lifecycle in ports (IMO, 2015).

CHAPTER 3

3.0 Port Energy Efficiency Regulations.

According to the International Energy Agency (IEA), Energy Efficiency (EE) governance is defined as: "the combination of legislative frameworks and funding mechanisms, institutional arrangements, and co-ordination mechanisms that work together to support the implementation of EE strategies, policies and programs" (IEA, 2012: 14).

The effectiveness of energy efficiency policies depends on several factors and varies greatly with country contexts. According to the recommendations by the International Energy Agency (IEA) factors like enabling frameworks, institutional arrangements and coordination mechanisms are key pillars in EE policies.

3.1 International legal frameworks.

European Union (EU)

EU's energy policies are motivated by the need to secure energy supply and combating climate change. The EU has created an ambitious energy strategy extending to the year 2020, aimed at mitigating emissions of greenhouse gases by 20% (compared to 1990 levels), to increase the share of renewable energies to 20% of final energy consumption, and to increase energy efficiency by 20%.

The European Seaport Organization (ESPO) Port Environmental Review 2013, identified the most significant environmental issues for EU ports through a survey which highlighted the progress that has been achieved over the years. 79 ports from 216 European Maritime States participated in the survey. ESPO and EcoPorts have been monitoring the top environmental priorities of the European port sector since 1996 through regular respective surveys. Surveys were conducted in 1996, 2004 and 2009. With changing global realities, interest in environmental issues has increased and this has been accompanied by evolving priorities. Politics has played a major role, with most environmental priorities reflecting political drivers.

Most EcoPorts member countries have in place legislative documents complying with the EU directives on energy efficiency (Directive 2006/32/CE), but the majority of them do not apply an energy consumption monitoring system in ports operation. A major challenge has been the fragmented nature of the relevant legislation in some member countries, including Bulgaria, Italy, Greece and Romania. This underscores the need for more detailed regulations and monitoring techniques to be developed and applied for a successful energy monitoring scheme.

The main EU legislative and Standardization documents on energy efficiency are:

1. The Directive 2006/32/CE on energy end-use efficiency and energy services repealing Directive 93/76/CEE" (IMO, 2015)

2. International Standard for Energy Management ISO 50001:2011 (based on the BS EN 16001 - Energy Management Systems).

The Directives provides guidance on implementing the processes necessary to evaluate the baseline energy usage, instituting action plans, targets and energy performance indicators for reducing consumption as well as identifying and prioritizing opportunities for improving energy performance.

MARPOL Annex VI – Regulations for the Prevention of Air Pollution from Ships.

MARPOL Annex VI Chapter IV- Regulations on Energy Efficiency -IMO regulations on NOx and SOx reduction targets ship operators, and likewise for the EU's legislation on the use of low sulphur fuel (LSF) for ships at berth. There are also some regulations that (in) directly affect ports and terminals: – The EU air quality legislation (Directive 2008/50) requires EU countries to meet certain air quality standards. The relevance for ports is that, depending on the local situation, they can only develop expansion projects if the local air quality limits are met and mitigation measures to compensate for a project's additional emissions are implemented.

The International Maritime Organization (IMO) has been the leading light in regards to global regulations to minimize the negative impact of shipping on the environment, which resulted in MARPOL 73/78 (The International Convention for the Prevention of Pollution from Ships) and its six annexes that govern the shipping industry's environmental performance. Despite the global stewardship provided by the IMO, the EU and Baltic Sea Region (BSR) countries have developed policy frameworks at their own pace, often being ahead of the global environmental regulations for shipping. Since the early 1970s the BSR countries have undertaken joint efforts aiming at stopping the deterioration of the Baltic. This resulted in the signing of the Convention of the Protection on the Marine environment of the Baltic Sea Area, also known as the Helsinki Convention. The Helsinki Commission (HELCOM) as a governing body plays an important role in the Baltic's protection, and has actualized significant environmental improvements in many areas. In order to further stimulate the work towards a cleaner Baltic, the HELCOM Baltic Sea Action Plan was adopted in 2007. Its aim is to restore the good ecological condition of the Baltic marine environment by 2021. Subsequently, in October 2009, the EU Strategy for the Baltic Sea (EUSBSR) was adopted by the European Council to address "the urgent environmental challenges arising from the increasingly visible degradation of the Baltic Sea," being the first EU macro-regional strategy. One of its policy areas is for the BSR "to become a model region for clean shipping," coordinated by the Danish Maritime Authority.

Reducing air emissions from shipping has been a hot topic in the maritime industry over the last decade. A discussion took place within the context where emission and fuel standards for international shipping lag behind those of land-based transport modes. Indeed, a wide range of regulatory measures has been adopted in recent years to curb air pollution from land-based sources, whereas shipping emissions remained untouched.

3.2 Regional Agreements and Strategies.

With growing awareness of the need to protect environment, regional trade agreements now tend to incorporate objectives and mechanisms to reduce emissions. Many have potential implications for maritime energy efficiency. There are a number of regional cooperation on the research for, development and demonstration of low-carbon energy technologies and development of policy frameworks to promote deployment of low carbon technologies

Examples of such Regional initiatives include Italy - Regional Law n.31 of October 21, 2008 concerning "rules about renewable energy sources, and for pulled releases' reduction and about environment"; Legislative Decree n.115 of May 30, 2008 "Implementation of Directive 2006/32/CE on energy end-use efficiency and energy services repealing Directive 93/76/CEE";

Although Ports authorities and terminal operators are important drivers for reduction of emissions at the ship-port interface, they are in many cases not the stakeholder directly affected by the regulation, nor responsible for implementation of the technical measures.

CHAPTER 4

4.0 Overview of Ports Energy Efficiency

The updating of the top ten environmental priorities has been a regular exercise for Ports sectors because it indicates the current issues at stake within ports sector.

According to available literature and as reaffirmed in the EcoPorts survey report, *Table 1* below, highlight the top ten environmental priorities issues for 2009 with the comparisons done on the same survey in 1996 and 2004 and the variations over that time is shown . In general observations, environmental issues that appears consistently over time are plotted with the same colour. Air quality remain to be the main priorities while energy consumption in ports is surpassing other environment priorities such as noise , relationship with community, port development and water quality. It is obvious that a lot of emphasis is now given to energy consumption hence growing awareness of the component that contribute to GHG emission and the climate change.

Table 1: Evolution of Top Ten Environmental Priorities overtime (1996-2019). Source-ESPO/EcoPorts Port environmental Review 2016.

	1996	2004	2009	2013	2016	2019?
1	Port Development (Water)	Garbage / Port Waste	Noise	Air quality	Air quality	Energy consumption
2	Water quality	Dredging Operations	Air quality	Garbage / Port Waste	Energy consumption	
3	Dredging disposal	Dredging disposal	Garbage / Port Waste	Energy consumption	Noise	

4	Dredging Operations	Dust	Dredging Operations	Noise	Relationship with community	
5	Dust	Noise	Dredging disposal	Ship waste	Garbage / Port Waste	
6	Port Development (Land)	Air quality	Relationship with local community	Relationship with community	Ship waste	
7	Contaminated Land	Hazardous cargo	Energy consumption	Dredging Operations	Port Development (Land)	
8	Habitat loss / degradation	Bunkering	Dust	Dust	Water quality	
9	Traffic volume	Port Development (Land)	Port Development (water)	Port Development (Land)	Dust	
10	Industrial effluent	Ship discharge (bilge)	Port Development (Land)	Water quality	Dredging Operations	

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4.1 Port Energy Management Strategy.

Energy Management strategy is a long-term undertaking intended to deliver more energy savings whilst focusing on continuous improvement. A good Energy management Strategy requires studies, research, programs and projects to improve overall power profile of Port operations in a manner that is protective of the natural environment and the Port's continued economic viability and national competitiveness. According to Burns & McDonnell Engineering Company, 2014, the process of implementing the Energy Management Action Plan (EMAP) begins with the development of Organizational foundation, followed by establishment of partnerships (collaboration and outreach). It also requires the carrying out of surveys and studies that contribute to the development of an Energy Master Plan, while prioritizing programs and projects that enhance the Port's five Energy Pillars. The above explained steps are illustrated in *figure 1 below*.

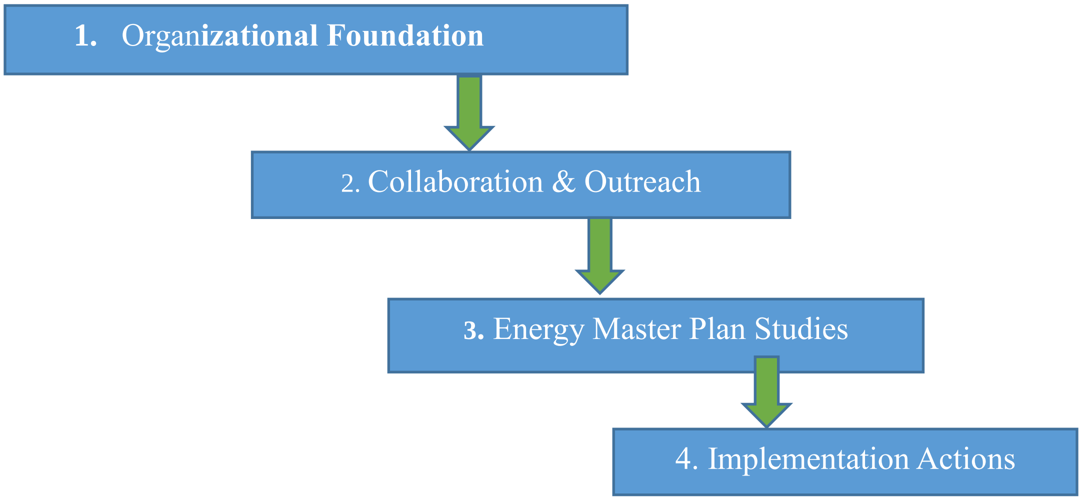


Figure 1: Overview of Energy Management Strategy. Source-Port of Los Angeles, 2014.

This approach has been broadly and successfully applied in a number of Ports. According to Boile et al, 2015 "ports are starting to develop Energy Management Plans (EnMPs), either at a port authority or at a terminal operator level, as part of their overall "green" port policy." (Boile et al, 2015). Green Port Policy is a concept that is redefining energy Management in Ports.

Acciaro et al, 2016 also note in the analysis of the Port of Hamburg (Germany) that: "Hamburg, in addition to being one of the major European Ports, has been particularly proactive in terms of energy efficiency and the promotion of energy management ." (Acciaro, Ghiara, & M. I.Cusano, 2014). Therefore, the Port of Hamburg provides an ideal case for benchmarking.

The Port of Los Angeles also commissioned an ambitious Energy Management Action Plan in 2013. According to the Port's officials, "The E-MAP would serve as the Port's blueprint to identify, develop and implement various programs to improve energy efficiency, reliability, quality, cost and resiliency while keeping up with the accelerating electrification and energy demand at the Port". (Port of Los Angeles, City of Los Angeles, 2013).

4.1.1 Port Energy Management Objectives and Goals.

From available literature, a port strategic plan, energy management objectives and goals should be built on five pillars: *Resilience* (ability of a port to sustain its business continuity during a power outage and resume operations after a catastrophic event). *Availability* (access to energy sources that are required in order to meet present and future power demand of port operations through energy generation, transmission and distribution). *Reliability* (availability of high quality and consistent energy able to meet predicted peaks in demand). *Efficiency* (reductions in energy demand through management practices and technologies that maximize operational productivity and cost effectiveness) and *Sustainability* (integration of energy management practices and renewable power generation to minimize the depletion of natural resources thus providing economic, social and environmental benefits).

4.1.2 Developing an Energy Management Plan

A number of steps are involved in the development of an energy management plan. These are illustrated in *figure 2* below. All the stages in the process are arranged in a structured approach that contributes to the attainment of Energy Management Goals.

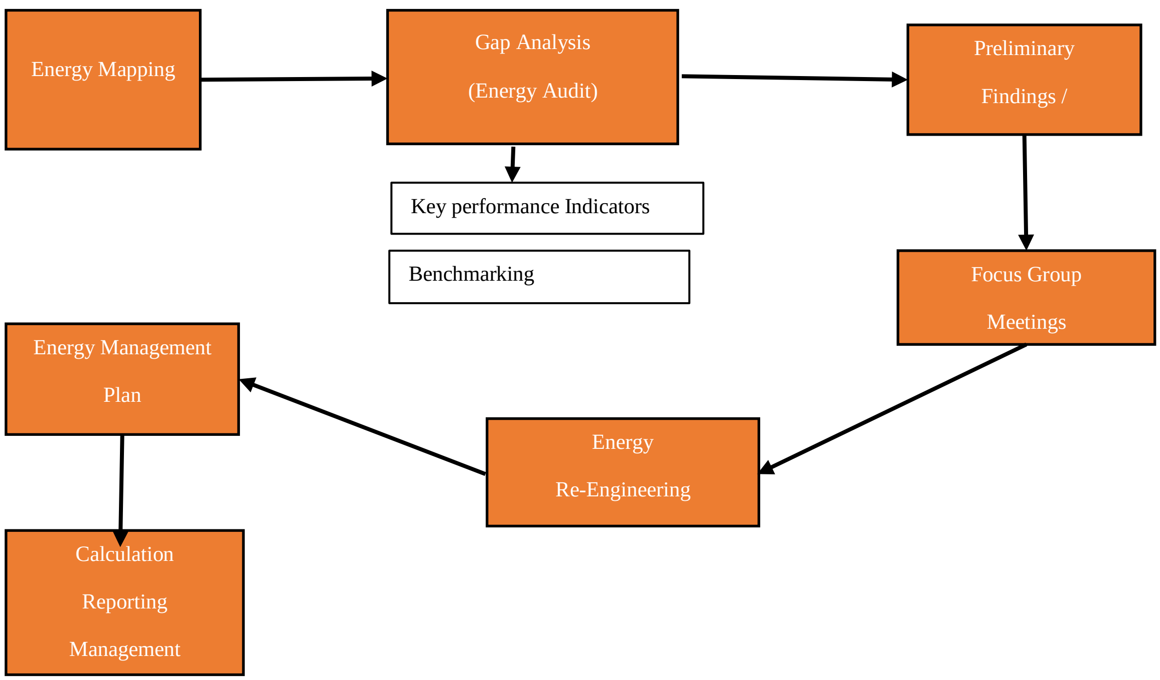


Figure 2: Structural representation of process of developing port Energy Management plan. Source-Boile et.al, 2015.

In a nutshell, this incorporate the following activities: *Energy Management vision, objectives and Goals* –which involves setting of targets Energy Policies, Regulations and standards; which is applied at four levels that is International level (for examples MARPOL), National level, Regional level (European Union (EU) and Helsinki Commission- HELCOM) and at Port Level (Baltic Port Organizations (BPO) and European Sea Ports Organization (ESPO)).

A Summary of main energy consumption data **-**by type of energy e.g. electricity or fuels

*Energy needs and potential measures for improvements***-** focused round the main port energy consumers. *Selection of criterial for energy improving measures and selection of measures to be adopted***-** taking into account the timeframe, CO2 emission reduction, total cost, cost effectiveness, technical feasibility, implementability, measurable result, co-benefits, funding opportunities and enforceability. *Timeline and responsibilities for plan adoption and implementation***-** for all relevant stakeholders.

After establishing the organizational foundation, *engaging stakeholders input and agreeing on an energy management master plan, the next step is the development of a Plan of Action***-** which basically informs implementation and timeframe. Effective implementation of the energy Action Plan steps requires the enumeration of the proposed activities in terms of short term (0-1 year), medium term (1- 2 years); long term (over 2 years).

4.2 Port Energy Performance Tracking.

The main objectives of undertaking Energy Performance Tracking are to enable initiation of sound operation, to be able to verify energy cost savings projects and to indicate additional savings which leads to positive environmental impact (GHG emission reduction).

For effective implementation of energy efficiency measures, there have to be detailed tracking of energy consumptions sources and energy demand. Consequently, Ports and terminals within maritime sector should be able to account for energy used in their operations. This therefore calls for a set of measuring and reporting procedures to be aligned with the energy performance tracking systems.

The main steps of carrying out energy performance tracking process include; use of information to detect problems in the systems- (e.g. data loggers, meters, and voltage / power analyzer), diagnose problem and identify solutions, action that is fixing the problems and see results and finally monitor and track the energy use.

Energy performance tracking is a continuous process as depicted in *figure 3* below

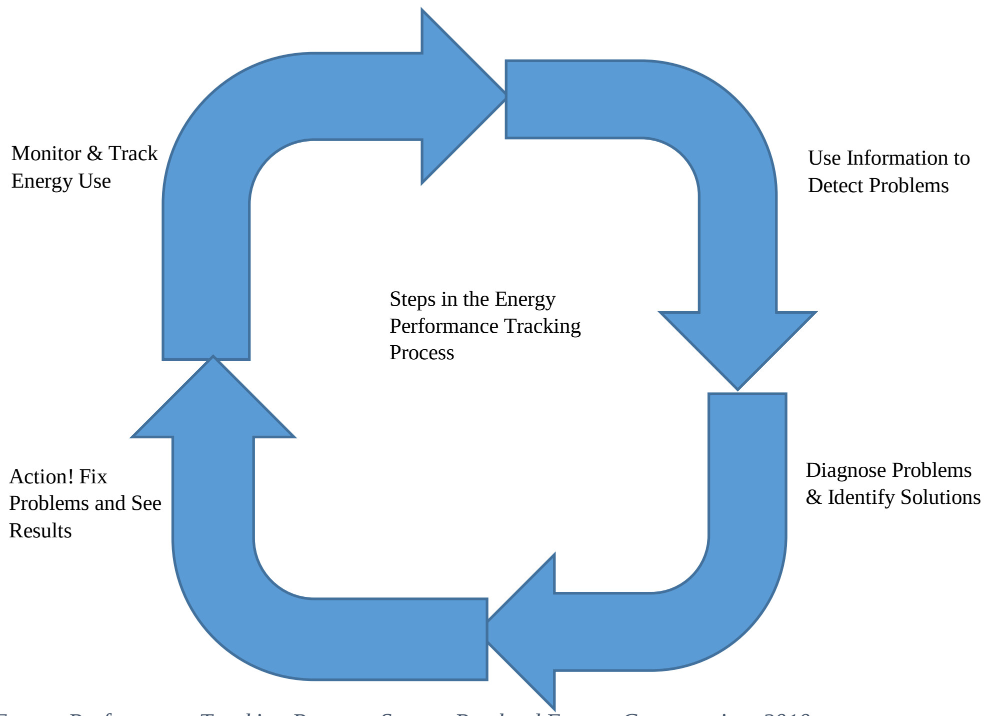


Figure 3: Energy Performance Tracking Process. Source-Portland Energy Conservation, 2010.

CHAPTER 5

5.0 Case Study of Kenya Ports Authority

5.1 Kenya Energy sector.

Management of the Energy Sector in Kenya is undertaken by a number of government entities which all work under the Ministry of Energy and Petroleum (MoEP). The four directorates under MoEP are- Petroleum, Electrical Power, Renewable Energy and Geo-exploration, (Sustainable Energy for All (Se4all), 2016).

Although the Energy Sector is dominated by the public players (Government Bodies), there are a few Independent Power Producers (IPP), who are involved in the generation of electricity. The Ministry of Energy and Petroleum has the overall responsibility for Management of Energy Sector as well as in facilitating provision of energy in Kenya. The Energy Regulatory Commission (ERC) is a public company established under the Energy Act 2006 with the following core functions: Regulating electrical energy, petroleum and related products, renewable energy and other forms of energy, Protecting consumers, investors and stakeholders' interests, maintaining the national register of accredited energy auditors and ensuring fair competition amongst the industry players. In the Electricity Generation sub-sectors, the two main players are the Kenya Electricity Generating Company (KENGEN) and the Independent Power Producers (IPPs).

Power Transmission is exclusively undertaken by Kenya Power and Lighting Company (KPLC) while Kenya Electricity Transmission Company (KETRACO), another government body is solely responsible for transmission on Grid above 132 KVA. Kenya Power and Lighting Company (KPLC) is solely responsible for power distribution to end users. The hierarchy of the Kenya energy sector is clearly shown in *figure 4* .The figure shows all the respective bodies involved in the power generation that is from the ministerial level to local end users. The ministry of energy is the overall head of the sector.

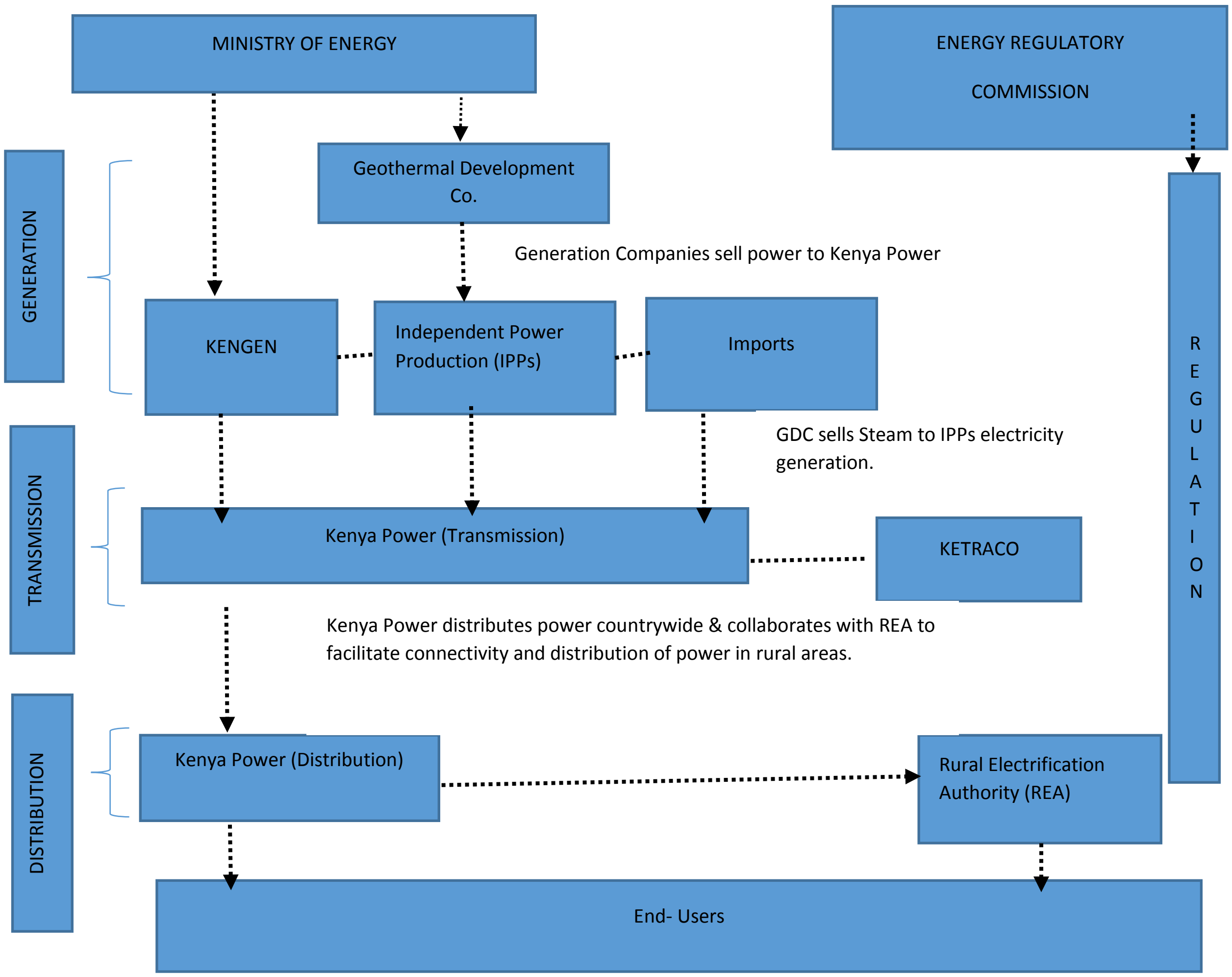


Figure 4: Hierarchy of Kenya Energy Sector. Source-Business Sweden

Kenya's Energy Mix.

According to ERC Kenya currently has an installed electricity generation capacity of 2,299MW comprising: hydro 821MW, thermal 827MW, geothermal 598MW, co-generation 26MW, and Solar 0.57MW as from June 2015. Currently up to 50% of Kenya Electricity is derived from Hydro sources, while Geothermal accounts for 14%. Based on the country's Energy projection for 2030, the contribution from hydro sources is expected to fall significantly, as gradual replacement with renewable sources continues.

Energy Regulatory Framework in Kenya.

The Energy sector legal framework is established in the following three documents: The Energy Act of 2006, which provides framework for climate change alleviation and implementation of energy policy; the Kenya's Energy Policy of 2004, which lays the foundation for the current energy policy and the Feed-in Tariffs policy of 2008 (Revised in 2012), which encourages electricity generation through renewable sources.

In 2010, the country adopted a new constitution, (Constitution of Kenya, 2010) which among many other key areas, acknowledged the importance of sustainability in energy and therefore recommended a number of policies aimed at stimulating the uptake of alternative fuels and renewable energy options. The Ministry of energy takes a lead role on energy policy matters. Development and Implementation of these various energy regulations is shared among a number of government regulatory entities.

5.2 Overview of Kenya Ports Authority.

Kenya Ports Authority (KPA) is a statutory body established by an Act of Parliament on the 20th January, 1978 operating under the ministry of transport and infrastructure of the government of Kenya. The Authority's core mandate is the management and operation of the Mombasa Port and other smaller seaports, the inland container depots in Nairobi and Kisumu, with Liaison offices in Kigali and Kampala that cater for transit countries.

The core business of the Kenya Ports Authority is to provide Marine services, which includes: Towage, Dry docking, Pilotage, Maintenance of the channel and turning basin; as well as Navigation aids, Stevedoring and shore handling services covering cargo handling services both for containers, general cargo, dry bulk and bulk liquids, and reception of the vessels.

The Port is located at 04°04'13.0"S and 39°39'52.0"E along Kilindini harbor which is a natural harbor extending over 7 nautical miles in length, and 300 m width with a maximum depth of 15m. KPA is a Public Service Port with staff population of around 5,000. It is bounded by a historical Mombasa City and serves an extensive hinterland that extends to Uganda, Rwanda and South Sudan. It is actually the main Port in the Eastern coast of Africa.

According to the Port's 2015 annual report, 26.732 million tons of cargo was handled, made up of Containerized Cargo (10,276,000 DWT)-38.44%, Conventional Cargo (2,256,000 DWT)-8.44%, Dry Bulk (6,928,000 DWT)-25.92% and Liquid Bulk (7,272,000 DWT)-27.20%. (Kenya Ports Authority, 2015). Imports increased by 9.2 per cent, from 20.777 million tons in 2015 to 22.680 million tons in 2015. Exports also registered an increase of 5.0 per cent, from 3.366 million tons in 2014 to 3,534 million tons in 2015. In 2015, a total throughput handled stood at 26.73 million tons and container traffic at 1,076, 118 TEUs, while the bulk of imports consist of 22. 680 million tons and exports 3,534 million tons.

Mombasa Port Berths Allocation.

The Mombasa Port has a sheltered deep, natural harbor over a terrestrial area extending over 7 ha and berthing area comprising a total of 22 berths (*See figure 5).* The berths are numbered from 1 to 21. The berth allocation is done by commodity types as shown in *Table 2* below.

Table 2: Mombasa Port Berths Allocation by Commodity Type. Source-KPA

Commodity	**Berths**
Motorcars	No.1, 3, 4, 5,7, 9,10, 11, 12, 13, 14
Steel	No.1, 3, 4, 5, 7, 8, 9, 10, 11
Container	No.1, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 16-19, 20-22
Bulk Wheat	No. 3
Bulk Clinker	Mbaraki, No.7, 9, 10
Bulk Fertilizer	No.1, 5, 7, 9, 10, 11
Bulk Coal	Mbaraki, No.9, 10, 11
Other Liquid Bulk	Mbaraki, No.8, 9, 10

Construction of passenger terminal at a cost of US $ 3.5 million was launched in December 2016 and is projected to handle a capacity of 140,000 passengers upon completion. The port has over the years registered significant growth in traffic volumes, with the total annual cargo throughput increasing by 6.9% and container traffic growing by 9.3% on average in the last decade. To serve the growing traffic, KPA and its development partners have been implementing various projects aimed at improving the port's efficiency and capacity. KPA's strategic direction is guided by her vision "World class seaports of choice". The mission is to "To facilitate and promote global maritime trade through the provision of competitive port services".

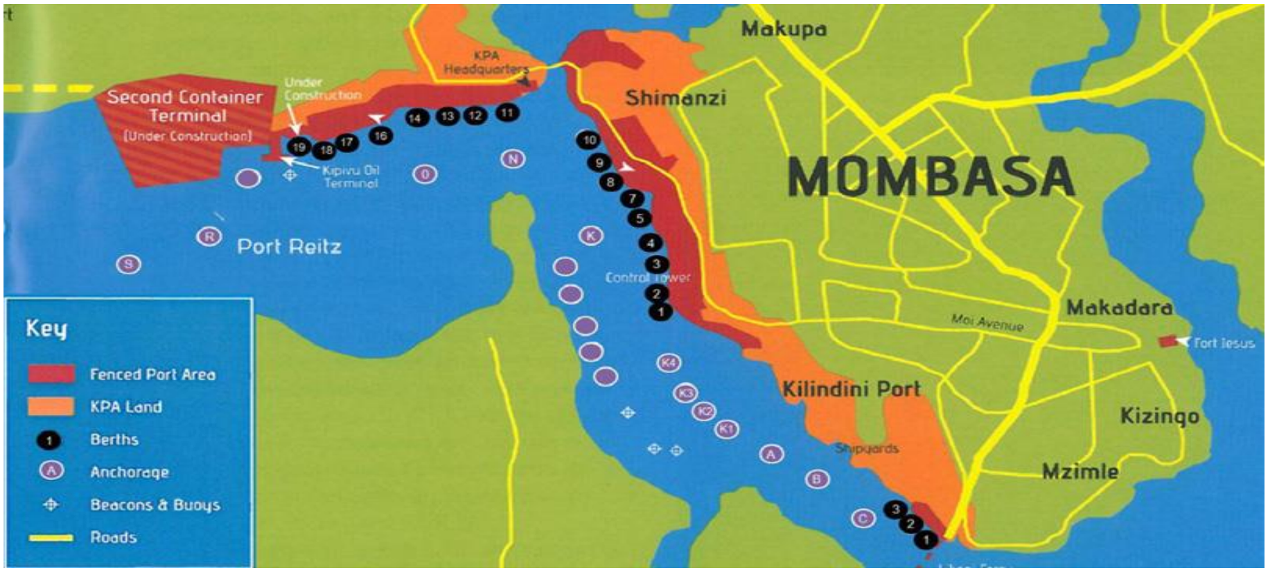


Figure 5: Overview of Mombasa Port. Source- KPA

5.3 Energy Profile of Mombasa Port

The main sources of Power at the Mombasa Port are electricity and automotive diesel. The Authority's electricity supply from the power utility company had previously been on the 11 KV bus. This supply was characterized by unplanned interruptions and outages with adverse effects on the port's operations. To help mitigate these challenges, the port has upgraded its power supply to be connected directly to the national grid at 132 KV. However, Kenya has continued to experience nation-wide blackouts and unreliable power supply that has ripple effects on port operations. With the ongoing and planned port expansions, the demand for power will more than double.

Recently, the port developed a comprehensive 'Green Port Policy' and implementation plan aimed at mitigating the negative externalities of port operations. The policy recommends reduction of port carbon emissions through implementing renewable energy initiatives including cold ironing, among others. From this standpoint, the Authority, with a grant from Trade Mark East Africa intends to engage a consultant to do a feasibility study on the energy needs, alternative energy sources and provision of shore power (cold ironing) for the Mombasa Port. Mombasa Port has seventeen (17) distribution substations with 11/0.415kV, 11/6.6kV & 11/3.3kV transformers and twenty-two standby power generators. (Banks, Ruijs, & Mwai, 2017).

Electrical Power Network.

Electricity for the Mombasa Port is supplied from the National grid from 132kV Bus-bars and 33/11kV through a Substation. There is an 11kV distribution network emanating from substations ‘M’ & ‘K’, which supply the entire port at 11kV, 3.3kV & 415V after transformation at substations ‘M’, ‘K’, ‘L’, ‘N’, ‘U’, ‘Y’, ‘A’, ‘T’, ‘C’, ‘R’, ‘S’, ‘V’, ‘7/8’. (as shown in the *figure 6* below) Additional substations are at the new container terminal which are supplied via 11kV ring circuit from substation ‘M’.

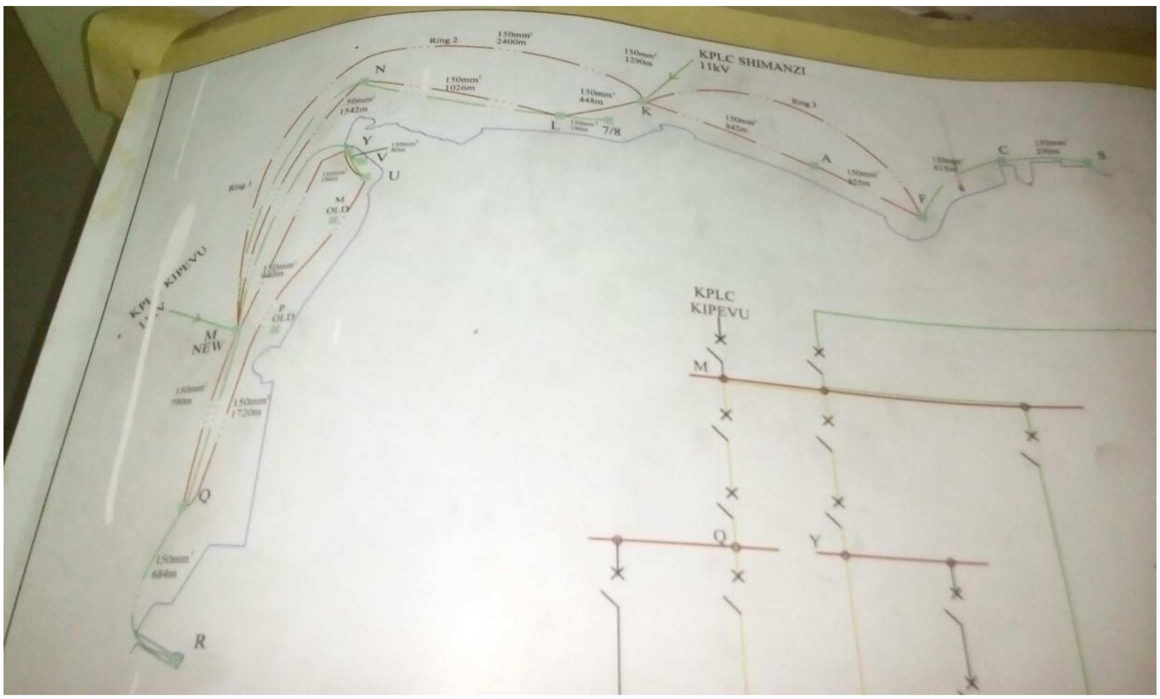


Figure 6: Reticulation diagram of Power Substation Network in Mombasa Port. Source-KPA

Energy Distribution and Consumption of Mombasa Port.

Analysis of the Energy Consumption of the Mombasa Port is based on Energy Consumption data, monthly Electricity bills, Fuel Consumption of Standby Generators, Port Yearly Throughput and Cargo handling equipment. The functional areas analyzed in terms of their energy consumption are: KPA Headquarters, Marine operations and Engineering; Terminal I and Terminal II operations and engineering; Convectional Cargo terminal; Port Integrated Security Systems; Oil Terminals; Yard Lightings and the Old Port office.

Standby Power Sources.

In case of power outages, Mombasa port relies on Standby generators (diesel fueled) for its standby source of power.

Table 3 below denotes the current distribution of standby diesel generators within the Mombasa Port. The generators are tabulated in terms of capacity (KVA), fuel consumption and cost. Terminal I (Operations & Engineering) has the highest installed capacity at 2283KVA, and the highest fuel consumption at 448 liters / hour. This table is useful in enabling the Port to focus attention in areas with high fuel consumption- especially when considering alternative fuels or low sulphur fuels for the generators.

Table 3: Analysis of Functional Areas in terms of their Energy Consumption. Source- KPA

Functional Areas	Generator Capacity (KVA)	Fuel Consumption Litres /Hours	Total Diesel cost @ U S $ 1.5 / Litre
KPA Headquarters Offices:			
Block 1 & 4	500	110	165.00
Block 2	500	91	136.50
Block 3	500	91	136.50
Totals	1500	292	438.00
Marine Engineering & Operations:			
• Slipways,	350	71	106.5
• workshops,			
• Dry dock area,	220	43.6	65.40
• Control Tower I			
• Ras- Saran Light Hse	30	7.1	10.65
Totals	600	121.71	182.55
Terminal I- Engineering & Operations:			
Equipment (Cranes & Reefers	1063, 610	206	309
) Accommodating offices and workshops	610	121, 121	181.50, 181.50
Totals	2283	448	672.00
Terminal II- Engineering & Operations:			
Equipment (Cranes& Reefers)	1000, 500	202	303
Accommodation offices and Workshops	360	91,64.1	136.50, 96.15

Totals	1860	357.1	535.65
Convectional Cargo Terminal: Harbor Cranes Port Logistic Functions	 500, 500 500	 110 110 110	 165 165 165
Totals	1500	330	495.00
Port Integrated Security Systems: Gate Facilities- Sliding gates, Wing Gates, Anti-Terror Barriers, Perimeter Fence, CCTV Cameras, Servers, Control Room,	 610, 500, 350 110, 80 & 80,	 121 & 91, 71 & 25 18.6 & 18.6	 181.50, 136.50 106.5, 37.50 27.90 & 27.90
Totals	1730	345.20	517.80
Oil Terminals: Kipevu and Shimanzi	 100 70	 21.8 16.8	 32.70 25.20
Totals	170	38.60	57.90
Old Port : Offices	100	22.60	33.90
Totals	100	22.60	33.90
Yard Lightings: Lighting Towers and High Mast Lights (Monopoles)	 610, 500, 350, 100, 110, 220, 70,80,	 121, 91, 71, 21.8, 25, 43.6, 16.8, 18.6	 181.50, 136.50 106.50, 32.70, 37.50, 65.40, 25.20, 27.90
Totals	1040	408.80	613.20
Total Cost of Fuel			3,546.00

From the graphical depiction below (*figure 7 and 8*), the two sections with the highest energy consumption are; *Terminal I* and the *Yard Lightings*.

Terminal I operations that draws significant levels of energy are loading and off-loading of containerized cargo while the main energy consuming operations within the yards (17% of the Port total energy consumption) are security lighting, and surveillance tool.

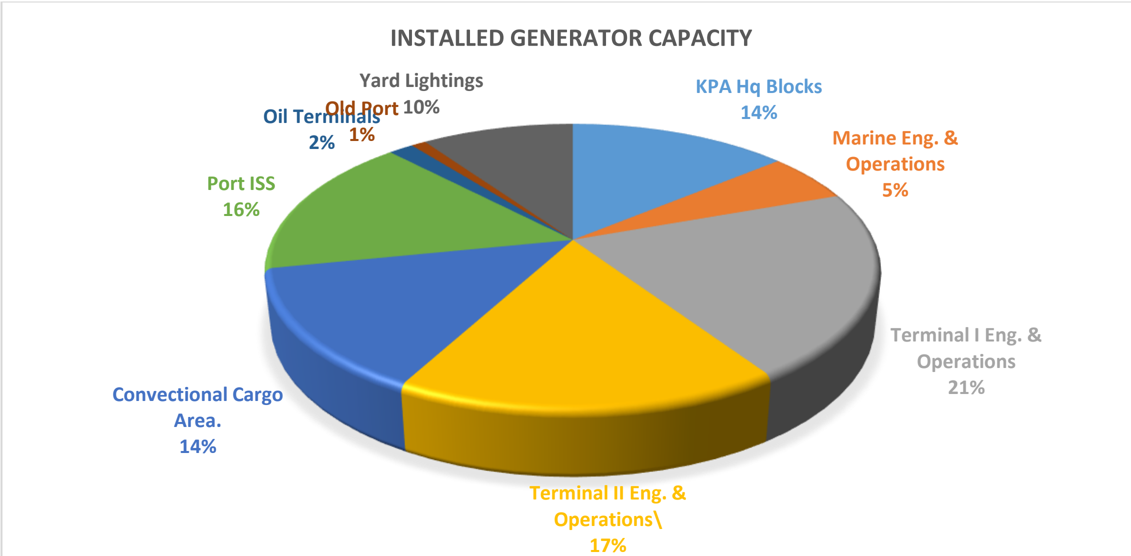


Figure 7: Installed Generator Capacity (in %) at Mombasa Port. Source- KPA

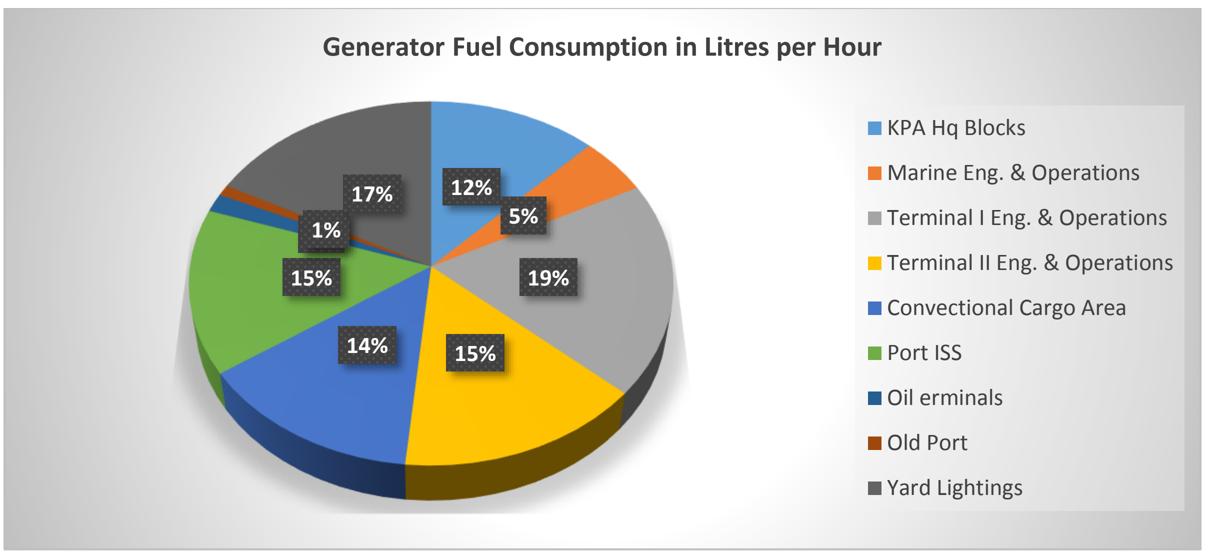


Figure 8: Generator Fuel Consumption (in Litres /hour). Source-KPA

Yard Lightings.

The total yard area of Mombasa Port is divided into five Zones (Zone A- E), and each zone is symmetrically fitted with a number of lighting towers (High Mast Lights – Monopoles). The lighting tower have different power rating ranging from 6,000 watts (6KW) to 12,000watts (12 KW) with a spacing between adjacent masts varying from 50M to 100 M and the heights of each mast (monopole) optimized to ensure maximum illumination. *See figure 9.*

Figure 9: Overview of Yard Lighting, Maximum Illumination of the Yards. Source- Mombasa Port

Container Terminal I (Berth 16 to 19).

Main energy consuming operations in Terminal I is loading and off-loading using specialized equipment; (i). Ship-To-Shore Cranes (STS) – ten in number, each is powered from a three phase, High Voltage Power (3.3 KV) drawn from the Port Substations; (ii). Rail Mounted Gantry Cranes (RMG)-two in number, also powered from three phase, High –Voltage power (3.3 KV) drawn from the Port substations. The terminal also accommodate 400 reefers via three phase, 415Volts, fed from the substation. Terminal I covers area from berth 16 to berth 19 as depicted in Table 4 below.

Table 4: Area covered in Container Terminal I- Mombasa Port. Source- KPA

Berth Number	**Length (M)**	**Draft (M)**	**Cargo Type**
16	**177.7**	**12.5**	**Container**
17	**182.9**	**12.5**	**Container**
18	**239.0**	**12.5**	**Container**
19	**240.0**	**13.5**	**Container**

Figure 10 and *figure 11* represent the most energy consuming cargo handling equipment in Terminal I these are the Ship-To-Shore (STS) Gantry Cranes and Rail Mounted Gantry Cranes (RMG)

Figure 10: STS Cranes at Mombasa Port -Terminal I Area Berth 18. Source-KPA

STS- are specifically located near the berths to facilitate the Loading and off-Loading of containers from or in to the vessel.

Figure 11: RMG Cranes at Berth 16, Terminal I-Mombasa Port. Source KPA

While the RMG are normally near the railway tracks.

5.4 KPA's "Green Port Policy"

According to available literature, Green Port Policy refers to "an aggressive, comprehensive and coordinated approach to reduce the negative impacts of Port operations." (Port of Long Beach, 2005). KPA developed a comprehensive Green Port Policy in 2015 through its stated mission namely: "*To facilitate and promote global maritime trade through the provision of competitive port services".*

The mission statement aims to "transform Mombasa Port into the premier Green Port in East Africa, and among the leading green ports in the world. In the Authority's stated observation, "this therefore requires a practical Green Port roadmap, and KPA needs to adopt certain principles for the roadmap to ensure it is successful." (Kenya Ports Authority, 2015). In this context of Green Port roadmap, KPA recommends actions that can limit the GHG emission through reduction in energy consumption, and outlines the necessary process for ISO 14001 operationalization through implementation and maintaining of its certification.

According to KPA management, the development of the Green Port Policy is basically to have in place an actionable Green Port Policy and its implementation Plan for Mombasa Port that is consistence with much focus on the economic, environmental, and social values of an investment, as well as investments for improving the environment. (Kenya Ports Authority , 2015).

The Green Port Policy statement for KPA and Mombasa Port is presented on the *Appendix V*.

Attainment of this goal calls for the adoption of the recognized five pillars (5Es) which are: Exemplifying; Enabling; Encouraging; Engaging and Enforcing currently applied by ESPO members. Expected key outcomes includes reduction in Port GHG emission, bio-diversity benefits and set the pace for Cold Ironing and utilization of renewable energy.

5.5 Mombasa Port Energy and Environmental Policy

Energy policies at the Port are informed by both national and international regulations and guidelines. Most of the national regulations emanate from the Energy Regulatory Commission (ERC) Act of 2006, while the international guidelines to improve energy management and efficiency are based on ISO standards. The ISO 14000 series comprises a range of standards on environmental management systems, environmental assessment, environmental performance evaluation, environmental labelling, and life cycle analysis and greenhouse gases. It is a framework for managing environmental responsibilities in such a systematic manner that contributes to the environmental pillar of sustainability. The intended outcomes of an environmental management system include: enhancement of environmental performance, fulfilment of compliance obligations, and achievement of environmental objectives. The basis of the approach underlying an environmental management system is found on the concept of Plan-Do-Check-Act {PDCA}, (European Committee for Standardization (CEN), 2015).

KPA's existing environmental policy is found in the Green Port Policy, which is appropriate for the port but not entirely compliant with the ISO 14001 requirements. The relevant Environmental procedures and manuals are yet to be documented for ISO 14001 elements. KPA is already on the road to implementing the recognized international standards for Energy Efficiency and Management, which began with an Environmental Management Gap Analysis in July, 2016. The next phase will involve full certification procedures for ISO 14001.

Key outcome from the gap analysis is that it identified the need to incorporate key energy and environmental goals in to the Port's corporate governance strategies. The relevant policies as they stand are included in appendix are: KPA Energy policy; KPA Green Port Policy and KPA ISO 14001- Environmental Management System (Ref. ISO/FDIS 14001:2015(E)).

The table 5 below describes some of the milestones attained so far by Mombasa Port in its process to improve energy efficiency and environmental management.

Currently Mombasa Port is striving to acquire some certification as shown in the table 5.

Table 5: Milestones: Energy and Environmental Management at Mombasa Port, Source- KPA

	ISO 9001-2008	**ISO 14001:2015**	**ISO 50001**
Policy	ISO 9001-2008 Quality Management System (QMS)	ISO 14001:2015 Environmental Management System (EMS)	ISO 50001 Energy Management Standard (EnMs)
Date of Adoption	2007	2014	In process
Date of Implementation	2007	2015	In process
Certification	2009	Pending (Gap Analysis carried out in 2016)	In process
Focus on	• Service delivery	• Green Port Policy	• Energy Efficiency gain

	customer satisfaction. • Operational efficiency. • productivity of internal resources	• environmental impact (GHG emissions) • Operating cost • Sustainable asset management • Protecting environment	• Quantifiable Energy cost reduction, • Verification of Energy savings , • Reduction in GHG emission.
Benefits of Standard.	• Improved port services and customer satisfaction. • Enhanced operation efficiency. • Productivity of internal resources.	• Reduce operating cost • Reducing environmental impact • Sustainable asset management • Improved public image	• A significant improvement of the energy performance level from an initial energy baseline. • A systematic approach (plan-do-check and act) that leads to continuous energy efficiency improvement. • Increase Efficiency and Port Performance Cost and Energy Savings

CHAPTER 6

6.0 Analysis and Discussion.

This chapter discusses and analyses the measures that can be undertaken to improve energy efficiency, rationalize consumption, reduce energy bills and mitigate externalities related to energy consumption at the Mombasa Port. It analyses the LCOE, CAPEX, OPEX and other related parameters. From previous studies and the computed LCOE (*refer to Appendix III and IV.),* Solar PV technology offers the best scope as it addresses multifaceted concern including GHG emissions, Energy Efficiency, Environmental Externalities and Sustainability. This research finding corroborates the recommendations of several previous studies undertaken at the Port.

6.1 Levelized Cost of Energy (LCOE).

The four important parameters used to gauge the feasibility of energy technologies are Levelized Cost of Energy (LCOE), Capital Expenditure (CAPEX) and Operating Expenditure (OPEX).

According to World Energy Council, “The Levelized Cost of Electricity (LCOE) is the price that must be received per unit of output as payment for producing power in order to reach a specified financial return – or put simply the price that project must earn per megawatt hour in order to break even.” (World Energy Council, 2013). The LCOE helps the port energy planners to ascertain whether a given renewable energy technology is feasible over its lifespan.

Mathematically, it is given by the total cost to build and operate a power-generating Plant over its lifetime divided by the total energy output of the asset over that lifetime.

$$LCOE = \frac{Lifecycle\ Cost\ (\$)}{2aLifetime\ Production\ (kWh)}$$

According to Lai & McCulloch, 2017, “Levelized cost of electricity provides comparisons of different technologies with different project size, life time, different capital cost, return, risk, and capacities. The LCOE can also be regarded as the minimum cost at which electricity must be sold in order to achieve break-even over the lifetime of the project.” (Lai & McCulloch, 2017)

Capital Expenditure (CAPEX) and Operating Expenditure (OPEX).

"Capital Expenditure (CAPEX) includes the total cost of developing and constructing a plant, excluding any grid-connection charges while the Operating Expenditure (OPEX) is the total annual operating expenditure from the first year of a project's operation, given in per unit of installed capacity terms." (World Energy Council, 2013).

Capacity factor

Also referred to as load factor, "is the ratio of the net megawatt hours of electricity generated in a given year to the electricity that could have been generated at continuous full-power operation, or 8,760 (p.a) full hours." (World Energy Council, 2013).

6.2 Proposed Solar Power Generation at the Mombasa Port.

Table 7 above depicts the evaluated available space in buildings within the port for installation of Solar panels. A total surface area of 205,555 m^2 is available with an estimated output of 52,417MWh / year. If fully utilized, the expected benefits in energy cost savings and GHG emission reduction is enormous.

Table 6: Proposed Site for Solar PV installation (Mombasa Port). Source-KPA

No.	Location	Name of Building		Length X Width (M)	Area in M^2	Solar Power Generation Potential (Based on 150Wp / M^2) in MWh / year
1	Dockyard	a	Marine Afloat	20 X 9 = 180	180	46
		b	Boat Shop	40X29= 1,160	1,160	296
		c	Plate Shop	50X30=1,500	1,500	383
		d	Electro/Mechanical workshop	60X45=2,700	2,700	689
		e	Electronic Workshop	45X20=900	900	230
		f	Dockyard Store	80X25=2,000	2,000	510
		g	Administration Block	35X12=420	420	107
2.	G-Section Shed		G-Section Shed	180X40=7,200 9X40=360	7,560	1,928

3.	Control	a	Pollution Control	140X50=7, 000		
	Tower			30X30=900	7,900	2,015
		b	Shed A	80X50=4,000	4,000	1,020
			Maritime Museum	50X24=1,200		
				15X12=180		
				6X6=36	1,416	361
1.	Zone A					
	Berth 1-5 &	a	Wine (Shed1/2)	150X45=6.750		
	yard			25X20=500		
				150X45=6.750	14,000	3,570
		b	BP1-World Food	160X40=6,400	6,400	1,632
		c	Program	160X40=6,400	6.400	1,632
		d	BP2-Michel Cotts	160X40=6,400	6,400	1,632
		e	BP3-Regional	160X40=6,400	6,400	1,632
		f	Logistics	90X12=1,080		
			BP4-Custom Shed	15X12=180		
			KEBs/Immigration	12X12=144	1,504	384
		g		110X18=1,980	1,980	505
		h		135X16=2,160	2,160	551
			Old Port Account			
			Baggage Hall			
2.	Zone B					
	Berth7-10	a	Shed 9/10	180X50=9,000	9,000	2,295
3.	New					
	Service					
	Area	a	Electrical	80X20=1,600		
	Kapenguria		Workshop	80X8=640	2,240	571
		b		80X20=1,600	1,600	408
			Mechanical	65X30=1,950		
			Workshop	65X12=780	2,730	696
		c	Motor Vehicle	68X15=1,020		
			Workshop	45X13=585		
				45X12=540	2,145	547
		d	SOW Workshop	110X30=3,300		
				60X13=780		
				8X8=64	4,144	1.057
		e	Central Stores	210X24=5,040	5,040	1,285
		f		140X21=2,940	2,940	750
		g	Gear & Equipment	50X17		
			Folk W/Shop /	24X16	1,234	315
		h	Battery W/Shop	44X12=528		
			CEME	44X12=528	1,056	269
			Fire Station			

4.	Zone C Berth 11-14	a b c	Kipevu Clinic Verification Shed (Scanner) One Stop Center	60X15=900 30X18=540 80X45=3,600 60X25=1,500	1,440 3,600 1,500	367 918 383
5.	Container Terminal I	a b	Gantry W/Shop Mobile Plant W/Shop	70X30=2,100 160X35=5,600	2,100 5,600	536 1,428
6.	Container Terminal II	a b	Workshop-Curved Roof Administration	60X30=1,800 44X24=1,056	1,800 1,056	459 269
7.	Non Building Location	a b c	One Stop-Baggage hall Stretch New Service Area-SOW stretch Kipevu Bridge-Gate 18 Stretch	900X30=27,000 350X25=8,750 760X60=45,600	27,000 8,750 45,600	6,885 2,231 11,628
TOTAL AREA					**205,555**	**52,417**

6.3 LCOE Calculator for Renewable Source of Energy

The LCOE Calculator tools gives a comparisons of all the various renewable energy technologies.

Assumptions used in LCOE Calculator for Renewable Sources of Energy in the *Appendix IV* are listed below.

- *Year of Commencement of Production -2018 (this follows a three year Agreed Energy Action Plan with Implementation date of 2015).*
- *Policy Year-2015 (Action Plan Date for Mombasa Port Green Port Policy)*
- *Lifespan -25 years*
- *USD –Currency used in calculating the cost of the Project*

6.4 LCOE Calculations for Solar PV.

Assumptions used in LCOE calculator for the Solar PV are as follows.

These calculations are based on parameters derived through *Table 7* above.

First year's Production in (Kwh)$= 52{,}417 MWh$.

Estimated Cost for Solar PV project $= \$\ 652{,}737$ (Equivalents to Kshs.65, 273,700 at the exchange rate of Kshs.100 to $1).

Cost of production in ($/Watt) $= \$\ 0.747$ *(See the Excel Sheet Table 8.)*

Estimated Operation & Maintenance Cost ($/Watt) $= \$\ 15$

Current Total Bills (per year) $= \$\ 2{,}996{,}355.69$=KSHs. 299,635,568.99 (See Appendix II)

LCOE in ($ /MWh) =$ 85 (*See Appendix V)*

Table 7: Solar PV Cost Projection Calculator. Source- LCOE Calculator

Solar PV Project Cost Calculator		*Levelized Cost of Energy (LCOE) -Solar PV for Mombasa Port.* August, 2017
Inputs highlighted in Yellow		
System Inputs		**Input Description**
System Size (kW-DC)	1000	*site)*
1st-Year Production (kWh)	52,417,000	*production at a site*
Annual Degradation	0.50%	*performance degradation)*
Direct Purchase Inputs		
Cost ($/W)	$ 0.747	*available, use the formula: Cost ($/W) = (Total-system-cost/Total-system-size-in-watts)*
Initial Rebate/Incentive	$ -	*(Please insert the total value of rebates/incentives received within the first year)*
O&M Cost ($/kW)	$ 15.00	*available, use the formula: O&M Cost ($/kW) = (1st-year-O&M-Cost/Total-*
O&M Escalator (%)	3%	*(Please insert the expected yearly escalation)*
PPA Inputs		
PPA Rate ($/kWh)	$ 0.15000	*available, use the formula: PPA Rate ($/kWh) = (1st-year-PPA-Cost/1st-year-*
PPA Escalator	3.00%	*(Please insert the expected yearly escalation. If not uniform, manually insert yearly escalation in Column I)*
LCOE Outputs*		
Direct Purchase		** Compare to expected utility costs over the next 20 years*
20 Year	$ 0.00115	
25 Year	$ 0.00105	
PPA		** Compare to expected utility costs over the next 20 years*
20 Year	$ 0.20054	
25 Year	$ 0.21709	
**Undiscounted Analysis*		
Solar PV CAPEX	65,273,700	Kshs.
currency Conversion :		
Kshs.(to USD)	652737	$
kwh to kw	873616.6667	kw
Solar PV Production	52,417,000	MWh/year
Cost ($/W)	0.747166377	$/w
Potential Savings	12,168,090	Kshs
PS in USD	121680.9	$

LCOE Calculator

Year	Production (kWh)	Direct Purchase Cost ($)	O&M Cost ($)	PPA Escalator (%)	PPA Rate ($/kWh)	PPA Cost ($)
0		$ 747,166		-		
2018	52,417,000		$ 15,000		$ 0.1500	$ 7,862,550
2019	52,154,915		$ 15,450	3%	$ 0.1545	$ 8,057,934
2020	51,894,140		$ 15,914	3%	$ 0.1591	$ 8,258,174
2021	51,634,670		$ 16,391	3%	$ 0.1639	$ 8,463,390
2022	51,376,496		$ 16,883	3%	$ 0.1688	$ 8,673,705
2023	51,119,614		$ 17,389	3%	$ 0.1739	$ 8,889,246
2024	50,864,016		$ 17,911	3%	$ 0.1791	$ 9,110,144
2025	50,609,696		$ 18,448	3%	$ 0.1845	$ 9,336,531
2026	50,356,647		$ 19,002	3%	$ 0.1900	$ 9,568,544
2027	50,104,864		$ 19,572	3%	$ 0.1957	$ 9,806,322
2028	49,854,340		$ 20,159	3%	$ 0.2016	$ 10,050,010
2029	49,605,068		$ 20,764	3%	$ 0.2076	$ 10,299,752
2030	49,357,043		$ 21,386	3%	$ 0.2139	$ 10,555,701
2031	49,110,257		$ 22,028	3%	$ 0.2203	$ 10,818,010
2032	48,864,706		$ 22,689	3%	$ 0.2269	$ 11,086,838
2033	48,620,383		$ 23,370	3%	$ 0.2337	$ 11,362,346
2034	48,377,281		$ 24,071	3%	$ 0.2407	$ 11,644,700
2035	48,135,394		$ 24,793	3%	$ 0.2479	$ 11,934,071
2036	47,894,717		$ 25,536	3%	$ 0.2554	$ 12,230,633
2037	47,655,244		$ 26,303	3%	$ 0.2630	$ 12,534,564
2038	47,416,968		$ 27,092	3%	$ 0.2709	$ 12,846,048
2039	47,179,883		$ 27,904	3%	$ 0.2790	$ 13,165,272
2040	46,943,983		$ 28,742	3%	$ 0.2874	$ 13,492,429
2041	46,709,263		$ 29,604	3%	$ 0.2960	$ 13,827,716
2042	46,475,717		$ 30,492	3%	$ 0.3049	$ 14,171,335
Total	1,234,732,305	$ 747,166	$ 546,889			$ 268,045,965

6.5 Gap analysis of Mombasa Port.

This analysis involves analyzing the Ports status quo on various angles such as the ports operations, applied technologies, governing policies and international standardizations. *Table 8* gives the summary of the Gap analysis in Mombasa Port.

Table 8: Gap Analysis Data. Source –Author.

	Aspect	Status Quo	possibilities
Policy	ISO 14001:2015- Environmental Management System (EMS)	Process of implementation	If implemented it will lead to clean air quality, reduction in GHG emissions, reduce health risks from toxic pollutions and improve port efficiency. Its certification will lead to make the port to be the Green Eco Ports
	ISO 18001:2015 Occupational Health & Safety Management System (OHSAS)	Process of implementation	This standard will lead to proper working conditions improvement, reduction in near miss incidents, number of accidents, GHG emissions, operating cost, breakdowns and general safety improvement.
	Port Energy Policy	Attained 2011	Gives overall directions on energy efficiency and management
	"Green Eco Port Policy"	Process started in 2015	Once attained will enable the port to minimize environmental impact whilst addressing energy efficiency.
	ISO 26000-Corporate Social Responsibility (CSR) ISO	Attained in 2010	Building up responsibility /sensitivity to the environmental effects on ports activities
	ISO 50001- Energy Management System(EMS)	Not yet implemented	If implemented it can lead to realization of benefits such as Energy Cost Reduction, Energy Efficiency, Energy Management and GHG emission Reduction
	Prioritization of projects policy	No policy to prioritize accomplishment of important project	Adoption of this policy will assist the Port in decision making process and give priority to most urgent and necessary projects.
	Star Rating Policy	Not yet implemented	Adoption of a formal policy on Star Rating Criteria when procuring of new equipment will enable port to select high quality, standard and modern equipment.

Operational.	Monitoring, Verification & Review (MVR)	No Data Verification & Reviewing	Supervisory Control And Data Acquisition System (SCADA) will lead to availability of energy consumption trends data, tracking of power fluctuations, monitoring of most power consumer areas/ sections reviewing of energy consumptions and reduce cost of power by eliminating unrealistic power billing.
	Emission Control measures on Vehicles operating within the Port	No Control measures in place	Deliberate Policy to bar High emitting Vehicles from Accessing the Port.
	Just-In Time Port arrivals	Vessels give 14-days Pre-Arrivals notice. A large number of anchorage where vessels wait up to several days for berth availability	14-days' notice can be extended , besides that a one stop vessel handling window can be implemented
Technologies	Renewable Energy Technology –Solar PV	Installation in progress	It will increase Power reliability and sustainability, reduce GHG emissions,
	Alternative Fuels – Low Sulphur Fuels	No restrictions on fuel quality	If implemented can lead to reduction of SOx emission in the port.
	Automated Mooring-Tug boats & Pilot boats	Manual mooring	If implemented it will cut down emissions, reduce mooring time, reduce accidents
	Electrification of cargo handling equipment	Mostly diesel Powered Equipment.	Electrification of cargo handling equipment will lead to increase turn-over, reduce turnaround time, reduce emissions, and reduce energy consumption, Increase port efficiency and breakdowns.
Institutional	Sensitization on importance of Energy Efficiency & Management Measures	Attained through Sensitization program conducted in 2015	More staffs and port users are aware of the Ports Energy efficiency and management programs and measures. This will make the Port staffs/ port users more responsible while at work and reduces energy wastage
	Training on energy Efficiency and Management Technologies	Attained and still going on (the author is an example of staffs on training on Energy Efficiency & Management at WMU)	More energy managers experts will lead to a n energy efficiency working environment, port will have energy professionals who can manage modern technologies in energy, new energy projects and save the ports large sum of cash in improving port's efficiency.

In addition to the energy efficiency and emissions reduction measures currently in place, and the identified areas for potential improvement, there are additional measures that can be implemented alongside. These include setting ambitious energy use reduction targets, systematic monitoring and analysis of energy use at the port, energy audits, identifying areas of high energy consumption and waste and taking reduction measures, identification and implementation of energy-saving measures that are techno-economically feasible, application of energy efficiency indicators and calculation of carbon footprint, capacity building related to knowledge of the various options for energy procurement as well as creation and implementation of a good energy procurement strategy.

This Solar PV technology has been applied in a number of ports. For an example in *Port of Stockholm* where the Solar PV represent a third of system facility. The installation was done on a flat roof of a customs building in the Port of Kapellskar. The area is around 400m2 with 225 Solar panels generating a maximum power of around 60kW.

Another practical applications of Solar PV technology application is at *Frihamnen Port.* The system has 885 Solar panels installed on an area of around 1400m2, with maximum power output of 225kW. The total cost of the facility was approximately SEK 3 million.

Also in *Port of Los Angele***,** a 10 MW Solar power program was developed as a means of supporting San Pedro Bay Ports Clean Air Action Plan (CAAP), a plan which was devised by Port of Los Angeles board of governor and Port of Long. The 10 Mw Solar PV is based on an estimated 3.7 million square feet of potential roof top area throughout the Port. T The original ten MW estimate for photovoltaic solar power was based on an estimated 3.7 million square feet of potential rooftop areas available throughout the Port for PV Systems. The project cost $ 3,358,288.58 was an incentive received from the City of Los Angeles Department of Water and Power (LADWP).This confirm the growing significance of Solar PV technology in addressing the energy efficiency needs and GHG emissions reduction in ports.

6.6 Benchmarking Analysis

There are several methods which can be used in tracking the energy performance in operations areas as well as in buildings. These include: Benchmarking, Energy Information Systems (EIS), Building Automation System (BAS) and Automated Fault Detection and Diagnostic Tools (FDDT).

According to the Cambridge English dictionary, benchmark is a level of quality that can be used as a standard when comparing other things. Kozak, 2004 and Quah, 2014, defined the common theme for benchmarking, according to which, benchmarking is "the continuous measurement and improvement of an organization's performance against the best in the industry to obtain information about new working methods or practices in other organizations." (Quah, 2014.)

Benchmarked Ports.

In this study three ports (Genoa, Gothenburg and Durban), which have demonstrated impressive levels of attainment in energy efficiency as a result of structured monitoring and good energy policies are reviewed.

Port of Genoa.

The Municipality (Liguria) of Genoa city owns the Genoa Port. Genoa Ports Authority manages the port of Genoa which is the principle gateway of the Southern European region, with the Liguria city offering an excellent geographical mix of ports destination, with particular focus on Far Middle East traffic moving via the Suez Canal, Eastern Mediterranean and North Africa (Indian subcontinent). The efficiency of the Genoa Port has a major impact on the economies of the countries it serves. Over 150 regular shipping liner services connect Genoa with 450 ports worldwide, offering a variety of choice to exporters and importers.

The port has continued to record significant growth in traffic volumes, with total annual cargo throughput at 50 million tons in 2014. To improve the port energy efficiency, Genoa port has implemented various projects and both the EC and international directives and regulations guide its strategic directions. The total energy consumption (kWh) per year of the port is about 49,900,000 kWh/ year.

Figure 12: Overview of Genoa Port Authority. Source- Genoa Port

Port of Durban

Port of Durban is a state-owned Port - South Africa's main Multi- cargo and container port, handling over 80 million tons of cargo each year. It is the busiest port on African continent with biggest container capacity. The port operates with two main terminals (Durban Multi-Purpose Terminal and Durban Container Terminal).

Over 65% of all exports and imports destined for South Africa pass through the port, thus it assumes a leading role in facilitating economic growth in South Africa. Strategically placed on the world shipping routes, the port plays a pivoted role in the life of the city. Durban's location on the east coast of Africa makes the port's terminal a pivotal hub for the whole of Southern African region of the Indian and South Atlantic Oceans, serving trade routes linking North and South America with Middle East, India, Asia and Australasia.

The terminal (DCT) also serves as a crucial interface for distribution of cargo between ocean carriers and the market of South Africa, Botswana, Zimbabwe, Zambia and DRC. The port has 6,000 employees, with more than 30, 000 people directly depend upon port's activities. (Total number of container handling cranes for both terminals are STS Gantry-13, RTG-4, Wharf cranes-4 and Gantries 2).

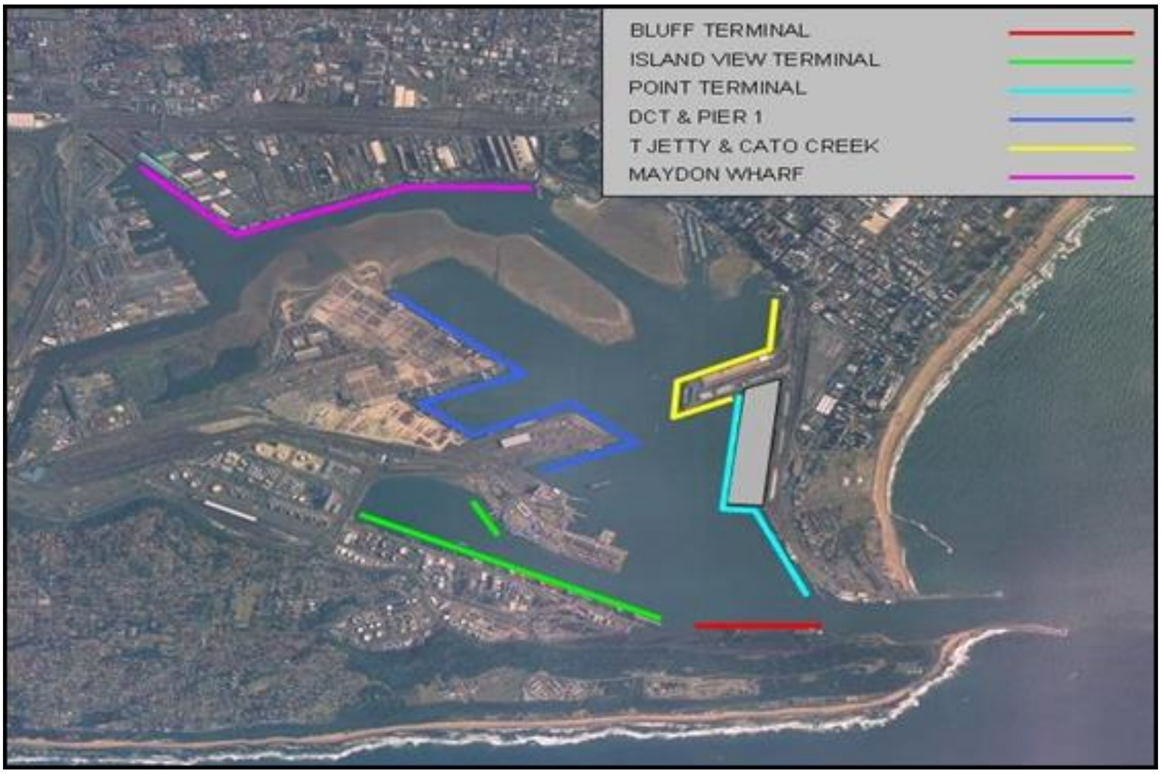


Figure 13: Overview of Port of Durban. Source- Port of Durban.

Port of Gothenburg

Port of Gothenburg is strategically located on the west coast of Sweden, and is the largest port in Scandinavia. 70 % of Scandinavia industry and population is concentrated within a radius of 500km, including areas such as Oslo, Copenhagen and Stockholm, with more than 30% of Swedish foreign trade passes through the port. The Port of Gothenburg provides a wide range of services including direct links to North America, North Africa, Middle East, India, South Korea, china and part of Asia. It also offers daily intra-European sea traffic. In 2015, port of Gothenburg took an important milestone in its Green development program. The Port has implemented the On-shore Power grid at six RoRo berths.

Figure 14: Overview of Port of Gothenburg. Source-Port of Gothenburg.

6.7 Discussion of Port Energy Performance from Benchmarked Ports.

The selection of the Ports for benchmarking was careful done to prove as wide scope as possible in the context of evaluation of energy planning. All the four ports (Mombasa, Genoa, Durban and Gothenburg) are located either adjacent to, or within urban cities, and can be considered as energy hubs based on their sheer relative energy consumption, vis a vis that of the adjacent urban city. This means their energy planning and related environmental policies are intertwined with those of the urban city, making the urban cities key stakeholders in the ports' energy policies.

Mombasa Port and Durban are state owned, while Genoa and Gothenburg are municipality owned. All the four Ports have already implemented environmental protection measures and have "Green Port" policies either already operational (Genoa, Durban and Gothenburg) or still in the process (Mombasa Port).

Genoa Port and Gothenburg Port are located in SECA areas and are subject to policy framework from their respective regions that is the ESPO and BSR whereas Mombasa and Durban are not part of SECA areas.

According to Acciaro, 2014 case study involving Ports are structured in four main subsections in order to ensure comparability; introduction, Energy Supply, Energy demand and the Port authority approach to energy management and main issues.

Genoa Port Authority (GPA) has developed a Port Energy Environmental Plan (PEEP). The ultimate goal of the PEEP is to bring down 20,000t of CO_2 emissions a year in the Port of Genoa with an overall investment of 60 million euros. This strategy will enable the port to save almost 10,000t of CO_2 emission annually with the introduction of 12 plug position of cold ironing in the naval reparations area, the ferry terminal and a container terminal (Voltri Terminal Europa) from an investment of 13 million euros(Acciaro,2014). It will also save 6000t from the wind system with an investment of 20.1 million euros and 3600t from the installation of photovoltaic structures with an overall investment of 24.4 million euros. GPA also targets to save 100t from three solar power stations in port buildings with an investment of 400,000 euros.

In terms of energy supply, Genoa port area presents characteristics that make it suitable for the realization of geothermal heat plants, i.e. energy production systems through a heat pump fed with seawater. The Port of Genoa is currently evaluating a more extensive use of geothermal heat plants. Five projects dealing with photovoltaic and solar technology have been carried out by private concessionaries in the port of Genoa. Due to the limitations imposed by Italian 84/94 law on Ports Authorities' ability to engage directly in business operations, GPA can only acts as a coordinator. Private firms are entrusted with the operational and commercial developments in view of their better capacity to manage the planning and financial aspects of the introduction of renewable energy sources. The main result that has been the creating of awareness among the terminal operators and providing them with guidelines that were lacking in the field of energy saving and sustainable energetic development.

Port of Gothenburg; according to the Port's stated vision, "The Port of Gothenburg applies a proactive approach in its initiatives to minimize the environmental impact of shipping and contribute to sustainable transport". The Port's environmental responsibility can be divided into three main areas: minimizing our carbon footprint, reducing the environmental impact locally, and reducing the use of consumption of resources.

The Port's environmental initiatives are grounded on the City of Gothenburg's environment and climate program, hence the port's environmental goals are therefore adapted to realize the city's objectives. Gothenburg Port authority is owned by the city of Gothenburg and Gotenborgs Stadshus AB, a parent company registered in 2014.

Table 9 below indicates some of the aspects that were considered in comparison of the benchmarked ports. The aspects were categorized into three; the general characteristics of the ports, the Energy Profiles and the Environmental aspects. This is because the three categories defines the port sector.

Table 9: Benchmarked Ports. Source-Author

Port of:					
		Mombasa	**Genoa**	**Durban**	**Gothenburg**
Characteristics	Size / Area	120ha	Land & Water 1200ha	1,854 Ha	360 ha
	River/ Coastal Port	Coastal Port	Seaport	Coastal Port	Coastal Port
	Located in / near Urban Area	Yes	Yes	Yes	Yes
	Located in SECA Area	No	Yes	No	Yes
	Ownership / Governance Mode	State-owned	Municipality	State-owned	Municipality
	Total Cargo (Tonnes-2014)	1.4 million	50 million	31.4 million	40.9 million
	Dominant Cargo	-Container Convectional -Liquid Bulk -Dry Bulk	-Container -Convectional -Liquid Bulk -Dry Bulk -Cruse/passenger	-container -dry bulk -liquid bulk -convectional -passengers	-Short-sea RORO -LOLO Container -Liquid Bulk
	Number of Employees	5,000	-	6,000	129

	Number of Terminals / Berths	-5 Terminals -21 Berths	-25 Terminals	-20 Terminal -59 Berths	40
	Number of Terminal Handling Equipment (Cranes)	-12 STS -4 RMG -38 RTG -5 Harbor -8 Mobile	-8Post-Panamax -4 Super post-Panamax -20 RTG -4RMG	-43 STS -12 RTGs	10 -5 Super post panamax
Energy Profile	Energy Demand / Supplied kWh/Year	12,750,000kWh	49,900,000kWh	11,412,000kWh	
Environmental Strategy	Environmental Aspects	-Air Quality -Waste -Noise -Energy Efficiency	-Air quality -Noise -Waste -Energy Efficiency -Local community	-air quality -waste -Energy Efficiency	-Air quality -Noise -Bio-diversity -Waste - Energy Efficiency
	Focus Strategy	-GHG emission -Renewable Energy (Solar) -Alternative Supply-Cold Ironing i.e. OPS -Waste	-Alternative Supply-Cold Ironing i.e. OPS -Renewable Energy (Solar) -GHG emission, SO_x , NO_x, PM -Waste	-GHG emission -Renewable Energy (Solar) -Waste	-Alternative Supply-Cold Ironing i.e. OPS -Renewable Energy (Solar) -GHG emission, SO_x , NO_x, PM -Waste
	Green Eco Port Policy	Recently adopted, waiting for	Green Eco-Port	Eco- Port	Eco-Port

		implementation			
	ISO Standardization: ISO 14001-Environmental Management System (EMS);	ISO 14001-Not yet implemented	ISO 14001 Certified	ISO 14001 Certified	ISO 14001 Certified

6.8 Road map to improved Energy Efficiency at Mombasa Port.

Previous assessment show that Mombasa Port has the potential to improve energy efficiency by introducing measures such as Green Port Policy, Eco-driving, ISO standards and renewable energy sources as well as technologies.

Table 11 describe the projects and studies carried out in Mombasa Port in previous years with the aim of improving the port energy efficiency.

Table 10: Initiatives in Improving Port Energy Management - Mombasa Port. Source-

Date.	**Consultant.**	**Scope.**	**Main Output.**	**Terms of Reference.**
January to September 2014	EMS Consultants Ltd	An investment grade energy audit at Kenya Ports Authority facilities in Mombasa and Nairobi in order to identify opportunities for Energy Efficiency and conform to the Energy Regulations 2012 issued by the Energy Regulatory Commission (ERC).	Energy needs were analyzed, Energy Managements strategies were propose, and energy cost reduction measures identified and proposed.	An Investment Grade Energy Audit conducted at Kenya Ports Authority, Mombasa
February 5, 2015	The Cornell Group,INC	• Conduct a Situation Analysis, including KPA's current port operations impacts on environmental degradation, identify current best practices, evaluate KPA's green port practices and how KPA may comply	(a) reduction of electricity and fuel consumption primarily by vessels, trucks and port equipment, (b) Implementation	Green Port Policy for Kenya Ports Authority: PO/20121134.

		with international best practices; • Develop monitoring methods and baselines, including inventory of direct and indirect Greenhouse Gas Emissions (GHG) baseline and forecast, establish Key Performance Indicators (KPIs) and determine KPA's capacity to implement international conventions; • Develop a comprehensive Green Port Policy and Implementation Plan for the Port of Mombasa.	of an equipment replacement policy with electric-powered or "clean fuel" equipment, (c) planting trees and (d) Complying with ISO 14001 certification. In addition the port must implement a regular Environmental Audit System and install an Environmental Management System to track, monitor and control environmental pollution;	
July 2016 to February 2017.	Royal Haskoning DHV (RHDHV) & Howard Humphreys	**Phase I:** a) Conduct detailed assessment of the port's energy needs b) Analyze alternative energy sources for the port. c) Conduct an analysis for the provision of shore power (cold ironing) **Phase II-** encompasses the design and implementation planning: a) Prepare the scope of works and detailed technical specifications of the recommended systems to improve the existing power supply quality; b) Prepare the scope of works and detailed technical specifications of the recommended alternative energy sources for the port;	**Phase I:** a) Current energy situation, b) The environmental and c) Social impact of prevailing energy situation. **Phase II:** Comprehensive costing including both Social and Economic cost for the projects, Applicable Regulatory framework clearly defined.	Port of Mombasa Feasibility Study: M&APB4628R001F0.1

		c) Prepare the scope of works and detailed technical specifications for cold ironing; come up with detailed designs and Bills of Quantities and prepare tender documents for the proposed cold ironing system.		

The following (*Table 12*) is a template of an Energy Action plan for the Proposed Solar PV project which is expected to be completed in 2018. The project is basically one of the measures adopted by KPA- Mombasa Port as a milestone to energy cost in yard lighting and buildings, cut-off the use of fossil fuels, improve energy system reliability and reduce GHG emissions while improving air quality.

Table 11: Energy Action Plan for Proposed Solar PV. Source Lecture Notes.

<table>
<tr><td colspan="2">Facility name: Mombasa Port</td><td colspan="2">Objective 1: Solar PV Production Technology</td></tr>
<tr><td colspan="4">Objective:
I. Reduce Energy Cost in Yard Lightings & Buildings (Offices)
II. Reduce GHG Emissions and Improve Air quality
III. Cut-off Fossil Fuel Consumption in Standby Generators
IV. Improve Energy System reliability</td></tr>
<tr><td colspan="4">Target: 52,417 MWh/ Year.</td></tr>
<tr><td>Initial date:2015[1]</td><td colspan="2">Anticipated completion date:2018</td><td>Actual completion date:2018</td></tr>
<tr><td colspan="4">Electricity high users addressed: Yard Lightings and Buildings in Terminal I Eng.& Operations</td></tr>
<tr><td colspan="2">Baseline: 2018</td><td colspan="2">Monitored completion date:2018</td></tr>
</table>

<table>
<tr><td colspan="6">Energy Action Plan</td></tr>
<tr><td colspan="2">Required action</td><td>Person Responsible</td><td>Target date</td><td>Status</td><td>Comment</td></tr>
<tr><td>#</td><td>List each step needed to ensure Objective &Target is Met</td><td>Enter Name</td><td>Enter date team expects this step to be done</td><td>Enter “Red”, “Yellow” or “ Green”</td><td>Enter status of this step and record the data beside it (e.g., “Completed [4/4/11]” or “Management has not yet responded, extending target date by 10 days to 4/18/ 18[4/4/11]”).</td></tr>
</table>

[1] 2015- Date of Project Launched (as details in chapter 4, Table No. 5).

1	Energy Audit	Port Management team			
2	Gap Analysis	Port Electrical Engineering			
3	Engagement of Consultant	KPA			
4	Feasibility Report	Consultant			
5	Award of contract	KPA			
6	Procurement	KPA			
7	Installations	Contractor			

Key:

- Green –indicate completed
- Yellow – Partly Done.

6.9 Challenges at the Mombasa Port.

The analysis of energy profile of the Mombasa Port has revealed some key areas, where the application of energy efficiency and paradigm shift in the management of energy, can bring positive results. The measures can be applied on flexible timelines, from short-term (0 – 1 year) to mid-term (1 – 2 years) or long term (3 – 5 years).

The Port Authority's Management decision to embrace a "Green Port Policy" and the applicable International standards of excellence in energy management (ISO Standards) lays a resilient foundation from which a successful energy management regime can be operationalized. Some of the prevailing challenges at the port, which require immediate intervention include:

Environmental pollution: Mombasa port has a high concentration of GHG emission production, mainly contributed by; vessels using heavier fuel, and running their generators while at the port, Diesel fueled trucks that haul cargo from the port, and the inability to bar operation of older, polluting vehicles within the port premises.

Ineffective regulations / framework: Mombasa Port has limited organizational capacity to confirm and apply international conventions and regulations for environmental protection. The actualization of the Green Port Policy will give the port some legitimate basis to require compliance by ships visiting the port.

Operational challenges: Unstable, insufficient and unreliable power supply- the supply from the national grid is erratic and sufficiently unstable for smooth port operations.

7.0 CHAPTER 7.

7.1 Conclusion.

From the analysis of the energy profile of Mombasa port, it is clearly evident that success in energy efficiency endeavors requires the application of both technical and operational measures, administered from an enabling framework. The existing measures for energy efficiency at the port, together with ongoing migration to "Green Port Policy" set good foundations for the attainment of energy goals. Much more can be achieved from the combined application of the measures discussed in this thesis and alternative fuels.

However, with the commitment that Mombasa Port want to be a regional leader in developing and implementing a green Port Policy, adherence to International Convention and Kenya Law governing port environment is an effort that the Port need to focus on.

The environmental management and Green Port Policy at Mombasa Port are currently in a nascent stage and is basically considered as an additional responsibility to the operational managers as well as departmental heads. The operation department lacks human resources, expertise, attention and funding to manage the environmental function because it has to focus on operating the port in an effectively and economically manner.

Equally, all the existing departments at Mombasa Port have no expertise suitable for managing environmental change. This is because Environmental Management has to be an independent entity with a direct mandate from the director general or managing director with its own resources and funding. The KPA's organizational structure is currently unprepared to effect the Green Port Policy. The Port also does not have the executive direction, mandate, resources and funding to effectively operate an environmental change department as well as developing and implementing the Green Port initiatives at Mombasa Port. (Kenya Port Authority , 2015)

However, for KPA to have an energy efficiency and environmental management, they have to focus on certain measures recommended in the thesis.

The author also recommends further research into the prospects of port energy strategy, port energy planning, renewable energy sources, technologies, infrastructure development, energy cost reduction measures and alternative fuels as a measure for improving energy efficiency and sustainability in the port of Mombasa.

7.2 Recommendations

This paper has examined the scope for the improvement of energy efficiency at the port of Mombasa. For an objective glimpse of where Mombasa port stands in relation to energy efficiency and management, a benchmarking process was used. Against the backdrop of efficiency improvement measures, there are critical environmental concerns, which increasingly exert pressure.

For Mombasa Port to effectively tackle environmental challenges there is a need to comply with the applicable ISO standards and certifications. For instance, the ISO 14001 (Environmental Management System) lays the foundation for the adaption and implementation of a Green Port Policy by prioritizing the tracking, monitoring and controlling of environmental pollution.

Some of the important measures for reducing emissions at Mombasa port are considered below.

Enforcing a regular inspection regime for vehicles and truck accessing the port, with a view to keeping very high emitters of PM, CO_2, SO_2, NO_2 at bay.

Provision of Shore Power (Cold Ironing)-this will reduces emissions from the ships by enabling them to shut down their auxiliary power generators while at berth.

The adoption of ISO 50001 Energy Management System (EMS) enables the port to regularize Energy Efficiency and Management procedures. The EMS standard stimulates port operations towards focusing on reducing electricity cost, fuel cost, GHG emission reduction and improving the efficiency at the port. Other measures include the electrification of the Port's mobile and fixed equipment, which mainly run on diesel fuels.

So far, a trend-setting energy blueprint, is already in the administrative system for corporate approval and contains active enablers for the growth of a positive and responsible culture to energy use, over the entire spectrum of port employees, users and stakeholders.

7.3 Recommendations on Energy Efficiency and Cost Reduction measures

Electricity from the National Power Grid is supplied to the Port through metered substations and is primarily used to power the entire port operations. The port's main power consumers includes terminal cranes, supply to reefers (cold stores), Port yard lightings, office lightings and air conditioning. The Port currently does not have a system in place to monitor this consumptions, no sub-meters installed hence depends entirely on the monthly bills posted by the grid power supplier which often features discrepancies with regard to accounting and costing.

In order to evaluate the consumption and opportunity to reduce energy cost Mombasa Port needs to strategize on: regular Electricity Consumption Audits - Using Power Loggers (Portable) attached to the electricity feeds of all the main equipment particularly terminal cranes, measuring and tracking power loads on a periodic pattern. The power logger will help in establishing the port's energy profile, which will then make it possible do analysis and identify areas for improvement including ascertaining the periods when the cranes consume power but without useful work (idling). This will assist in setting up normalized consumption targets, enabling calculations of individual consumptions and regular monitoring in order to assess whether the improvements have been achieved.

Renewable energy sources, notably Solar, offer new possibilities in efficiency improvements and energy bill cost cutting. Local generation of electricity from Solar PV installations (on the roofs of the buildings) can be utilized to provide electric power in areas such as yards lightings, port building lightings includes offices, workshops and air condition systems.

Fuel Efficiency Audit for all diesel fuel equipment can be undertaken in order to evaluate how well each equipment operates within its designed parameters in terms of fuel consumption and efficiency. Also, Equipment Replacement Policy, whereby replacements are done, based on energy efficient benchmarks, ensure reduced operating cost, emissions, and environmental impacts.

Power Factor Correction (pf)-the current power factor at the Port substations Q, T and R is low at 0.62, 0.76 and 0.60 respectively. This should be perpetuated by maintaining a proper balance between inductive and capacitive load distribution.

$$Power\ Factor, pf = \frac{\text{Active Power (kW)}}{\text{Total Power(kVA)}} = \text{Cos}\ \boldsymbol{\Phi}$$

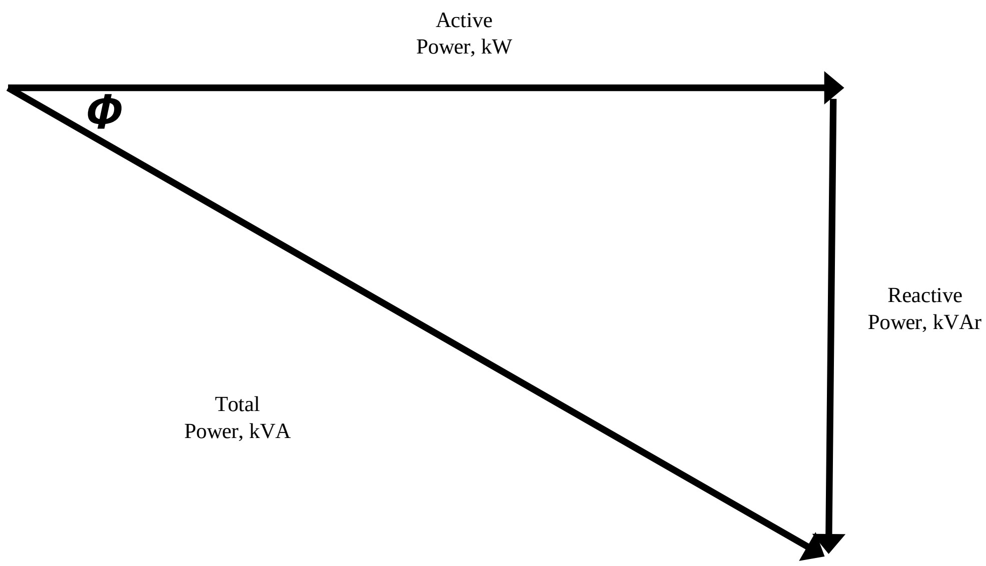


Table 12: Power Factor Triangle. Source-KPA

Improved power factor (pf) at substations will lead to less Total Power demand, reduced overall reactive power (kVAr) and losses (I^2R) in the intermediate power conductors.

Installation of Alternatives Occupancy Sensors in places where occupants' behavior will be used to dictate when to shutoff lights, air conditioners, hence reduce wastage upon exiting an area of work e.g. offices, workshops and washrooms. The sensors should be equipped with specific timers for regulating energy usage.

References

Acciaro, M., Ghiara, H., & M. I.Cusano. (2014). Energy management in seaports: A new role for port authorities. *Energy Policy 71 ·*, 4–12.

Ballini, F. (2017). *Renewable Energy in Ports.* Malmo: World Maritime University.

Boile, T. S. (2015). Developing a Port Energy Management Plan : Issues , Challenges and Prospects.

Burns & McDonnell Engineering Company . (2014). *Port of Los Angeles Energy Management Action Plan.* California: Burns & McDonnell Engineering Company , INC.

Business Sweden . (2016). *Energy Sector Opportunities in Kenya.* Nairobi: Business Sweden .

Chang, Y.-T. ((2013)). Environmental efficiency of ports: a Data Envelopment Analysis approach. *Maritime Policy & Management The flagship journal of international shipping and port research*, 467–478,.

Comisión Económica para América Latina y el Caribe (CEPAL). (2016). Energy consumption and container terminal efficiency. *Facilitation of Transport and Trade in Latin America and the Caribbean -FAL Bulletin Issue No 350*.

EIA, International Energy Outlook 2016, International Energy Statistics and Oxford Economics. (2016). Global energy intensity continues to decline. *TODAY IN ENERGY*.

Energy Regulatory Commission (ERC) KENYA. (2016). *2014-2015 ERC Annual Report Final .* NAIROBI: Energy Regulatory Commission (ERC), KENYA.

Energypedia. (2017). *Kenya Energy Situation.*

ESPO . (2012.). *"ESPO Green Guide; Towards excellence in port environmental management and sustainability.* Brussels: ESPO .

European Committee for Standardization (CEN). (2015). Environmental Management System. In E. C. (CEN), *EN ISO 14001.* Avenue Marnix 17, B-1000 Bussels: CEN-CENELEC Mnanagement Centre:.

European Sea Port Organization. (2015). *ghj.* European Sea Port Organization.

Fairplay . (2016). Poor energy efficiency holds back Africa's ports.

FAIRPLAY. (2016). Asia ports outlook 2017: Southeast Asia dynamic with port developments. *Fairplay*.

Fawkes, S. (2016). *Energy Efficiency: Definive Guide to the Cheapest, Cleanest, Fastest Source of Energy.* London and New York: Routledge Taylor & Francis Group.

Global legal Group. (2017). Energy 2017 Kenya. *global legal insights.*

I.Hippinen, J. (2014). *Fact-finding study on opportunities to enhance the energy efficiency and environmental impacts of ports in the Baltic Sea Region.* Helsinki,: Motiva Services Ltd.

Ilkka Hippinen, J. F. (2014). *Fact-finding study on opportunities to enhance the energy efficiency and environmental impacts of ports in the Baltic Sea Region.* Helsinki, .

International Energy Agency. (2017). Database Documentation (2017 preliminary edition). *World Energy Balances (OECD COUNTRIES):*.

International Maritime Organisation (IMO). (2016). *Module 5 – Ship Port Interface for Energy Efficiency.* London,: International Maritime Organisation (IMO).

International Maritime Organization (IMO). (2015). *Study of Emission Control and Energy Efficiency Measures for Ships in the Port Area.* London SE1 7SR: international maritime organization .

Ismayilov, T. (2014). *Analytical Assessment of Energy Efficiency Policies: A case Study of Norwegian Policy Making .* Lundi: Lundi University.

Japan International Cooperation Agency (JICA). (2015). *Mombasa Port Master Plan including Dongo Kundu .* MOMBASA: The Overseas Coastal Area Development Institute of Japan Oriental Consultants Global Co., Ltd. Nippon Koei Co., Ltd. .

Kenya Port Authority. (2016). *Mombasa Container Terminal Equipment.* Mombasa: Kenya Port Authority.

Kenya Ports Authority . (2015). *Development of a Green Port Policy and Implementation Plan.* Mombasa: Kenya Ports Authority .

Kenya Ports Authority. (2015). *Annual Review and Bulletin Statistics for 2015.* Mombasa: Kenya Ports Authority.

Kenya Ports Authority. (2015). *Development of a Green Port Policy and Implementation Plan in Mombasa Port.* mombasa: Kenya Ports Authority.

Kenya Ports Authority. (2015). *Investment Grade Energy Audit Report For Kenya Ports Authority, Mombasa.* Mombasa.

Kenya Ports Authority. (2017). *Port of Mombasa Feasibility Study.* Mombasa: Kenya Ports Authority.

Lahmeyer International GmbH, 2016. (2016). *Development of a Power Generation and Transmission Master Plan, Kenya Long Term Plan 2015 – 2035 – Renewable Energy.* Friedberger Str. 173 61118 Bad Vilbel, Germany.

Lai, & McCulloch. (2017). Levelized cost of electricity for solar photovoltaic and electrical energy storage. *Elsevier*, 191–203.

M. Adams, P. Q. (2009). Environmental Issues in Port Competitiveness. *Researchgate*, 3-22.

M.ACCIARO: T. Vanelslander: SYS, C., FERRARI, C., ROUMBOUTSOS, A., GIULIANO, G., & KAPROS§, J. S. (2014). Environmental sustainability in seaports: a framework for successful innovation. *Maritime Policy & Management The flagship journal of international shipping and port research*, 480–500,.

M.Puig, A.Michail, CWooldridge, & Dabra, R. (2017). Benchmark Dynamics in the environmental Performance of Ports. *Marine Pollution Bulletin* , 111-119.

Maritime and Port Authority of Singapore. (2017). *Maritime Singapore Green Initiative.* Singapore: Maritime and Port Authority of Singapore.

Maritime and Port Authority of Singapore. (2017). *Port of Singapore : Port Operations , Port Infrastructure, Terminals.* Singapore: Maritime and Port Authority of Singapore.

Mateo, A. R. (2017). Duterte signs Paris pact on climate change. *The Philippine Star*.

National Climate Change Secretariat Strategy Group Prime Minister's Office (NCCS). (2017). Singapore's Approach to Alternative Energy. *Climate Change and Singapore*.

Palgrave Macmillan. (2009). Operations research methods in maritime. *Maritime Economics & Logistic*, 1–6.

Philippine Statistics Authority. (2013). Electricity is the most common source of energy used by households. *Energy Consumption*.

Port of Durban. (2016). *South Africa Port of Durban.* Durban : Port of Durban.

Port of Gothenburg. (2017). *The Port of Gothenburg .* Gothenburg: Port of Gothenburg.

Port of Long Beach. (2005). *Green Port Policy.* Long Beach: Port of Long Beach.

Port of Los Angeles, City of Los Angeles. (2013). Port of Los Angeles to Develop Energy Management Action Plan 'E-MAP' . *SAFETY4SEA*.

Port Technology Organization. (2013). *Mombasa power outage cripples port operations.* Port Technology Organization.

Port technology.org. (n.d.). Improving energy and emission efficiency in port terminals. *Port Technology Internatinal Journal - Edition 46*.

Portland Energy Conservation, Inc. (2010). Energy Performance Tracking: Tools and Best Practices. *18th National Conference on Building Commissioning* (pp. 1-76). California: The California Energy Commission.

Quah, J. S. (2014.). Benchmarking for Excellence: A Comparative Analysis of Seven Asian Anti-Corruption Agencies. *Asia Pacific Journal of Public Administration*, 171-195,.

R. Matulka, J. D. (2013). *Moving Towards Resiliency: An Assessment of the Costs and Benefits of Energy Security Investments for the San Pedro Bay Ports.* Los Angeles .

REEEP. (2013). Degree of reliance on important energy. *Republic of the Philippines (2014)* .

Sheldon Yoder. (, 2017). Energy Intensity of Global Economy Rises, Reversing Longtime Trend. *2016 Worldwatch Institute*.

Styhre, L., & Winnes, H. (2016). *Energy efficient port calls-Study of Swedish Shipping with International Outlook.* Stockholm: IVL Swedish Environmental Research Institute 2016.

Sustainable Energy for All (SE4All). (2016). *Kenya Action Agenda.*

Sustainable Development Solutions Network . (2012). *Indicators and a Monitoring Framework Launching a data revolution for the Sustainable Development Goals.*

The World Bank Group,. (2017). Global Tracking Framework database (2015).

UNDP. (2015). Sustainable Development Goals (SDGs) Goal 7: Affordable and clean energy. *United Nations Development Programme : Green Commodities Programme*.

united nation . (2017). *Progress towards the Sustainable Development Goals-Report of the Secretary-General .*

United Nations. (2016). *Energy Statistics Newsletter.*

United Nations. (2017). Sustainable Development Goal 7. *Sustainable Development Knowledge Platform*.

World Energy Council for sustainable energy. (2013). *World Energy Perspective; Cost of Energy Technologies.* London: World Energy Council.

Wu, Y. (2012). *Electricity Market Integration: Global.*

Appendix I
KPA Energy Policy

Kenya Ports Authority

P. O. Box 95009 - 80104 Mombasa, Kenya.
Tel: +254 - 41 - 2112999 / 2113999
Mobile: 0720 202424 0734 221211
0720 202525 0734 312211
0720 312211 0735 337941 - 6
0722 208661 - 5
Wireless: +254 - 20 - 3575880 - 9
Fax: +254 - 41 -2311867
Website: www.kpa.co.ke

Energy Policy

Kenya Ports Authority is committed to energy management and the efficient and sustainable use of energy resources. The Authority recognizes that through Energy efficiency, it will contribute to conservation of our Environment.

To translate this commitment into action, the Authority shall:

Conform to all the Kenyan statutes and regulations in respect of energy usage including the energy Act 2006

Provide resources necessary to achieve energy efficiency

Establish an energy committee to spearhead the implementation of measures to achieve energy efficiency

Facilitate the establishment of annual budgets, objectives and targets on energy conservation

Identify training needs and train staff to ensure competence in the efficient use of energy

Ensure that this policy is reviewed at least once annually to ensure its continued adequacy and effectiveness

Ensure that this policy is communicated to all our staff and it shall be available for review by the public.

Approved by: ------------------------

Managing Director

Date-------------------

Kenya Ports Authority

P. O. Box 95009 - 80104 Mombasa, Kenya.
Tel: +254 - 41 - 2112999 / 2113999
Mobile: 0720 202424 0734 221211
0720 202525 0734 312211
0720 312211 0735 337941 - 6
0722 208661 - 5
Wireless: +254 - 20 - 3575880 - 9
Fax: +254 - 41 -2311867
Website: www.kpa.co.ke

Energy Policy -Responsibilities

To appoint an energy officer responsible for implementation of the energy policy in all the sites

To establish energy committees with representation from all the key departments

To identify measures for energy efficiency and develop annual budgets and programs for implementation

To continuously measure, monitor, analyze and control energy consumption

To conduct energy audits according to the energy management regulations 2012 and other relevant legislation

To establish a training program to ensure training of key staff on energy management.

To Encourage awareness and employee participation in improving energy efficiency

To implement a procurement policy that promotes energy efficiency in new purchases and projects

To include Energy management as an agenda during the Quality management review meetings

To comply with local legislation

Approved by: ------------------------

Managing Director

Date-------------------

Appendix II

KPA Monthly Energy Bill

ITEM NO.	LOCATION	ENGINE TYPE	ENG.MODEL NO.	RATING (KVA)	CONSPUTION L/HR	KPLC POWER BILLS FOR 2016	
1	K. O. T.	JOHN DEERE	4045HF120	100	21.8	MONTH	AMOUNT (KSHS)
2	SUB STATION T	CUMMINS	KTA38-G5	1063	206	JANUARY	23,358,865.80
3	SUB STATION Q	VOLVO PENTA	TAD 1642 GE	610	121		
4	SUB STATION M	VOLVO PENTA	TAD 1642 GE	610	121	FEBRUARY	22,709,451.10
5	GATE18/20	PERKINS	1104C-44TAG1	80	18.6		
6	HQ BLK 1	VOLVO PENTA	TAD 1641 GE	500	91	MARCH	25,980,514.20
7	HQ BLK 2	VOLVO PENTA	TAD 1641 GE	500	91		
8	HQ BLK 1 & 4.	CATERPILLAR	C-18	500	110	APRIL	28,081,960.50
9	IT BLK SERVER ROOM	PERKINS	2206A-E13TAG G2	350	71		
10	S. O. T.	JOHN DEERE	4045TF150	70	16.8	MAY	30,718,859.20
11	SUB STATION K	CATERPILLAR	C-18	500	110		
12	GATE 12	PERKINS	1104C-44TAG1	80	18.6	JUNE	24,739,119.80
13	SUB STATION A	CATERPILLAR	C-18	500	110		
14	GATE 9/ 10	CUMMINS	6B TA5.9-G5	110	25	JULY	23,852,602.70
15	CONTROL TOWER	JOHN DEERE	6068HF475	220	43.6		
16	SUBSTATION C.	PERKINS	2206A-E13TAG G2	350	71	AUGUST	23,398,818.19
17	BANDARI CLINIC	PERKINS	GCB 275	200	45.2		
18	BANDARI COLLEGE	VOLVO PENTA	TAD 1642 GE	610	121	SEPTEMBER	23,861,417.70
19	MBARAKI SPORTS CLUB.	CATERPILLAR	3406 C (M)	365	77		
20	MD'S HOUSE KIZINGO	PERKINS	404D-22	22	4.8	OCTOBER	24,567,682.90
21	RAS SERANI LIGHT HSE	PERKINS	1103A-33G	30	7.1		
22	OLD PORT	PERKINS	1104C-44TAG2	100	22.6	NOVEMBER	20,456,013.40
23	MAKUPA WELFARE	PERKINS	6TWGM	145	30		
24	AQUA FACILTY B. COLLEGE.	JOHN DEERE	4045TF120	75	17.6	DECEMBER	27,910,263.50
25	TERMINAL II (ADMIN)	VOLVO PENTA	TAD 1641GE	500	91		
26	TERMINAL II (SUBSTATION)	VOLVO PENTA	TAD 1341GE	360	64.1		
27	TERMINAL II (REEFERS)	CUMMINS	QST30-G4	1000	202		
	APPROXYMATE TOTAL FOR KVA AND ANNUAL POWER COST.			9550			299,635,568.99

Appendix III

SOLAR PVC Project Cost calculator

Solar PV Project Cost Calculator *Levelized Cost of Energy (LCOE) -Solar PV for Mombasa Port* August, 2017

Inputs highlighted in Yellow

System Inputs		Input Description
System Size (kW-DC)	1000	*for a site)*
1st-Year Production (kWh	52,417,000	*system production at a site*
Annual Degradation	0.50%	*performance degradation)*

Direct Purchase Inputs		
Cost ($/W)	$ 0.747	*If not available, use the formula: Cost ($/W) = (Total-system-cost/Total-system-size-in-watts)*
Initial Rebate/Incentive	$ -	*rebates/incentives received within the first year)*
O&M Cost ($/kW)	$ 15.00	*available, use the formula: O&M Cost ($/kW) = (1st-year-O&M-*
O&M Escalator (%)	3%	*escalation)*

PPA Inputs		
PPA Rate ($/kWh)	$ 0.15000	*not available, use the formula: PPA Rate ($/kWh) = (1st-year-PPA-*
PPA Escalator	3.00%	*escalation. If not uniform, manually insert yearly escalation in Column I)*

LCOE Outputs*

Direct Purchase		*the next 20 years*
20 Year	$ 0.00115	
25 Year	$ 0.00105	

PPA		*the next 20 years*
20 Year	$ 0.20054	
25 Year	$ 0.21709	

**Undiscounted Analysis*

Solar PV CAPEX	65,273,700	Kshs.
currency Conversion :		
Kshs.(to USD)	652737	$
kwh to kw	873616.667	kw
Solar PV Production	52,417,000	MWh/year
Cost ($/W)	0.74716638	$/w
Potential Savings	12,168,090	Kshs
PS in USD	121680.9	$

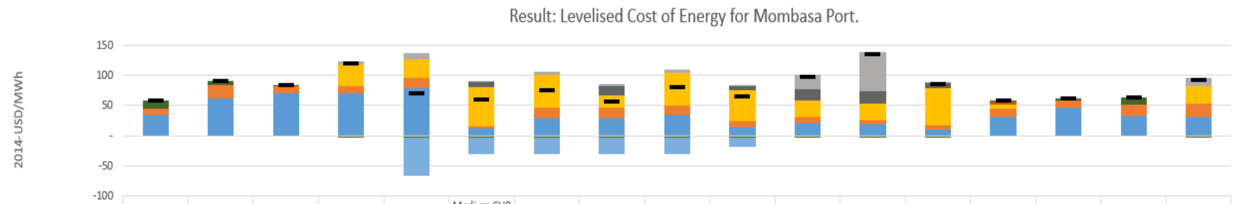
LCOE Calculator

Year	Production (kWh)	Direct Purchase Cost ($)	O&M Cost ($)	PPA Escalator (%)	PPA Rate ($/kWh)	PPA Cost ($)
0		$ 747,166		-		
2018	52,417,000		$ 15,000		$ 0.1500	$ 7,862,550
2019	52,154,915		$ 15,450	3%	$ 0.1545	$ 8,057,934
2020	51,894,140		$ 15,914	3%	$ 0.1591	$ 8,258,174
4	51,634,670		$ 16,391	3%	$ 0.1639	$ 8,463,390
5	51,376,496		$ 16,883	3%	$ 0.1688	$ 8,673,705
6	51,119,614		$ 17,389	3%	$ 0.1739	$ 8,889,246
7	50,864,016		$ 17,911	3%	$ 0.1791	$ 9,110,144
8	50,609,696		$ 18,448	3%	$ 0.1845	$ 9,336,531
9	50,356,647		$ 19,002	3%	$ 0.1900	$ 9,568,544
10	50,104,864		$ 19,572	3%	$ 0.1957	$ 9,806,322
11	49,854,340		$ 20,159	3%	$ 0.2016	$ 10,050,010
12	49,605,068		$ 20,764	3%	$ 0.2076	$ 10,299,752
13	49,357,043		$ 21,386	3%	$ 0.2139	$ 10,555,701
14	49,110,257		$ 22,028	3%	$ 0.2203	$ 10,818,010
15	48,864,706		$ 22,689	3%	$ 0.2269	$ 11,086,838
16	48,620,383		$ 23,370	3%	$ 0.2337	$ 11,362,346
17	48,377,281		$ 24,071	3%	$ 0.2407	$ 11,644,700
18	48,135,394		$ 24,793	3%	$ 0.2479	$ 11,934,071
19	47,894,717		$ 25,536	3%	$ 0.2554	$ 12,230,633
20	47,655,244		$ 26,303	3%	$ 0.2630	$ 12,534,564
21	47,416,968		$ 27,092	3%	$ 0.2709	$ 12,846,048
22	47,179,883		$ 27,904	3%	$ 0.2790	$ 13,165,272
23	46,943,983		$ 28,742	3%	$ 0.2874	$ 13,492,429
24	46,709,263		$ 29,604	3%	$ 0.2960	$ 13,827,716
25	46,475,717		$ 30,492	3%	$ 0.3049	$ 14,171,335
Total	**1,234,732,305**	**$ 747,166**	**$ 546,889**			**$ 268,045,965**

Appendix IV

Levelized Cost of Energy for Renewable sources

Basic user settings	Default value	Override	Current value	Explanation	
Result view					
Currency	EUR	USD	USD	(Predefined)	The results can be viewed in number of currencies. All input data should be in EUR2015
Price year	2015	2014	2014	(Predefined)	Price year for results
Financial settings					
First year of production	2018		2018	(Predefined)	The first year of production should be related to the technology year.
Lookout period (years)	Technical		Technical	(Predefined)	Period for discounting fuel and CO2 prices. If you choose "Technical" the lookout period equals the technical lifetime of the specific technology
Discount rate	4%		4%	(Free to set)	Set discount rate. Used for annuation of capital costs and discounting fuel and CO2-prices. The value 0 will not work. Choose instead a very small value
Discount prices	YES		YES	(Predefined)	Choose YES to discount prices for fuel, CO2-prices etc. through lookout period
Interest during construction	YES		YES	(Predefined)	Set to YES to take into account interest during construction
Scenarios					
Fuel and CO2-price scenario	New Policy 2015	ent Policies 2015	Current Policies 2015	(Predefined)	Choose which scenario for future fuel and CO2-prices should be applied. The IEA fuel and CO2 price projections from World Energy Outlook 2015 are predefined in the model. In the sheet "FuelPrices" custom fuel and CO2-prices can be defined
Technology scenario	TechBase	TechBase	TechBase	(Predefined)	Choose scenario for technical data. See the TechData sheet for further information
Technology year	2015		2015	(Predefined)	Year for technology data
Heat value					
Set methodology to value heat production	Cost allocation		Cost allocation	(Predefined)	Choose method to value heat from combined heat and power plants. Set to YES to use a cost allocation methodology. Otherwise a heat price will be used
Heat efficiency if cost allocation is selected	125%		1.25	(Free to set)	Set the efficiency of heat production used for allocation of fuel and CO2 costs. It is by default set to 125%. Other often used efficiencies are 150% and 200%
Heat price (EUR/GJ) if heat price is selected	6.7		7.1	(Free to set)	Choose the price of heat (set to NO). New values should be typed in EUR2014/GJ. If heat price is selected the value of heat is shown as a heat revenue (negative cost) in the graph.
Inclusion of costs					
Include air pollution	YES		YES	(Predefined)	Set to YES to include air pollution in the LCOE calculation



	Wind onshore	Wind offshore	Solar power	Medium CHP - wood chips	Medium CHP - straw	Medium CHP - natural gas SC	Large CHP - wood pellets	Large CHP - coal	Large CHP - refurb. Wood pellets	Large CHP - natural gas CC	Coal FGD INT	Coal no FGD INT	Natural gas CCGT INT	Nuclear INT	Solar PV INT	Wind onshore INT	Biomass plant INT
Heat revenue	-	-	-	-	-64	-27	-26	-26	-26	-15	-	-	-	-	-	-	-
System costs	12	8	2	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	2	2	12	-4
Air pollution	-	-	-	5	11	3	5	4	5	2	24	65	2	-	-	-	14
Climate externalities	-	-	-	0	0	8	0	15	0	7	19	19	8	-	-	-	0
Other costs	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Fuel cost	-	-	-	35	29	65	55	21	54	51	28	28	62	8	-	-	29
O&M costs	11	21	12	12	18	4	17	17	17	10	9	7	7	14	13	18	22
Capital cost	34	62	70	70	78	12	29	29	34	14	21	18	10	30	46	33	31
Total LCOE	57	91	84	119	70	60	75	56	80	65	97	134	86	58	61	64	93

Summary of the LCoE-calculation

	Wind onshore	Wind offshore	Solar power	Medium CHP - wood chips	Medium CHP - straw	Medium CHP - natural gas SC	Large CHP - wood pellets	Large CHP - coal	Large CHP - refurb. Wood pellets	Large CHP - natural gas CC	Coal FGD INT	Coal no FGD INT	Natural gas CCGT INT	Nuclear INT	Solar PV INT	onshore INT	Biomass plant INT
Capital cost	34	62	70	70	78	12	29	29	34	14	21	18	10	30	46	33	31
O&M costs	11	21	12	12	18	4	17	17	17	10	9	7	7	14	13	18	22
Other costs	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Fuel cost	-	-	-	35	29	65	55	21	54	51	28	28	62	8	-	-	29
Climate externalities	-	-	-	0	0	8	0	15	0	7	19	19	8	-	-	-	0
Air pollution	-	-	-	5	11	3	5	4	5	2	24	65	2	-	-	-	14
System costs	12	8	2	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	2	2	12	-4
Heat revenue	-	-	-	-	-64	-27	-26	-26	-26	-15	-	-	-	-	-	-	-
Levelized cost of electricity production, 2(	**57**	**91**	**84**	**119**	**70**	**60**	**75**	**56**	**80**	**65**	**97**	**134**	**86**	**58**	**61**	**64**	**93**

	Coal2	New Technology 2	New Technology 3	Technology 4	New Technology 5	New Technology 6	New Technology 7	New Technology 8	New Technology 9	Technology 10
Capital cost	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
O&M costs	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Other costs	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Fuel cost	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Climate externalities	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Air pollution	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
System costs	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Heat revenue	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Levelized cost of electricity production, 2(	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**

Appendix V.

KPA Green Port Policy Statement.

Kenya Ports Authority Green Port Policy Statement

The Kenya Ports Authority will continuously strive to improve and attain the highest standards of environmental performance for the benefit of the Mombasa Port Community and all other port communities under its stewardship.

To accomplish this goal the KPA will:

1. **Protect people from the harmful environmental impact of port operations.**
2. **Comply with current national and international environmental standards.**
3. **Implement sound environmental improvement practices in all activities.**
4. **Invest in new environmental technologies as available.**
5. **Continually improve the quality of water, air, soil and environmental habitats in the Port community.**
6. **Work with port operators, port users and tenants to accomplish improvement.**
7. **Educate & Train employees and the community to create a culture of sustainable environmental improvement & stewardship.**
8. **Communicate regularly with and be accountable to the community and the public for successes and failures against environmental targets.**
9. **Provide adequate funds & resources to accomplish environmental targets.**

The Chief Executive and Senior Management of the Port are responsible and accountable for effective implementation of this Policy.

Green Port Policy for Mombasa Port

GREEN PORT POLICY STATEMENT FOR THE PORT OF MOMBASA

The Port of Mombasa will be a leading world port in the sound stewardship and management of the environment affected by port operations, and will seek to continuously improve the environment for the community and KPA staff. The port promises to:

1. **Put people first – protect people from harmful impact of port operations, and improve their environment**
2. **Invest in Sustainable operations and port development with new technology**
3. **Co-opt stakeholders and educate the community in improving the environment**
4. **Implement and phase in economically sustainable and non-onerous measures to protect and improve the environment. Share the cost of implementation where appropriate.**
5. **Become a Green Port leader in the region in the next 10 years, and a world leader in 20 years**
6. **Maintain and improve Stewardship of the planet – maintain and improve biodiversity. Leave the planet better off**

To implement these goals and achieve these objectives, the Port will:

- **Establish a plan, specific pollution reduction targets and firm schedules to reduce GHG and other pollution from all business operations at the port**
    - **Work with port operators and tenants to mitigate and eliminate all cargo operations-related health hazards to the community, within 2 years**
    - **Work with vessel operators to reduce all vessel-related pollution**
    - **Work with truckers to upgrade vehicles to cleaner fuels and phase out older vehicles**
- **Implement environmentally sound best practices in port administration, waste management and management of business activities, with specific targets and time frame. Improve recycling and minimize energy usage.**
- **Conform to all Kenyan and international regulations on environmental protection. Implement zero tolerance policy.**
- **Use new technology and recyclable materials for all new construction and development to reduce carbon footprint.**
- **Measurably improve the quality of water, air, soil remediation, biodiversity**
- **Educate and train the port employees, stakeholders and community in supporting and assisting the port in improving the environment. Communicate the importance of environmental stewardship to all levels of employees and stakeholders, and promote a business culture of environmental stewardship.**
- **Allocate sufficient and financial and other resources for implementation.**
- **Be accountable to the community for failure to achieve targeted environmental improvements.**
- **Review and improve green port policy initiatives at least once each year**