MARITIME TECHNOLOGY COOPERATION CENTRE FOR AFRICA (MTCC-Africa)

CAPACITY BUILDING FOR CLIMATE MITIGATION IN THE MARITIME SHIPPING INDUSTRY

THE GLOBAL MTCC NETWORK (GMN) PROJECT

MTCC-AFRICA PILOT PROJECT 1

UPTAKE OF PORT ENERGY EFFICIENT TECHNOLOGIES AND OPERATIONS

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HOST OF MTCC AFRICA

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1.0 INTRODUCTION

The main objective of this pilot project is to promote the uptake of energy efficient technologies and operations within the African ports through the implementation of energy efficiency strategies. More specifically, the project aims at collecting and analyzing the various audit reports undertaken for the Port of Mombasa (POM), Determining the impacts of the proposed energy saving/emission reduction strategies at the Port of Mombasa, undertake a level 2 Energy Audit for the POM and a level 1 energy audit on one African ports for purposes of obtaining baseline data on the current situation on the ports and identifying the various measures that can help to improve energy efficiency.

2.0 REPORTS AND ANALYSIS ON PREVIOUS ENERGY AUDITS DONE FOR THE PORT OF MOMBASA.

2.1 BACKGOUND OF PORT AUDITS AND ENABLING ENVIRONMENT

The Port of Mombasa is the gateway to East and Central Africa and is one of the busiest Ports along the East African coastline. The Port provides direct connectivity to over 80 Ports worldwide and is linked to a vast hinterland comprising Uganda, Rwanda, Burundi, Eastern Democratic Republic of Congo, Northern Tanzania, Southern Sudan, Somalia and Ethiopia by road. A railway line also runs from the Port to Uganda and Tanzania.

Established in January 1978 under an Act of Parliament, KPA is mandated to manage and operate the Port of Mombasa and all scheduled seaports along Kenya's coastline that include Lamu, Malindi, Kilifi, Mtwapa, Kiunga, Shimoni, Funzi and Vanga. In addition, the Authority manages Inland Waterways as well as Inland Container Depots at Embakasi, Eldoret and Kisumu.

Being a public entity, the port is by law required to adhere to guidelines on Energy conservation in factories and buildings according to the Energy Act 2006. This Act stipulates that the occupier of a building/factory shall conserve energy, audit and analyze energy consumption in his building/factory in accordance with the standards, criteria, and procedures as prescribed in the regulations. The act stipulates that a person who fails to comply with the energy conservation provision commits an offence and shall, on conviction, be liable to a fine

not exceeding one million shillings, or to a maximum term of imprisonment of one year, or to both.

To broaden the scope of the Energy Act 2006, the parliament enacted the Energy Act 2019. This Act of Parliament consolidate the laws relating to energy, to provide for National and County Government functions in relation to energy, to provide for the establishment, powers and functions of the energy sector entities; promotion of renewable energy; exploration, recovery and commercial utilization of geothermal energy; regulation of midstream and downstream petroleum and coal activities; regulation, production, supply and use of electricity and other energy forms; and for connected purposes.

In addition to the provisions in Energy Act 2006, Energy Act 2019 stipulates that The Authority shall coordinate the development and implementation of a prudent national energy efficiency and conservation programme. In addition, the Cabinet Secretary has powers to enforce efficient use of energy and its conservation. This includes but not limited to specify the norms for processes and energy consumption standards for any equipment, appliances which consumes, generates, transmits or supplies energy; specify equipment or appliance or class of equipment or appliances, as the case may be, for the purposes of this Act and prohibit manufacture or sale or purchase or import of equipment or appliance specified under paragraph (b) unless such equipment or appliances conform to minimum energy efficiency performance standards. The penalty for contravention of the energy saving provision in the Energy Act 2019 is reduced to a fine not exceeding five hundred thousand shillings but the imprisonment term is extended to a period not exceeding two years or both.

2.2 KPA LEVEL I ENERGY AUDIT AND ITS RECOMMEDATIONS

The Port of Mombasa conducted its first investment grade energy audit in 2014.EMS Consultants Ltd was contracted by the Kenya Ports Authority to carry out 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).

The audit entailed interviews with site management and staff, measurement of energy parameters using various audit instruments, identification of energy efficiency opportunities, a financial analysis of the energy conservation (efficiency) measures; covering life cycle cost and internal rate of return (IRR). This approach took into account the energy savings and maintenance costs during the life of the project. The audit report provided financial

justification for the key energy conservation measures which enabled the executing departments to seek budgetary allocations for their implementation.

The sources of energy at Kenya Ports Authority Ltd, were identified as electricity and automotive diesel. The Company then owned fifteen (15) transformers and twenty-two (22) standby power generators.

During the energy Audit (October to December 2014) electricity was supplied to the facility by KPLC at 11 KV at tariff CI2 and distributed through fifteen (15) transformers. However, during the presentation of the draft energy audit report on 14th January, 2015, the organization had completed the installation and commissioning of a 132KV substation under the new tariff CI5.

At the time of audit, the port had already implemented the following energy saving measures-:

a) The Company had replaced some of the 4ft long x 36 w T8 fluorescent tubes with T5 4ft long x 28w especially at Bandari College
b) Timer switches and photocell had been installed to control the switching on and off of Monopole/tower lights and security lights
c) Aircosavers have been installed in some of the air conditioners on a pilot basis
d) Compact Fluorescent lamps had been installed in the corridors and security lights of Bandari College
e) The organization has completed the installation of a 132KV substation thus enabling tariff migration from CI2 to CI5.

In achieving their tasks, EMS Consultant limited used the below audit procedure methodology

1. A desk review of the energy and service levels at Kenya Ports Authority
2. Energy management 3-day training for key staff
3. One-hour sessions of Energy management awareness for various departments
4. A physical survey of the facilities to develop an appreciation of the scope of work, understand the key energy consumers and to help in planning for measurements.
5. Measurements of the energy parameters using various instruments
6. Interviews with various staff regarding modes of operation
7. Taking photos of areas with potential for energy saving
8. Technical and financial analyses to determine opportunities for energy efficiency and
9. Compiling of the energy audit report.

The audit involved carrying out measurements in various parts of the building and installations. The instruments used include:

- Power loggers
- Power quality analyzers
- Tong Testers
- Light Meters
- Vane Anemometers
- Dry and Wet bulb Thermometers
- Humidity and Temperature meters and
- Infra-red thermometers

2.3 ENERGY COST REDUCTION OPPORTUNITIES AT KENYA PORTS AUTHORITY

The consultant (EMS) identified the following as energy saving opportunities within the port precincts.

2. 3.1 POWER FACTOR CORRECTION

2.3.1.1 EMS Findings

The power factor was noted to be low at 0.62, 0.76 and 0.60 for substation Q, T and A respectively prior to the audit. The Kenya power company supplies total power to the port via the main substations at Kipevu and Shimanzi where metering is done. The total power demand (KVA) will be less with higher power-factor at downstream substations due to reduced overall reactive power. If total power is less, the I^2R losses in the intermediate conductors will also be less thus enhancing the life of the conductors.

2.3.1.2 Recommendations

EMS recommended Installation of capacitor banks to correct the power factor to 0.98 in all substations. Power factor correction is same as power factor improvement from any value to another value closer to unity. The Power factor for these substations have since been improved to above 0.98.

2. 3.2 CHILLER AND AC IMPROVEMENTS:

2.3.2.1 EMS Findings

- The condenser fins (heat exchange surfaces) on the old chillers were found clogged mainly due to dust generated during offloading of dusty materials from the ships including clinker, coal and cement
- The volume damper for makeup air for Theatre air conditioning is not graduated.
- The coefficient of performance of the old chillers is poor at an average of 1.7 compared to a new chiller with an average of 3.3.
- The old chillers use R22 refrigerant (not environmentally friendly) whereas the new ones use R410A which is environmentally friendly

The coefficient of performance (COP) of the chiller is the ratio of cooling effect (kw) divided by the electrical power input (kw).

2.3.2.2 Description of energy conservation measure:

To improve COP, the following measures were proposed-:

a) Establish a policy to procure window and split air conditioners that meet the minimum energy performance standards in Kenya.
b) Install Aircosavers on the air conditioning units detailed
c) improve compressor efficiency by overhauling (replacement of worn out parts)
d) Replace the air-cooled condensers as cleaning alone will not achieve the rated heat transfer efficiency
e) Install occupancy sensors in areas served by the chillers including the training and meeting rooms
f) Descaling of the evaporators to improve heat transfer efficiency

However, the expenses associated with the above may be enormous and replacement with new chillers which use environmentally friendly refrigerants is the preferred option.

2.3.3 USE OF AIR CURTAINS

2.3.3.1 EMS Findings

- The door to the Bandari college main kitchen cold room is frequently opened when storing or removing goods. The doorway is fitted with plastic strips (curtains) to minimize air infiltration when the door is opened.
- The main door to the library is frequently opened when users go in and out. The door is fitted with a door closer to minimize air infiltration

2.3.3.2 Recommendations

- Install an air curtain and interlock with the cold room door so that air curtain runs only when the door is open.
- Install an air curtain and interlock with the Library main door so that the air curtain runs only when the door is open.

2.3.4 LIGHTING IMPROVEMENTS

2.3.4.1 EMS Findings

Several areas of the port do not have skylights and thus do not allow the facility to take full advantage of natural lighting. This leads to use of artificial lights in several places especially workshops (Mobile, Motor Vehicle and Electrical workshops) during the day. Different types of lamps are in use at Kenya Ports Authority including the following:

- 5ft long T8 twin fluorescent lamps (58W)
- 4ft long T8 twin Fluorescent Lamps (36W)
- 2 ft long T8 twin fluorescent lamps (18W)
- 50w Downlighters
- 11w Compact Fluorescent lamps

2.3.4.2 Recommendations on Lighting Improvements

- Install LED lamps as a replacement of all the existing less efficient lamps
- Replace electromagnetic ballasts with electronic type.
- Replace basic T8 fluorescent tubes with standard OSRAM T5 tubes
- Use of skylights to facilitate use of natural lights during the day
- Replace the old skylights in the plant
- Install skylights on the roof of workshops (Mobile, Electrical and Motor vehicle workshops).

2.3.5 USE OF OCCUPANCY SENSORS

2.3.5.1 EMS Findings

There are no electrical/ electronic interlocks between doors and the air conditioning equipment and lights in the hostel rooms and conference rooms resulting in situations where lights remain on when rooms are not occupied and air conditioning equipment sometime runs with windows open leading to energy losses.

2.3.5.2 Description of Energy Conservation Measure:

- Install magnetic switches on doors and windows in both hostel rooms and conference rooms and interlock with air conditioners to ensure they don't run with windows or doors open.
- Install occupancy sensors (dual type) in training and conference rooms and interlock with lights and air conditioners to ensure no air conditioning and lighting without room occupancy.
- Fit foam inserts in the gaps between window type AC units and the walling and seal using timber to minimize infiltration.
- Seal all openings at high level in the common office for senior electrical engineers to minimize infiltration and thus air conditioning load.
- Adjust AC temperature setting for the common office to a minimum of 20°C

2.3.5.3 Alternatives to Occupancy Sensors

Occupancy sensors are used in place of establishing the occupants' behavior to shut off lights upon exiting a room. For applications where the installation of occupancy sensors is cost prohibitive, the following options were proposed:

- raise awareness for building occupants with light switch stickers and educational materials,
- require custodial and security personnel to turn lights off and consider controlling lights with timers or through existing energy management systems.

2.3.6 USE OF SOLAR WATER HEATERS FOR BANDARI COLLEGE HOSTEL & KITCHEN

2.3.6.1 EMS Findings

- Bandari college kitchen uses LPG for water heating
- Bandari college hostel showers are equipped with 69 No. of instant hot water heaters each with a rating of 2kw.

2.3.6.2 Description of energy conservation measure:

- Install solar water heaters to supply hot water to Bandari kitchen.
- Install solar water heaters to supply hot water to Bandari hostels:

2.3.7 LIFT CONTROLS UPGRADE

2.3.7.1 EMS Findings

Block 2 building at port headquarters has two machine room type of lifts with the following specifications:

TABLE 2.1 SPECIFICATIONS FOR THE PORT HEADQUARTERS LIFT

Capacity	1050 kg (13 passengers) Lifts
Make	Mitshubishi Duplex
Type	Machine Room Type
Speed(rpm)	1380
Driven	Thyristor Driven
Motor	Geared (Pulley System)
Rating	15kW

Lifts in other blocks are machine room-less type which are energy efficient.

2.3.7.2 Description of energy conservation measure on Lifts Controls

OPTION1

- Install VFD (VSD) in lieu of Thyristors to control operation of lifts
- Replace controls in the machine room
- Change the door controls on the cars
- Replace geared motors with high efficiency gearless type

OPTION 2

- Replace the existing lifts with the type of lifts which use variable speed drives and do not require a machine room

2.3.8 RETROFIT (USE OF PREMIUM EFFICIENCY MOTORS) MOTOR

2.3.8.1 EMS Findings

Several motors within the organization have standard efficiency rating as shown in Table 2.2

TABLE 2.2: MOTOR SPECIFICATIONS IN THE AUTHORITY

	Motor Description/section		**Qty**	**Motor size (kW)**	**RPM**	**Open / closed**	**Motor premium efficiency.**	**Motor standard efficiency.**
	Motor description	**Location**						

1	Chiller pump	Police station	1	5.5	2920	open	88.5%	81%
2	Swimming pool pump no 1	Swimming pool	1	7.5	1440	open	91.7%	82%
3	Swimming pool pump no 2	Swimming pool	1	7.5	1440	open	91.7%	82%
4	Diving pool pump no1	Swimming pool	1	7.5	1440	open	91.7%	82%
5	Diving pool pump no2	Swimming pool	1	7.5	1440	open	91.7%	82%
6	Control tower pump no 1	Control towers	1	3	2850	open	86.5%	80%
7	Control tower pump no 2	Control towers	1	3	2850	open	86.5%	80%
8	Booster pump no 1	Block 1	1	1.5	1680	open	85.5%	80%
9	Booster pump no 2	IT Block	1	1.5	1680	open	85.5%	80%

Table 2.3 shows the list of motors used on the container cranes

TABLE 2.3 EXISTING MOTOR SPECIFICATIONS FOR GANTRY CRANES

Type of motors	Location	Quantity	Rating(kw)	Speed(rpm)	Premium efficiency	Standard efficiency
Travelling Motors	ZPMC 1901 STS CRANE	20	13	1750	93.0%	84.0%
Hoisting Motors	ZPMC 1901STS CRANE	2	375	1750	96.0%	94.0%
Boom Hoist Motor	ZPMC 1901STS CRANE	1	160	1750	95.8%	93.8%
Trolley Motors	ZPMC 1901STS CRANE	4	60	1750	95.4%	89.0%
Travelling	ZPMC 1902 STS	20	13	1750	93.0%	84.0%

Motors	CRANE					
Hoisting Motors	ZPMC 1902STS CRANE	2	375	1750	96.0%	94.0%
Trolleys Motors	ZPMC 1902 STS CRANE	4	60	1750	95.4%	89.0%
Travelling Motors	OLD ZPMC STS CRANE	20	17.5	1750	93.6%	84.0%
Hoisting Motors	OLD ZPMC STS CRANE	2	400	1750	96.0%	94.0%
Hoisting Motors	RTG OLD KALMAR STS CRANE	2	200	1486	0.917	0.82

2.3.8.2 Description of energy conservation measure on Motor Efficiency

- Establish a procurement policy to replace standard efficiency with premium efficiency motors.
- Replace the standard efficiency motors with the premium efficiency type as detailed in t he tables

Note: Depending on availability of funds, the motors which are rated above 100kw (Capital i ntensive) may be replaced at the end of useful life.

2.3.9 ENERGY MANAGEMENT SYSTEM

2.3.9.1 EMS findings on Energy Management System

The Kenya ports Authority is supplied with electricity through two KPLC energy meters which are located at Shimanzi and Kipevu substations. However, the energy consumption data can only be obtained from KPLC electricity bills or by taking readings from the energy meters. The trends of consumption can be worked out by using a Microsoft excel sheet. The energy data is combined for all the port departments and utilities and it is not possible to determine the actual consumption by each department or utility from the KPLC energy meters or the electricity bills.

2.3.9.2 Description of Energy Conservation Measure on Energy Management

- Install smart meters and energy management software to monitor energy consumption by the following units on real time basis: substations, workshops, office blocks, bandari college, chillers, server rooms, electrically driven cranes and the 'reefer' containers power supply system. The recommended system is "AMPLEX SMARTHARBOUR"
- The key benefit of the proposed energy management system is to facilitate timely response for corrective action to promote energy efficiency.

2.3.10 SOLAR POWER GENERATION OPTION:

2.3.10.1 EMS Findings

The Kenya Ports Authority has two sources of electrical power viz. the national Grid (Kenya power and Lighting Company) and diesel generators in the event of failure of grid power.

It is advisable to make use of a renewable energy source as a supplement to the other two sources. This will reduce greenhouse gas emissions and contribute to mitigation of climate change

2.3.10.2 Description of Energy Conservation Measure on Solar Power

Install a 500kw solar power system (Renewable energy source) to supplement the supply from the Grid and diesel power generators. The proposal is to replace the Asbestos roofs for the port Electrical and Mechanical Engineering workshops with solar panels that will serve as both roof covering and electricity sources. The power generated will be fed into one of the substations and made available to several facilities including mechanical workshop, electrical workshop, civil Engineering workshop, dockyard and terminal Engineering workshops subject to a maximum power demand of 500kw. In case the load exceeds the capacity of the solar plant, part of the load will be shed and then supplied from the national Grid through an automatic change-over arrangement. However, a similar solar power plant can be installed at the Civil Engineering, Dockyard and terminal Engineering workshops.

2.3.11 ENERGY SAVINGS ON COMPUTERS

2.3.11.1 EMS Findings

- The company has LCD Computer monitors.
- Some computers are left on 24 hours a day even though they are not used during the night.

2.3.11.2 Description of Energy Conservation Measure on Computers

- Conduct staff training to promote operation in energy saving mode and Switching off computers and other office equipment when not in use
- Establish a procurement policy to replace LCD Monitors with LED type or more efficient models

Table 2.4 shows the comparison between LCD monitors and LED Monitors and their associat ed characteristics

TABLE 2.4 COMPARISON BETWEEN LCD MONITORS AND LED MONITORS

Parameter	**LCD Monitor**	**LED Monitor**
Slim design Factor	Bulky, the back size is proportionate to the size of the monitor	LED backlighting allows for a slim, sleek design. LED monitors are much thinner and lighter than LCDs monitors because LED do not use fluorescent bulbs. This slimness brings along a host of advantages such as space saving and portability.
Viewable screen	The viewable area is always about 0.9 - 1.1 inch smaller than the size specified on paper. This is due to the frame around the glass screen.	A 15-inch LED always has a same size of viewable area as the specifications say. Larger displays may have their viewable area reduced by at most 0.1 inches.
Screen Flatness	Many manufacturers tout true flatness for their LCD monitors, but the sad truth is that most are fake.	100% ninety degrees true perfect flat screen
Power Requirements	Higher power usage, more than 30-50% to an LED of equivalent size.	Considerably lower power usage.
Display	Slightly less sharp images - but it	LED monitors have impressive contrast

Sharpness	is noticeable when comparing with LEDs	ratios that deliver a brighter picture and Sharp images.

2.3.12 ENERGY EFFICIENCY IN USE OF CONTAINER CRANES

2.3.12.1 EMS Findings

- The company has several container cranes which use diesel generated electricity
- The Company also has container handling cranes powered electrically at 3.3kv (STS & RMG) and mobile Harbor cranes powered at 415 volts.
- RTG& RMG cranes have standard efficiency motors i.e. Travelling motors and hoisting motors as detailed in Table 2.5

TABLE 2.5 STANDARD AND HIGH EFFICIENCY MOTORS SPECIFICATIONS

Type of motors	**Location**	**Quantity**	**Rating(kw)**	**Speed(rpm)**	**Premium efficiency**	**Standard efficiency**
Travelling Motors	ZPMC 1901 STS CRANE	20	13	1750	93.0%	84.0%
Hoisting Motors	ZPMC 1901STS CRANE	2	375	1750	96.0%	94.0%
Boom Hoist Motor	ZPMC 1901STS CRANE	1	160	1750	95.8%	93.8%
Trolley Motors	ZPMC 1901STS CRANE	4	60	1750	95.4%	89.0%
Travelling Motors	ZPMC 1902 STS CRANE	20	13	1750	93.0%	84.0%
Hoisting Motors	ZPMC 1902STS CRANE	2	375	1750	96.0%	94.0%
Trolleys Motors	ZPMC 1902 STS CRANE	4	60	1750	95.4%	89.0%
Travelling Motors	OLD ZPMC STS CRANE	20	17.5	1750	93.6%	84.0%
Hoisting Motors	OLD ZPMC STS CRANE	2	400	1750	96.0%	94.0%
Hoisting Motors	RTG OLD KALMAR STS CRANE	2	200	1486	0.917	0.82

2.3.12.2 Description of Energy Conservation Measure on Cranes

- Install premium efficiency motors to replace the existing standard efficiency motors

(Note; -Motor retrofit for cranes should be done only upon consultation with the manuf acturers)

- Install the RIS-GA system to monitor and control the running of diesel generators in RT G &MHC cranes

2.3.12.3 The Justification for the Use of RIS-GA System on RTG and MHC

With the increase in fuel prices, maximizing fuel efficiency is more important than ever. Control Techniques offers an innovative solution to reduce consumption.RIS.GA.is a compact low-cost fuel saving system that can be easily installed on new or existing RTG and MHC diesel electric cranes. It reduces the speed of the diesel generator during the crane's stand-by mode and typically reduces total fuel consumption by 20%.

Diesel generators on-board RTG crane usually run at a constant speed to supply the drive system and auxiliaries regardless of whether the crane is in operation or in stand-by mode. This means that during stand-by the system is highly inefficient as it consumes excessive fuel while producing minimal power. RIS.GA. manages the diesel generator allowing its speed to be reduced during stand-by, while still supplying power for auxiliary equipment.

2.3.13 GENERAL AREAS OF IMPROVEMENT:

- Switch off unnecessary lighting
- Introduce occupancy sensors in washrooms to control lights
- In future replace washroom sanitary ware with dual flush (6litre/9litre) toilets, infrared operated urinals and wash hand basins.

2.4 SUMMARY OF VIABLE PROJECTS AS PER ENERGY AUDIT 2015 REPORT

From the above analysis, the first-grade energy audit came up with the projects detailed in Table 2.6 as viable and implementable projects for the Port of Mombasa. The Potential savings in Tonnes of CO2, estimated investment costs, the simple payback period and potential energy savings of the projects are all tabulated in the same table.

TABLE 2.6 VIABLE AND IMPLEMENTABLE PROJECTS FOR THE PORT OF MOMBASA

No.	Opportunity	Potential Savings kwh p.a (electrical)/ kg p.a (Thermal)	Potential Savings GJ. p.a	Potential Savings metric tonnes CO2. p.a	Potential Savings Kshs p.a	Estimated Investment Cost (Kshs)	Simple Payback Period(yrs)	Simple Payback Period (Months)
1	power factor correction			0.0	653,883	800,000	1.2	14.7
2	Chiller improvement	347,982	1253	226.7	5,855,940	16,000,000	2.7	32.8
3	Use of Aircosaver in Air conditioning	176,470	635	115.0	2,969,693	1,584,000	0.5	6.4
4	Use of Curtains	7,068	25	4.6	118,943	200,000	1.7	20.2
5	Use of LED lamps	376,382	1355	245.2	6,333,868	18,449,933	2.9	35.0
6	Motor Retrofit	495,343	1783	322.7	8,335,785	21,421,162	2.6	30.8
7	Use of Occupancy sensors	301,724	1086		5,078,020	4,500,000	0.9	10.6
8	Use of solar water heaters	25,658	92	16.7	431,773	1,285,000	3.0	35.7
9	Lift controls upgrade	28,120	101		473,205	1,000,000	2.1	25.4
10	Energy management systems.		0.0	931	6,404,298	17,544,462	2.7	32.9
11	Energy savings on Computers	34,398	124		578,860	300,000	0.5	6.2
	TOTAL	1,793,145	6,455	1,862	37,234,268	83,084,556		
	Annual energy bill		**320,214,912**					
	% potential savings		**12**					
	Average payback period (years)		**2.2**					
	Grid emission factor for Kenya (kg of CO2/ mwh)				0.6515			
	1 TJ = 1000 GJ	1 kwh = 3.6MJ			3.6			

2.5 OTHER ENERGY AUDITS AND EMMISSION REDUCTION STUDIES CONDUCTED IN THE PORT OF MOMBASA AND THEIR RECOMMENDATIONS

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

This dissertation study was carried out by a World Maritime student Ms. Mariam Kidere in Partial Fulfilment of the Requirements for the Award of a Master's Degree in Maritime Energy Management in the year 2017. In her study, Kidere (2017) zoned the port depending on functional areas and analyzed these areas in terms of their energy consumption. The areas considered were 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.

The study found out that Terminal I (Operations & Engineering) has the highest installed capacity of generators at 2283KVA, and the highest fuel consumption at 448 litters / hour during outages. Through this data, it was concluded that the table could be useful in enabling the Port to focus its attention on areas with high fuel consumption- especially when considering alternative fuels or low Sulphur fuels for the generators.

2.5.1.1 Gap analysis of Mombasa Port.

The study carried out an analysis of the Ports status quo on various aspects such as the ports operations, applied technologies, governing policies and international standardizations all geared towards improved energy efficiency and improved productivity. Table 2.7 gives the summary of the Gap analysis in Mombasa Port as per the study.

The study concluded that 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.

TABLE 2.7 SUMMARY OF GAP ANALYSIS IN MOMBASA PORT

CATEGORY	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)	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	14-days' notice can be extended,

		Pre-Arrivals notice. A large number of anchorage where vessels wait up to several days for berth availability	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 turnover, 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	More energy managers experts will lead to a n energy efficiency working environment, port will

		on training on Energy Efficiency & Management at WMU)	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.

Source: Kidere (2017)

2.5.2 THE GREEN PORT POLICY

The Port engaged the services of The Cornell Group, Inc., USA in 2014 to develop a green port policy and its implementation plan. This was funded by Trade Mark East Africa as an initiative to make the port operations sustainable.

The consultant had the following as the scope of works-:

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 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.

The key output presented in their report was an actionable Green Port Policy and Implementation Plan for the Port of Mombasa that is consistent with a "triple bottom line" approach, and which focuses on the economic, environmental, and social value of an investment, including investments in improving the environment.

The following conclusions and recommendations were made from the green port policy report-:

There are immediate and urgent environmental pollution problems caused by port operations at Mombasa that can and must be immediately addressed to minimize and limit the harm caused to the health of port workers and the surrounding community; Environmental pollution at other KPA ports and facilities is not significant in comparison with Mombasa.

In comparison with major world-class ports, Mombasa Port produces high concentrations of Green House Gas, caused primarily by ships using heavier fuel and running their generators

while in port, and the Port's inability or unwillingness to restrict access by older, polluting vehicles to the port premises.

There is a noticeable degradation of the bio-diversity systems caused by port operations, which if not reversed will cause significant economic and environmental harm to the natural resources around the port.

KPA has the ability, for a period of over 10 years, to match the emissions reduction targets of world-class ports by investment in "cold ironing" systems for ships at port and restricting truck entry to non-polluting trucks. The new rail system planned for the port will also limit truck traffic and reduce emissions.

Although a signatory to all the key international environmental conventions and local laws and regulations, KPA does not have the organizational capability at this time to apply and conform to international conventions and regulations for environmental protection, nor does it have an Environmental Audit or Environmental Management System in place

The report proposed and recommended a number of practical and implementable GHG reduction strategies focusing on (a) reduction of electricity and fuel consumption primarily by vessels, trucks and port equipment, (b) implementation 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 report required the port to implement a regular Environmental Audit System and install an Environmental Management System to track, monitor and control environmental pollution. Stakeholders are fully interested in implementing a Green Port Policy at Mombasa Port, and have prioritized actions that the Port must take to "green" the port: These Greening Projects are as given in Figure 4.4.

Both Stakeholders and KPA Management are broadly in agreement about the prioritization of Green Port Policy strategies and objectives of the port:

KPA Green Port Objectives - Prioritized:

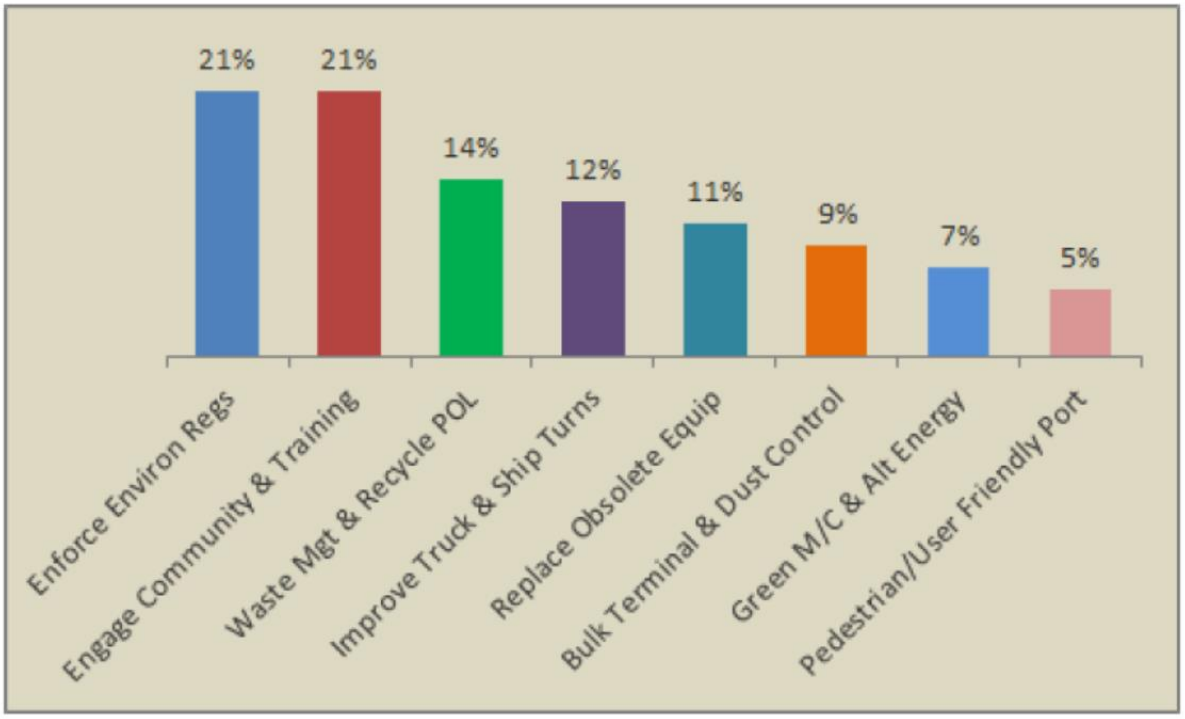
- Put People First
- Invest in New Technology
- Co-opt Stakeholders
- Phase in & share in econ sustainable changes
- Green Port Leadership
- Maintain Stewardship of planet

Energy efficiency measures

The following are energy improvement measures contained in the report. The measures focus mainly on the reduction of Greenhouse gas emission

1. Provision of shore power to ships at berth
2. Electricity from renewable energy
3. Cargo handling equipment switched to electricity
4. Switching of freight transport from road to rail

FIGURE 2.1 PRIORITISED GREENING PROJECTS IN THE PORT



Source: The Cornell Group (2014)

2.5.3 CONSULTANCY SERVICES FOR THE PROPOSED STUDY OF ENERGY NEEDS, ALTERNATIVE ENERGY SOURCES AND PROVISION OF SHORE POWER (COLD IRONING) FOR THE PORT OF MOMBASA

As part of implementation of the Green Port Policy, KPA with a grant from Trade Mark East Africa (TMEA) appointed Royal HaskoningDHV (RHDHV), in association with Howard Humphreys to do a feasibility study on energy needs, alternative energy sources and provision of shore power (cold ironing) for the port of Mombasa.

This feasibility study report made an in-depth analysis of current energy situation and investigated the environmental and social impact of prevailing energy situation as part of Phase I deliverables.

The study was executed by RHDHV and Howard Humphreys in the period from July 2016 to February 2017.

The study was divided into two main phases namely phase I and phase II.

Phase I comprises the following scope:

a) Conduct detailed assessment of the port's energy needs taking into account existing and planned port development programmes in line with the port master plan.

b) Analyse alternative energy sources for the port including a detailed feasibility study on the alternative sources with emphasis on renewable energy for the port.

c) Conduct a detailed analysis for the provision of shore power (cold ironing) taking into consideration the different vessel categories calling at the port of Mombasa.

Phase II which essentially encompasses the design and implementation planning comprises the following scope:

a) Prepare the scope of works and detailed technical specifications of the recommended system/s to improve the existing power supply quality; come up with detailed designs and bills of quantities and prepare tender documents.

b) Prepare the scope of works and detailed technical specifications of the recommended alternative energy sources for the port; come up with detailed designs and bills of quantities and prepare tender document/s for the recommended alternative energy sources.

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.

2.5.3 1 RHDHV Study Findings

The results of the study show that:

- The internal electrical power distribution system is generally in good condition and has sufficient capacity also for the expected growth in the near future; The Power quality is however poor, which is caused by external circumstances;
- If improvement of power quality by the public grid operator is not possible POM can take their own measures. Three options were available, and a choice needs to be made

in close coordination with POM as each measure has its specific benefits and drawbacks;

- Solar power generation potential within the POM is high, even more than the actual consumption of electricity. Large scale solar power application requires additional measures such as feedback into the grid at acceptable commercial conditions, large scale energy storage and/or automatic balancing of power generation and consumption. Other methods of renewable power generation are not feasible within the POM.
- Reduction of diesel fuel consumption can best be achieved by electrification of RTG's. Other methods need further investigation before a conclusion on feasibility can be drawn;
- Cold ironing is currently not economically feasible due to the high cost price of power from the public grid, the high initial investment and the limited number of shore power ready ships. In combination with large scale solar, shore power can become more feasible. Cold ironing should therefore not be considered as highest priority. In future, with solar power available and more ships prepared to connect, it will become an effective measure to improve the environmental performance of POM.

2.5.4 MONETARY AND ECOLOGICAL COST-BENEFIT ANALYSIS OF ONSHORE POWER SUPPLY; A CASE STUDY OF THE PORT OF MOMBASA

This dissertation study was carried out in 2013 by Mr. D. Mulwa as part of his study work for the attainment of a Master's Degree in Shipping and Port and management. The report is a quantitative analysis of the Consumption levels of all the vessels that visited the Port of Mombasa in the year 2012. The research draws up the vessels' profiles of power and other properties, comes up with a relationship between these properties and hotelling power demand and then empirically calculates the overall fuel quantity consumed by these vessels while in port, total cost of these bunkers and the externality costs.

Additionally, an OPS system capable of supplying the total vessel visits with OPS was designed and quotations for its costs obtained. A likely power bill had the vessels used OPS, is calculated using the then current prevailing power rates in Kenya. A project appraisal was then undertaken taking into consideration all the above costs and recommendations based on the outcome of the appraisal are made to Kenya Ports Authority.

Based on the above, the following recommendations were made to Kenya Ports Authority-:

Having analysed the vessel power characteristics and cost of implementing an OPS and after carrying out an appraisal of the project, which was found to be a viable undertaking, the report recommended to KPA that the authority should consider offering this important service to the visiting vessels.

The OPS project need not be implemented in one go due to the financial implications involved. Phasing-out the project in four parts may make the implementation process less taxing to the port authority in fiscal terms. In its recommendation, the Port Electrical Department, through the Head of Port Electrical Engineering, should advocate and push for increase in their budgetary provisions so as to accommodate a phased-in implementation of OPS. There are currently trenches running along the berths where PVG rails for the power supply to the conventional slewing gantry cranes used to be. These are found in the Bulk Carrier berths, near the SOT and the berths near the KPA Headquarters from Berth 11 to Berth 14. These trenches can be easily converted to house OPS cables by installing PVC ducts and covering them permanently with concrete to achieve a secure working environment. By doing so, a large proportion of the OPS trenching costs could be saved.

A very large amount of power, roughly 7GWh, was consumed by visiting tugs, KPA tugs and other small vessels, especially patrol crafts. Most of these vessels take long times at the berth side and can be good users of OPS. More than 90% of the average loads of these vessels' AE rating are less than 500kW and with an applicable loading factor of 22%, it is very easy to connect these vessels to OPS, even on LV systems, with relatively small sizes of cables from a distribution board located near the shore. These vessels should serve as the starting point in the OPS implementation.

2.6 ANALYSIS OF THE RECOMMENDATIONS OF THE VARIOUS ENERGY AUDIT REPORTS/STUDIES CARRIED OUT ON THE PORT OF MOMBASA

Several recommendations and conclusions cut across all or most of the studies that have been carried out at the port of Mombasa. Key among them are as given in Table 2.8 below: -

TABLE 2.8 MATRIX OF PROPOSED EMISSION REDUCTION MEASURES AND IMPLEMENTATION STATUS

INITIATIVE	GREEN PORT POLICY	ENERGY AUDIT REPORT	RHDNV REPORT	MS. KIDERE REPORT	MR. D MULWA REPORT	IMPLEMENTATION SITUATION	COMMENTS
Implement Shore power for the Port of Mombasa	Recommended	Recommended	Recommended with a rider on prior Installation of Solar Power	Recommended	Recommended based on Consideration of Ecological Costs	Pilot project on shore power under execution. Tender evaluation	Capital intensive and sensitive project.

						scheduled for end of July 2019	**Main project awaiting funding**
Renewable Energy Technology – Solar PV	**Recommended**	**500kw solar power system Proposed**	**Recommended 5MWpk Solar Power**	**Recommended**	**Recommended**	**Two pilot solar power plants already installed on roof tops with capacities of 400kWpk and 350KWpk**	**The proposed main plant of 5MWpk awaiting funding from Trademark East Africa**
Electrification of cargo handling equipment	**Recommended**		**ERTG Proposed**	**Recommended**		**Plans in place to electrify the Habour Mobile Cranes through provision of shore power**	**Projects like retrofiting of eRTG are capital intensive and requires major changes on the operation yard that would mean stoppage of operations hence difficult to implement**
Install LED lamps as a replacement of all the existing less efficient lamps	**Recommended**	**Recommended**		**Recommended**	**Recommended**	**Phased replacement of conventional lighting system ongoing starting with offices and monopoles**	**Full implementation is capital intensive hence the phased approach**
Sensitization on importance of Energy Efficiency & Management Measures	**Recommended**	**Recommended**	**Recommended**	**Recommended**	**Recommended**	**Ongoing**	**Attitude change and working patterns affecting fast implementation**
Training on energy Efficiency and Management Technologies	**Recommended**	**Recommended**		**Recommended**		**Ongoing at different capacities of the workforce**	**Training budget among the key hurdles**
Energy Efficiency in Use Of Container Cranes		**RIS.GA. proposed**	**Recommended**			**Implementation yet to start**	**Issues of manafucturer's warranty and liability at play**
Old trucks removed from the road	**Recommended**	**Recommended**	**Recommended**	**Recommended**		**Previous attempts proved not successful due to external interference and replacement cost**	**Good will from all stakeholders required**

						considerations	
Use of Premium Efficiency Motors	**Recommended**	**Recommended**				**Effected during old motors replacement**	**Procuring policy favoring high efficiency motors/equipment not yet in place**
ISO 14001:2015-Environmental Management System (EMS)	**Recommended**			**Recommended**		**Kenya Bureau of Standards to has started to develop EMS ISO14001 and ISO 45001**	**Capacity barriers and need for awareness/ training**
Ships within port area burning low Sulphur fuel	**Recommended**		**Recommended**	**recommended**	**Recommended**	**Standards of fuel for ships being adopted**	**Currently 3.5%S being used**
GHG offset from tree planting	**Recommended**		**Recommended**	**Recommended**		**17,000 Trees planted in Mombasa and neighboring Counties.**	**More budget being sought for increased forest cover acreage**
Star Rating Policy		**Recommended**		**Recommended**		**Not yet implemented**	**Awaiting favorable procurement policy**
Power Factor Correction	**Recommended**					**Fully Implemented**	**Factored in procurement plans**
Energy Management System	**Recommended**	**AMPLEX SMARTHARBOUR" Proposed**		**Recommended**		**Not Yet Implemented**	**Not yet factored in the procurement plans**

Source: Author

2.7 CONCLUSION ON ANALYSIS OF PREVIOUS AUDITS CARRIED OUT AT THE POM

Based on the review of the different reports and from the implementation matrix it is quite clear that the port of Mombasa has implemented a number of the recommendations focusing on energy efficiency and control of emissions. This is part of the efforts of the port to implement the framework green Port Policy. However, a lot needs to be done to achieve the desired objectives and to integrate sustainability into port operations and development.

Three projects have been implemented based on the recommendations that is; installation of 400kWpk Grid Tie solar Power plant, LED lights, power-factor correction and tree planting which contributes to a national drive by the government to attain a 10% forest cover by 2022. Other phases of some of the projects are ongoing. The projects that in the process of implementations include installation of 350kWpk Grid Tie solar Power plant, development of ISO 14001 and ISO 45001 and installation of a 2000kVA, 60hz,6.6kV shore power at Berth No.1.

There are however other flagship projects that the port should have started due to the importance attached to their outcomes. Key among these are the installation of the Energy Management system (EMS). This project will be a milestone in analyzing the energy flow to the different functional areas of the port with the aim of energy saving by controlling and containing any power wastages that may be found from analysis of the PMS outcomes.

The Port should also be keen on implementing the Star Rating Procurement Policy to ensure that only high energy saving equipment are procured by the authority. Other projects that need urgent attention include implementation of policies to ensure that Ships within port area burn only low Sulphur fuels, Use of Premium Efficiency Motors Old, development of policies to ensure that old and polluting trucks are removed from Port precincts, Sensitization on importance of Energy Efficiency & Management Measures and Electrification of cargo handling equipment.

3.0 IMPACTS OF THE PROPOSED ENERGY SAVING/EMISSION REDUCTION STRATEGIES AT THE PORT OF MOMBASA.

3.1 BACKGOUND OF STUDY

Further to the report on analysis of all energy audit reports done for the Port of Mombasa; this report delves to study the impacts of the proposed energy saving/emission reduction strategies at the Port. In detail, the report would aim at determining which of the proposed energy saving measures have been implemented at the Port of Mombasa, Estimating the impacts of the implemented strategies on the energy consumption and emissions at the Port of Mombasa; Identifying the energy saving measures that are yet to be implemented at the Port of Mombasa and eventually Identifying the challenges/barriers that have been encountered

the in implementation of the proposed energy saving measures and then proposing measures that can be put in place to ensure that more energy savings are realized.

These energy saving measures and their impacts will be drawn from the five reports earlier analyzed namely the first investment grade energy audit of 2015 by EMS Consultants Ltd; Analytical Assessment of Port Energy Efficiency and Management: A Case Study of the Kenya Ports Authority of 2017 by Ms. Kidere; The Green Port Policy done by the Cornell Group, Inc., USA of 2014; The Consultancy Services For The Proposed Study Of Energy Needs, Alternative Energy Sources And Provision Of Shore Power (Cold Ironing) For The Port Of Mombasa by the Royal HaskoningDHV (RHDHV) in association with Howard Humphreys and finally the study on Monetary and Ecological Cost-Benefit Analysis of Onshore Power Supply; A Case Study Of The Port Of Mombasa by of 2013 Mr. Denis Mulwa.

These impacts have been given on monetary terms with the presumed assumptions for each case well highlighted besides the impacts. These results were arrived at after measurement of energy parameters using various audit instruments, identification of energy efficiency opportunities, a financial analysis of the energy conservation (efficiency) measures covering life cycle cost and internal rate of return (IRR) and taking into account energy savings and maintenance costs during the entire project life.

3.2 IMPACTS OF THE PROPOSED ENERGY SAVING MEASURES

3.2.1 POWER FACTOR CORRECTION

Following the energy audit conducted by EMS consultants in the month of November 2014, Power factor correction was implemented in the following substations as detailed below;

Substation	Initial Power factor	Current Power factor
Q	0.62	0.96
T	0.76	0.94

The period considered for the base line information is from January to September, 2014; period after which the audit was conducted.

Facility operating hours per annum: 8736(All year round)

The base year energy use was 2014; the energy consumption is measured in terms of kWh and average consumption during the base year was 1,582,148 kWh /Month. This translates averagely to approximately 2MW of consumption every hour.

The Projected energy savings due to power factor correction amount to Kshs. 653,883 per annum. The estimated cost of investment is Kshs. 570,000with a simple payback period of 0.9 year.

3.2.2 CHILLER IMPROVEMENTS:

Upon auditing of the chillers, the main indicator showing a chiller effectiveness is the coefficient of performance (COP) of the chiller which is the ratio of cooling effect (kw) divided by the electrical power input (kw).

Two of the current chillers are old and to improve COP, replacement with new chillers with smaller energy ratings and same outputs and which use environmentally friendly refrigerants was the preferred option.

One of the old audited chillers is described in Table 3.1 and had the performance characteristics in Table 3.2

TABLE 3.1 KPA ADMINISTRATION BLOCK 2 CHILLER DETAILS

1	**KPA Administration block 2 Chiller (chiller no 1-old model.)**	
	Chiller specification:	
	Make:	
	CARRIER	
	MODEL	30GTN050-K920
	Refrigerant (Not environmentally friendly)	R22
	Design pressure(psi)	450
	Test pressure (psi)	278.0
	power supply:	
	380/415 v, 3 ph, 50HZ	415
	RLA	65
	LRA	345
	Condenser entering air temperature °C	33.9
	Leaving cooling water temperature (LCWT) °C	8.0
	Speed(rpm)	1450

The chiller performance was assessed and the results are shown in Table 2.10

TABLE 3.2 ADMINISTRATION BLOCK 2 CHILLER PERFORMANCE CHARACTERISTICS

The performance chart indicates the following:				
cooling kw	187.3			
input power (kw)	60.8			
cooling water flow rate (l/s)	8.1			
Corresponding COP	3.08			
Leaving cooling water temperature (LCWT) °C	8			
Using the Carnot formula				
Useful work (kw)		54.84	cooling effect	
% loading (step 1)		29		
power input to compressor (kw)		33.50	measured by logger	
Coefficient of performance		COP		1.64
evaporator temperature (measured)		T1	8	281
condenser temperature (measured)		T2	111	384
Based on the performance chart above, the chiller was on step 1 during the audit.				
Assuming that the chiller runs 42% loaded on average i.e at step 2, then the energy consumption scenario will be as detailed below:				
Useful work (kw)		78.67	cooling effect	
% loading (step 2)		42		
power input to compressor (kw)		48.06		
Coefficient of performance		COP		1.64
evaporator temperature		T1	8	281
condenser temperature		T2	111	384

From the foregoing, a new chiller of equivalent cooling capacity would have a far much less power consumption requirements resulting in very large energy savings. A new chiller would have the properties detailed in Table 3.3 and the resultant payback period for such a new investment would be 2.6 years.

It therefore follows that considering the operation & maintenance cost savings and taking the period from January to September 2014 as the base year and Chiller Operating hours per annum being 4680hours, the average energy consumed during the base year was 1,582,148 kWh /Month. With the new chillers, the projected energy savings due to chiller improvements amount to 173,991 kWh equivalent to Kshs 2,927,970 p.a. The estimated investment cost is Kshs.8,000,000 with a simple payback period of 2.6 years

TABLE 3.3 RECOMMENDATIONS ON CHILLER IMPROVEMENT

RECOMMENDATION				
Replace chiller with a new one as "CARRIER Model 30RB0262-B0785-PE" whose details are given in the table below:				
Cooling capacity (kw)	280			
Power input (kw)	84			
Leaving chilled water temperature °c	8			
Cooling water flow rate (l/s)	**13**			
Coefficient of performance	**3.3**			
Refrigerant (environmentally friendly)	R410A			
Useful work (kw)		78.67	cooling effect	
power input to compressor (kw)		23.60		
Coefficient of performance				3.33
evaporator temperature		T1	8	281
Projected condenser temperature		T2	111	384
Energy savings (kwh p.a)		**91,572**		
Energy savings (GJ p.a)		**330**		
Energy savings (kshsp.a)		**1,541,000**		
Estimated cost of investment (kshs)- For new chiller		**4,000,000**		
Simple payback period (years)		**2.6**		

3.2.3 SAVINGS ON USE OF AIRCOSAVERS ON AIR CONDITIONERS

The audit confirmed that the air conditioning units installed in various places within the organization are not fitted with Aircosavers (energy saving devices). Installation of Aircosavers on the air conditioning units was proposed as the best energy saving solution.

Table 3.4 shows a sample of the ACs in offices and the cost of installing Aircosavers on them.

TABLE 3.4: AC INVENTORY IN OFFICES

No	**Location**	Ac Equipment Specification	Suitable for Aircosaver	Cooling Capacity Each Indoor Unit (Btu/H)	Cooling Capacity Each Indoor Unit (Kw)	Power Input (Kw)	Cop	QNTY	Energy Consumption (Kwh P.A)
1	CEME Block	AIRKOOL	**yes**	**18,000**	**5.3**	2.6	2.0	4	22,776
		TADIRAN SPLIT	**yes**	24,000	**7.0**	3.1	2.3	3	20,367
		UNIONAIRE	**yes**	24,000	**7.0**	3.1	2.3	1	6,789
3	One Stop Centre	AIRKOOL	**yes**	48,000	**14.1**	6.2	2.3	5	67,890
		AIRKOOL	**yes**	24,000	**7.0**	3.1	2.3	3	20,367
4	Kipevu	AIRKOOL	**yes**	18,000	**5.3**	2.7	2.0	9	

	Dispensary								53,217
		AIRKOOL	**yes**	24,000	**7.0**	3.1	2.3	2	13,578
5	Gate18 and 20	AIRKOOL	**yes**	18,000	**5.3**	2.7	2.0	3	17,739
		AIRKOOL	**yes**	24,000	**7.0**	3.1	2.3	5	33,945
7	Kipevu Headquarters	AIRKOOL	**yes**	24,000	**7.0**	3.1	2.3	37	251,193
		WESTPOINT	**yes**	60,000	**17.6**	8.2	2.1	4	71,832
		LG WINDOW	**yes**	48,000	**14.1**	6.2	2.3	7	95,046
8	Kapenguria Electrical	AIRKOOL	**yes**	18,000	**5.3**	2.6	2.0	3	17,082
		UNIONAIRE	**yes**	24,000	**7.0**	3.1	2.3	1	6,789
9	Kpa Substation	AIRKOOL	**yes**	36,000	**10.5**	5.4	2.0	30	354,780
		LG WINDOW	**yes**	24,000	**7.0**	3.1	2.3	12	81,468
		WESTPOINT	**yes**	60,000	**17.6**	8.2	2.1	2	35,916
		AIRKOOL		18,000	**5.3**	2.6	2.0	1	5,694
TOTAL- For ACs To Be Fitted with AIRCO SAVER						72.2		132	1,176,468

Considering the audit period from January to September 2014 as the base line period and assuming that the operating hours per annum for ACs as 8736hrs, then, the average energy consumption measured in terms of kWh during the base year was 1,582,148 kWh /Month

Upon installation of Aircosavers savings to the tune of 176,470 kWh per annum which is equivalent to Kshs. 2,969,693 per annum can be realized. With the estimated cost of investment being Kshs.1,584,000, the simple payback period is calculated as 0.5 year for this project as shown in Table 3.5.

TABLE 3.5: SAVINGS ON ACS ON AIRCOSAVERS INSTALLATION

Current annual energy consumption (kwh. p.a)- by air conditioners to be fitted with AIRCO SAVER			**1,176,468**
Potential Energy savings (kwh p.a)	**15%**		**176,470**
Potential Energy savings (kshs p.a)			**2,969,693**
Estimated cost of investment (kshs) - on AIRCOSERVER @ KSH 12,000 each AC for the units	**12,000**	**132**	**1,584,000**

Simple payback period (years)	**0.5**

3.2.3 IMPACTS ON LIGHTING IMPROVEMENTS

The audit came up with several energy conservation measures on lighting improvement as option worth considering. These included the following-:

3.2.3.1 Installation/Retrofit of existing lights with LED lamps

Table 3.6 shows an inventory of the existing lighting systems and probable equivalent LED Lights. **The potential savings due to installation of LED lamps amount to 376,382kwh (1,355GJ) equivalent to ksh. 6,333,868 per annum**. The investment cost for this option will be kshs. 18,449,933 with a payback period of 2.9 Years.

3.2.3.2 Option II: Replace Electromagnetic Ballasts With Electronic Type and The Basic T8 Fluorescent Tubes With Standard OSRAM T5 Tubes

From analysis on this option, the audit estimated that The potential savings due to installation of electronic chokes and T5 tubes in lieu of T8 tubes and electromagnetic chokes amounts to 51171kwh (184.2 GJ) equivalent to ksh. 821,932 per annum. The investment cost for this option will be kshs.3, 545740 with a payback period of 4.3 Years.

TABLE 3.6 EXISTING LIGHTS AND PROBABLE RETROFIT

Existing Lamps	Proposed Led Lamps-AICA Model/ Philips Lumilec/ CREE From USA	Existing Lamp Rating (W)	Consumption With Choke (W)	LED Rating (w)	Quantity
4ft long T8 twin fluorescent (36W) lamp	18 DP1013C 98 2936 287728 -LED Tube-AICA	36	46	18	1562
5ft long T8 twin fluorescent (58W) lamp	DP1013D -AICA	58	67	20	185
8ft long T8 twin fluorescent (125W) lamp	DP1013D -AICA	30	135	20	30
2ft long twin fluorescent (18W)	DP1013A-AICA	18	28	9	132

lamp					
High pressure mercury vapour lamps(250w)	DP-150GKAL52040-AICA	250	250	40	28
Incadescent lamps(75w)	DP-BE27F5W-AICA	75	75	5	14
High pressure sodium vapour lamp(400w)	DP-720LD100W-AICA	400	400	100	2
High pressure sodium vapour lamp(1000w)	PHILIPS LUMILEDS-300w,U shaped bracket model HTI-CS-TFL10M18(with 10 modules design)	1000	1000	300	72
High pressure sodium vapour lamp(2000w)	PHILIPS LUMILEDS-300w,U shaped bracket model HTI-CS-TFL10M18(with 10 modules design) OR XP-TD300w floodlight as "CREE" from USA	2000	2000	300	12
High pressure sodium vapour lamp(600w)	DP03-570FG140	600	600	140	12
Halogen Downlighter 50w	AC85-265V	50	55	11	42
Halogen floodlights	DP01-FL70MEA	400	400	70	4
Mercury vapour lamp(400W)	DP01-FL70MEA	400	400	70	47

3.2.3.2 Option III: Use of skylights to facilitate use of natural lights during the day:

Audit analysis established that with installation of skylights to facilitate the switching off of lamps during bright days, potential savings amount of up to 53769kWh equivalent to Kshs.904,839per annum was feasible. The estimated cost of investment is Kshs. 900,000 leading to a payback period of 1.0 years

3.2.4 POTENTIAL IMPACTS ON USE OF OCCUPANCY SENSORS

The audit established that there are no electrical/ electronic interlocks between doors and the air conditioning equipment and lights in the hostel rooms and conference rooms resulting in situations where facilities remain on when rooms are not occupied and air conditioning equipment sometime runs with windows open leading to energy losses.

The audit then proposed energy saving measures including Installation of magnetic switches on doors and windows in both hostel rooms and conference rooms, Installation of occupancy

sensors (dual type)in training and conference rooms and fitting foam inserts in the gaps between window type AC units and the walling and sealing using timber to minimize infiltration.

Table 3.7 shows the areas to be fitted with occupancy sensors and air conditioner interlocks. From this analysis, it was established that with installation of interlocks and occupancy sensors, Savings amounting to 301,724kWh(1086GJ)per annum equivalent to Kshs 5,078,020 p.a were feasible. The estimated investment cost is Kshs.4,500,000 with simple payback period of 0.9years

TABLE 3.7: AREAS WITH INTERLOCKS AND OCCUPANCY SENSOR ENERGY SAVINGS POTENTIAL

Section	**Air conditioner capacity (Btu/hr)**	**AC capacity (kw)**	**Qnt of rooms**	**Energy Consump-tionp.a(kWh)**	**Type of lamp**	**Rating (W)**	**Consump-tion with choke (w)incase of fluoresent lamps**	**Quantity of lamps**	**Energy Consump-tionp.a(kWh)**
A) BANDARI COLLEGE									
Hostel Rooms & Bathrooms	12,000	3.5	69	371,184	Compact Flourescent	20	20	138	24,178
Common Wash Room hostels				-	T8 single fluorescent	36	46	6	2,418
				-	T8 Flourescent tubes(twin)	36	46	4	1,612
Theatre	120,000	35.2	1	53,795	Compact Flourescent(flower type)	60	60	8	4,205
				-	Compact Flourescent(Downlighters)	20	20	12	2,102
Theatre Washrooms				-	T8 Flourescent tubes(twin)	36	46	10	4,030
B) PORT ELECTRICAL DEPARTMENT									
Conference room (18,000btu/hx 4No.)	18,000	5.3	4	32,277					
Senior Electrical Engineers'	60,000	17.6	1	26,897					

office									
C) ONE STOP CENTER									
Conference room	48,000	14.1	1	21,518					
D) MARINE ENGINEERING DEPARTMENT									
Conference room	48,000	14.1	1	21,518					
E) KPA HEADQUARTERS-BLOCK 2									
Conference room	48,000	14.1	1	21,518					
			Total	527,189					38,544

Potential Savings

Actual Energy Consumption p.a(kWh) when ac & lights are left on without occupants	**301,724**
Actual Energy Consumption p.a(GJ) when ac & lights are left on without occupants	**1,086**
savings kshp.a	**5,078,020**
estimated Investment on occupany sensors, door and window interlocks plus cabling per room	**45,000**
estimated Investment on occupany sensors, door and window interlocks plus cabling for all rooms	**4,500,000**
Simple Payback period (years)	**0.9**

3.2.5 USE OF SOLAR WATER HEATERS FOR BANDARI COLLEGE HOSTEL & KITCHEN IMPACTS

Bandari college hostel showers are equipped with 69 No. of instant hot water heaters each with a rating of 2Kw. Opportunities for energy savings include installation of solar water heaters for both showers and replacement of the LPG Gas used in the kitchen.

Table 3.8 shows the potential saving for using solar water heaters rather than LPG gas in the kitchen while Table 3.9 shows the potential savings on replacement of the instant water heaters with solar water heating. The potential Savings due to installation of solar water heaters amount to 25,658 kWh p.a (92GJ) equivalent to Kshs.431,773 p.a. The estimated investment cost is ksh. 1,285,000with a payback period of 3 years

TABLE 3.8 POTENTIAL SAVING ON REPLACING LPG WITH SOLAR HEATING

OPPORTUNITIES FOR ENERGY SAVING IN SOLAR WATER HEATERS AT BANDARI COLLEGE MAIN KITCHEN

		Unit of Conversion		
Operating hours p.a	**8760**	**kwh**		**Mj**
Operating days p.a	**365**		**1**	**3.6**
Tariff CI2				
Electricity charges ksh/ kwh	**520**			
Consolidated charge (ksh/kwh)	**16.83**			
KVA Demand charge per unit kshs	**4500**			
Calorific value of LPG (MJ/kg)	**46.1**			
Specific heat capacity of water (kj/kg-°C)	**4.19**			
cost of solar panel (2m²) and storage tank	**200,000**			

EXISTING SITUATION;					
Bandari kitchen is currently using LPG for water heating.					
Average LPG consumption per day(kg)	**2.5**				
Energy consumption (kwh p.a)	**11685.1**				
RECOMMENDATION					
Install solar water heaters as detailed below:					
Solar water heaters as "DAYLIFF Model SWD 29/320- Superline XXL"					
Panel area -2m²					
maximum heat output per day (kwh)	**16**				
minimum heat output per day (kwh)	**11.0**	Savings are realizable if orientation of panels is optimized.			
Average heat output per day (kwh)	**13.5**				
Recommended No of solar panels to be mounted on the roof.	**2.4**	**2**			
Potential savings (kwh p.a)	**11,685**		Energy mgt regulations 2012 require 60% contribution.		
Potential savings (GJ p.a)	**42**				
Estimated cost of investment (ksh)- equipment & Materials	**400,000**				
Labour -15% of cost of equipment	**60,000**	0.15			
Total Estimated cost of investment (ksh)	**460,000**				
Potential energy savings (ksh. p.a)	**196,640**				
Simple payback period (years)	**2.3**				

TABLE 3.9 OPPORTUNITIES FOR ENERGY SAVINGS IN SOLAR WATER HEATERS INSTALLATION-BANDARI COLLEGE HOSTELS

		Unit of Conversion			
Operating hours p.a	**8760**		**kwh**		**Mj**
Operating days p.a	**225**		**1**		**3.6**
Tariff CI2					
Electricity charges ksh/ kwh	**4.73**				
Consolidated charge (ksh/kwh)	**16.83**				
KVA Demand charge per unit kshs	**400**				
Calorific value of LPG (MJ/kg)	**46.1**				
Specific heat capacity of water (kj/kg-°C)	**4.19**				
cost of solar panel (2m²) and storage tank	**130,000**				
EXISTING SITUATION;					
Bandari hostel showers are equipped with 69 No. of instant water heaters each with a rating of 2kw					
Number of instant water heaters -Electric	**69**				
Capacity of instant water heaters (kw)	**2**				
Total maximum kw demand	**138**				
Duration of usage (hours per day)	**0.50**				
Average occupancy level (%)	**0.90**				
Energy consumption(kwh p.a)	**13972.5**				
RECOMMENDATION					
Install solar water heaters as detailed below:					
Solar water heaters as "DAYLIFF Model SWD 29/320- Superline XXL"					
Panel area -2m²					
maximum heat output per day (kwh)	**16**				
minimum heat output per day (kwh)	**11.0**	Savings are realizable if orientation of panels is optimized.			
Average heat output per day (kwh)	**13.5**				
Recommended No of solar panels to be mounted on the roof.	**4.6**	**5**			
Potential savings (kwh p.a)	**13,973**				
Potential savings (GJ p.a)	**50**				
Estimated cost of investment (ksh)- solar panels, common tank, circulating pump & pipework	**750,000**				
Labour -10% of cost of equipment	**5,000**	0.1			
Total Estimated cost of investment (ksh)	**825,000**				
Potential energy savings (ksh. p.a)	**235,133**				
Simple payback period (years)	**3.5**				

3.2.6 LIFT CONTROLS UPGRADE

By replacing the two Lifts in blocks 2 at the KPA headquarters with machine room-less type which are energy efficient, Savings amounting up to 28120kWh equivalent to Kshs.473,205 p.a can be realized. The estimated investment cost is Kshs.18,000,000 with a simple payback period of 38years. This option has a very long payback period. A better option proposed was upgrade of Lift controls to VSDs which has savings amounting up to 28120 kWh equivalent to Kshs.473,205p.a. The estimated investment cost is Kshs.1, 000,000with a simple payback period of 2.1 years.

3.2.7 USE OF PREMIUM EFFICIENCY MOTORS

With the establishment of a procurement policy to replace standard efficiency with premium efficiency motors and replacement of standard efficiency motors with premium efficiency type, and taking base line information as from January to September, 2014 (period of audit) with the Facility Operating 8736 hours per annum, The average energy consumption in terms of kWh is 1,582,148kWh /Month. Installation of premium efficiency motors would result to a saving of 495,343 kWh (1783GJ) per annum equivalent to Kshs 8,335,785 p.a. The estimated investment cost is Kshs. 21,421,162 with simple payback period of 2.6 years.

This saving is as a result of the different efficiencies as shown in Table 3.10

TABLE 3.10: DIFFERENT MOTOR CAPACITIES AND THEIR EFFICIENCIES

Type of motors	Location	Quantity	Rating (kw)	Speed(rpm)	Premium efficiency	Standard efficiency
1. Travelling Motors	ZPMC 1901 STS CRANE	20	13	1750	93.0%	84.0%
Hoisting Motors	ZPMC 1901STS CRANE	2	375	1750	96.0%	94.0%
Boom Hoist Motor	ZPMC 1901STS CRANE	1	160	1750	95.8%	93.8%
Trolley Motors	ZPMC 1901STS CRANE	4	60	1750	95.4%	89.0%
Travelling Motors	ZPMC 1902 STS CRANE	20	13	1750	93.0%	84.0%
Hoisting Motors	ZPMC 1902STS CRANE	2	375	1750	96.0%	94.0%
Trolleys Motors	ZPMC 1902 STS CRANE	4	60	1750	95.4%	89.0%
Travelling Motors	OLD ZPMC STS CRANE	20	17.5	1750	93.6%	84.0%
Hoisting Motors	OLD ZPMC STS CRANE	2	400	1750	96.0%	94.0%
Hoisting	RTG OLD	2	200	1486	0.917	0.82

Motors	KALMAR STS CRANE					

3.2.8 ENERGY SAVING FROM THE ENERGY MANAGEMENT SYSTEM

The main cost for this system is the Installation smart meters and energy management software to monitor energy consumption by the following units on real time basis: substations, workshops, office blocks, Bandari College, chillers, server rooms, electrically driven cranes and the 'reefer' containers power supply system. The recommended system is "AMPLEX SMARTHARBOUR"

The Projected energy savings with this system is estimated to amount to Kshs 6,404,298 p.a. The estimated investment is Kshs.17, 544, 462 with a simple payback period of 2.7 years. Table 3.11 shows the costing and computation of these savings.

TABLE 3.11 COMPUTED ENERGY SAVINGS WITH AMPLEX SMARTHABOUR

Port Operating hours p.a	**8760**		**Euro**	**Ksh**	
No of days per annum	**365**		**1**	**108**	
No of days per week	**52**				
No of days per week	**7**				
Tariff CI2					
Electricity charges ksh/ kwh	**8.25**				
KVA Demand charge per unit kshs	**520**				
Consolidated electricity charge kshs.	16.83				
The following are the components of the proposed Energy Management system:					
ITEM DESCRIPTION	**QUANTITY**	**Factor**	UNIT COST (EUROS)	AMOUNT (EUROS)	AMOUNT (KSHS)
Hardware,software & hosting	**Lot**			100,030	10,803,240
Shipping, installation, configuration & training (40%)		**0.4**		40,012	4,321,296
SUBTOTAL				**140,042**	15,124,536
16% VAT		**0.16**		**22,407**	2,419,926
TOTAL				**162,449**	**17,544,462**
Annual energy bill (ksh)	**320,214,912**				

Total savings (ksh p.a)-2% of annual bill	**6,404,298**	**0.02**	**(As a result of timely interventions for corrective action)**		
Investment cost (kshs)	**17,544,462**				
Simple payback period (years)	**2.7**				
Annual hosting cost (Euros)	**5,757**				
Annual hosting cost (ksh)	**621,756**		Maintenance		

3.2.9 SOLAR POWER GENERATION OPTION:

The energy conservation measure proposed Level 1 audit was installation of a 500kw solar power system (Renewable energy source) to supplement the supply from the Grid and diesel power generators.

The Cost benefit analysis showing computed savings on installation of such a solar power plant is as in Table 3.12.

TABLE 3.12 COST BENEFIT ANALYSIS OF A 500KW SOLAR POWER PLANT

Operating hours p.a	4380	**USD**	**Ksh.**
No. of operating hours per day	12	**1**	**92**
Operating days per week	7		
No. of weeks p.a	52	**Euro**	**ksh**
Operating days p.a	365	**1**	**108**
Tariff- CI2			
Consolidated Electricity charges (Kshs/kWh)	16.83		
Tariff charge (Kshs/kWh)	8.25		
Demand charge (Kshs/KVA)	520		

Average maximum KVA demand during baseline period			3264
Capacity of proposed solar power plant (kw)			500
Estimated investment cost on plant (Euro)			620,987
Estimated investment cost on plant (ksh)			**67,066,596**
Savings from avoided expenditure on resincoat sheets(kshs)			**1,792,896**
Estimated Net investment cost on plant (ksh)			**65,273,700**
Projected annual energy pv output (mwh)			775
Projected annual energy feed to Grid (mwh)			723
Feed in tariff for solar Grid (US cents/kwh)			12
Feed in tariff for solar Grid (ksh/kwh)			11.04

Potential savings -Amount Paid To Kplc For Equivalent Energy (kshp.a)				**12,168,090**
Simple payback period (Years)				**5**

The Consultancy Services for the Proposed Study of Energy Needs, Alternative Energy Sources And Provision Of Shore Power (Cold Ironing) For The Port Of Mombasa also did their own detailed analysis on Solar Power Plant installation. According to this report, the solar power generation potential in Kenya is quite high with the yearly solar irradiation for Kenya being approximately 2200kWh per m2 per year.

In their report, installing solar panels on all available locations will require an investment in the order of magnitude of 45M USD. Taking into account a yearly percentage of 7% for interest, maintenance and depreciation the cost price per MWh will be approx. USD60 per MWh, which is less than 50% of the current price for grid power.

3.2.10 ENERGY SAVINGS ON COMPUTERS

The computed potential savings due to awareness training to promote operation in energy saving mode and switching off computers and other office equipment when not in use amounts to 34,398 kWh equivalent to Kshs. 578,860 per annum. The estimated cost of investments is Kshs. 300,000 leading to a payback period of 0.5 year. Table 3.13 shows the justification for awareness training on efficient use of computers and usage of LED Computers as opposed to LCD

TABLE 3.13: JUSTIFICATION FOR EFFICIENT USE OF COMPUTERS

Assumed Operating Hours per day	9	
Operating days per week	5	
Operating weeks per annum	52	
Operating Hours per annum	2340	
Tariff CI2		
Electricity charges Ksh/ kWh	8.25	
KVA Demand charge per unit Kshs	520	
Consolidated energy charge (ksh/kwh)	16.83	
	kWh	**MJ**

	1	**3.6**

No.	**Equipment**	**rating(W)**	**rating(kW)**
1	computers (CPU)	55	0.055
2	17" CRT Computer monitor	90	0.090
3	17" LCD Computer monitor	35	0.035
4	19" CRT Computer monitor	110	0.110
5	19" LCD Computer monitor	35	0.035
6	19" LED Computer monitor	20	0.020
7	17" LED Computer monitor	18	0.018
	Estimated cost of 17" LED Computer monitor (ksh)		9,000

	Switch off computers after work.		
10%	Assume 10% of computers currently left on 24 hours a day		24
	Potential energy savings (kwh p.a)	**34,398**	
	Potential energy savings (kshs. p.a)	**578,860**	
	Estimated investment - staff awareness to operate in power saving mode and switch off computers when not in use (ksh)	**300,000**	
	Simple payback period (years)	**0.5**	

3.2.11 ENERGY EFFICIENCY IN USE OF CONTAINER CRANES

The energy conservation measure proposed for the fuel consuming gantry cranes is the installation of the RIS-GA system to monitor and control the running of diesel generators in RTG and MHC cranes.

The RIS-GA system reduces the speed of the diesel generator during the crane's stand-by mode and typically reduces total fuel consumption by 20%.

RIS.GA. field tests show that terminal operators can save up to 50% of fuel consumption during the crane's stand-by mode and more than 20% fuel consumption overall. This produces a fast ROI, typically one to two years (depending on the country oil cost) and long-term savings.

3.2.12 SHORE POWER IMPACTS FOR THE PORT OF MOMBASA

The Consultancy Services For The Proposed Study Of Energy Needs, Alternative Energy Sources And Provision Of Shore Power (Cold Ironing) For The Port Of Mombasa concluded that while the investment in cold ironing is not feasible for all ship categories in strictly financial terms, the economic benefits to society do outweigh the costs when avoided pollution and greenhouse gas emissions are taken into account.

The study also proposed that if in future a large-scale solar power generation is implemented at Port of Mombasa, then the cost price of electricity could be reduced from USD 110 to USD60 per MWh and shore power will become profitable. In this illustration, the yearly profit will be approx. USD 500.000, which results in a payback time in the order of magnitude of 7 years.

Using the model for cold ironing as developed by CE with the input values as detailed in the study, the results of the cold ironing project for the Port of Mombasa were found to be very positive. The Table 3.14 details the costs when using auxiliary engines and the costs when using onshore power supply. The assumptions for this table are low oil prices (reflecting the then current levels, USD 350 per ton of IFO380 fuel), medium prices for emissions and including local as well as upstream emissions.

TABLE 3.14 SAVINGS ON SHORE POWER CONSIDERING ENVIRONMENTAL BENEFITS

Cost category	Onshore power (thousand USD p.a.)	Auxiliary engines (million USD p.a.)
Investment costs	590	0
Operational costs • Maintenance • Fuel	 39	 2.838
Electricity	4.919	0
Pollution / GHG emissions • CO_2 • NO_x • PM • SO_2	 489 49 77 62 677	 2.913 4.089 1.534 899 9.435
Total costs	5.596	12.273

Source: RHDNV Study 2017

The report by Monitory and Ecological Cost benefit Analysis for the port of Mombasa came up with the following calculated fuel consumption values (Table 3.15) for the different vessels

TABLE 3.15 CALCULATED FUEL USED (HFO &OFF-ROAD DIESEL) USING SOF, LF AND KWH

VESSEL TYPE	ANNUAL KWH USED	ANNUAL GWH USED	FUEL TYPE	LOAD FACTORS	LOAD KWH USED	SOF g/kW-H	FUEL USED (Tonnes)
CONTAINERS	197,105,103.78	197.11	HFO(2.5% S)	22%	43,363,122.83	220.00	9,539.89
BULK CARRIERS	39,638,311.52	39.64	HFO(2.5% S)	10%	3,963,831.15	220.00	872.04
RORO	35,388,696.33	35.39	HFO(2.5% S)	26%	9,201,061.05	220.00	2,024.23
PRODUCT CARRIERS	68,958,132.07	68.96	HFO(2.5% S)	26%	17,929,114.34	220.00	3,944.41
GENERAL CARGO	36,652,407.77	36.65	HFO(2.5% S)	22%	8,063,529.71	220.00	1,773.98
TUGS	7,501,201.90	7.50	HFO(2.5% S)	22%	1,650,264.42	220.00	363.06
KPA OWN VESSELS	25,300,340.00	25.30	Offroad Diesel	22%	5,566,074.80	230.00	1,280.20
Total HFO(2.5% S) Fuel Used(Tonnes)		18,517.60					
Total Offroad Diesel Used(Tonnes)		1,280.20					

TABLE 3.16 EMISSION VALUES (TONNES) ANALYZED USING EMISSION FACTORS AND UTILIZED POWER

VESSEL TYPE	CO_2	NOx	SO_2	PM
CONTAINERS	31,308.17	637.44	533.37	43.36
BULK CARRIERS	2,861.89	58.27	48.76	3.96
RO-RO	6,643.17	135.26	113.17	9.20
PRODUCT CARRIERS	12,944.82	263.56	220.53	17.93
GENERAL CARGO	5,821.87	118.53	99.18	8.06
TUGS	1,191.49	24.26	20.30	1.65
KPA OWN VESSELS	4,018.71	81.82	68.46	5.57
TOTAL	**64,790.11**	**1,319.13**	**1,103.77**	**89.74**

Table 3.16 shows the emission values associated with the consumed fuels by the different vessels while Table 3.17 shows the total costs of these externalities as extracted from the study.

TABLE 3.17 TOTAL COST OF EXTERNALITIES

Pollutant	Amount(Tonnes)	Cost per Tonne	Env. Cost(USD)
CO_2	**64,790.11**	**7.20**	**466,488**
NOx		**417.60**	

	1,319.13		**550,870**
SO_2	**1,103.77**	**619.20**	**683,451**
PM	**89.74**	**17107.20**	**1,535,149**
Total Environmental Costs (Year 2012)			**3,235,959.23**

From the foregoing, a project appraisal is conducted considering all the costs. These costs include the cost of pollution, cost of alternative shore power bill, the OPS project costs and fuel costs. Table 3.18 gives a summary of the project costs and the figurative project cash inflow from the project undertaking. The power costs are subtracted from the sum of fuel costs and cost of externalities because it is the opportunity cost of the two.

TABLE 3.18 SUMMARY OF PROJECT COSTS

Project Costs Summary (USD)		
	OPS Costs	**Opportunity Costs**
Total OPS Installation Cost	14,267,895.60	
Fuel Costs		12,268,455.02
Cost of Externalities		3,235,959.23
Less Power Costs		- 13,178,142.13
Total	**14,267,895.60**	**2,326,272.12**

Upon appraisal, the NPV was positive on considering the cost of externalities and hence using this method, the project is accepted on the basis that the NPV> 0 (Positive). This project also has a IRR of 14% over a period of 15 years upon using the IRR appraisal method proving its viability.

3.2.13 IMPACT ON EMS 14001:2015(ENVIRONMENTAL MANAGEMENT SYSTEM) IMPLEMENTATION AND OLD TRUCKS REMOVAL FROM THE ROAD

Building upon the GHG inventory and Baseline developed by the Green Port Policy, a forecast of future GHG emissions was developed for the port of Mombasa. This was based on the then latest available business forecasts from the KPA Business Plan 2012/13 to

2014/2015 (Nov 2012) and the KPA Master Plan (Sep 2009). Table 2.19 shows the 5- year projected traffic increase, modelled on the Master Plan projection data. The resulting forecast of total GHG emissions in tCO2e (Tonnes of CO2 emissions), classified by Scope, is shown in Table 3.20

It is evident that the carbon foot print profile from port operations has a steady incline and a lot need to be done to reduce this trend including implementation of the ISO 14001:2015EMS and banning of old polluting trucks from accessing the Port.

FIGURE 3.1 BASIS FOR FUTURE GHG EMISSIONS

Scope	Item	Item	Item	Rationale for Emissions
Scope 1	Fuel	Diesel	Generators	Partly linked to the increased harbour traffic forecast (70% at this increased rate, 30% at half this increased rate, equivalent to an overall increase of 85% of the increased traffic forecast).
			Vehicles	Based on 20% of traffic increase
			Equipment	Based on traffic increase
		Kerosene		Based on traffic increase
		Petrol	Vehicles	Based on 20% of traffic increase
			Equipment	Based on traffic increase
Scope 2	Electricity			Partly linked to the increased harbour traffic forecast (70% at this increased rate, 30% at half this increased rate, equivalent to an overall increase of 85% of the increased traffic forecast).
Scope 3	Ship	Local	Movement	Based on ship calls projections
			Idle ships	Based on ship calls projections
	Road	Local	Movement	Based on traffic increase
			Idle	Based on traffic increase
		Associated	Movement	Based on traffic increase
			Idle	Based on traffic increase
	Rail	Local		Small increase of 2% every 5 years.
		Associated		Small increase of 2% every 5 years.

FIGURE 3.2 FOOTPRINT OF FUTURE GHG EMISSIONS

Footprint (tCO2e)				Year			
				2013	2018	2023	2028
Scope 1	Fuel	Diesel	Generators	242	318	405	552
			Vehicles	420	452	481	522
			Equipment	16,953	23,233	30,684	43,767
		Kerosene		1.4	1.9	2.5	3.5
		Petrol	Vehicles	189	203	216	234
			Equipment	3.7	5.1	6.7	9.6
Scope 2	Electricity			4,108	5,401	6,874	9,365
Scope 3	Ship	Local	Movement	5,046	5,821	6,685	7,258
			Idle ships	119,528	129,490	148,776	163,829
	Road	Local	Movement	4,577	6,272	8,283	11,815
			Idle	3,982	5,457	7,207	10,280

3.3 STATUS OF ENERGY SAVING MEASURES IMPLEMENTATION AT THE PORT OF MOMBASA.

TABLE 3.19: IMPLEMENTATION STATUS AND CHALLENGES FOR ENERGY SAVING MEASURES AT THE PORT OF MOMBASA

Initiative	Implementation Status	Challenges
Implement Shore power for the Port of Mombasa	Pilot project on shore power already evaluated. The project cost is USD.2.5Million.	• Installation costs very high. The Cost for installation of one container berth is over USD.6.5Million. • Not many ships are shore power ready. There is a likelihood of the system remaining underutilized hence less zeal for its installation
Renewable Energy Technology –Solar PV	Three sites of 400kW, 350KW and 500kW already installed at the Port.	• The cost of implementing the 5MWpk solar power plant is very high. Awaiting funding from TradeMark East Africa for its execution
Electrification of cargo handling equipment	Not actioned yet	• Projects like retrofitting of eRTG are capital intensive and requires major changes on the operation yard that would mean stoppage of operations hence difficult to implement
Install LED lamps as a replacement of all the existing less efficient lamps	Project rolled out especially for offices and some of the floodlights	• Full implementation is capital intensive hence the phased approach
Sensitization on importance of Energy Efficiency &	Process Ongoing	• Attitude change and working patterns affecting

Management Measures		fast implementation • Quantification of results a challenge hence difficult to convince management to implement
Training on energy Efficiency and Management Technologies	Energy managers trained	• Training budget among the key hurdles • Only critical trainings affecting operations directly gets first priority in funding
Energy Efficiency in Use Of Container Cranes	Not actioned yet	• Voiding of manufacturers' warranty and liability at play • Interparty discussions needed to implement this initiative
Old trucks removed from the road	Previous attempts proved not successful	• External interference a major issue. • Truck replacement cost high hence likely of loss of business
Use Of Premium Efficiency Motors	Process Ongoing	• Procuring policy favoring high efficiency motors/equipment not yet in place
ISO 14001:2015-Environmental Management System (EMS)	Kenya Bureau of Standards has started to develop EMS ISO14001 and ISO 45001	• Capacity barriers and need for awareness/ training
Ships within port area burning low Sulphur fuel	Implementation not yet started	• No local regulations in place to enforce burning of low Sulphur diesel while at the berth
GHG offset from tree planting	Already ongoing. 17,000 Trees planted in Mombasa and neighboring Counties.	• More budget being sought for increased forest cover acreage
Star Rating Policy	Not yet actualized	• The Public procurement rules favours the lowest evaluated bidder
Power Factor Correction	Already implemented. Factored in procurement plans	• No challenges
Energy Management System	Recommended	• Large Installation cost required. Over Ksh.17million required. • Cost not yet factored in the

		procurement plans

3.4 CHALLENGES/BARRIERS IN IMPLEMENTATION OF THE PROPOSED ENERGY SAVING MEASURES.

- Lack adequate capital for implementing energy efficiency measures. The investment priorities of the organization tend to favour other infrastructural projects as opposed to energy efficiency projects hence low budget allocation.

- Lack of harmonized approach by the different functions/ departments of the organization (operations, mechanical engineering, electrical engineering and Marine engineering) in implementing energy saving measures. The departments may not be on the same page in terms of energy management and each department manages its own budget.

- Information and awareness levels on the benefits of energy efficiency is generally low. Lack of adequate information on the subject hinders implementation.

- Some of the energy efficiency technologies/projects are costly with long pay-back period and this discourages top management to give such projects a priority. One common barrier in the utility sector is the perception that energy efficiency actions will reduce the company's revenue. While true in some cases, energy efficiency programs can help electricity companies better manage peak demand and also defer the need for investing in new power infrastructure, and thus can be very profitable for electricity companies.

4.0 LEVEL 2 ENERGY AUDIT FOR THE PORT OF MOMBASA AND LEVEL 1 ENERGY AUDIT FOR THE PORT OF DOUALA

4.1 EXECUTIVE SUMMARY

The Maritime Technology Cooperation Centre-Africa carried out level 2 energy audit at the Port of Mombasa from 7th – 8th November 2019 and level 1 audit at the Port of Douala from 20th – 22nd November 2019 as part of the implementation of its commitment under pilot project 1 on energy efficiency.

The Port of Mombasa (POM) is located on the waterfront of Kilindini Channel. The geographic position of the port is approximately 4' 00' S, 39" 40' E. It is one of the busiest Ports along the East African coastline and a gateway to East and Central Africa. The Port of Douala (PAD) is the largest and a significant Port in Cameroon, which is located on the shores of Wouri river estuary in the city of Douala, the largest and economic capital of Cameroon

The main cargoes handled at the POM are containers, oils (fuel, vegetable), motor vehicles, general cargo, dry bulk cargo (Clinker and Coal), grains, agricultural inputs (fertilizer) among others . The main services offered include; Marine services, stevedoring services, shore handling services, conventional cargo operations, container terminal operations

The main sections of PAD are: Container terminal, Cement terminal, Timber areas, fruit exports, general cargoes and fishing port. The PAD operates the general cargo and fishing activities while the other sections are operated privately through concessions.

The Energy Audit covered all of the sections of the two ports and data collected through desktop discussions, site visits to different parts of the port and site interviews on the operations, energy types and consumption.

The current energy infrastructure at POM is quite stable and able to support the energy demand of the port operations and all ports installations.

The annual energy consumption at POM is approximately 24GWh with the Ship-to-shore cranes being the biggest consumers of electric power at the port of Mombasa while the heavy diesel fuel consumers include the RTG cranes, marine crafts and terminal tractors.

The PAD is currently supplied by the utility supplier ENEO through 11 independently positioned substations that serve the different port areas. Supplied at a low voltage of 410V, the current energy infrastructure at PAD is not able to supports the energy demand of the port operation hence the use diesel generators especially at the container terminal and other port areas.

To realize the potential energy saving measures at the port disposal, It is imperative that PAD upgrades its reticulation network to allow for a robust port power distribution system and redundancy in its operation. In line with this, the technical team requested for benchmarking with the Port of Mombasa and further asked for frequent follow-up on the initiatives that MTCC Africa will suggest further to their mission.

4.2 INTRODUCTION

4.2.1 SITE LOCATION

The Port of Mombasa is located on the waterfront of Kilindini Channel. It is one of the busiest Ports along the East African coastline and a gateway to East and Central Africa. The Port of Douala is the largest and a significant Port in Cameroon, which is located on the shores of Wouri river estuary in the city of Douala, the largest and economic capital of Cameroon

4.2.2 INFRASTRUCTURE AND EQUIPMENT

The major activities and infrastructure at the POM are; Two container terminals, General Cargo handling berths, Bulk cargo handling berths, Two oil terminals, Bulk grain handling terminal (privately operated), Dockyard/dry dock facilities. Equipment include ship to shore cranes, terminal tractors, marine crafts (pilot and tug boats, mooring boats), rubber-tyre cranes, reach stackers, forklifts.

The major activities and infrastructure at the Port of Douala are; Container handling, Fish landing, General Cargo handling, Bulk cargo handling especially clinker, Timber yards

Equipment include ship to shore cranes, terminal tractors, marine crafts (pilot and tug boats), rubber-tyred cranes, reach stackers, forklifts floating barges and excavators for handling of timber/wood logs.Other infrastructure at the two ports include large storage sheds and offices.

4.2.3 OBJECTIVE OF THE AUDIT

The main objective of the audit was fulfil the commitment by MTCC-Africa to carry out an energy for two ports in Africa where Port Douala for Level 1 Audit while the Port of Mombasa was selected for a follow up audit (Level 2). The audits were conducted together with IMO preferred consultants, Royal HaskoningDHV to establish energy infrastructure and energy use at the ports, energy saving potential available, energy saving measures already undertaken and identify areas of improvements.

The objectives of the level 2 Audit as per the Terms of Reference for Pilot Project 2 on Uptake of Port Energy Efficient Technologies and Operations included-:

1. Determining which of the proposed energy saving measures have been implemented at the Port of Mombasa.
2. Estimating the impacts of the implemented strategies on the energy consumption and emissions at the Port of Mombasa with the assistance of an IMO consultant.
3. Identifying the energy saving measures that are yet to be implemented at the Port of Mombasa.
4. Identifying the challenges/barriers in implementation of the proposed energy saving measures and proposing measures that can be put in place to ensure that more energy savings are realized.
5. Utilizing and based on the Global maritime energy efficiency partnerships (GloMEEP) project Port Emission Toolkit, provide training on developing an Emissions Reduction Strategy (ERS) to relevant stakeholders at the selected port(s).

4.3 AUDIT METHODOLOGY

Different techniques were used to collect information during the audit as follows-:

- Opening meeting with senior staff from selected departments at the POM including Electrical engineering, terminal engineering and Marine operations. The audit questionnaire earlier sent by the IMO consultants was discussed. Tasks were assigned to the port staff with regards to submission of all the information requested by the consultants. A similar meeting was held with senior staff at PAD where the schedule of activities were discussed, reviewed and some verbal data received.
- Separate meetings with staff at selected relevant departments
- Request for data through email where the relevant department were addressed to provide specific information requested especially for the department that were not represented in the opening meeting.

- Site inspection at sections of the ports
- Interviews of staff at the visited sites

4.4 AUDIT FINDINGS, RECOMMENDATIONS AND CONCLUSION - POM

4.4.1 FINDINGS ON POM ENERGY AUDIT

The POM has consistently continued to implement energy saving initiatives recommended in past energy audits. This has especially been so on the areas of replacement of existing lamps to energy saving lights, installation of Solar power plants, replacement of old computers with LED ones, drive to implement shore Power and implementation of ISO 14001:2015-Environmental Management System (EMS).

The port will be undertaking the second statutory energy audit in the year 2020 in line with the energy act 2019. According to the Act, the occupier of a building/factory shall conserve energy, audit and analyze energy consumption in his building/factory in accordance with the standards, criteria, and procedures as prescribed in the regulations. The act stipulates that a person who fails to comply with the energy conservation provision commits an offence and shall, on conviction, be liable to a fine not exceeding one million shillings, or to a maximum term of imprisonment of one year, or to both.

Table 4.1 shows the energy saving initiatives that have been proposed for the Port of Mombasa, the implementation status for these initiatives, the impacts of the full implementation of the initiatives and the associated challenges with the project implementations.

TABLE 4.1 PROPOSED ENERGY SAVING INITIATIVES, INITIATIVES IMPLEMETATION STATUS, PROJECT IMPACTS AND CHALLENGES FACING ENERGY SAVING PROJECTS IN KPA

Initiative Proposed	Implementation Status	Impacts	Challenges
Implement Shore power for the Port of Mombasa	Evaluation report for Tender No. KPA/082/2018-19/EE on Provision of shore power for ships at Berth No. 1 was held on 29th and 30th July 2019. The project has since been awarded but awaiting funding approval from Parent Ministry	Pilot project estimated to cost USD.2.5Million.	1. Major challenge facing shore power Installation is the very high installation cost The Cost for installation of one container berth is over USD.6.5Million. 2. Not many ships are shore power ready. There is a likelihood of the system remaining under-utilized for long period hence less zeal for its installation
Installation of LED lamps as a replacement of all the existing less efficient lamps	Offices have all been fitted with LED Lights. 23 out of 79 monopoles already retrofitted with 600W LED lights from the original 1000W sodium Lamps. A tender for retrofitting all the remaining sodium lamps and installation of fully compliant additional LED monopoles awarded and ongoing	Cost of Tender No. KPA/80/2018-19/EE for LED Lights retrofitting on monopoles with LED lamps already awarded at a cost of USD:4Million The potential savings on installation of LED lamps amount to 376,382kwh (1,355GJ) equivalent to ksh. 6,333,868 per annum	1. Full implementation is capital intensive hence the phased approach. The last batch already under installation
Installation of Renewable Energy Technology –Solar PV	Three sites of 400kW, 350KW and 300kW already installed at the Port.	The estimated savings on Power for the three sites is USD242, 800.The cost for the 3 sites is roughly 3Million USD. Payback period is 12 Years	1. The cost of implementing the 5MWpk solar power plant is very high. Awaiting funding from TradeMark East Africa for its execution
ISO 14001:2015-Environmental Management System (EMS)	Kenya Bureau of Standards has started to develop EMS ISO14001 and ISO 45001	Already ongoing. 17,000 Trees planted in Mombasa and neighboring Counties.	1. Capacity barriers and need for awareness/ training 2. More budget being sought for increased forest cover acreage
Use of Premium Efficiency Motors	Replacement of Standard efficiency motors with premium efficiency type upon end of useful time.	Installation of premium efficiency motors would result to a saving of 495,343 kWh (1783GJ) per annum equivalent	1. Procuring policy favoring high efficiency motors/equipment not yet in place 2. Award of Contracts to lowest evaluated bidders leads to substandard products at the

		to Kshs 8,335,785 p.a. The estimated investment cost is Kshs. 21,421,162 with simple payback period of 2.6 years.	expense of energy efficiency
Electrification of cargo handling equipment	Not actioned yet	The actual impact needs to be determined from power versus fuel consumption savings study. Social costs of carbon also need to be established.	1. Projects like retrofiting of eRTG are capital intensive and requires major changes on the operation yard that would mean stoppage of operations hence difficult to implement
Energy Saving From The Energy Management System	Partly implemented. Mains power supply and feeder to main substations metered. Individual leads still not metered	"AMPLEX SMARTHARBOUR" system recommended. The Projected energy savings amount to Kshs 6,404,298 p.a. The estimated investment is Kshs.17, 544, 462 with a simple payback period of 2.7 years.	1. Project cost included in 2019/2020 FY budget
Sensitization on importance of Energy Efficiency & Management Measures and Training on energy Efficiency and Management Technologies	Process Ongoing. Energy Managers trained	The computed potential savings due to awareness training to promote operation in energy saving mode and switching off computers and other office equipment when not in use amounts to 34,398 kWh equivalent to Kshs. 578,860 per annum. The estimated cost of investments is Kshs. 300,000 leading to a payback period of 0.5 year	1. Attitude change and working patterns affecting fast implementation 2. Quantification of results a challenge hence difficult to convince management to implement 3. Training budget among the key hurdles 4. Only critical trainings affecting operations directly gets first priority in funding
Energy Efficiency in Use Of Container Cranes	Not actioned yet	RIS.GA. field tests show that terminal operators can save up to 50% of fuel consumption during the crane's stand-by mode and more than 20% fuel consumption overall. This produces a fast ROI, typically one to two years (depending on the country oil cost) and long-	1. Interparty discussions needed to implement this initiative 2. Voiding of manufacturers' warranty and liability at play

		term savings.	
Old trucks removed from the road	Previous attempts proved not successful	The projected carbon foot print profile from port operations has a steady incline and a lot need to be done to reduce this trend including implementation of the ISO 14001:2015EMS and banning of old polluting trucks from accessing the Port. The pollution by 2028 will reach 529,000tCO2 from the 2018 value of 421000tCO2 if not implemented	• External interference a major issue. • Truck replacement cost high hence likely of loss of business
Use of Premium Efficiency Motors	Replacement of Standard efficiency motors with premium efficiency type upon end of useful time.	Installation of premium efficiency motors would result to a saving of 495,343 kWh (1783GJ) per annum equivalent to Kshs 8,335,785 p.a. The estimated investment cost is Kshs. 21,421,162 with simple payback period of 2.6 years.	• Procuring policy favoring high efficiency motors/equipment not yet in place
Ships within port area burning low Sulphur fuel	Implementation not yet started	The Sulphur Cap 2020 will eliminate this challenge. A total of 6000tSO_2 to be saved	• No local regulations in place to enforce burning of low Sulphur diesel while at the berth •
Power Factor Correction	Already implemented. Factored in all procurement plans	Surcharges from the utility supplier eliminated. The Projected energy savings due to power factor correction amount to ksh. 653,883 per annum. The estimated cost of investment is Kshs. 570,000with a simple payback period of 0.9 year.	• No challenges. Project undertaken
Chiller Improvement	All 5 chiller plants at the Authority Headquarter replaced with New energy efficient ones with	With the new chillers, the projected energy savings due to	• 2 Port Police Chillers awaiting budget for replacement

	environmentally friendly refrigerant All split units use user friendly refrigerant R401	chiller improvements amount to 173,991 kWh equivalent to Kshs 2,927,970 p.a. The estimated investment cost is Kshs.8,000,000 with a simple payback period of 2.6 years	
Savings on use of aircosavers on air conditioners	Aircosavers installed on pilot project basis on some split units. Full retrofitting on all ACs not yet done	Upon installation of Aircosavers savings to the tune of 176,470 kWh per annum which is equivalent to Kshs. 2,969,693 per annum can be realised. With the estimated cost of investment being Kshs.1,584,000, the simple payback period is calculated as 0.5 year for this project	1. Budget for Aircosaver Implementation not yet set aside

4.5 RECOMMENDATIONS FOR THE POM

This audit recommends that the port should continue with the implementation of energy saving projects as recommended by various audit reports.

Key among the projects that the Port is recommend to undertake in order of priority include-:

1. Finalize on the implementation of pilot project on shore power at berth No.1.
2. Implement the Solar PV arrays project for the 5MWpK project recommended in the 2017 RHDHV design study.
3. Complete the programme of Yard Lighting upgrades on LED Lamps
4. Undertake a study to determine how the dirty cargo can be handled efficiently and with little pollution especially on Particulate matter at the New Service Area.
5. Develop and implement a programme of studies to determine the extent to which vehicles and cargo handling plant within the Port of Mombasa could be electrified.

4.6 CONCLUSIONS ON POM AUDIT

Based on Level 2 energy audit findings, it is clear that the port of Mombasa has implemented a number of the recommendations focusing on energy efficiency and control of emissions. This is partly because of the statutory requirements as per the Energy Act 2019 and partly because of own initiatives based on efforts to implement the green Port Policy. However, a lot needs to be done to achieve the desired objectives and to integrate sustainability into port operations and development.

Three projects have been implemented based on the recommendations that is; installation of 400kWpk Grid Tie solar Power plant, LED lights, power-factor correction and tree planting which contributes to a national drive by the government to attain a 10% forest cover by 2022. Other phases of some of the projects are ongoing. The projects that are in the process of implementations include installation of 350kWpk Grid Tie solar Power plant, development of ISO 14001 and ISO 45001 and installation of a 2000kVA, 60hz,6.6kV shore power at Berth No.1.

There are however other flagship projects that the port should have started due to the importance attached to their outcomes. Key among these are the installation of the Energy Management system (EMS) which is set for budgeting in the 2020/2021 financial year. This project will be a milestone in analyzing the energy flow to the different functional areas of

the port with the aim of energy saving by controlling and containing any power wastages that may be found from analysis of the PMS outcomes.

The Port should also be keen on implementing the Star Rating Procurement Policy to ensure that only high energy saving equipment are procured by the authority. Other projects that need urgent attention include implementation of policies to ensure that Ships within port area burn only low Sulphur fuels, Use of Premium Efficiency Motors Old, development of policies to ensure that old and polluting trucks are removed from Port precincts, Sensitization on importance of Energy Efficiency & Management Measures and Electrification of cargo handling equipment.

4.7 AUDIT FINDINGS, RECOMMENDATIONS AND CONCLUSION – PAD

4.7.1 ELECTRICAL DISTRIBUTION SYSTEM

PAD is supplied by the Utility Company ENEO from 11 substations distributed along the port area. The substations are supplied at 415V and due to the Port equipment rating of 380V, the power is taken through a transformation process to achieve 380V. This results in unnecessary no load losses of around 1.5% as a result of hysteresis and eddy current losses. In addition, there is no monitoring system for the billing system that the port can use to crosscheck the readings submitted for payments by the utility supplier. This has had the impact of irregular and high readings and surcharges to the port that it cannot cross check.

The Substations themselves are not interlinked and therefore there is no redundancy as a result of spur operations of the substations from the utility supplier. The low supply voltage is also susceptible to frequent outages as a result of sharing with all customers around the port hence being affected by operations of immediate neighbors such as voltage swings as a results on starting of large motors from the neighboring firms.

4.7.1.1 Recommendation on the Current Electrical Distribution System

NEO Cameroun S.A. currently operates three independent transmission and distribution networks in Cameroon-:

- The Southern Interconnected Grid (RIS): 225 kV network connecting the major hydropower stations (Edea and Song Loulou) and 6 main thermal power plants to supply the main consumption areas around Yaoundé (90% consumption).
- The Northern Interconnected Grid (RIN): 110 kV and 90 kV structure dispatching the power generated by Lagdo power station sufficient to cover the region's modest demand.
- The Eastern Isolated Grid (RIE): low voltage distribution grid of 30 kV, supplied mainly by isolated diesel power plants with the capacity of ~43 MW.

Being a strategic asset, The PAD should invest in a new main substation supplied at high voltage and tapped from the national grid at levels of either 225kV or 110kV.This substation should then supply the other smaller substations that could be located at the positions of the current substations for ease of upgrading from one system to the other. The reticulation system can be done at 11kV or 33kV and then transformed to the equipment voltage of 380V at the various substations. Alternatively, the Port could also upgrade the equipment to modern ones at voltages of 400/415V progressively as it phases out the old system. The substations should be connected to each other via several loops to ensure redundancy of supply in case of faults and outages in some of the substations. A second incomer station, capable of carrying the whole Port load should also be envisaged and included in the power modernization program.

The port should also invest in a power management system to ensure that its consumption patterns and levels are well monitored and analyzed.

Smart meters and energy management software should be installed at the main substation and in each of the other 11substations to monitor energy consumption by the following units on real time basis: substations, workshops, office blocks, electrically driven cranes, 'reefer' containers power supply system and the yard lighting. This power management system would also be instrumental in monitoring of Power Factor values to avoid unnecessary surcharges by ENEO.

The key benefit of the proposed energy management system is to facilitate timely response for corrective action to promote energy efficiency and power management controls.

4.7.2 EQUIPMENT ENERGY SUPPLY

All Quay side and yard equipment are all diesel driven including the STS, HMC and RTGs. The reefer points at the container terminal are partly electric and partly generator supplied. This has a lot of impact on environmental pollution as the generators have to run continuously to supply the loads. The disadvantage with this is high fuel consumption, low efficiency especially when idling and high wear and tear as a result of the continuous running.

4.7.2.1 Recommendation on the Equipment Energy Supply

The PAD should invest in supplying power to all quay and yard equipment. The port should start with electrification of STS and Reefer points then progressively invest in powering the HMCs and establishment of eRTGs.

In the meantime, before this is done, the container terminal should consider Installation of the RIS-GA system to monitor and control the running of diesel generators in the reefer points, STS, MHC and RTG cranes. This system reduces the speed of the diesel generator during the crane's stand-by mode and typically reduces total fuel consumption by 20%. By so doing, a lot of savings on fuel, maintenance and emissions can be achieved.

4.7.3 PAD MASTER PLAN

PAD has developed a port master plan which contains major port infrastructure improvements at the port up to the years 2050. The masterplan includes building of new container yards, New quays and terminals, modern office blocks and additional maintenance workshop. The master has however not incorporated energy management aspects and Eco-friendly infrastructure in its designs

4.7.3.1 Recommendation on the Port Masterplan

Being at design stage, it is important for PAD to include energy efficiency measures in all projects and in particular use of renewable energy and energy saving techniques in all planned infrastructure. Back bone infrastructure for facilities like shore power, ERTGs, renewable energy connection sites, power duct to all quay equipment and reforestation programs should be included in the designs and initial civil works.

4.7.4 RENEWABLE ENERGY USE.

The PAD is considering demolition and renovation of old sheds in the Port yards. The plans for this exercise are underway and a large surface area will be availed in terms of roof surface.

4.7.4.1 Recommendation on Renewable Energy Use

The renovation of the roofs provides a perfect timing for the installation of solar power plants. It is advisable to make use of a renewable energy source as a supplement to the current power sources most of which are diesel driven generators. This will reduce greenhouse gas emissions and contribute to mitigation of climate change.

Being large surface areas, the energy potential for solar placed on the roofs is enough to power operations not only in the shed themselves, but also supply power to other port areas. PAD should consider including solar power plants on the roofs of the shed as part of the deliverables of the projects.

4.7.5 PORT LIGHTING STATUS

The port has monopoles all installed with the 1000W Mercury lamps. Several areas of the port offices are still supplied with the fluorescent tubes and energy saving bulbs. The workshops do not have skylights and thus do not allow the facility to take full advantage of natural lighting. This leads to use of artificial lights in several places especially workshops during the day.

4.7.5.1 Recommendation on Renewable Energy Use

It is highly recommended that the PAD takes advantage of the long life and energy saving nature of the LED Lights. The 1000W mercury bulbs should be replaced/ retrofitted with either the 400W or 600W LED floodlights. This report therefore recommends as follows-:

- Installation of LED lamps as a replacement of all the existing less efficient la mps as shown in the Port
- Replace electromagnetic ballasts with electronic type.
- Replace basic T8 fluorescent tubes with standard OSRAM T5 tubes
- Use of skylights to facilitate use of natural lights during the day:

4.7.6 AIR-CONDITIONING OF OFFICE BLOCKS

The PAD main office is air-conditioned by use of split units installed all along the office walls. Being a large office block, a lot of energy is required as a result of the large numbers of the units installed and the efficiency of the high numbers.

4.7.6.1 Recommendation on Air Conditioning

It is highly recommended that the PAD installs a central cooling system for the office block. This will reduce dramatically the cooling power requirements. The outdoor units on the clocks will also be removed making the office block to be presentable. A chiller system for the block is advisable the coefficient of performance of the compared to a new chiller at an average 3.3 is very good and all new chillers come with environmentally friendly refrigerants.

The other offices can have their ACs installed with Aircosavers while the port establishes a policy to procure window and split air conditioners that meet the minimum energy performance standards in Cameroon.

4.8. TRAINING ON GLOMEEP

The IMO consultants conducted the training and awareness sessions on GloMEEP for both the MTCC Africa Staff, Kenya Ports Authority Staff and the Port Authority of Douala Staff at the Port of Douala. MTCC Africa staff comprised of the Energy efficiency experts and the Project Head (PH) while PAD staff were mainly drawn from engineering and environment department staff. The training focused Port energy efficiency in terms less demand for energy, use of cleaner energy sources, cleaner fuels and generation of renewable energy. Several technologies available to achieve energy efficiency at port were presented and discussed.

The consultant gave practical examples of implemented projects at the Port of Mombasa, Kenya especially on solar power generation. The session was quite participatory especially the question and answer session.

During the training, the team was briefed on documents detailing the first environmental audit undertaken for the Port Douala with a section on status on energy management and improvement areas.

4.9 RECOMMEDATIONS AND CONCLUSION FOR THE PAD AUDIT

The main concern for the port of Douala in terms of energy saving is the power reticulation network. Supplied on low voltage, the port misses out on improved tariffs associated with large power consumers, gets frequent interruptions as a result of the operations of nearby clients and suffers power distribution losses as a result of high $\mathbf{i^2r}$ losses associated with low voltage supply. The power supply and reticulation network upgrade for the port is therefore of utmost necessity if any power saving initiatives are to be implemented.

Powering of port equipment especially quay side gantry cranes and the reefer points with diesel run engines is also an issue that demands for immediate action. The issue of frequent voltage fluctuations as the reason for running on Diesel engines should be sorted by tapping high on the power grid. It's therefore imperative that these two programs should run together.

The masterplan presents a very important opportunity for PAD to be green. Backbone Infrastructure for ecofriendly and green port should be put in place at the design stage and implemented from the onset to achieve a very low-cost implementation of the suggested initiatives compared to having to retrofit them on completed infrastructure.

5.0 REPORT CONCLUSION

Based on analysis of previous energy audit reports and the energy audits carried out in the two ports, the following conclusions have been drawn-:

The solar power generation potential in Africa is quite high. Kenya and the surrounding countries for example have solar irradiation of approximately 2200kWh per m2 per year. Maximizing and optimally utilizing this potential can result in great savings in carbon footprint and stabilization of the power supply systems for the African Ports. Some ports are already taking advantage of this natural asset and have installed grid tied mini solar grids to supplement the local utility supplies.

On 1 January 2020 the UN IMO global Sulphur cap 2020 took full effect and will be strictly enforced by the world's Port State Control authorities. This requires all ships to use fuels with Sulphur content values of less than 0.05% while staying in Ports. These requirements all the more makes the implementation of shore power for visiting vessels very attractive. In addition, studies have confirmed that with a clean electricity mix coupled with installation of solar power plants in ports makes the shore power implementation very viable considering environmental benefits. Shore power systems for small crafts which are comparatively less

expensive cost-wise have been touted as having great environmental benefits in terms of savings in carbon footprint and the best starting points for implementation of shore power.

The coastal zones of most African ports are prone to high temperature and humidity. These two attributes make office cooling the African ports a necessity. Air conditioning is one of the main power consumers in most of the ports and therefore the use of highly efficient AC systems with environmentally friendly refrigerants such as R401A and R 410A to mitigate climate change cannot be over emphasized. Also, paramount is the prioritization of the use of AirCo-Savers on the window type and split unit ACs to optimize on energy consumption.

As was witnessed with the Port Authority of Douala, some ports in Africa still use fossil fuels to power their operations. These ports use diesel generators to run their gantry cranes and cool their reefer containers. This situation is highly polluting and expensive. Investing in electrical power systems with strong and robust distribution infrastructure with redundancy systems and with power supply tapped high on the countries' grid would ensure clean operations, reliable supply to the ports and conducive work environment. These ports also need to invest in Power Management Systems (PMS), SCADA Systems and Power factor Correction Banks (PFCBs) in tandem to avoid surcharges from the respective utility suppliers.

Policies such as implementation of ISO 14001:2015, the Star Rating Policy and use of premium efficiency motors not only help in reduction of GHG gases but also greatly impacts on cost control improvements. Implementation of ISO14001:2015 for example helps in not only improving a firms' image and credibility internationally as customers are getting increasingly concerned about the environmental practices of the companies that produce the services/products they consume but also ensures high rate of success when implementing changes and enables quick improvement of the process.

In conclusion, while acknowledging the great disparity between the two ports surveyed in terms of the strides made in reducing carbon footprint, the survey observed that the great need for MTCC-Africa to make follow-up on the measures and recommendations proposed to the ports visited. It would also be imperative for the IMO and the GMN to consider how to sustainably run these centres of excellence in order to continue promoting energy efficient technologies and operations and to realize the goal of capacity building for climate change mitigation in the maritime shipping industry by reaching out to the other ports that are yet to be covered by the past initiatives.

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