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Barriers to implementing ports energy efficiency and greenhouse gas emission reduction measures: Kenya's Mombasa Port in consideration

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BARRIERS TO IMPLEMENTING PORTS ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSION REDUCTION MEASURES:

KENYA’S MOMBASA PORT IN CONSIDERATION

By

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DECLARATION

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

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

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ABSTRACT

Title of Dissertation: **Barriers to Implementing Ports Energy Efficiency and Greenhouse Gasses (GHG) Emission Reduction Measures: Kenya's Mombasa Port in Consideration**

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Concerns about environmental degradation, fluctuations in fuel costs, public scrutiny on energy consumption patterns and projected stricter emission regulations, have increased the demand for energy efficiency improvement in ports. As such, ports around the world have shown potential for improving energy performance. However, many ports are still lagging behind in implementing operational and technical measures that could cost-effectively reduce energy usage and mitigate the impact of Greenhouse Gasses (GHG) emissions. Such phenomena depict energy efficiency gaps, best described as Energy Efficiency Barriers.

This research therefore, explores, categorizes and analyzes barriers from the shipping context that are directly influential to Port energy efficiency and GHG emissions reduction. Informed by findings of various studies that there is a slow uptake of energy efficiency best practices for ports in developing economies, Mombasa port was chosen as the case in study.

A total of 47 port-related barriers were extracted from the shipping industry and categorized into five disciplines. Analysis was based on stakeholders' feedback on the priorities and importance levels of these barriers. Results show that all barriers are relevant to port energy efficiency although they differ in importance and priorities. Equipment barriers and Information hindrances were perceived to be most significant while energy measures were given less consideration. From the benchmarking analysis, it was observed that collaboration, organizational structure, Government incentives, training and awareness and port city integration are key to overcoming energy efficiency challenges.

KEY WORDS: Greenhouse Gasses (GHG) Emissions, Energy Efficiency, Energy Efficiency Barriers, Shipping, Mombasa Port

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Air Conditioning
AIS	Automatic Identification System
AMS	Automatic Mooring System
BAU	Business as Usual
CAAP	Clean Air Action Plan
CAC	Course Assessment Committee
CARB	California Air Resources Board
CH4	Methane
CHE	Cargo Handling Equipment
CHP	Combined Heat Power
CMP	Copenhagen-Malmo Port
CO2	Carbon Dioxide
COP	Conference of Parties
CSR	Corporate Social Responsibility
EC	European Commission
EDE	Electronic Data Exchange System
EE	Energy Efficiency
EEO	Energy Efficiency Obligation
EESI	Environment and Energy Study Institute
EET	Energy Efficiency Technology
EGD	European Union Green Deal
EGD	European Union Green Deal
EMP	Energy Management Plan
EMS	Environmental Management System
EnMS	Energy Management System
ERC	Energy Regulatory Commission
ESPO	European Seaports Organization
ESS	Energy storage system
ETS	Emission Trading System
EU	European union

FAL	Facilitation Committee
GHG	Greenhouse Gas
GMN	Global MTCC Network
GPA	Genoa Port Authority
GPP	Green Port Policy
GPS	Global Positioning System
HFO	Heavy Fuel Oil
HMC	Harbor Mobile Cranes
IAEA	International Atomic Energy Agency
IAPH	International Association of Ports and harbors
IEA	International Energy Agency
IMO	International Maritime Organization
IOT	Internet Of Things
IRENA	International Renewable Energy agency
ISO	International Organization for standards
KOT	Kipevu Oil Terminal
KPA	Kenya Ports Authority
KPI	Key Performance Indicators
KV	Kilovolts
KVA	Kilovolt Ampere
KW	Kilowatts
LCA	Life Cycle Analysis
LED	Light Emitting Diode
LNG	Liquid Nitrogen Gas
MARPOL	International convention on Prevention of Marine Pollution from Ships
MTCC	Maritime Technology Cooperation Centre
MW	Megawatts
N2O	Nitrous Oxide
NOx	Nitrogen Oxides
OPS	Onshore Power Supply
PDCA	Plan-Do-Check-Act
PEEP	Port energy and Environmental Plan
PM	Particulate Matter

POA	Port of Antwerp
POLA	Port of Los Angeles
POLB	Port of Long Beach
PP	Payback Period
PV	Photovoltaic
QMS	Quality Management System
RE	Renewable Energy
RMG	Rail Mounted Gantry Cranes
RTG	Rubber Tired Gantry
SEU	Significant Energy Users
SEU	Significant Energy Users
SG	Smart Grid
SHS	Solar Heater Systems
SLM	Smart Load Management
SME	Small and Medium Scale Enterprises
SOT	Shimanzi Oil Terminal
Sox	Sulfur Oxide
STS	Ship-To-Shore
SWOT	Strengths Weaknesses Opportunities and Threats
TAT	Turnaround Time
TENT	Trans-European Transport Network
TEU	Twenty-Foot Equivalent Unit
UK	United Kingdom
UN SDG	United Nations Strategic Development Goals
UNCTAD	United Nations conference on Trade and Development
UNFCCC	United Nation Framework Convention on Climate Change
USA	United States of America
USED	United States Energy Department
VA	Virtual Arrival
VPP	Virtual Power Plant
WMU	World Maritime University
WPCI	World Port Climate Initiative

CHAPTER ONE: INTRODUCTION

1.1 Background information

Greenhouse Gasses (GHG) and Global climate change are high-ranking agendas in international policy that calls for drastic measures by the maritime transport sector (UNCTAD, 2020). Due to the increase in global population, maritime transport has seen an exponential rise in demand in the recent decades (Barberi et al., 2021) resulting to accelerated port operations and subsequently increased energy consumption. The expansion in energy requirements and over dependency on fossil fuel has negatively impacted ports environment and increased concerns of GHG emissions. Although port emissions are arguably small accounting to about 3% of the total global emissions, under the business as usual, projected air pollutant remains ports Authorities' subject of concern (Gibbs et al.,2014).

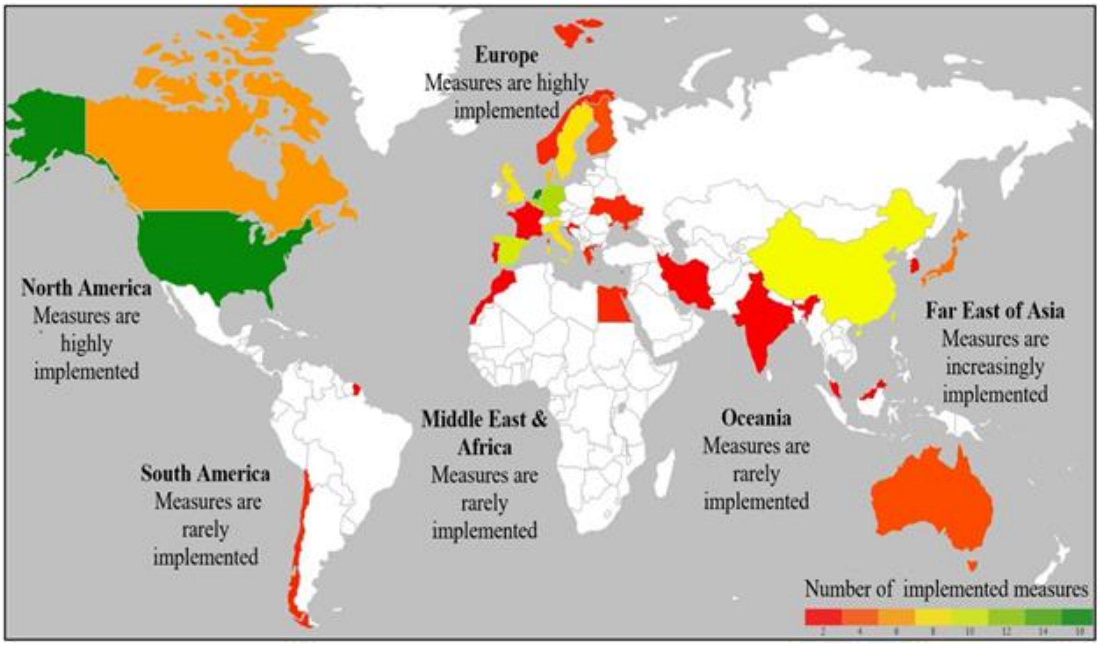
Despite justified role of ports in mitigating climate change, key pillars to achieve sustainable greener ports are energy efficiency and GHG emission reduction. Ports being frontiers in pollution, besides climate change mitigation, attention has been shifted to their role in reduction of carbon emissions and improvement of environmental credibility. As well, there is a growing pressure influenced by many factors that calls for ports to implement cost-effective techno-economic measures for improving their energy performance and reducing negative environmental externalities resulting from fossil fuel combustions.

The International Maritime Organization (IMO) initial strategy adopted in 2018 aims to reduce GHG emissions from ships to 50% by mid-century compared to 2008 baseline. Implementing this ambitious target calls for proactive application of measures by maritime actors including ports Authorities. Although MARPOL Annex VI of the 2010 IMO regulations on energy efficiency and air pollution focus on ships, reducing shipping emissions requires a holistic approach in addressing all emission sources related to ports. Thus, the intrinsic linkage between shipping and ports calls for extension of efforts for reducing shipping emissions beyond seagoing vessels. According to Benamara et al. (2019) environmental issues are twofold: Impact of maritime transport on environment for example CO2 emissions and effect of environment to maritime transport such as climate change. Thus it is vital to effectively address global challenges in line with the 2030 UNSDGs and the Paris agreement without relenting efforts to reduce marine pollution and GHG emissions resulting from port activities.

Besides National regulatory requirements on mitigation of climate change and air quality, regional regulations including EU and California Air Rescue Board (CARB) regulations play a vital role on Global GHG reduction and Energy efficiency targets. For example, the role of the EU's Energy Union of 2015 which has profoundly impacted the European ports energy production and consumption patterns. With energy import amounting to over 50% by 2016, the EU has strategized and highly prioritized energy efficiency in its future sustainability goals (Sdoukopoulos et al., 2019). While the European Union Green Deal (EGD) is aimed at decarbonizing the EU by mid-century, it is arguably impactful on global market and energy balance in particular on Energy security, Oil and Gas production and global trade through Carbon border adjustment (Mark et al., 2021). In addition, the EU has promulgated stricter air pollution regulations on ships calling their ports. In light of the Sulfur directives including Directive 2005/33/EC, Decision 2016/802/EU of the EU, and focusing on Sulphur regulations while avoiding competition distorsion, the current maximum allowable marine fuel SOx content for EU ports is 0.1% (Jonson et al.,2015).

Although many countries have ratified IMO instruments including the MARPOL Annex VI with a view to accelerate the organization’s strategic ambitions on reducing global GHG emission in the shipping industry, majority of ports especially in developing economies have not satisfactorily implemented energy efficiency measures. This is attributed to factors including lack of global standard regulations on ports emission measures, varying Governance models, priority targets, economic impacts and geographical conditions. There is substantial economic and technical potential for energy efficiency improvement in the maritime sector (Bouman et al., 2017) as well as promising regulatory framework which could help in cost saving. However, these factors have remained mare potentials in the shipping industry despite political and economic attractiveness of energy efficiency techniques and measures (Knorring, 2019). This phenomenon could well be explained as energy efficiency gaps, best known as barriers to energy efficiency.

Figure 1: State of Global implementation of Ports EE and GHG emissions reduction measures



Source: Alamoush et al. (2020)

Despite the global volatility of fuel prices, many ports do not exercise cost-effective measures for energy conservation exposing barriers that need to be identified and a framework be developed for adoption by ports energy decision makers. Non-implementation of attractive measures for energy efficiency could be as well due to constraints and conditions within an established organization, including business model, policies and technological arrangements. In pursuit for sustainability, economic growth and a meaningful contribution to global GHG ambitions, ports need to promulgate robust approaches for overcoming energy efficiency barriers.

Mombasa ports being among the high energy intensity government entities in Kenya's maritime circles has the obligation to abide by the highest standards of the national energy regulatory framework. The provisions of Kenya's energy act of 2006, complemented by energy act 2019 stipulates the role of the Organization in coordinating prudent implementation of national programs aimed at energy production, consumption, conservation and efficiency. Although the Port's potentials to drastically reduce its emissions by 2024 through shore-based power (OPS), stricter rules for truck emissions and adoption of rail transport has been hailed (Cornel group, 2015), heavy burning of fossil fuel by ships, use of diesel generators and unregulated truck emissions could position the port among the highest GHG emitters compared to major world class ports. Despite the maturity of many Energy efficiency technologies, there exists direct and indirect hindrances in adopting these technologies. These barriers need to be addressed through research, design, development and implementation of effective energy policies and practices.

1.2 Problem statement

The growing global warming concern resulting from heavy consumption of fossil fuels has culminated in the implementation of various measures and policy instruments such as Carbon emission trading systems (ETS) and IMO Sulfur Cap 2020. It is projected that further policy instruments may influence energy price fluctuations as well as increased energy efficiency demand. Rohdin & Thollander (2005) argued that there are always barriers to energy efficiency resulting from non-implementation of cost-effective energy efficiency measures.

Mombasa Port is among the energy intensity government owned organizations in Kenya with annual energy consumption of about 12.5GW (MTCC Africa, 2019). With the increased expansion projects such as New Kipevu Oil Terminal(KOT) and the Lamu Port project, there is a projected increase in energy consumption due to increased operations. Consequently, the Ports could expect higher operating costs resulting from intensive energy consumption as well as an exponential rise in CO2 emission due to fossil fuel combustion.

Although Mombasa ports have implemented several energy efficiency measures, like other ports from developing economies, it still lags behind in implementing innovative, cost-effective and mature energy efficiency measures such as Energy management systems (EnMS), Energy storage systems, CHE Electrification, Hybridization, Digitalization and smart grids. Moreover, despite adoption of Green Port Policy, there is no significant reduction of Electricity and fossil fuel consumption.

While energy efficiency in Mombasa port is a well-penetrating techno-operational subject, barriers-related investigative studies are scarce. Thus there is a need for studies to identify these barriers and adopt effective policies for overcoming them. It is against this backdrop that this research seeks to investigate the existence of barriers hindering implementation of techno-operational measures for energy efficiency and GHG emission reduction in Mombasa port. Although not manifested in the initial objective, this study also explores the energy efficiency state of practices coupled with illustrations of best practices from successful implementing ports.

1.3 Aim and Objectives of Research

The aim of this study is to investigate the barriers in implementing port technical and operational measures for energy efficiency and GHG emission reduction in Kenya's Mombasa port.

The finality of this research is based on the following research objectives

1. To explore viable techno-operational measures for improving Ports energy efficiency and reducing GHG Emissions
2. To Identify and categorize the barriers to implementing measures for improving energy efficiency and reducing GHG emissions in Mombasa port
3. To rank and analyze the barriers to energy efficiency in Mombasa Port with a view to recommend a framework to overcome these barriers.

1.4 Research questions

1. What measures for improving energy efficiency and reducing GHG emissions are/or can be implemented in Mombasa port?
2. What are the barriers to implementing energy efficiency and GHG emission reduction measures for Mombasa port?
3. Could Kenya Ports Authority be an energy efficiency promoter through adoption and implementation of effective Energy efficiency practices?

1.5 Methodology

This research encompasses a qualitative survey targeting multi-stakeholders input in identifying actual port-related barriers. Primary data shall be sourced through questionnaires to obtain expert opinions from port representatives and expert actors. The researcher seeks to involve experts in Energy efficiency who are directly linked to the maritime sector and in particular port operations.

Secondary data shall encompass extensive review of relevant literature from credible sources including Peer reviewed articles, journals, periodicals. IMO reports shall be used for regulatory insight in the maritime sector, complemented with maritime eBooks. Other resources include the International Energy Agency (IEA), International Renewable energy Agency(IREA), World Bank reports, Clarkson's, DNV-GL, Lloyd register and WMU databases.

Besides information from the port in question, best practices from successful implementing ports and regional projects such as from the European Union shall be reviewed to help understand the state of practice in policy side of energy efficiency

Finally, a SWOT analysis shall be conducted to point out opportunities, strengths threats and weaknesses of Mombasa port, and to provide recommendations to port decision makers on effective Energy Efficiency practices and policies frameworks.

1.6 Key assumptions and Potential limitations

The researcher relies on primary data from expert opinions with the assumption that data obtained shall reflect the objectives of the research topic. There might be limited control of data or information provided, as well, different experts may require different timelines to present data to the researcher which might result in delays. However, efforts shall be made to ensure credible data is timely obtained.

1.7 Scope of research

Globally, there is varying implementation patterns of Ports EE measures with different hindering factors. This research is aimed at investigating the barriers to implementing measures for improving energy efficiency and reducing GHG emissions in Mombasa Port. Despite not explicitly discussed in the main objective, Techno-operational measures for EE and GHG emission reduction shall also be reviewed alongside illustrations of best practices from successful implementing ports.

The physical boundaries for the research shall encompass Mombasa Port as an intersectional player between Sea and Hinterland.

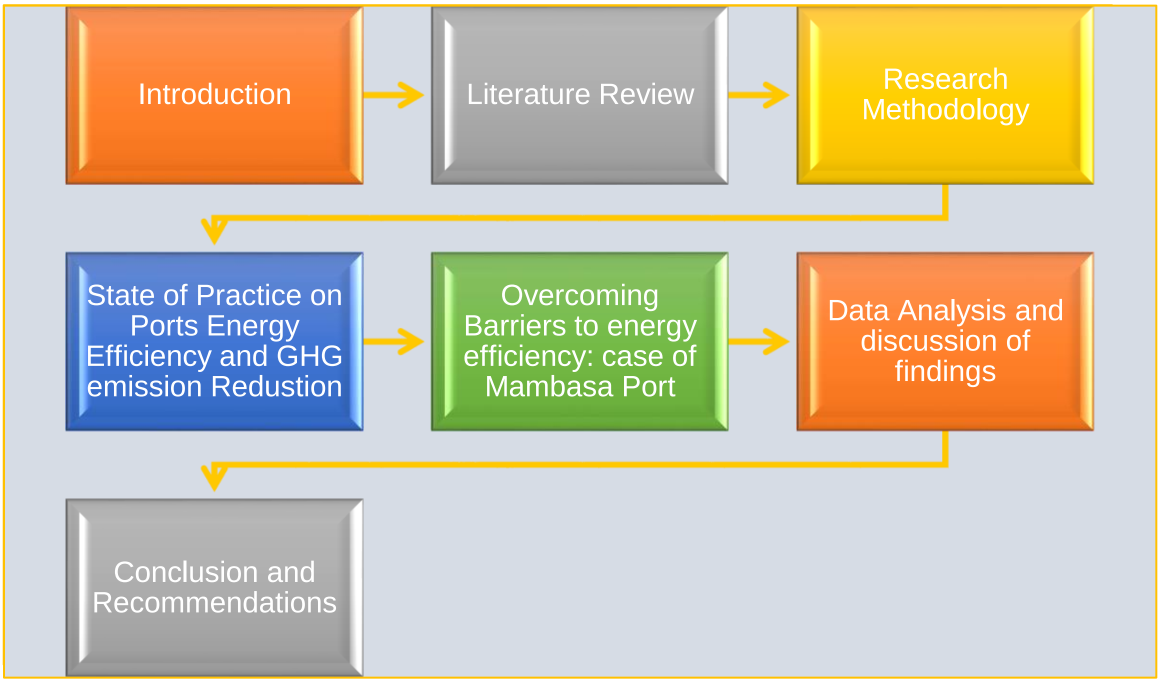
Figure 2: Physical boundary of research

1.8 Research Outline

This Research is organized into seven chapters. Chapter one encompasses a holistic background of the research area including aim and research objectives, research questions, key limitations and assumptions. Chapter two delves on extensive literature review that explores Applications, barriers and drivers of energy efficiency, and methods and findings from previous studies. Chapter three provides the methodology used in data collections, presentation and analysis.

Chapter Four reviews state of practice on ports EE and GHG emission reduction. Best practices from successful implementing ports are reviewed in this chapter. Chapter Five highlights Mombasa port energy efficiency practices and potentials for overcoming EE barriers. Chapter Six analyses and discusses the barriers from research results. Conclusion and recommendations is drawn in chapter Seven.

Figure 3: Sequence of research.



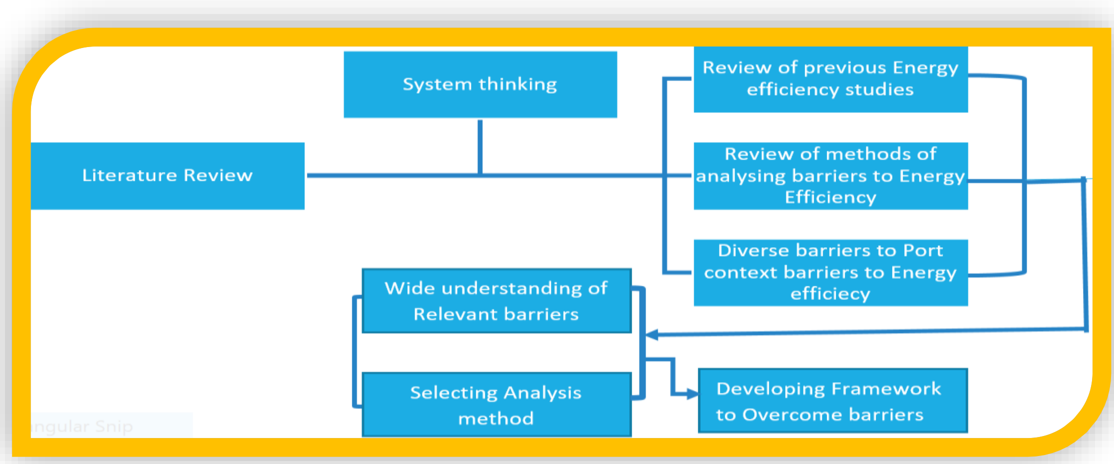
Source: Author

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter will review various literature pertaining energy efficiency and associated barriers for implementation of energy efficiency measures in the maritime sector. Qualitative results from previous energy efficiency studies employing different methods will be presented in this chapter. The ultimate goal of this literature review will be to attain a wider understanding of sector-specific barriers with a view to select the actual barriers for ports energy efficiency. Despite many studies about energy efficiency barriers in the shipping industry, very little research has been done in ports. However, the valuable findings of different researchers will be utilized in the port's context, to assist in finding solutions to energy efficiency barriers and develop a framework for overcoming these barriers.

Figure 4: Flow diagram of literature review objectives



Source: Author

This research presumes the literatures reviewed as an interconnection of diverse concepts, ideas, methods and analytical techniques for energy efficiency and its implementation barriers that requires system thinking for handling complexities through integration of key literature components. Purposely, system thinking aids in identification and understanding of available literature and devices necessary modifications in order to produce desired results (Arnold and Wade, 2015). Developing an effective framework for overcoming barriers depends on the analysis of methods used and the degree of understanding of key barriers from the review of literature.

2.2 Ports Energy efficiency

Environmental and Energy Study Institute (EESI) defines energy efficiency as utilizing less energy to do the same work, objectively to eliminate energy wastage, reduce energy demand and GHG emissions. IEA (2021) report brands energy efficiency as the 'first fuel' due to its cleanest representation and as the most cost-effective way to meet energy demand. Although there exist many definitions of energy efficiency, the baseline is to reduce energy losses and minimize negative externalities caused by combusting fossil fuels.

To improve ports competitiveness, productivity and sustainability, Port performance requires continuous improvement. However, high quality performance measurement is still a challenge to port management (FAL, 2016) as well the link between energy consumption, performance efficiency and sustainability has not been satisfactorily analyzed. Despite being under environmental and economic pressure, and rising costs and rates of energy use, strategies and energy efficiency measures are still minimal.

2.2.1 Applications of energy efficiency

Conceptually, energy efficiency has penetrated many applications. Diogo & Martins (2020) explored the potential of machine learning tools in energy efficiency for industrial processes. Such studies have justified myriads of challenges in energy efficiency in the petroleum industries and suggested ways of addressing these challenges. Pinto & Castor (2017) on the other hand argued that inadequate tools and knowledge hinders energy efficiency software designs and development, posing threat to emerging software developers. Some researchers have studies energy efficiency capabilities of buildings which account for 40% of global energy consumption (Omrany et al., 2016). In the maritime sector, speed optimization and enhanced communications with ports and charterers to facilitate virtual arrival are potential measures for energy efficiency and emission reduction in ports (Jia et al., 2017) while in the airline, capital efficiency was ranked among key factors for determining energy efficiency of aircraft (Cui & Li, 2015).

Alamoush et al. (2020) identified and classified technical and operational measures for improving EE and reducing GHG emissions in ports considering Sea-Port-Land interfaces. Results revealed that EE measures have different complexities, cost implications and abatement potentials. It is however challenging to create synergies, particular in developing economies due to hindrances including scarce resources.

2.2.2 Drivers of Energy Efficiency

There are various factors that influence the environmental consciousness and operational sustainability in the maritime industry including policy and regulatory enforcement, promulgation of major international conventions, Technological innovations and research and development. However, due to lack of standard decarburization solutions, reducing emissions calls for adoption of a variety of stringent measures including operational and technical efficiencies and enactment of effective policies (Nisiforou et al., 2022) by shipping players.

Environmental pollution

Overdependence on fossil fuels and reluctance of ports in harnessing Renewable energy has exponentially increased Carbon Dioxide (CO2) emissions. In addition, high Sulfur contents of these low quality fuel emits further pollutants into the atmosphere (GHGs, NOx, Sox) with significant impact on human health and climate change. In addition to emissions due to energy production, crude oil handling and use results in volatile organic compounds and ozone depleting substances (Salo et al.,2016). This has contributed to public scrutiny on ports' energy use patterns and promulgation of regulations to mitigate these negative externalities resulting from the shipping activities.

Climate change mitigation

Prior to COP 26, states around the globe committed renewed net-zero emission targets by mid-century. These commitments included measures to transform the energy sector which account for 75% of the global emissions and whose transformation is vital in mitigating the impact of global climate change. According to the IEA Sustainable development scenario, 40% of the emission abatement required by 2040 is represented by Energy efficiency. This calls for transformation of current energy systems. Thus countries are challenged to prioritize transformative strategies for energy efficiency in order to achieve climate goals.

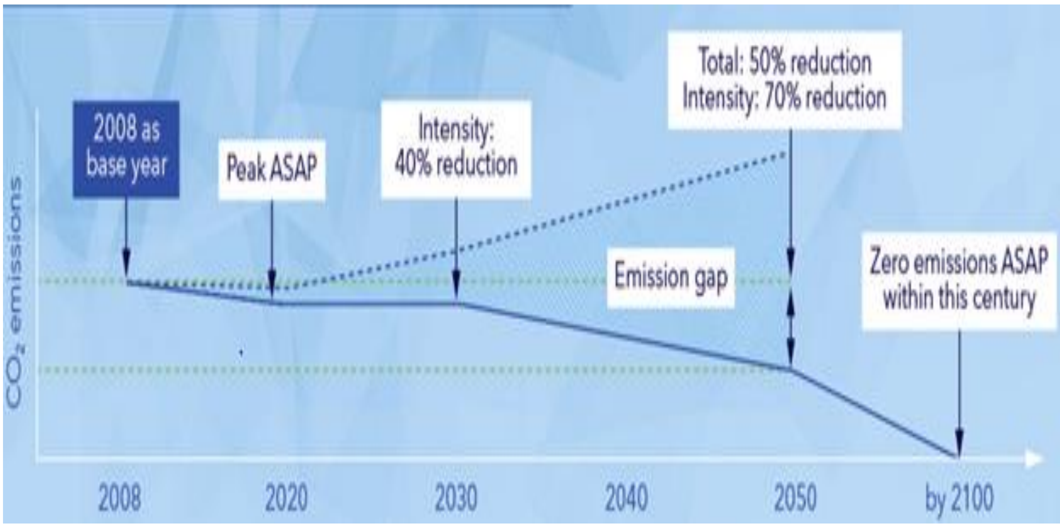
Ports play an intersectional role by strategic application of GHG reduction measures between portside and the hinterland (Gonzalez-Aregall et al.,2015). GHG and climate change being universal issues and ports being the gateways to international shipping, it is vital to examine their implementation potentials as well.

Regulatory and policy frameworks

Despite the existence of shipping regulations dated to the early civilization of mankind, it was not until recently that regulators captured its attention and included it in the international agreements (Linne & Svensson, 2016). Additionally, emerging scientific studies on pollution and environmental impact have accelerated environmental regulatory awareness from shipping activities. In a global review of policy and taxonomy, Christodoulou et al. (2021) found that measures that encourage best practices in environmental conduciveness, infrastructure development and policies are among the top practices (Nisiforou et al.,2022).

In pursuit for climate change and Global warming solutions, the United Nation conference on Environment and development (UNCED) held in 1992 at RIO de Janeiro deliberated among other solutions, the replacement of fossil fuel with clean alternative energy sources. As a result of this initiative, the Kyoto protocol, an international agreement within the framework of the United Nations conference on climate change(UNFCCC) was established (UN, 1998), charged with promulgation of international law targeting emission reduction. Consequently, IMO has formulated energy efficiency regulations aimed at reducing GHG and CO2 emissions from shipping, as mandated by the protocol of 1998.

Figure 5: IMO GHG strategy



Source: DNV-GL, 2019

It is projected that under unsustainable conditions, GHG emissions might reach 130% compared to the 2018 baseline (Fourth IMO GHG study, 2020). As well, the European Union Energy consumption in shipping has increased Carbon emissions by about 48% by 2018 compared to 1990 levels (IMO GHG study, 2014). Consequently, IMO adopted the initial GHG emission reduction strategy in 2018 from shipping and further stringent compliance regulation on SOx and NOx emissions from ships.

On the other hand, ESPO, 2017 survey report on European Union (EU) ports observed key environmental priorities such as Air quality, Energy consumption, Noise, Water quality, Waste management, Port development, Corporate Social Responsibility (CSR) and Climate change.

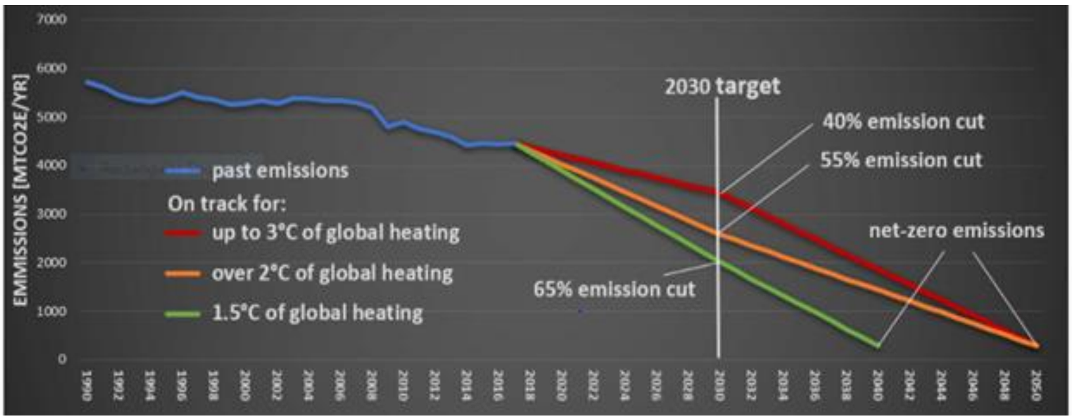
Table 1: Top 10 environmental priorities

	2017	2018	2019	2020	2021
1	Air quality	Air quality	Air quality	Air quality	Air quality
2	Energy consumption	Energy Consumption	Energy Consumption	Climate change	Climate change
3	Noise	Noise	Climate change	Energy efficiency	Energy Efficiency
4	Water quality	Relationship with locals	Noise	Noise	Noise
5	Dredging Operations	Ship waste	Relationship with locals	Relationship with locals	Relationship with locals
6	Garbage/Port Waste	Port development	Ship waste	Ship waste	Water quality
7	Port development	Climate change	Garbage/Port waste	Water quality	Ship waste
8	Relationship with locals	Water quality	Port development	Garbage/Port waste	Dredging Operations
9	Ship waste	Dredging Operations	Dredging Operations	Dredging Operations	Port development
10	Climate change	garbage/Port waste	Water quality	Port development	Garbage/Port waste

Source: ESPO, 2021

Unlike African Countries, the EU has regional unified port regulations for port area emissions. For example, the adoption of directive 2005/33/EC for regulating emission from ships which set a 0.1% Sulfur limit for marine fuels for ships calling at EU ports (Hamalainen, 2015).

Figure 6: EU GHG emission reduction pathway



Source: Climate action network Europe, (2020) As such, EU has remained consistent in its below 20% target for GHG emission reduction by 2020. According to EEA, 2020 EU GHG emissions reduced by 24% compared to 1990 baseline. Coupling emission reduction with economic growth is a product of the EUs sound climate policies that have been implemented by the EU states with a view to improve environmental credibility and sustained economic growth (Brittany Demogenes, 2020).

United Nation Sustainable Development Goals (UNSDGs)

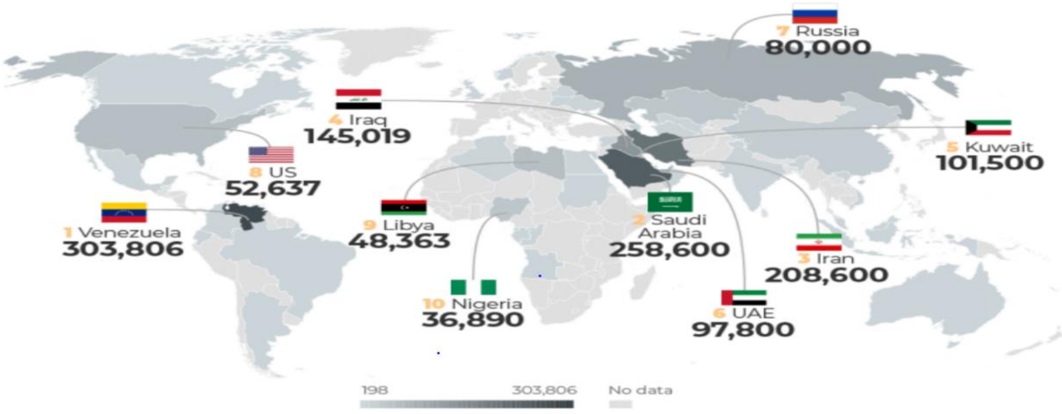
It is worth noting that the global climate change impact is threatening livelihood and human kind (United Nations 2016) and calls for holistic implementation of measures that are aligned with UNSDGs. There is a strong relationship between energy consumption and port energy efficiency, and sustainable development. In line with UNSDG 7, ports have an obligation to enhance energy efficiency and are capable of joining forces with international corporations in order to harness renewable energy, and accessibility of clean energy (FAL,2016). On the other hand, there is a need to integrate Goal 13 in national plans, strategies and policies in order to strengthen institutional and human capacity for mitigating climate change impact, raise awareness in early warnings and help in implementing adaptation measures. Notably, UNSDGs are interlinked.

2.2.5 Energy security and energy prices

According to the International Energy Agency (IEA), Energy security is referred to as "the uninterrupted availability of energy sources at an affordable price". Present industrialization and modernization heavily depends on energy. Thus energy could be regarded as an intersectional point of socio-economic development, energy-related policies and technologies related to states. Consequently, energy security has been the top priority for nations, influencing national, regional and global strategies and policies.

With the growing energy requirement by seaports (Brickman, 2018), the projected escalation of fuel prices, need to reduce cost and pressures of environmental impact by fossil fuels, ports around the globe are called to promulgate strategies that align with energy efficiency measures. Figure 7 shows the global top oil producers in million barrels

Figure 7: Top oil producers globally



Source: IEA 2022

Energy demand of seaports has increased resulting in increased cost of energy, pollution and GHG emissions (Iris & Lam, 2019).

2.3. Barriers to energy efficiency

The existence of mechanisms that hinders implementation of energy efficiency measures aimed at reducing energy cost, and limiting negative externalities caused by emissions from fossil fuel combustions in any energy consuming facility is termed as energy efficiency barriers. Consequently, manifestation of energy efficiency gaps resulting from barriers prevents the usage of economical and energy efficiency technological investment.

According to Vakili et al. (2022), barriers to energy efficiency exist where there are hindrances in economic investment for innovative technologies in energy efficiency, due to incompatibilities between best implementation practices and real - time implementation of energy efficiency measures. While various studies have suggested the existence of adoption potential for energy efficiency technologies in industries, USED report of 2015 admitted that there's a gap in the industrial sector that hinders adoption of energy efficiency best practices.

Bagaini et al. (2020) assessed the relevance of barriers in assisting policy makers to set goals either by reduction of ambitious targets or encompassing mitigation measures for barriers. Newell & Siikamaki (2015) examined the correlation between discount rate and energy efficiency. It was found that energy efficiency investment could highly be influenced by individual preferences in terms of payback period (PP), choice of product and tax credits. Hobman et al. (2016) argued that imbalances between production and supply cost of power, and the customers' actual cost contributes significantly to energy inefficiencies.

2.3.1 Categories of barriers

Many studies about barriers to energy efficiency have been conducted with varying results of barriers categorization and classification. While Vakili et aol. (2022) categorized barriers into five disciplines (Organizational, Technical, Policy, Operational and Economical), Yap et al. (2020) suggests that market failure is the baseline for energy inefficiency and inaccessibility, and the bottleneck in harnessing renewable energy. According to Gerarden et al. (2017) energy barriers are categorized into behavioral hindrances, Market failures and measurement and model errors while Fawcett & Hampton, 2020 base their augment on policy explanations. Soepardi & Thollander (2018) presents a ranking analytical ranking of industrial sector's organizational and managerial barriers to improving energy efficiency while Myers, 2020 explores gaps in energy cost information in Landlord-Tenant relationship.

While Thollander & Palm (2012) discussed four major categories of barriers including market failure(economic), market failure (non-economic, Behavioral and Organizational barriers, Fleiter et al. (2012) utilized technical and informational perspective, and relative advantage to come up with twelve distinct properties of energy efficiency measures. By using empirical study, theory and policy analysis, Fawcett et al. (2020) suggested that energy efficiency in SMEs are policy-neglected. As a result, the group focused on addressing data and evidence gaps. In his study on the role of policy intervention on energy efficiency, Cattaneo (2019) broadly classified barriers into internal and external. A level of barriers interaction is identified from Cattaneo which encompasses information, Regulatory, finance and economic programs in policy category, with several policy options within the domains of investment and energy. Munos (2017) cited the theory of Adam smith (1776) encompassing four types of market failure: Imperfect competition, asymmetric information, imperfect information and imperfect market. However, market failures are differentiated from barriers on the basis of characteristics and scope that should include operational, organizational and economic perspectives (Backlund et al., 2012). Vogel et al. (2015) Categorized energy efficiency barriers into four levels (Contextual, sectoral, component and project levels) based on structure of the system. However, this system does not align with the ports structure which is not only a structural system but a complex system constituting different interconnected subsystems, stakeholders and a global mandate.

Organizational barriers

Organization structures differ from one organization to another. As well there exists variations in departmental, sectional and individual cultures, priorities and interests. The ambiguities resulting from such rationalities can complicate optimization of decision making processes. Thus the formation of an organization can result in barriers to implementing energy efficiency measures, emanating from culture and power. Power plays where there are competing interests for scarce resources. Consequently, the status of managers can determine which projects can be prioritized. Lack substantive energy managers in many ports is a challenge that needs to be address. Ports energy manager can advocate for prioritization of energy efficiency resource allocations and investment. On the other hand, organizations are required to develop cultural complements such as norms, ideologies and knowledge that promote values centered towards energy efficiency and environmental matters, through sensitizations and awareness programs.

Technological barriers

Although there are several potential technological measures to reduce energy consumption and GHG emissions in ports, they are rarely implemented. While economists point out the lack of cost-effective measures of energy saving, Technologists consider failure to adopt energy efficiency measures which are cost effective, as the basis of technological deficiencies (Jafarzadeh & Utne, 2014).

Performance of technology influences economic viability of a given investment which in turn affects project survival. Moreover, Authority perspectives on uncertainty and risk factor of technology adoption is relative to the expected benefits of energy savings.

Economic barriers

One crucial approach for reducing energy use and GHG emissions in shipping is to invest in energy efficiency measures. However, decisions in energy efficiency investments are affected by numerous factors, hindering implementation of appropriate measures (Ares et al., 2020).

Most energy efficiency investments in ports are capital intensive especially cost of acquisition and installations. The funding mechanisms either external or internal are constrained due to factors like economic crisis which impacts capital cost. On the other hand, inadequacy of information on the benefits and returns by capital lenders as well as the borrower's financial risk of borrowing could be an obstacle in accessing capital. Technology investment risks and uncertainties may also determine attractiveness, viability, acceptability or rejection of a given port project. Thus market barriers influence the adoption and diffusion rate of energy efficient technologies regardless of economic efficiency. it is also vital to consider the cost-benefit analysis between policy intervention and implementing an EE measure in order to eliminate the impact of imperfect competition.

Information Barriers

Information plays an important role in closing the gaps in energy efficiency. However, precision, clarity, timeliness and simplicity of information as well as trustworthiness and reliability of its source is pivotal. As well, groups can be influenced to contribute to energy efficiency through incorporation of attitudes, habits and norms in awareness programs, and consistently promoting best cultural and behavioral practices in organizations. Lack of knowledge and information on the significance of modernized energy management systems (EnMS) and unawareness of availability of energy efficiency utility incentives leads to failure by ports authorities to identify cost-effective energy-saving opportunities. Principal-Agent relationship has also led to information barriers due to either unwillingness to share information or problems in information transmission. Insufficient data, irrationality or disagreement among parties may affect prioritization of projects by decision-makers.

Policy barriers

Any complex system of socio-economic and environmental impact has to be regulated through established policy frameworks either national or international. Policy makers utilize the organizational, behavioral and technological environment in understanding the different dimensions of energy efficiency and determining which policy interventions can cost-effectively address the gaps. As an example, the European Commission's (EC) initiatives including Voluntary agreement, Energy services Market, Long term agreement and support programs in finance were measures aimed at overcoming energy efficiency barriers through provision of financial support, increasing EE technologies' demand and energy cost. Nevertheless, high cost of energy may lead to diversion of energy-dependent activities towards low cost energy areas.

One way to build understanding of the benefits of energy efficiency in ports is for the authorities to actively participate in industry's energy efficiency programs, especially those organized by national and international energy agencies. This can help in developing knowledge and skills for energy resource planning and improve awareness in environmental permitting processes.

2.3.2 Review of methods

Based on the nature of studies and investigated sites, different studies employed different methods. Nevertheless, most studies in this area utilized qualitative analysis while a few used mixed methods of analysis. Rohdin & Thollander, (2005) used semi-structured interviews to conduct an exploratory study for the manufacturing industry. Vakili et al. (2022) applied a transdisciplinary approach with a proposal of five phases namely system analyzing, Goal setting, Scenario construction, Multi-criteria evaluation and strategy building for overcoming energy efficiency barriers for existing ship operations. For analysis, synthesis and results interpretation from previous literatures, Viktorelius et al. (2022) used three phased methods: findings summarization and identification of supportive and clear findings; findings comparison and aggregation; and Interpretation of findings based on core themes.

A qualitative survey based on exploratory technique was used by Dewan et al. (2018) to identify barriers to implementing operational measures for shipping energy efficiency while Johnson et al. (2014) utilized a snow-balling method to select interviewees and conducted structured interviews, emphasizing on energy management barriers and bottlenecks. To gauge Technology implementation as an energy efficiency and CO2 reduction measure in the shipping sector, Rehmatulla et al. (2017) employed a cross-sectional survey and involved major shipping stakeholders.

Although researchers strive to achieve credible results in their studies, data collection and validation has been identified as among the major challenges of qualitative research. Key drawbacks in data collation include time consuming data collection due to non-generalized results, access restrictions from key stakeholders, decentralized information and low coverage for projects which are non-bank financed. On the other hand, Ports are complex organizations involving many other influential stakeholders such as shipping companies, Regulators, energy suppliers, Ship owners, Tax agencies and other Government agencies that may impact energy efficiency measures. Thus it is crucial to diversify the qualitative assessment for the barriers to energy efficiency and GHG emission measures with a view to optimize credibility of the results.

In this context, this research adopts an exploratory qualitative technique based on Dewan et al. (2018). In order to obtain reliable data, survey questionnaires will be distributed online to participants' stakeholders with impacting roles in ports energy efficiency and GHG emissions. Based on implementation measures and perceived importance and priorities of the port, participants will provide expertise responses on barriers to improving port energy performance and reducing GHG emissions.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

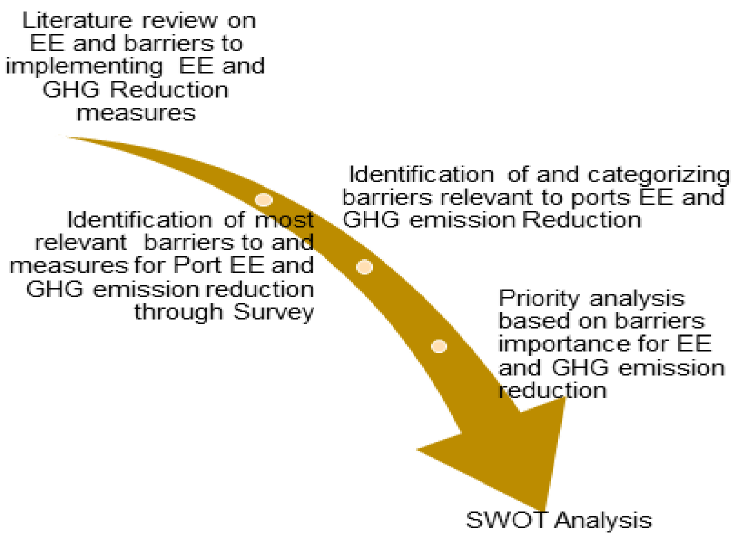
This chapter delves on comprehensive description of research methods, methodology and approach. It highlights how port barriers to energy efficiency were extracted from diverse literature and industry perspectives. It encompasses information on tools and procedures for data collection, presentation and analysis. Participants selection criteria from relevant stakeholders, their cadres and the sampling techniques are also discussed. In addition, guiding research ethics, protocols and procedures are also discussed in this section.

3.2 Methodology design

One key consideration for identifying actual barriers hindering implementation of cost-effective energy efficiency measures is to integrate the contributions of different port actors such as Shipping companies, Ship owners, Energy generation firms, Port cities, Environmental agencies and Regulators. Thus, it is important to consider concept designs when developing effective approaches to eliminate barriers.

As shown in figure 8, systematic literature review from several credible sources (peer reviewed Journal articles, reports and eBooks) related to the maritime sector is an initial step for identifying and nominating port-related barriers to energy efficiency and and subsequent categorization into disciplines. The diversity of Energy efficiency calls for careful segmentation with a view to nominate actual barriers directly influencing ports' energy inefficiencies.

Figure 8: Methodology flowchart



Source: Author

Although many techniques for reducing energy consumption in ports exist, most of these techniques are either not utilized or are underutilized regardless of their economic potential in removing energy efficiency barriers. This is due to the broader perspective of barriers (Vakili et al., 2022). For effective analysis of gaps in adopting energy efficiency measures, discipline categorization for barriers was conducted based on sectoral functionalities.

Since data pattern identification, hypothetically tests for assumptions and discovery of data anomalies requires critical preliminary investigation through graphical representation and summary statistics, this study utilized exploratory qualitative technique based on Dewan et al.(2018), with a view to attain easily interpretable solutions. Exploratory data analysis involves Graphics, tables or words that could be used as supplements to each other to achieve statistical communication (Du Toit et al., 2012) essential for conveying simplified and informal visual forms of trends and relations that are interpretable to the statistical layman. This study employed online Survey questionnaires to gather information on the priority levels for EE and GHG reduction measures. The results were then graphically presented and used to examine the key barriers for EE and GHG emission reduction measures for Mombasa port.

Finally, to conduct impact assessment of the organization performance relative to multi-perspective factors influencing the port energy efficiency barriers and to establish an effective framework to overcome port EE barriers, it is vital to understand Port’s strengths, weaknesses, opportunities and threats (SWOT) that affect efficient port operations through SWOT analysis.

3.3 Pilot Survey

Although many port- related barriers have been identified through the literature review process, it is important to bracket the key barriers through an insight into the current state of practice on barriers to energy efficiency. Therefore, it is crucial to explore observational methods prior to the main qualitative analysis. online google survey forms were utilized for conducting surveys, designed and intended for key actors in ports and the shipping industry with a view to extract main barriers hindering the implementation of ports energy efficiency and GHG emission reduction measures. Participants were expected to select from the literature review extracts, barriers perceived to be impactful in Mombasa ports. Analysis was based on the Importance or priority level of the identified barriers.

3.4 Qualitative Survey

In qualitative research, quality evaluation criteria are interconnected to ethical standards and encompasses good practice and trustworthiness in qualitative data interpretation. An effective qualitative research is centered on illumination of subjective actions, social contexts and meanings as understood by participants themselves (Fossey et al.,2002).

As discussed in the previous chapter, the explorative nature of this study calls for utilization of online survey questionnaires. Respondents selection was based on their responsibilities and experiences in port energy issues. Although the research involved multi-stakeholders, key was those with direct interactions with port activities in order to generate relevant output. The selection criteria for respondents was designed as illustrated in table 2.

Table 2: Participants selection criteria

Organization	Expertise	Experience
Port Authority	Energy management Environmental Administration Engineering(Electrical/Mechanical/Civil/Marine) Finance and planning Legal	3 years and above
Maritime Administration	Marine Engineering Inspection and Survey Marine environment IMO conventions	5years and above
Municipality (Port City)	Maritime law /Policy Circular economy	5 years and above
Shipping Companies	Port logistics and management Shipping Management	5 years and above

As shown in table 2, the respondents were drawn from different stakeholders with strict adherence to qualifications and experiences as indicated. This would upscale the credibility of the research output.

3.5. Sampling

Researchers employ different types of sampling techniques in order to systematically select subsets of data from pre-defined data sources for experimental purposes depending on the study objectives. Sampling is used where testing for all items in a bigger population is almost impossible. However, the samples are considered to be a true representation of the whole population in terms of time management, cost and convenience in research (Sharma, 2017). Sharma further classifies sampling into probability and non-probability sampling techniques.

Although the procedure for sampling is influenced by many factors, this research was mainly driven by the objective of the study and nature of the investigation. As well a sound judgment is required when selecting the respondents and the manner in which data is obtained to avoid ambiguities during analysis. While probability sampling regards importance of randomization in sample selection, non-probability sampling considers subjective methods in selecting elements for inclusion in the sample (Alkassim &Tran, 2015). In this context, non-probability, purposive sampling used deliberately to select participants based on their qualities was employed. In some cases, expert sampling is used as complement to judgment (Purposive) sampling to select the most information-rich persons guaranteed to give first hand expertise responses based on their vast experience on the subject topic.

3.6 Data collection

Plausibility as well as trustworthiness and objectivity of research findings could be achieved through semi-structured interviews that are rigorously developed and conducted (Kallio et al., 2016). Although it may be difficult to verbally engage the respondents, open-ended questions might challenge them to provide constructive feedback based on their experiences from outside the box, adding weight to the research findings.

This research involves a survey questionnaire with open-ended and closed-ended questions. The questions were designed considering clarity and where possible, examples were included. As shown in appendix A, the questionnaire starts with general questions to confirm expected understanding of the subject by participants. Next section delves on participants' perception on the port energy efficiency measures. This section will help the researcher to understand the port energy efficiency and GHG emission reduction state of practice. Part three deals with the categorized barriers to determine importance and priority levels of barriers in each discipline. Open ended question is contained in the last part of the questionnaire for the participants’ additional information related to the subject.

3.7 Data analysis

Fundamentally, qualitative analysis is case-based, where single or multiple entities of phenomena become the focus of research study. While qualitative data is visualized as intense, contextual, non-linear, engaging, challenging and highly variable with potential productivity for fresh insight and grounded understanding, data analysis should not be perceived as leaning towards participants' quotes (Bazeley, 2013). Thus researchers need to carefully study the responses of participants, highlighting emerging patterns, themes and categories in order to match identified similarities and recurrences. Henceforth, data analysis emanates from the research questions of the research study, followed by literature review where insights for better understanding of the barriers to energy efficiency and interpretation of findings were built. Central to the researcher's role in achieving his understanding of the participants' experiences and accurately interpreting how sense of participants' experiences is achieved, this approach helps to greatly improve the quality of findings.

3.8 SWOT Analysis

As suggested by Stavroulakis and Papadimitriou, 2015, SWOT analysis can be utilized to show precise strategic overview of and clear direction for achieving strategic objectives of a case under study. In order to determine the potential of Mombasa port in overcoming the barriers to implementing energy efficiency and reducing associated negative environmental externalities, an analysis of strengths, opportunities, Weaknesses and threats is crucial (Tseng & Pilcher, 2021). SWOT analysis technique being an instrument that is readily available will contribute in provision of an effective strategic framework for overcoming the barriers to port's energy efficiency by analyzing the situation.

3.9 Research Ethics

The main role of the researcher is to undertake independent research based on the approved research topic. Since this research involves human elements, it is the sole responsibility of the researcher to administer the survey questionnaire and interview where applicable and ensure a bias-free process. The researcher is also responsible for ensuring confidentiality and safe custody of participants' information, and seeking voluntary participation in the survey process.

In this context, survey questionnaires were administered to participants from port stakeholders who filled consent forms as a confirmation of voluntary acceptance of participation in the survey. Participants' data shall be discarded after successful submission, assessment of the research work by the University's Course Assessment Committee (CAC), and conferment of the degree Certificate.

CHAPTER FOUR: STATE OF PRACTICE ON PORTS ENERGY EFFICIENCY AND GHG EMISSION REDUCTION

4.1 Overview

Ports around the world have increasingly been pressurized and scrutinized in their energy activities and credibility of the environment (Sornn-Freise et al.,2021). This has resulted in shifting response towards mitigating impact of climate change through reduction of GHG emission (Du et al.,2019). Nations worldwide have designed and implemented Energy Efficiency Obligations(EEO) that obliges parties within their jurisdictions to comply with quantitative energy efficiency targets and other environmental objectives (IEA, 2012). These obligations are anchored in systems defining activities of energy production, consumption and saving measures to be implemented as well as verification and reporting procedures to meet the required targets.

Different studies with varying perspectives for strategies and measures for reducing GHG emissions from ports have been conducted for example ship-port interfaces (Acciaro & Wilmsmeier, 2015), Energy Efficiency (Martinez-Moya et al.,2019), Technical Measures (Jonathan and Kader, 2018), Hinterland transport (Bishop et al.,2012), Technical and operational (Alamoush et al., 2020) and policies (Sdoukopoulos et al., 2019). As well, regional studies and reports including EU projects such as European Seaports Organization (ESPO, 2018), Fit 55, European Union Green deal (EGD) and the report by USA San Pedro bay (DNV GL, 2016). Internationally, IMO introduced various studies (IMO, 2015, IMO 2018a) and International Association of Ports and Harbors (IAPH) reports e.g. (IAPH, 2020).

4.2 Port energy Measures

When a port provides clean energy in the form of Renewable energy, fossil-free fuel, or alternative power supply to end-users in port activities, it is said to implement energy measures.

4.2.1 Harnessing renewable energy (RE)

In pursuit towards more sustainable and decentralized power supply, and realization of growing energy needs, ports need to upscale investment and deployment of renewable energy and explore the potential of their strategic locations in harnessing Wind, Solar, Geothermal and Ocean energy (Hentschel et al.,2018). Alternatively, ports can utilize initiatives in Renewable energy purchase in situations where direct generation and use of RE is impossible (Kandiyil, 2022). It is arguably possible to significantly reduce Carbon Dioxide (CO_2) by up to 80% and attain energy saving of about 84% by combining two or more REs (Fahdi et al.,2019).

Port of Amsterdam's investment of 28.2MW wind power, 45MW investment by Antwerp and 200MW wind power in Rotterdam (Green efforts, 2014) are evidences of significant potential for wind power. Similarly, Rooftops of warehouses, Buildings, Yards and open fields in port areas can be used to build solar panels to generate electricity by photovoltaic (PV) system or Solar Heater Systems(SHS). Studies conducted in Egyptian ports have shown that incorporating solar energy can considerably reduce emission (Kotrikla et al.,2017), enhance ports' greening (Iris & Lam, 2019) and reduce cost of energy (E-Harbors Electric, 2012)

Additionally, Electricity can be generated from heat energy stored from the earth (Geothermal). EU ports including the port of Hamburg and Antwerp are exploiting geothermal energy (EU Green Effort, 2014). As well, Ocean temperature difference, salinity, tides and ocean waves can be exploited in different capabilities to generate Ocean energy.

Table 3: Renewable energy capabilities

Renewable energy	Power generation capability(MW)	Applicability
On-ground Solar PV	>50MW	High expertise and mature technology; High energy efficiency
Rooftop Solar PV	>2MW	
Tidal Energy	>0.75MW	High energy efficiency, Multi-applicability and acceptability; Suitability in large ports
Wave energy	>250MW	
Wind Turbine	>6MW	High energy efficiency in unallocated space; Large ports sustainability
Geothermal Energy		Low expertise technology; High acceptability; High efficiency

Source: Pianc,2019; Hoang et al.,2022

4.2.2 Alternative fuels

The comparative low cost of Heavy fuel oil (HFO) and diesel oil has led to its dependence by shipping sector. This has significantly contributed to increased Sulfur oxide (SOx) emissions in ports areas due to heavy combustion by calling ships and by the cargo handling Equipment (CHE) generators. While diesel sulfur content is about 0.5%, HFO emits about 2.5% of sulfur content (Hoang et al.,2022). One way of lowering air pollution in particular CO2 is by shifting from the use of HFO to marine Diesel Oil which has a reduction potential of 5% per fuel tonnage (IMO, 2010).

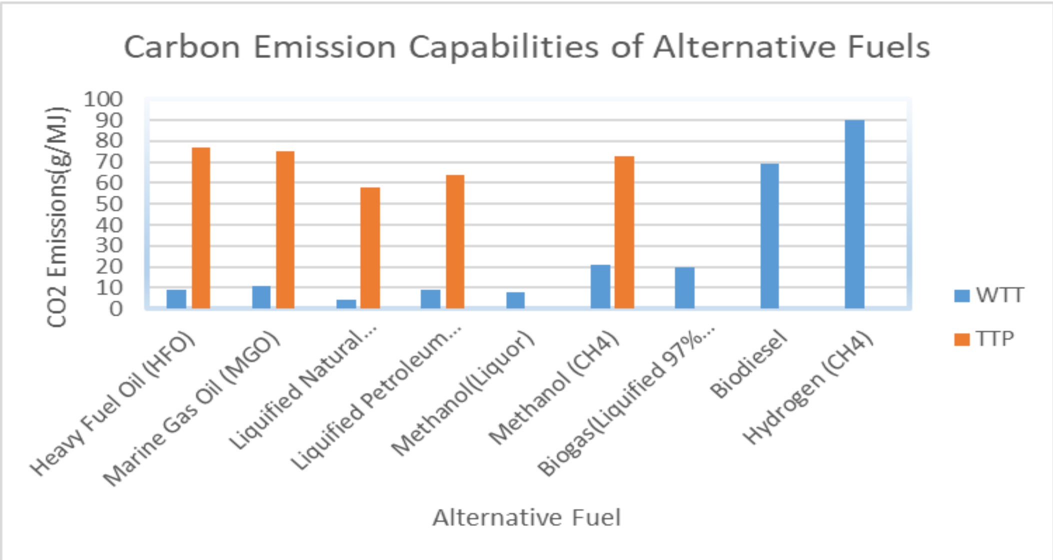
On the other hand, LNG is a promising fuel for clean shipping due to its relatively lower GHG emissions and other pollutants (Carbon, PMs, NOx, Sox), and lower energy density (IMO, 2009). Despite infrastructural, operational and regulatory challenges (Schinas & Butler, 2016), various ports employ LNG in their operations. Port of Rotterdam, POLA and POLB utilizes LNG for powering crafts and mobile equipment.

Biofuels which can be generated from bio waste from industries, ships and ports are also potentially environmentally-friendly options with high CO2 reduction capabilities

(Gaurav et al.,2017) considering its simplicity in storage and handling, emission reduction potential, high energy density and diversity of production materials (Olcer et al.,2021). Methanol is another potential alcoholic fuel despite its low energy density.

Apart from LNG and Biofuels, Hydrogen and Ammonia are among the most promising clean fuels. PMs, SOx and CO2 emissions in Hydrogen are nearly zero. Considering its Life cycle assessment (LCA) in shipping, and per transport work, Hydrogen has 40% carbon emission reduction potential (Biser and Dinser, 2018). Ammonia on the other hand is Carbon free fuel with a potential system efficiency of approximately 44 Percent. Hydrogen is applicable in fuel cells while domestic Ferries, boats and electrical generation can utilize Ammonia fuels. Spain's Port Valencia is an example of ports utilizing hydrogen while POLB and POLA applies Hydrogen in mobile equipment.

Figure 9: CO2 emission capability of alternative fuels in shipping



Adopted from DNV GL 2018

4.2.3 Alternative source of power

Different ports are exploiting different power saving and clean energy opportunities through utilization of technological measures with lower GHG emissions levels than fossil fuels particularly for running generators and engines. Such measures include Hybridization and Electrification of CHE.

Terminal equipment hybridization can take the form of Electric plug-in for vehicle rechargeable batteries, Electric-fuel such as battery and engine or Hydraulic-diesel hybrids. Helsingborg Port for example utilizes hybridization in Reach stackers while Spanish ports and POLA uses Electric-Hybrid RTGs. According to Wei et al.,2018, RTG hybridization can achieve energy saving of up to 70%.

Although Electrification is rarely used in ports' bulk handling equipment such as Rail Mounted Gantries (TMGs), Shore to Ship cranes (STSs) (Alasali et al.,2018) widely use fully electrification in addition to battery-electric. Ports e.g. US's San Pedro bay uses electrification of Yard trucks, Rail movers, Forklifts while RTG electrification is utilized by POLB(SPBP,2017).

4.3 Port Equipment Measures

Equipment measures are applicable in CHE, Air Conditioning systems, Lighting and Harbor crafts such as tugs. Equipment aging or degradation can result in increased GHG emissions due to increased functional inefficiencies. To sustain energy efficiency of such equipment various ports considers replacement and repowering processes. New York replaces their trucks with new ones based on their duty cycle of 5-10years while San Pedro Bay are guided by the Clean Air Action Plan (CAAP) for old CHEs replacement after set duration of time. On the other hand, RTGs retrofit as suggested by Martinez-Moya et al. (2019) has a 43% reduction potential for CO2 emissions.

4.4 Port information measures

Ports use emission inventories and energy consumption data to set emission baselines, track and continuously report emissions. Ports such as POLB and POLA have established air and weather monitoring whereas Canada's Port Halifax traces gas concentration utilizing spectrometers (Gonzalez Aregall et al., 2018; Wiacek et al., 2018). Moreover, in the EU, there is a well-established culture of Auditing and monitoring for Energy and Environment. However, Emission quantification approaches may vary from port to port. For example, some ports operations are based on ship data and AIS systems while others are based on fuel purchases and consumption (Poulsen et al.,2018). Thus ports need to broaden their emission sources visibility in order to account for and identify significant port emitters through proper documentation of all operations data.

4.5 Ports Energy efficiency measures

Ports endeavors to minimize wasted energy by maximizing consumption efficiency. One key indicator of a green port is energy saving. However, this requires ports to develop ambitious energy efficiency programs and adopt RE measures. For example, 20% of EU ports adopted RE measures (Chen & Yang, 2018).

4.5.1 Energy Saving Measures

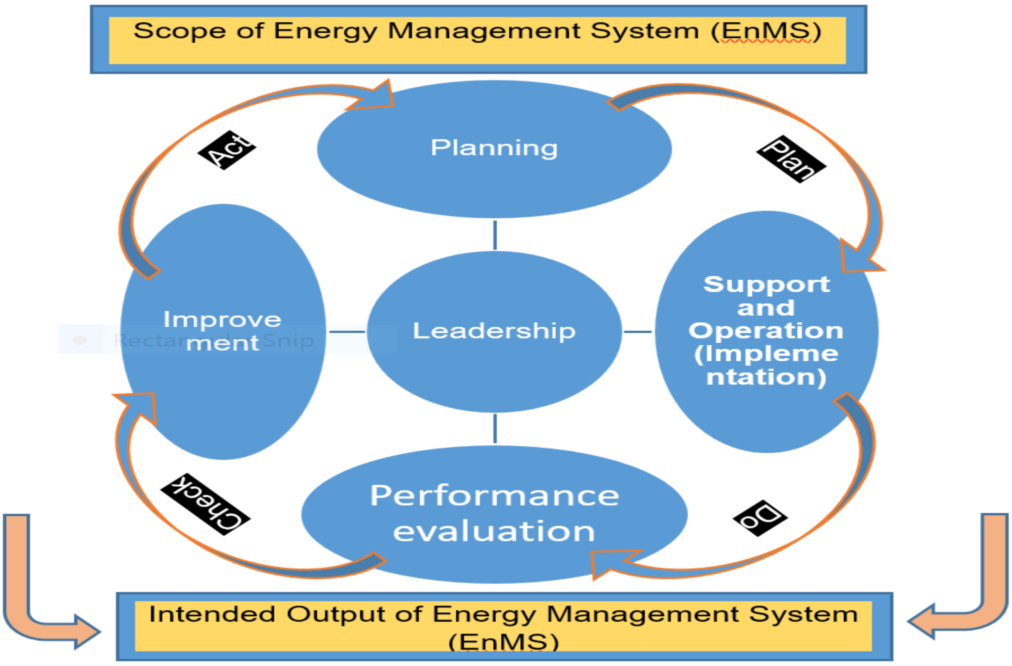
Any measure implemented by port that contributes to overall reduction of consumed energy also couples as energy efficiency contributor. This can be achieved through various ways. The Port of Venice has realized an energy saving of about 80% by implementing LEDs in its Yards, Docks, tugs and warehouses while Rotterdam attained annual CO2 reduction of 1000 tonnes (Van Duin et al.,2017). Finnish Ports on the other hand uses Automatic sensors and lighting controls.

Other measures include slow steaming, updating Global Positioning System (GPS) and Electronic Charts which has a potential fuel saving of 10%. In addition, staff training and awareness in energy efficiency, environment and eco-driving can reduce fuel consumption and repair cost by about 15% (Sdoukoupolous et al.,2019). Further energy saving can be achieved by tire pressure control, Energy storage systems and flood light in CHE (Schmidt, 2019).

4.5.2 Energy Management Systems

In pursuit to address environmental priorities, ports are required to work extensively to establish policies, set up target action plans, proper management systems and frameworks as prerequisites for identification of right implementable measures and solutions with a view to achieve substantial energy saving and environmental benefits. Successfully addressed environmental concerns reflects Port Authority's commitment for energy performance improvement. Plans for implementation of various energy efficiency measures are encompassed in the Energy management system (EnMS). EnMS such as ISO 50001 can be easily integrated into other organization's management systems e.g. ISO 14001 Environmental Management System (EMS) and ISO 9001 Quality Management systems. EnMS utilizes the Plan-Do-Check-Act (PDCA) framework for continuous Energy Performance improvement (ISO 50001: 2018).

Figure 10: Energy Management System based on PDCA approach



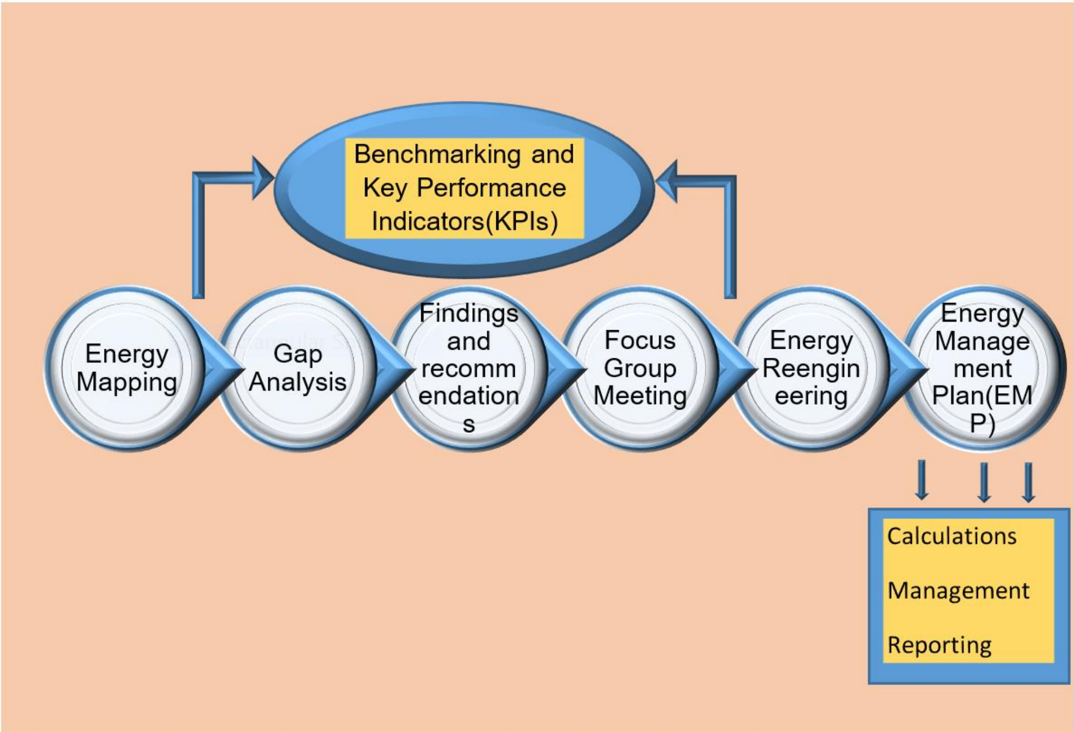
Adopted from: ISO 50001 (2018)

The Planning stage involves understanding of the Organization (Port) and setting up energy policy, establishing Energy team, identifying significant Energy Users (SEUs), and action plans for achieving energy targets. Implementation support and Operation mechanisms involves identification and allocation of responsibilities to appropriate Energy team members and creation of timelines. Nonetheless Leadership is central to any EnMS. Properly implemented EnMS can potentially improve ports energy saving as well as competitiveness.

4.5.2.1 Energy Management Plan (EMP)

From production to distribution to consumption, energy planning and management is crucial. Port energy management planning can result in significant reduction of energy use hence reduced cost, GHG emissions, Peak loads and also help raise energy policy awareness to port actors and decision makers (Pavlic et al.,2014).

Figure 11: Developing Port Energy Management Plan



Adopted from: Boile et al. (2016)

Globally, many ports have continued to implement EMPs. In addition, Key Performance Indicators (KPI's) are increasingly becoming crucial Port energy management elements which ports adopt to publicly avail their carbon footprints. Ports such as Genoa, Antwerp, Rotterdam employs EMPs (ESPO 2018).

4.5.2.2 Energy Storage systems(ESS)

Kotrikla et al. (2017) suggests that to avoid problems of electricity fluctuations from national grids and standalone RE utilization, generated RE can be integrated with

ESS where excess energy can be stored and feedback to the local grid when required. Although further simulation and modeling studies are required for Ports decision-making, ESS such as Flywheels and Batteries used in RTGs can achieve energy saving of about 30% and 57% respectively.

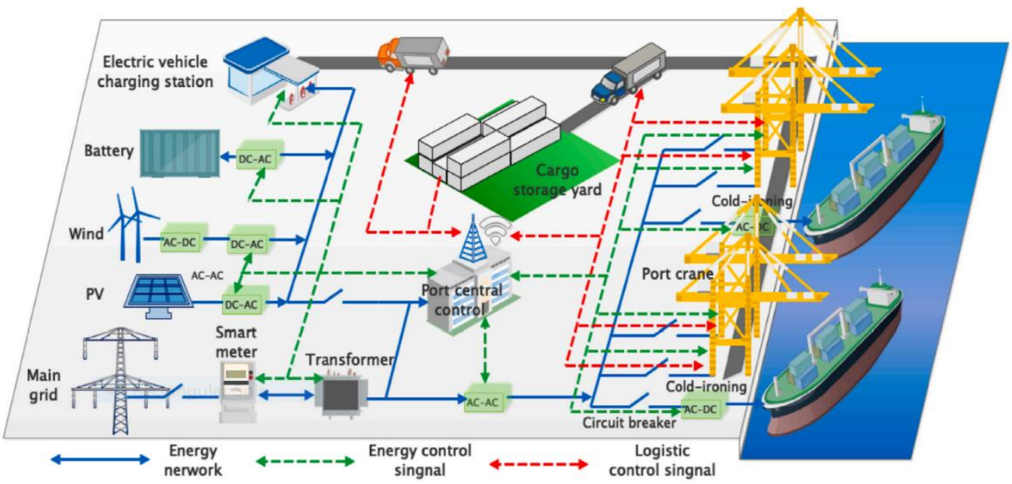
4.5.2.3 Smart load Management (SLM)

SLM smartly addresses electricity fluctuations by smart load shifting where high peak electricity demand is moved to lower demand period with an aim of minimizing electricity consumption and bills at high peak times. Terminal load management has been addressed in various studies e.g. demand forecast of electrified RTGs, Load forecast in Felixstowe and energy balance for port cranes (Alasali et al.,2018; Parise et al.,2015). Power demand can also be managed by peak sharing or application of load shedding during peak times by using yard lights, HVACs, Intelligent sensors, reefers, Office heating or cooling (Van Duin et al.,2018).

4.5.2.4 Smart Grids (SG) and Virtual Power Plants (VPP) and Micro grids

SGs incorporates VPPs functionally to remotely control and aid in decision-making on appropriate timing for using power generation facilities including combined heat and power (CHP) plants and generators.

Figure 12: Smart grid Energy management scheme



Source: Fang et al.,2019

SGs can integrate CHE ESS and reduce CO2 emissions. SG concept has become a center of discussion in present day's ports projects especially in the EU ports projects.

By utilizing VPP, Ports can increase their potential to reduce GHG emissions, harness RE and improve energy security. On the other hand, Micro grids (Energy Islands) are projected to be future ports energy management systems that meet energy regulations, emission requirements and electrification standards. POLB employs micro grids (DNV GL, 2016), while Ahmad et al. (2018) has discussed its sustainability benefits and suggested possible integration with Cold Ironing in ports.

4.6 Ship-Port Interface Measures

There is a positive correlation between number of port calls and magnitude of ports emissions (Styhre et al.,2017) with ships arguably responsible for 18M tons of global CO2 emissions. Depending on factors such as terminal size and technological maturity, ports apply different measures to reduce ship-related emissions and improve energy efficiency,

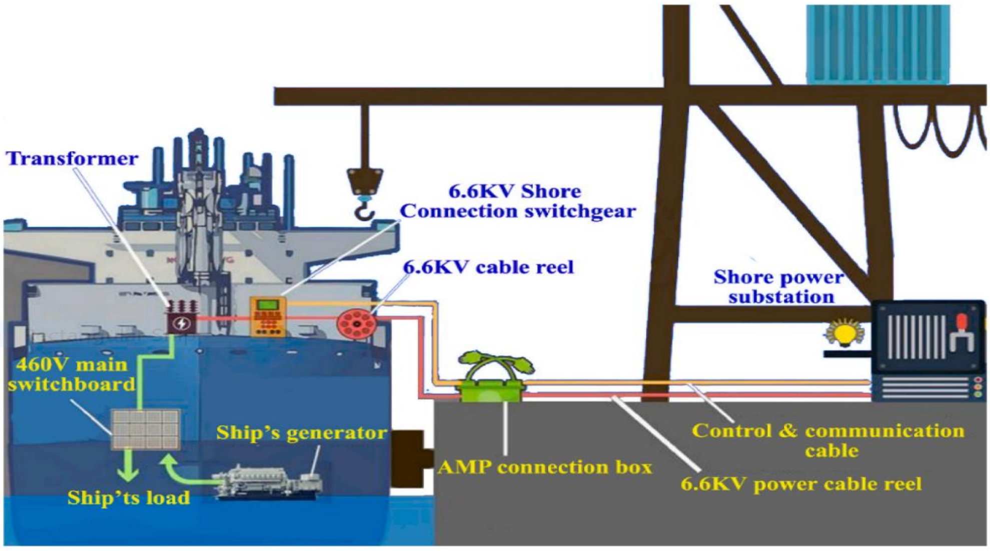
4.6.1 On-shore Power Supply(OPS) and Alternative Fuel Bunkering

Fulfilling ships' power requirements through connection to the local ports grid while at berth could substantially reduce air pollution by ships. Depending on the source of electricity, this approach is perceived to be potentially effective in GHG emission reduction (Styhre et al.,2017). Zis et al. (2014) suggested that up to 70% abatement can be achieved with OPS.

Despite the high cost and complexity of OPS infrastructure, various ports have continued implementation. Norway achieved 99% CO2 reduction by applying Hydroelectricity while France attained 85% CO2 abatement using Nuclear power. WPCI indicated that, globally, there is a slow uptake of OPS with about 28 of the large ports implementing OPS in specialized terminals (Bergqvist and Monios, 2019).

Alternatively, ports are increasingly initiating fuels bunkering infrastructures and mobile bunkering facilities for alternative fuels including Methanol and LNG. Examples of implementing ports include Gothenburg, Rotterdam and Stockholm (Fung et al.,2014) while regional plans for implementations in US ports, EU Ports, China and Australia are underway.

Figure 13: Connectivity of Onshore power supply



Source Agarwal, 2020

4.6.2 Reduction of Ship Turnaround Time(TAT)

Some of the benefits for reducing TAT for ships in ports includes increased berthing throughput and improving productivity. Moon and Wonn (2014) suggested that 37% CO2 abatement can be achieved by reducing TAT while Johnson & Styhre, 2015 reported that up to 8% energy saving can be achieved by reducing TAT by 4hours. TAT measures include Yard scheduling, Berth Allocation, Automated mooring system (AMS) and midstream operation. By applying AMS, Port Santander estimated 70% CO2 reduction (Piris et al.,2018). Ports of Netherlands, Finland and Denmark also embrace AMS.

4.6.3 Virtual Arrival (VA), Just in Time (JIT)

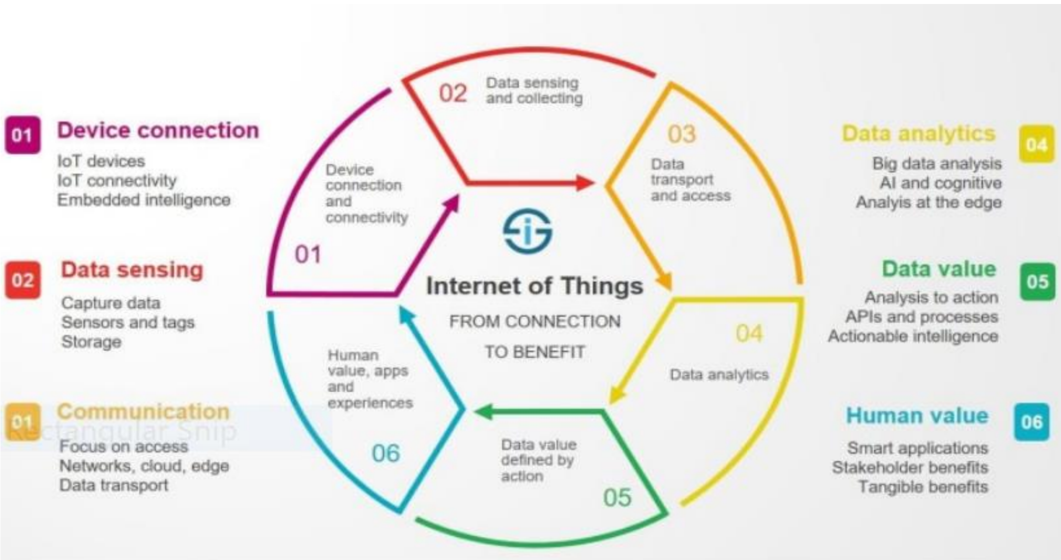
Due to facors berth congestion or inadequate space ports and ships could communicate and agree on suitable arrival time which may call for vessel speed reduction along the voyage (Jia et al.,2017). Vessel speed reduction while approaching or leaving port earlier reduces emissions and fuel consumption. Bergqvist & Monios (2019) estimates that 20% VSR can achieve 40% fuel saving and 7% CO_2 emission reduction.

4.7 Operational measures

4.7.1 Digitalization

Ports utilize digital solutions e.g. Internet of Things (IOT) and intelligent logistics such as big data analytics and remote sensing for monitoring ports logistics, smart operations and fuel consumption with a view to optimize their operational efficiency and energy consumption (Wand et al.,2015; Azturk et al.,2018).

Figure 14: Application of Internet of Things



Source: I-SCOOP (2020)

Remarkably, information exchange between shipping lines and terminals can be smartly facilitated using one-stop E-business portals and Electronic data Exchange (EDE). Cloud computing and big data is used by Singapore port while Hamburg employs 3D printing technology. POLA utilizes Centralized maritime information portal (SPBP, 2017), Antwerp port utilizes block chain, Rotterdam applies IOT for repair and maintenance.

4.7.2 Green Port Policies

In response to the stricter IMO environmental regulatory requirements, Ports are expanding their green ports initiatives to promote public welfare and sustainability through environmentally-friendly operations from ships and ports (Kim et al.,2014). Green policies applied by ports include green procurement, green dredging and towage, green electricity, green commuting, eco driving, green berthing and green buffer zones (IAPH, 2008; Acciaro, 2014; I2S2, 2013). POLB employs green planting to develop green buffers while Zeebrugge uses green electricity purchase, and Panama Canal applies green berth allocation for green ships.

4.7.3 Port-City Integration

Port sustainability in development and governance models calls for upgrading of knowledge, upscaling of partnerships on coastal ecosystems (Schipper et al.,2017). And establishment of multi-functional framework for designing and operating port infrastructure (Wesenbeeck et al.,2016). Ports - Cities collaboration areas include Waste management, Waste-to-energy generation and Circular economy. Remarkable cooperation initiatives include Hamburg's port-city eco-partnership focusing on CTs, recycling hubs established by Japanese ports and Rotterdam’s waste-heat initiative (Notteboom and Lam, 2018; Woo, 2018).

4.8 Land transport Measures

Ports play an intersectional role in the shipping sector. Although Hinterland emissions are arguably lower than emissions from shipping, hinterland can exceed CO2 emission levels of port operations. Gibs et al. (2014) showed that Fellixtowe hinterland traffic emission reached 138Kilotons of CO2, 67 Kilotons more than the port emissions. Thus Ports are required to expand their responsibility to the hinterland through implementation of appropriate emission reduction measures such as Modal split, Reduction of truck congestion and truck emissions reduction

Banning of old emitting trucks is implemented by ports of Seattle and POLB, a strategy that projects annual CO2 emission reduction of up to 46% by 2031 (SPBP, 2017). CO2 emissions can also be significantly reduced by intermodal transport (IMO, 2018).

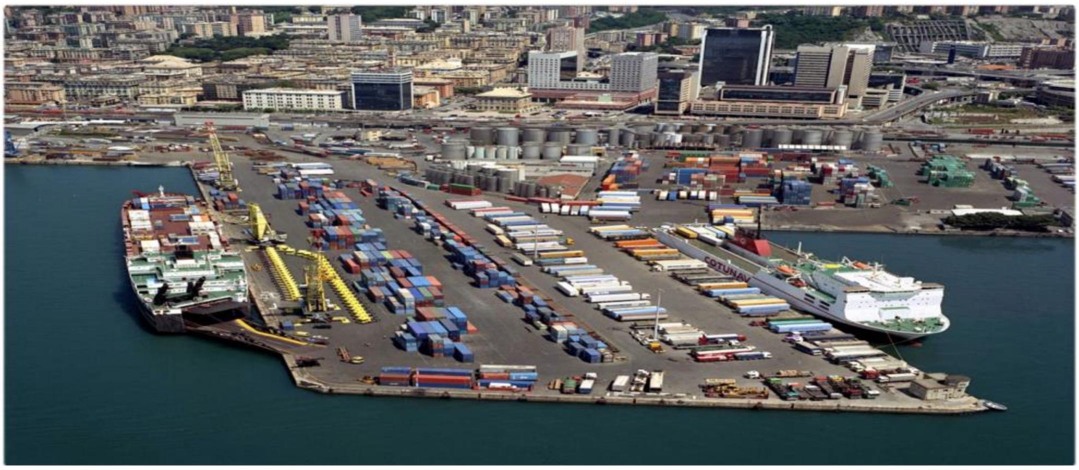
Gothenburg Port in Sweden utilizes rail shuttling, attaining 70% energy saving. EU ports are supportive to Rail links, Dry ports and TEN-T concepts to upscale their logistic operations. In pursuit to reduce track congestion, ports such as Vancouver in Canada utilizes the truck appointment system while Hong Kong employs Smart Identification for tractors. Thus, numerous land-based cost-effective measures exist that could enhance ports economic growth and environmental requirements**.**

4.9 Benchmarking studies

4.9.1 Genoa Port (GPA)

Genoa port is owned by the Liguria municipality and managed by the Port Authority of Genoa. GPA occupies a land size of approximately 700 hectares, extending through 22KM length of coastal strip. A breakwaters system protects the port from the open Seas.

Figure 15: Aerial View of GPA



Genoa Port Energy Efficiency Potentials

GPA has been proactive in planning and implementing energy measures through the Port Environmental Energy plan (PEEP) with a view to improve energy performance and environmental development in the port area. Based on the 2011 baseline, GPA projected a 197,000 tons saving on Carbon emissions by 2020 (Acciaro, 2014).

Table 4: Genoa Port Energy Efficiency Potentials and barriers

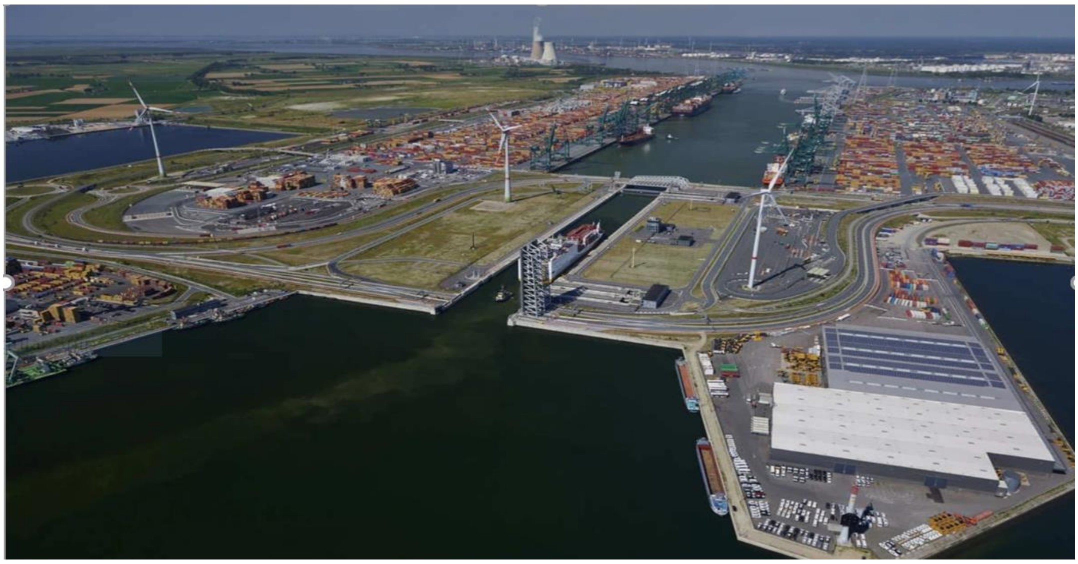
Energy efficiency Measures	Port Potentials	Barriers
Energy measures	Geothermal Energy generation through feed sea water to heat pump	Evaluation of environmental impact and technical requirement
	Solar Photovoltaic projects	Port own premise while concession given by private terminal operators (Governance model and management) Lack of unilateral role/Independent action by port management
	Wind energy production	Long and costly adoption procedure e.g requirement for 1 year onsite monitoring (Policy)
	Incentives by regional and local Government for Renewable energy use	-Legislative processes/Policies (GP cannot engage direct in energy production without legislative amendment
	Policy interventions through EU conducive for Genoa port to develop and Implement RE strategies	-Interaction with different institutional levels that are legislatively involved in energy matters
		Complex processes for port to implement energy policies
Equipment measures	Quay electrification project Collaboration (National Government, Regional Government and Port Authority)	
	Infrastructure expansion to increase capacity (Bettolo and Derna Quays)	
Informational measures	Awareness and training for port operators on energy saving and sustainable development	
	Monitoring and reporting a collective responsibility to terminal operators	No shared specific disaggregated energy consumption data(limited information sharing)
		Lack of personnel and resources to conduct energy diagnosis-to evaluate port energy reconversion capabilities
	PEEP created awareness to uninformed companies about the role and presence of Energy management coordinator	Lack of awareness, education and preparedness by locals on policy requirement for RE installation in their buildings
	Emission inventories through spatial planning policies-supported by EU project APICE	
Port-City integration	District heating policy (aimed at Port as energy reservoir) Stakeholders engagement (Private actors, University, Muvita, National research Council)	
	Smart City projects with support from the EU (Access to external funding)	
Onshore power supply (OPS)	Abatement potential of about 80%	Transfer of energy efficiency policies to the City's Industrial districts

Genoa port has characterized itself as an energy promoter. As shown in table 4, Genoa port endeavors to implement energy efficiency measures. Although the port has several energy potentials, barriers exist in successful implementation of these cost-effective practices.

4.9.2 Port of Antwerp (POA)

Germany's Port Antwerp is the second largest European port handling an annual freight of over 240 million tons. Moreover, POA is the largest Maritime logistics and industrial platform in Europe. In terms of Governance, Antwerp Port operations are managed by Antwerp Port Authority. With a daily average of 39 sea going ships, the port is capable of handling the largest vessel in the world.

Figure 16: Overview of POA



Source Donnelly, 2022

POA has up scaled its ambitious targets for continuous emission reduction, through sustainability actions in energy transition, research and greener ports initiatives (Demir et al.,2022). In terms of renewable energy measures, Antwerp port produces green heat by solar energy sources as well as biomass energy. POA also has an annual wind energy potential of 200MW in addition to the project dubbed Power-to-Methanol which is aimed at reducing Carbon emission by about 800 tons, and the work-in-progress hydrogen generation process.

Port of Antwerp Energy Efficiency Potentials

Guided by its Goal-Oriented transition framework that encompasses collaboration among partners POA aims to achieve its 2050 climate neutrality target. The framework which is aligned to six (6) UNSDGs involves a plan of actions on improving port accessibility, port systems, integrated digitals network and efficient port energy management. The six UNSDGs in focus are: Goal 3 (Good Health and well-being), Goal 8 (Decent work and economic growth), Goal 9 (Industry, innovation and infrastructure), Goal 11 (Sustainable Cities and community), Goal 13 (Climate Change action) and Goal 17 (Partnership for the goals).

Table 5: POA Energy efficiency projects and state of practice

Energy Projects	**Shipping Projects**	**Industry Projects**
Expansion of offshore wind production capacity (Hyoffwind)	Tugboats on Methanol and H2	Anterp@C-CCS
Coalition on Hydrogen import (Pilot)	Onshore Power Supply (OPS)	NextGen District (Circular Economy hotspot)
Sustainable flow back born(CO2, Waste-Energy, H2)	Offer on Alternative fuels(Multi-fuel Port)	Power to Methanol for Green Methanol Production(CCU)
Alternative Fuels	**Vessel Port Authority**	**Digitalization**
LNG powered vessels	Hybrid Patrol Vessels	Energy Generation, Distribution and storage systems
LNG Bunkering Sea going vessel	Methatug	Data Management
Shore to Ship LNG transfers	Hydrotug	Advanced metering
LNG loading station for Bruges and Tankers	RSD Energy Efficient Tugs	Utility Communication
		Efficient building systems
Energy Management Systems(EnMS)	**Transport Connectivity**	Consumer portal and building EnMS
ISO 14001 EnMS	49200 Barges annually	Dynamic control systems
ISO 50001 EnMS	Well connected International motorways to Europe (Hinterland)	Smart end user devices
	1000KM track of rail (130 trains/day)	
	1000KM pipeline	

Adopted from POA Bruges, 2022

With a strong conscience in EnMS implementation, and as a front runner in energy transition, POA has continuously invested in sustainable projects within Energy, shipping and industrial sectors that has positively impacted energy performance and economic growth.

It can be noted that, regardless of Ports Governance models, either Public ports, Landlord, Municipality or private owned, Ports energy efficiency and GHG reduction strategies remain a global challenge. The vital intersectional role of ports in mitigating climate change, credit environmental condition and improve energy performance is hindered by among other factors, lack of standards and diversity of alternative measures. However, regional policies such as ESPO, EU play an important role in implementation capabilities of EE measures to member ports. Nevertheless, ports should integrate Energy efficiency in their strategic plans in order to achieve energy efficiency and environmental tartgets.

CHAPTER FIVE: CASE STUDY OF MOMBASA PORT

5.1 Overview of port Governance Model and Operations

Mombasa port is the main Government-owned seaport in Kenya. The Government's Seaports' management and operations are under the Kenya Port Authority (KPA), an agency established under the act of parliament on 20th January, 1978. Besides handling Marine Cargo, terminal operations, Stevedoring and shore handling services KPA is also mandated to oversee other supportive and infrastructure developments including Port expansion and establishment of other scheduled small ports along the Kenya coastline and Inland waters.

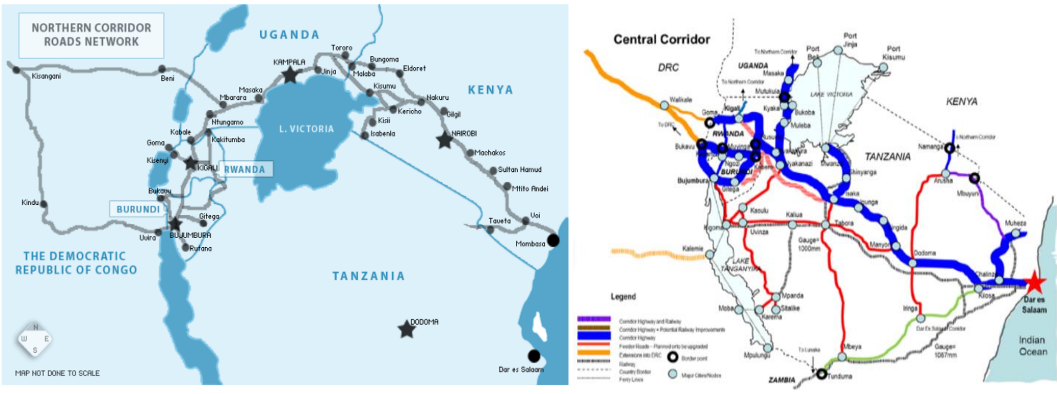
Geographically, the port lies at 04º 04' 13.0" S and 39º 39' 52.0" E. Mombasa Port is strategically positioned as the gateway to East and Central Africa through the East and Northern corridors. It is bounded by the Mombasa Port City and extends to the vast hinterland of Uganda, Rwanda, Democratic Republic of Congo, Burundi, Ethiopia, South Sudan and Somalia through Rail and Road transit transport infrastructure. Being among the top 120 global container ports and ranked among top six in Africa, the port of Mombasa is among the busiest African ports connecting with over 80 ports globally and serving more than 40 shipping lines.

In terms of operations, Mombasa port has continuously recorded improved annual performance. According to the port Authority, 26.17Million tones were handled between January and September, 2021, a 1.12 Million (4.4%) increase compared to corresponding period in 2020. Container volume traffic also recorded a 9.3% (93467 TEU) increase by registering 1099554 TEUs up from previous year's 1006087 TEUs during the same period, and a record increase of daily container throughput of 4662

TEUs against 4279 TEUs in 2019. As well, the port also maintained a lion share of the domestic market at 65.2%.

Figure 17: East African corridors

(a) Northern corridor (b) Central corridor



Source: Northern Corridor Transit Transport Facilitation Authority; Central Corridor Transit Transport Facilitation Agency

5.2 Power Sources and Requirements

Electricity from the national grid is the main power source for Mombasa port, supplied at 132 KV rating. The Port electricity is supplied through two Metered-substations of Kipevu and Shimanzi at 33/11 KV and later stepped down and distributed to the entire port facility through substations of varying ratings power (e.g. 415V, 3.3 KV and 11kV). In addition to electricity from the national grid, standby diesel generators are also utilized to provide operational continuity in case of power failure. Energy consumption data relies heavily on meter readings and billing by the utility company, Kenya Power that is analyzed through worksheets, and generators' fuel consumption cost based on prevailing cost of fuel.

5.3 Mombasa Port Energy Policies and Environmental strategies

Like many other ports from developing countries, Mombasa port being a public port is obliged to abide (to the highest standards) by the national energy regulations provided for by Energy Act 2006 and Energy Act 2019, stipulating the Authority's obligations in Energy efficiency. Under these Acts the Authority's requirement is in coordinating, developing and implementing Energy efficiency measures including Energy conservation, Energy Auditing and Energy Analysis of the Authority's facilities taking into account the required Standards, criteria and procedures.

There are no standard international energy regulations for ports. However, due to the strong linkage between Ports and Ships. Like other ports, Mombasa Port have endeavored to implement recommended energy efficiency measures aligned to IMOs MARPOL Annex VI in order to contribute to the global mitigation efforts for climate change and reduce energy consumption level with a view to reduce its operational costs as well as negative environmental externalities.

Environmentally, the Port of Mombasa has implemented its Green Port Policy (GPP) that can be well incorporated with ISO 14001 Environmental Management System (EMS) which was implemented in 2015. The GPP is aimed at improving the overall environmental impact and reducing emission levels resulting from port activities as well as establishment of a framework for meeting international standards. Although The port has adopted and implemented ISO 9001 quality management system (QMS) and ISO 14001 both of which are based on Plan-DO-Check-Act (PDCA) approach, Implementation of ISO 50001 Energy Management System (EnMS), which utilizes the same framework is yet to be realized.

5.4 Port Significant Energy Users (SEUs)

The key energy consumers of the port include Buildings, Container terminals, Quays, reefers (Lighting and Air conditions) as well as Electricity and fuel supply for Cargo handling equipment (CHE) e.g. RTGs, STSs, Reach stackers and other mobile equipment such as Forklifts;

5.4.1 Mombasa Port Lighting

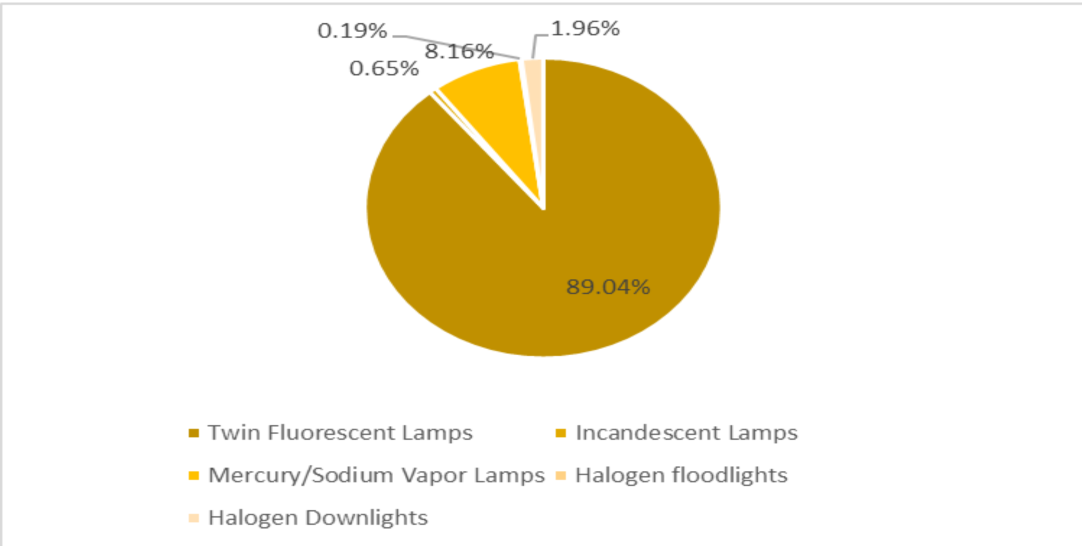
Table 6: Mombasa Port lighting consumers

Energy Consumer	Type	Normal Rating range(W)	Equivalent LED Rating range (W)	Quantity
Lighting	Twin Fluorescent Lamps	18 - 58	9 – 20	1909
	Incandescent Lamps	75	5	14
	Mercury/Sodium Vapor Lamps	250 - 600	40-140	175
	Halogen floodlights	400	70	4
	Halogen Downlights	50	11	42
Total				**2144**

Source: adopted from MTTC Africa, 2019

As shown in table 6, power rating range for LED lamps is much lower (5-140 watts) than the normal used ratings (18-600watts). Thus, replacement of traditional energy inefficient lamps with LED equivalent could result to significant energy saving. For example, LED equivalent for incandescent lamps can potentially achieve up to 93% saving while Halogen floodlights equivalent could attain up to 83% energy saving.

Figure 18: Mombasa port lighting Lamps by type



5.4.2 Port Equipment

The Port's equipment and facilities are distributed to four sections of the port facility (Marine, Container terminal, Conventional cargo and transit market offices).

Marine equipment and facilities encompasses the Port's 21 berths including the four container terminal berths 16-19, 12 Anchorages (A-W), a 306.6M long multi-purpose Mbaraki Wharf, 9 Mooring Buoys (K1-K4; M1-M5), three Oil Jetties (SOT, KOT and a Newly Launched KOT) and Tugs.

Container terminal includes berth numbers 16,17,18 and 19, with a total of 341 equipment including Goosenecks, forklifts, Mobile cranes, STS cranes and Gantry cranes.

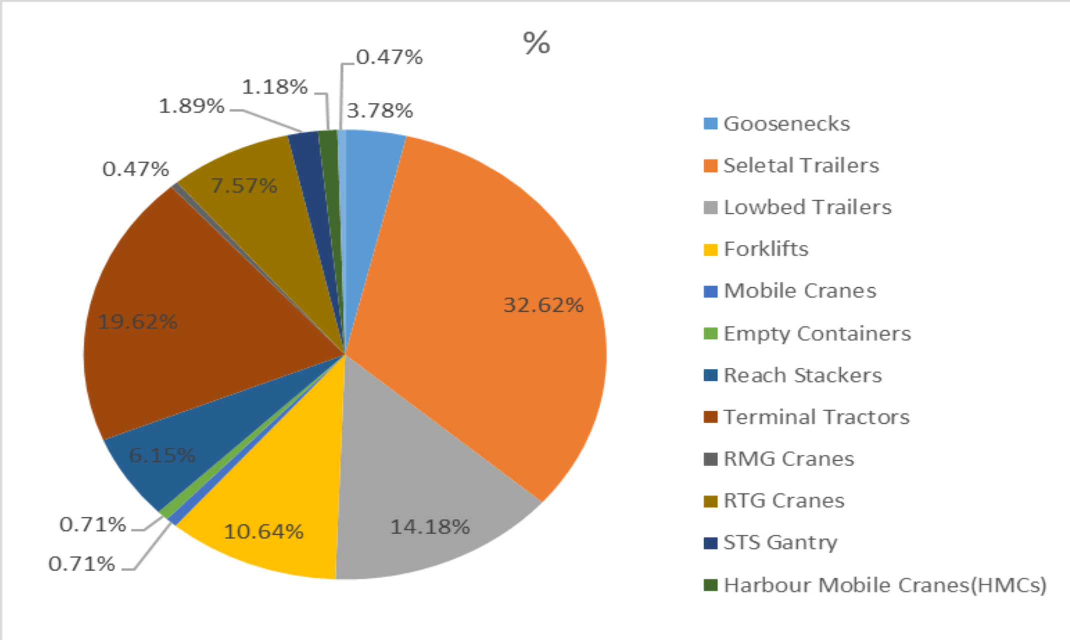
Table 7: Mombasa Port's equipment distribution

Equipment	Container Terminal	Conventional Cargo	Total	Percentage%
Goosenecks	15	1	16	3.78%
Seletal Trailers	128	10	138	32.62%
Lowbed Trailers	30	30	60	14.18%
Forklifts	26	19	45	10.64%
Mobile Cranes	3	0	3	0.71%
Empty Containers	3	0	3	0.71%
Reach Stackers	16	10	26	6.15%
Terminal Tractors	78	5	83	19.62%
RMG Cranes	2	0	2	0.47%
RTG Cranes	32	0	32	7.57%
STS Gantry	8	0	8	1.89%
Harbour Mobile Cranes(HMCs)	0	5	5	1.18%
Empty Containers Handlers	0	2	2	0.47%
Total	**341**	**82**	**423**	**100.00%**

Source: KPA, 2022

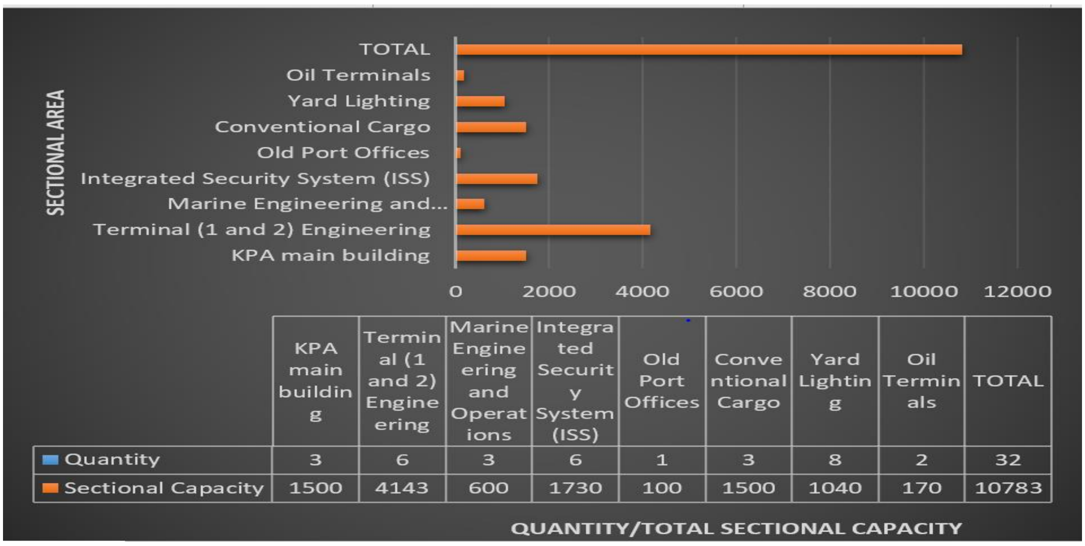
As shown in table 7, a total of 423 mobile equipment are used within the container terminal and Cargo handling. Limited electrification or hybridization has been employed to this equipment with about 80% of the equipment still driven by fossil fuels.

Figure 19: Mombasa Port equipment by type



During power failure, Generators of varying capacities are installed in different sections of the port premise to provide emergency power supply. The registered capacities range from 30 KVA to 1063 KVA (Kidere, 2017)

Figure 20: Mombasa Port Sectional Generator capacity

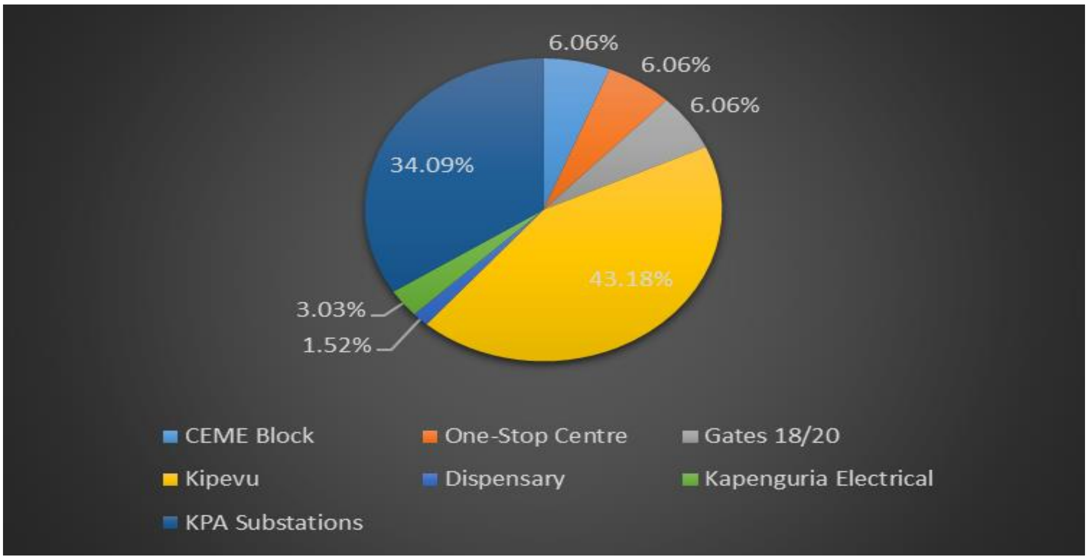


	KPA main building	Terminal (1 and 2) Engineering	Marine Engineering and Operations	Integrated Security System (ISS)	Old Port Offices	Conventional Cargo	Yard Lighting	Oil Terminals	TOTAL
Quantity	3	6	3	6	1	3	8	2	32
Sectional Capacity	1500	4143	600	1730	100	1500	1040	170	10783

5.4.3 Air Conditioning

Another key energy consumer at the port is the air condition system. Most of the offices at the port utilizes Split Air Condition systems. According to an Audit report released in 2019, many AC systems are not fitted with energy saving devices (ESDs). These ESDs are reported to have a potential annual energy saving of 176470 KWh (15% reduction in overall AC energy consumption).

Figure 21: Mombasa Port AC distribution



As shown in the diagram, Kipevu terminal has the highest Air conditioning requirement accounting for 43% followed by KPA substations at 34.09%. The least AC energy consuming facility is the Dispensary at 1.5%. This is due to high energy loss from heating resulting from electricity transformation at the substations as compared to normal cooling required by the other facilities.

5.5 Mombasa Port Energy Efficiency measures

As shown by continuous Energy Audits and research (Cornel Group, 2014, Kidere, 2017, MTCC Africa, 2019), Mombasa port has continuously endeavored to improve its energy performance and promote environmental credibility. Between 2014 and 2015, the Port Authority replaced 11KV tariff C12 with Tariff C15, 132 KVA substation.

This measure is important in reducing transformer losses, consequently reducing energy wastage.

Table 8*:* Mombasa port energy efficiency state of practice

Energy Efficiency Measure	Area of implementation	State of Implementation
Equipment measures	Lighting System	Replacement of Old inefficient bulbs with LED Lamps on going
	A/C Energy Saving Devices	Replacement of VRF systems with Inverter A/Cs Recommendation for installation of AIRCON SAVER
	Cargo handling Equipment (CHE) - (Repairs / Engine replacement / New Equipment)	Partial hybridization of CHEs e.g. RTGs, Repairs HMCs fitted with electrical options for shore power supply Most Gantry cranes using inefficient standard motors - Proposal to shift to premium motors with projected efficiency of up to 91%
Energy measures	Harnessing of Renewable Energy (Solar)	Solar energy generation in progress Solar heating systems at cruise terminal (300kw, 450kw, 400kw)
	Electrification of CHE	Slow Electrification of CHE Diesel engines still in use
	Alternative Fuels	Diesel Fuel No Alternative fuel Bunkering infrastructure
Energy Management Systems (EnMS)	Energy Management System(EnMS) e.g. Energy management Plan(EMP)	Slow pace of implementing EnMS ISO 14001 implemented ISO 50001 not implemented No dedicated Energy Manager
	ISO Certifications	ISO 9001 QMS implementation
Energy Management Technologies(EMTs)	Energy saving Systems(ESM)	Few RTGs using capacitor banks to store and reuse power during container handling process
	Smart Grids and Vi	Not Implemented
	Micro grids	Not Implemented

Land transport measures	Intermodal transport (Rail/Road/Short sea Shipping)	Rail cargo Implemented Short sea shipping not practiced
	Truck Congestion reduction	Port Expansion projects/Rail cargo/Inland Depots-Not satisfactorily addressed
	Truck emission reduction	Not implemented old emitting truck restrictions
Operational Measures	Digitalization (IOT/Big data/Automation)	Maritime Single Window system, Gates Automation implemented IOT, Big data not implemented
	Port City Integration	No regulations in place
	Green Port Policy (GPP)	Implemented Not well aligned to ISO 14001EnMS
Ship To Shore Interface Measures	Virtual Arrival / JIT	Not satisfactorily Implemented(Use of 14 days list unreliable)
	Berth / Quay Allocation	Allocation on arrival

Adopted from KPA

Further measures include Close monitoring of dredging activities to ensure Air quality, water quality and biodiversity are not negatively impacted. As well the implementation of Green Port Policy, replacement of inefficient lighting lamps with LED-based, Installation of Onshore power supply at Berth number 1 and efforts to harness RE through Solar energy production. However, many cost effective measures including Energy management systems, CHE Electrification, Truck Emission reduction, Digitalization, Just In Time arrival, Energy Saving measures are either not implemented or not satisfactorily implemented.

CHAPTER SIX: DATA ANALYSIS AND DISCUSSION

6.1 Analysis of literature review

This chapter presents and analyzes data collected, and discusses the findings. The literature on energy efficiency and barriers to implementing cost-effective energy efficiency measures in ports was derived from various segments in the shipping industry, with illustrative cases of successful implementations and potential measures for overcoming barriers.

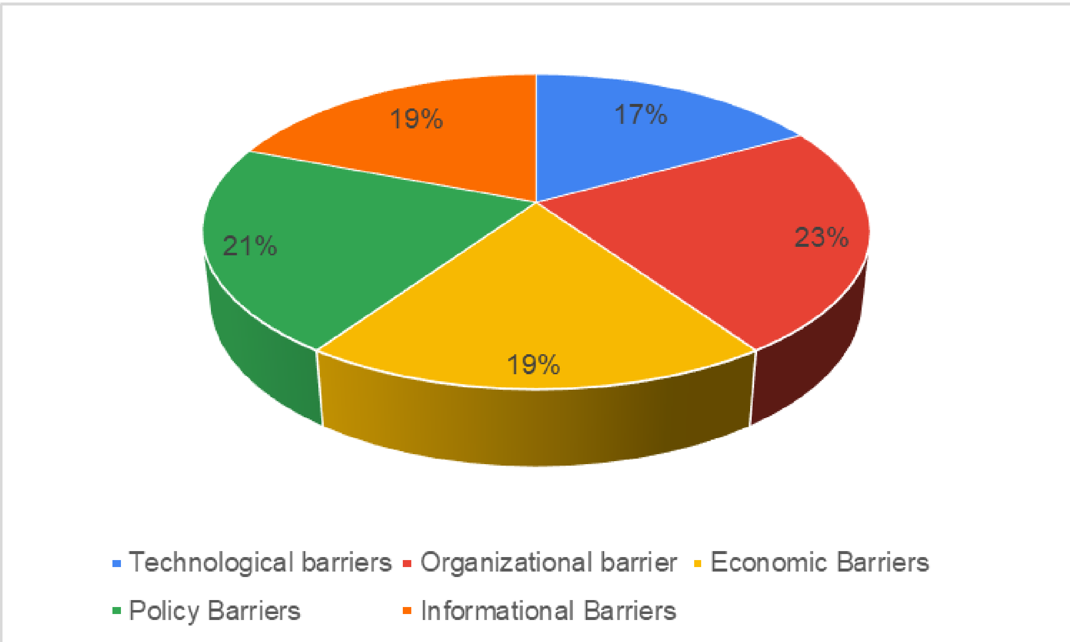
Table 9: Summary of reviewed literature

No.	**Resources**	**Previous studies**	**Categories of Barrier Disciplines**	**Research Methods/ Methodologies**	**Drivers of Energy Efficiency**
1	Journal Articles	Energy Efficiency in shipping	Organization	Snow-bowling	Regulatory /Policy Framework
2	E-Books	Maritime Energy Management	Technological	Cross-sectional Survey	Environmental Pressure
3	Annual Reports (IRENA,IEA, KPA)	Greenhouse Gases in shipping	Economical	Semi-structured interviews	UNSDGs
4	Databases (IMO,DNV-GL)	Ports efficiency	Financial	Exploratory studies	Energy Security/Energy Prices
5	Press releases	Energy Efficiency and GHG emission Measures	Behavioral	Multi-Criteria evaluation	IMO and EU strategies
6		IMO GHG studies	Informational		
7			Policy		

Identification, categorization and prioritizing barriers to energy efficiency is not an easy process especially in large organizations like ports, involving different stakeholders. Without proper and effective tools, and procedures, analyzing data becomes a challenge. According to Allen et al, 2010, besides provision of template based and exemplary development issues, concept design is paramount in addition to developing, implementing and evaluating an energy policy framework.

It is important to organize barriers to simplify the barrier identification process in a complex organization, for ease of analysis. Considering limitations of resources, and to avoid complexities, a practical but simple taxonomy was adopted from different literatures with modifications appropriate to port facilities. Since the literature was cutting across board within and outside the shipping industry, some barriers were eliminated from the list and only those related to ports were considered. Considering the priorities and interests of the organization, a total of 47 barriers were identified and categorized into five disciplines. For simplicity of presenting and ranking process, disciplines of barriers and barriers were uniquely coded **(see appendix B).**

Figure 22: Barriers distribution according to discipline categories



As shown in figure 22, 23% of the barriers were organizational while 21% were policy-related.17% of hindrances were technological influenced whereas Informational and economic barriers were 19% each.

6.2 Benchmarking analysis

Table 10: Tabulated findings of benchmarking ports

Characteristics	**Port**		
	Genoa Port	**Port of Antwerp**	**Mombasa Ports**
Governance model	Municipality	State owned	State owned
ECA/SECA	SECA	SECA	Non-SECA
Proximity To City	Yes	Yes	Yes
Approximate energy demand(KWh)	50Million		13Million
Green port policy	Implemented	Implemented	Implemented
Energy management system (ISO 14001 EnMS)	Implemented	Implemented	Adopted
Energy Efficiency focus	-Energy Measures (Geothermal, Solar, Wind) -Quay electrification -infrastructure expansion -Operators awareness and training -Monitoring and reporting (collective responsibility) -Emission inventory -Port-city Integration (stakeholders' collaboration) -Onshore power supply(OPS) Energy management system (ISO 14001 EnMS) -Energy management plan (EMP)	-Offshore wind Onshore Power Supply(OPS) -Sustainable flow back born (Waste-energy, CO2) -Alternative fuel (Hydrogen, Methanol, LNG) -Alternative fuel bunkering infrastructure -Circular economy projects -Energy efficient port vessels (Alternative fuel-operated) -Transport connectivity (Barges, International motorways, Rail, pipelines) -Digitalization (Data management, utility communication, Smart end-user devices, Advanced metering, Dynamic control) -Energy Management System EnMS and technologies(ISO 14001 EnMS, Energy Storage systems)	-Equipment measures (Lighting, Air-conditioning) -Hybridization -Terminal gated automation -Pilot project in Offshore Power Supply(OPS) Solar heater systems -Information measures (awareness and training) -Truck congestion

Table 11 shows comparative energy and environmental profiles for the benchmarked ports of Genoa and Antwerp relative to Mombasa port. As manifested in this research, mitigating climate change, reducing GHG emissions and improving energy performance is not an issue of a single port, as well it is challenging to have a standard measure for ports due to distinct ports characteristics. Thus measures vary from port to port, country to country and region to region.

Despite the different implementation strategies for ports EE and GHG measures, there exists common features, common barriers and a mix of potentials. While Mombasa port strategizes in Equipment and Information measures, POA has invested heavily in energy measures, Renewable energy, Alternative fuels and Digitalization. POA has also strongly integrated the port city, implemented effective EnMS and employed modal shifts. On the other hand, GPA applies information measures, ship-shore power, Renewable energy and port-city integration.

All the three ports indicate that there are adequate mature cost-effective EETs for ports. However, GPA and POA shows that integrating (EnMS) in organizational frameworks could significant improve ports Energy Efficiency. Training, awareness and sound energy policies are also important in port energy performance. One distinct element between the three ports is however the role of regional policies for GPA and POA, which is not the case of Mombasa port. EU ports, being members of EU and ESPO are impacted by regional policies and projects including Sulfur cap directives, Green efforts 2014 and Fit 55 projects.

6.3 Human element Survey

Primary data collected was based on a survey questionnaire with Ten questions (see appendix A). Question One and Two were aimed at confirming IMO regulatory awareness, and understanding of ports' perception on energy and environment performance by the respondents. Question Three up to Nine allowed the participants to present their expert opinion on priorities and importance of the Energy Efficiency Barriers as perceived by the port Authority. The last question was open ended for the participants to provide additional information related to the subject.

6.3.1 Participation

A total of Eleven participants were recruited from four stakeholder groups from the maritime space. Five participants from the ports Authority, three from Maritime Administration, one from a recognized shipping company and Two professional sea seafarers currently working on board ships. As shown in table 12, Four respondents representing 36% of the total number of participants were recruited from the High management level, six from Supervisory level and one from the Operator (Junior) level representing 55% and 9% respectively.

Table 11: Participants qualities

Stakeholder	Number of Participants	Profession	Rank
Port Authority	5	Port Engineer (1) Electrical Engineers (2) Marine Engineers (1) Administrator (1)	Management Level (2) Supervisory level (2) Junior Staff(1)
Maritime Administration	3	Marine Engineer (1) ICT Officer (1) Maritime Safety Officer(1)	Management Level (1) Supervisory Level(2)
Shipping Company	1	Shipping and Logistics (1)	Supervisory level(1)
Ship	2	Second Engineer (1) Third Engineer (1)	Management Level (1) Supervisory (1)

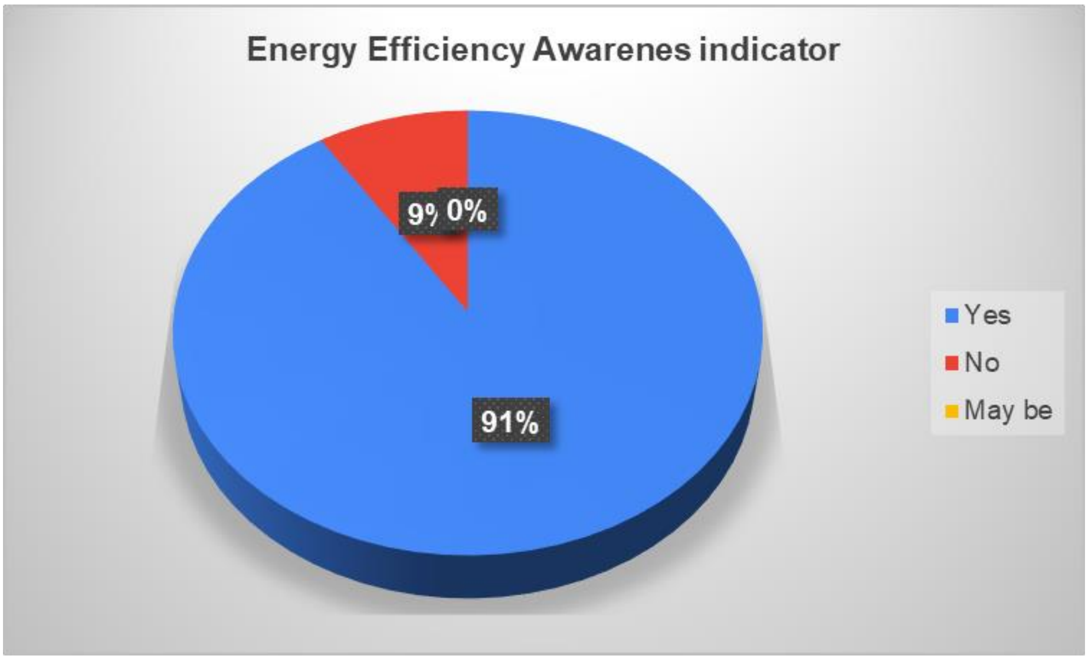
About 64% of the respondents are directly related to port energy issues while the remaining 36% possess vast knowledge of the port's activities that influences overall operational efficiency e.g. environment, logistics and Organizational structure.

6.3.2 Energy efficiency and GHG regulatory awareness

Knowledge and awareness are significant elements in promoting port's strategies to improve energy performance and reduce GHG emissions. This allows effffective identification of operational and technical measures as well as appropriate budgetary allocations and implementation schemes. Port Authorities could then employ different management tools and policies in accelerating uptake of cost effective measures (Alamoush et al.,2020)

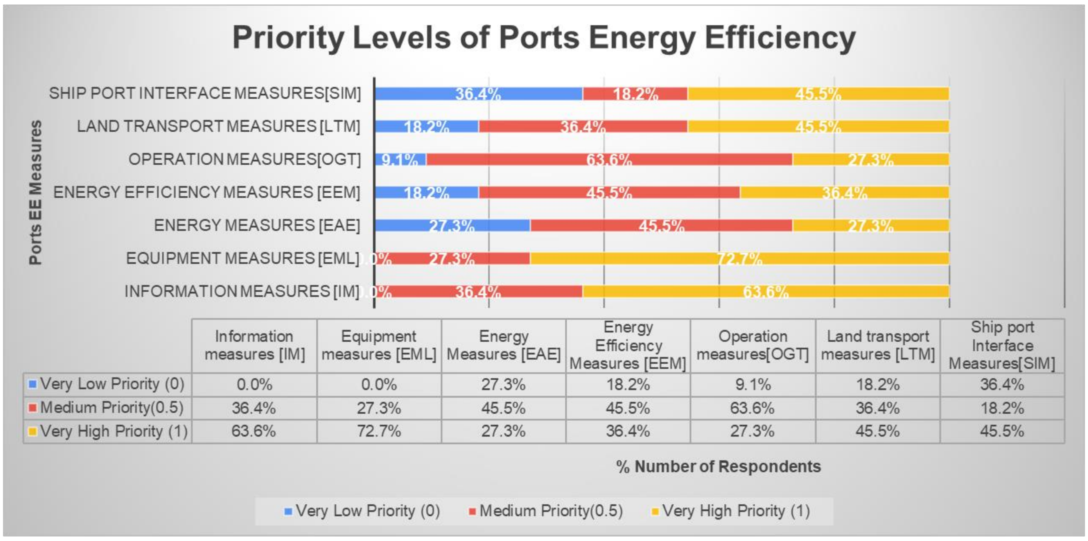
As shown in figure 23**,** 91% of the respondents are aware of the energy efficiency regulations against 9% who are not aware. This is an indication that maritime players are in full realization of the significance of energy efficiency in port operations.

Figure 23: Respondents awareness on IMO Energy efficiency regulations



Energy efficiency measures, energy measures and operational measures are the least important according to the survey. This could be attributed to the slow pace of implementing EnMS such as ISO 14001 and ISO 5001 as well as slow uptake of renewable energy. Although the port has started employing renewable energy in areas like the Automated gates, Renewable Energy (RE) uptake is still low. Further operational measures such as Terminal automation, Green port policy and potential of Port city integration has not been fully utilized.

Figure 24: Priority levels of Port Energy efficiency measures



As shown in figure 24, 72.9% of respondents suggested that equipment measures are most prioritized by the port followed by information measures at 63.6%. Land transport measures tied with Ship port Interface measures in third very high priorities followed by Energy Efficiency measures at 36%. Energy and operation measures were rated the least in priority at 27%. It is further observed that 36% of respondents suggest that ship port interface measures are of very low priority while all respondents suggest that equipment and information measures are from medium to very high priorities.

The port has for example rolled out plans to replace all inefficient lighting systems and Air Conditioners with efficiency technologies such as LEDs and inverter ACs. Furthermore, proposals are in place to replace CHEs standard motors with premium ones with projected efficiency of up to 91.7%. As well, hybridization of RTGs is expected to lower consumptions, reduce emission as well as life cycle cost.

On the other hand, although establishment of Inland container depots and operationalization of the Cargo rails system seems to have improved operational efficiency, more needs to be done to reduce the effect of truck emissions within the port. As well as ongoing onshore power projects including Installation of auxiliary shore power connection options for HMCs which is aimed at reducing energy consumption, wear and tear and subsequently lower operating costs, and installation of shore power facilities in small water crafts seems to have yielded little impact in reducing the port's energy efficiency gap.

6.4 Stakeholders Response characteristics on Barrier Disciplines

6.4.1 Response characteristics

In order to develop an effective framework for overcoming port hindrances for energy performance and measures to reduce GHG emission, it is vital to characterize barriers disciplines based on discipline importance.

Figure 25: Response characteristics of barrier disciplines

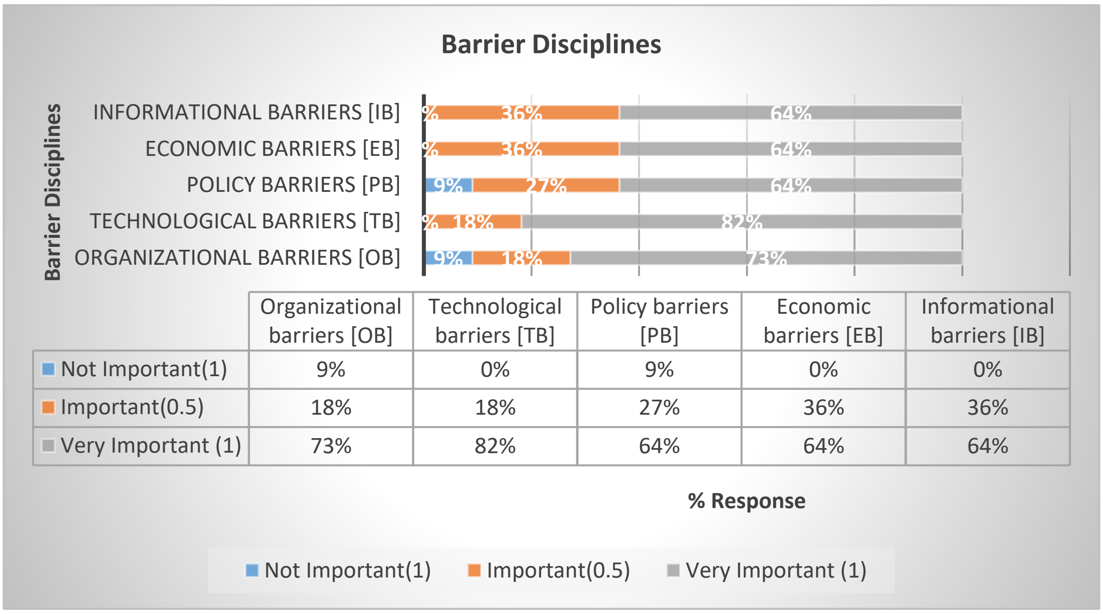


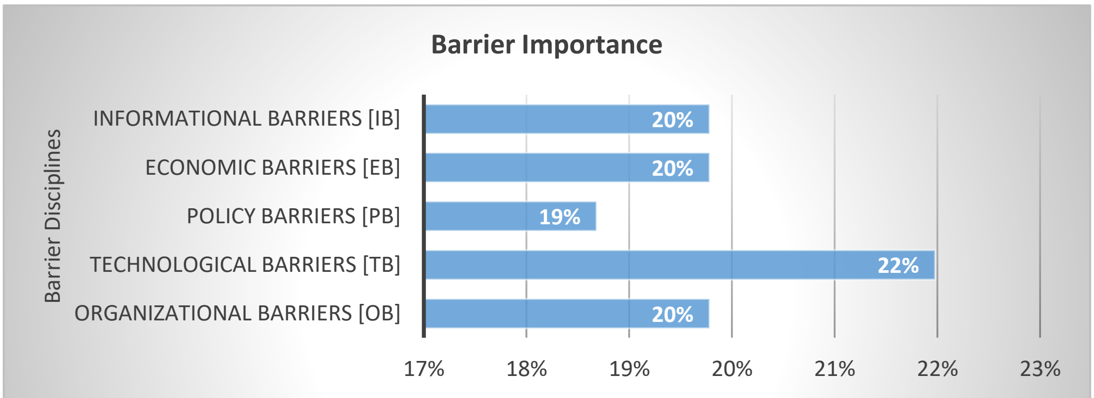
Figure 25 shows how barrier disciplines were rated. Accordingly, 82% of the respondents rated technological barriers as the most important hindering factors for implementing EE and GHG emission at the port, followed by Organizational barriers.

Policies, economy and informational perspectives were rated equally important at 64% each. Although 9% of the respondents rated Organizational and policy barriers as not important, 91% of the respondents agree that all barrier disciplines are important.

6.4.2 Barrier disciplines Importance Ratios

Based on the overall rating of the barriers importance, Technological barriers are ranked the highest at 22% followed by organizational, informational and economic barriers at 20%. each. With a 19% importance ratio, policy barriers are ranked the least impactful discipline in implementation of energy efficiency measures.

Figure 26: Barriers importance ratios



	Organizational barriers [OB]	Technological barriers [TB]	Policy barriers [PB]	Economic barriers [EB]	Informational barriers [IB]
% Importance	20%	22%	19%	20%	20%

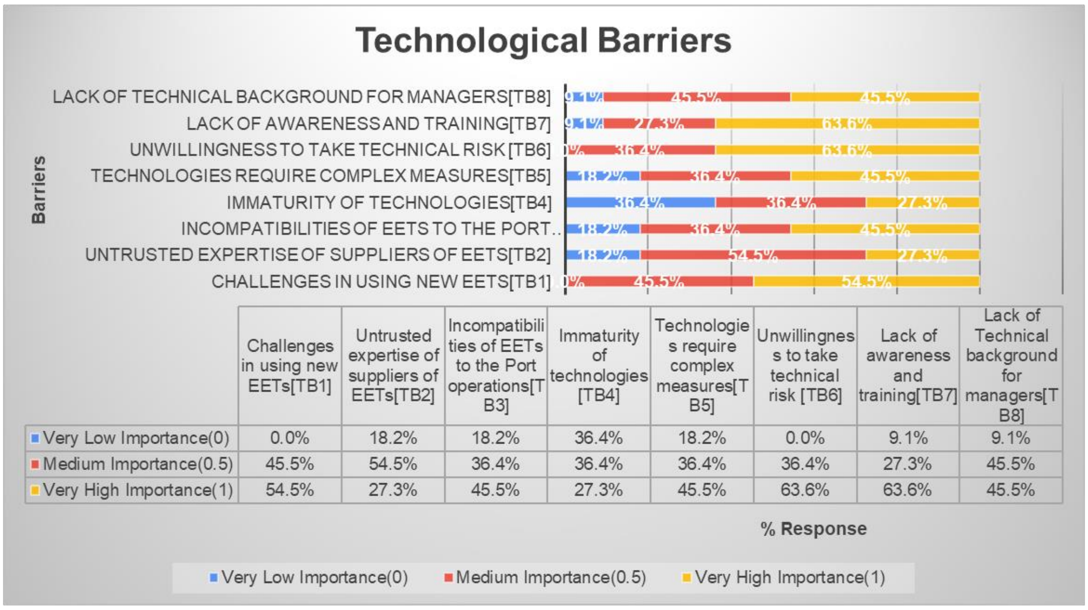
As shown in figure 26, the importance range between barrier disciplines is 1%. This shows that all barriers are worth consideration for developing and implementing effective approaches for overcoming the barriers.

6.5. Response characteristics of Barriers

6.5.1 Technological Barriers

Risk factor and awareness are crucial technological aspects of port EE barriers.

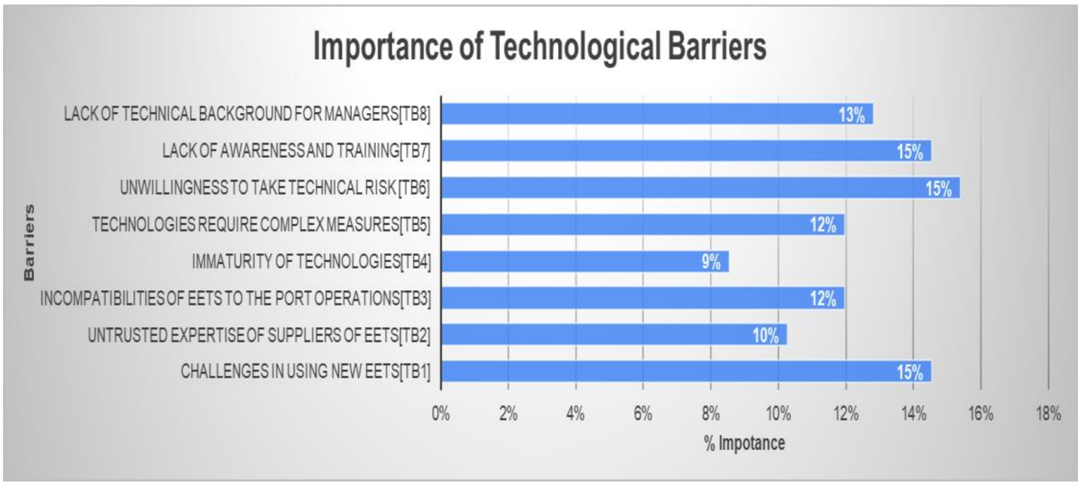
Figure 27: Technological barriers response



	Challenges in using new EETs[TB1]	Untrusted expertise of suppliers of EETs[TB2]	Incompatibilities of EETs to the Port operations[TB3]	Immaturity of technologies [TB4]	Technologies require complex measures[TB5]	Unwillingness to take technical risk [TB6]	Lack of awareness and training[TB7]	Lack of Technical background for managers[TB8]
Very Low Importance(0)	0.0%	18.2%	18.2%	36.4%	18.2%	0.0%	9.1%	9.1%
Medium Importance(0.5)	45.5%	54.5%	36.4%	36.4%	36.4%	36.4%	27.3%	45.5%
Very High Importance(1)	54.5%	27.3%	45.5%	27.3%	45.5%	63.6%	63.6%	45.5%

As shown in figure 27, unwillingness to take technical risks, lack of awareness and training and operator's challenges in using new EETs are the main technological barriers, followed by compatibility of EETs, managers' inadequate technical skills and complexities in technical requirements. It is also shown that, Untrusted expertise of suppliers and immaturity of technologies are the least impactful barriers in this perspective.

Figure 28: Importance level of technological barriers



Due to the high cost of EETs, training both for managers and operators should be emphasized to boost the port's confidence in its investment. As well, survey indicates that there are many mature EETs in the market today and suppliers are upscaling their services in order to place themselves in the competitive market.

As discussed in previous section and shown in appendix A, barriers and barrier disciplines were coded for ease of presentation.

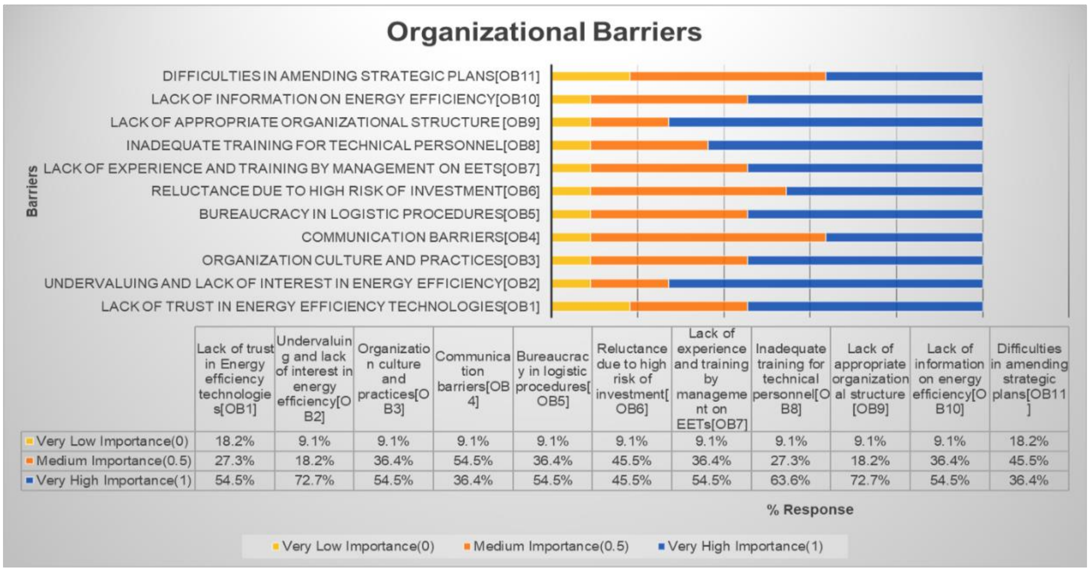
Table 12: Ranking of Technological barriers

Barrier	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
Rank	1	7	5	8	5	1	1	4

Table 13 illustrates random ranking of technological barriers where 1 represent highest ranked. Accordingly, TB1, TB6, TB7 are the highest ranked followed by TB8, TB3 and TB5. TB2 and TB4 are the least important barriers according to the survey.

6.5.2 Organizational Barriers (OBs)

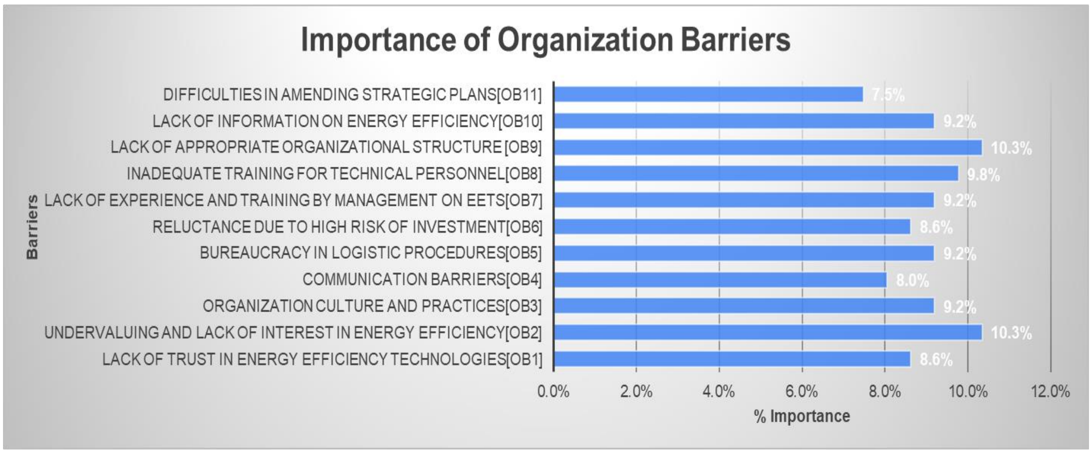
Figure 29: Organizational barriers response



	Lack of trust in Energy efficiency technologies[OB1]	Undervaluing and lack of interest in energy efficiency[OB2]	Organization culture and practices[OB3]	Communication barriers[OB4]	Bureaucracy in logistic procedures[OB5]	Reluctance due to high risk of investment[OB6]	Lack of experience and training by management on EETs[OB7]	Inadequate training for technical personnel[OB8]	Lack of appropriate organizational structure [OB9]	Lack of information on energy efficiency[OB10]	Difficulties in amending strategic plans[OB11]
Very Low Importance(0)	18.2%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	18.2%
Medium Importance(0.5)	27.3%	18.2%	36.4%	54.5%	36.4%	45.5%	36.4%	27.3%	18.2%	36.4%	45.5%
Very High Importance(1)	54.5%	72.7%	54.5%	36.4%	54.5%	45.5%	54.5%	63.6%	72.7%	54.5%	36.4%

According to stakeholders' responses, undervaluing and lack of interest in Energy efficiency, exclusion of Energy efficiency management in the organization structure and inadequate technically trained managers, bureaucracy in procurement processes, culture and practices, and lack of trust of EETs by management are the most important organizational barriers. Communication barriers, fear of risk and lack of flexibility in strategic plans also contribute to hindrances in implementation of energy efficiency measures (see figure 29).

Figure 30: Importance level of Organizational barriers



Survey results indicate that all organization barriers should be considered in the Energy efficiency decision-making process. However, communication barriers and challenges in amending strategic plans have the least significance on the port's Energy efficiency barriers.

Table 13: Ranking of Organizational barriers

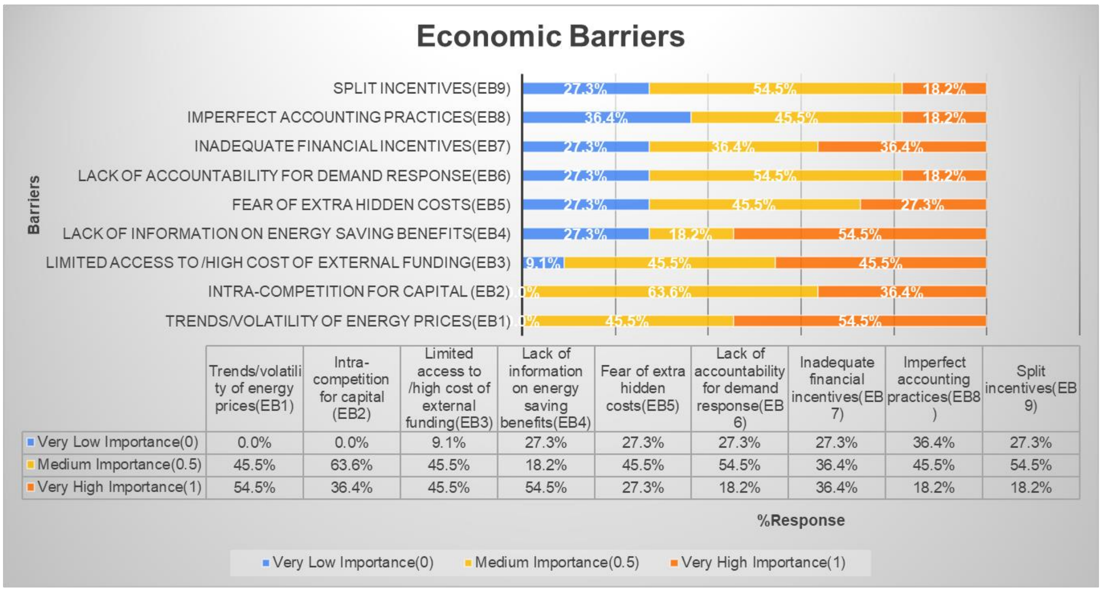
Barrier	**OB 1**	**OB 2**	**OB 3**	**OB 4**	**OB 5**	**OB 6**	**OB 7**	**OB 8**	**OB 9**	**OB10**	**OB11**
Rank	**8**	**1**	**4**	**10**	**4**	**8**	**4**	**3**	**1**	**4**	**11**

OB2, OB9, OB8, OB3, OB5 and OB7 are the most important barriers in organizational aspect whle OB4 and OB1 have least significance. Lack of substantive energy management department and consequently lack of dedicated energy manager position depicts the inappropriateness of the organization structure that could have a positive influence on energy performance, environmental culture and values. Developing environmental support mechanisms, improving staff awareness through technical training and hiring of technically competent management staff could help in realizing the benefits of energy efficiency and hence help to seal the Energy inefficiency barriers gap.

6.5.3 Economic Barriers

Lack of information on energy saving benefits, trends and volatility of energy prices and high cost and limited access of external funding are the significant barriers in the economic aspects of energy efficiency. By improving energy performance, utility expenses could be drastically reduced and stability of energy volatility and prices be achieved.

Figure 31: Economic barriers response



The Authority needs to adopt appropriate financing approaches in order to overcome the problem of underfunding energy-related departments through avoidance of intra-competition for capital. Being a public port, the management could engage the government at national level to secure adequate financial incentives.

Figure 32: Importance level of economic barriers

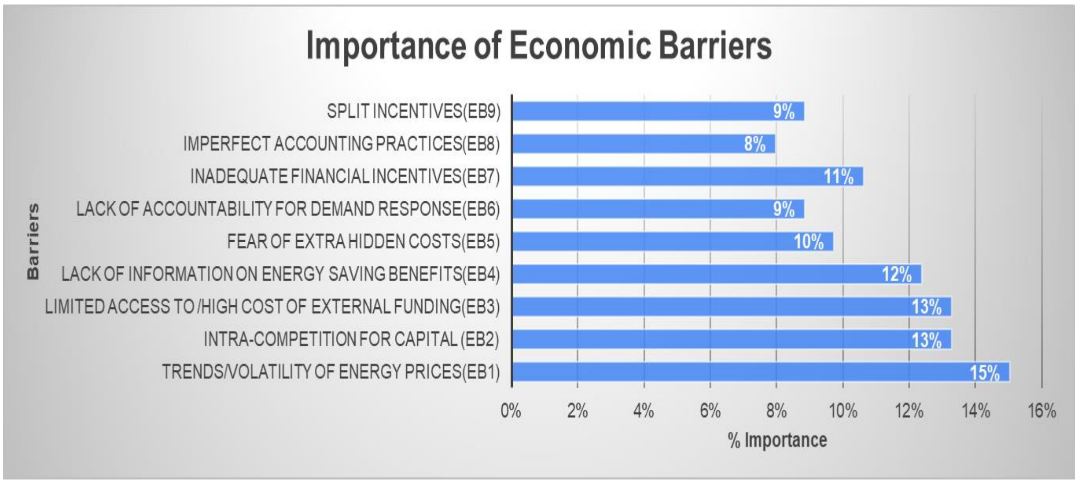


Table 15 depicts the ranking based on importance ratios and priority levels of economic hindrances. EB1, EB2, EB3 and EB4 are the top port considerations in energy efficiency while EB8, EB9 and EB6 are the least important barriers. However, EB5 and EB7 also influences ports energy performance and GHG emission strategies.

Table 14: Ranking of Economic Barriers

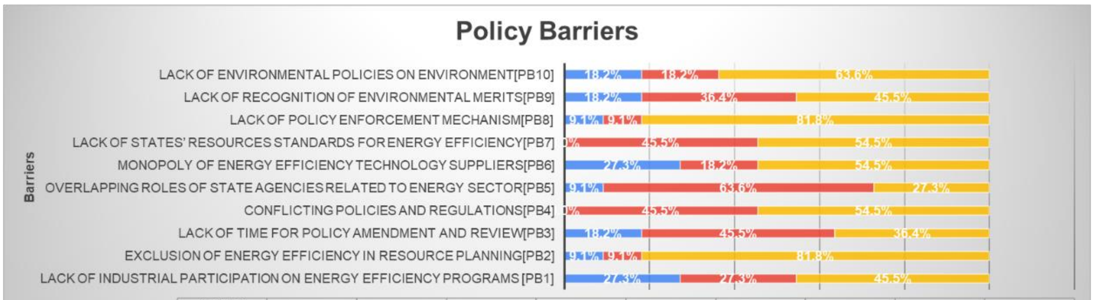
Barrier	**EB1**	**EB2**	**EB3**	**EB4**	**EB5**	**EB6**	**EB7**	**EB8**	**EB9**
Rank	**1**	**2**	**2**	**4**	**6**	**7**	**5**	**9**	**7**

The governance of Mombasa port permits for Government incentives on energy efficiency technologies. Being an energy intensive facility, Mombasa port also needs to reevaluate its tendering and evaluation processes in order to appropriately invest in cost-effective energy saving measures. The Authority could also aim to create balance in budget allocation and integrate Energy efficiency in its structure in order to improve the implementation of energy related projects.

6.5.4 Policy Barriers

In response to the Paris agreement on climate change adaptation, energy efficiency has become a priority in the international policy framework. This calls for not only developing and implementing sound energy efficiency policies but also effective monitoring and enforcement of relevant energy regulations. As shown in Figure 6.5.7 responders indicated that exclusion of energy efficiency from ports resource planning, lack of policy enforcement mechanisms and inefficient environmental policies are the most important barriers in policy perspective followed by inadequate EE resource standards, monopoly of EETs suppliers and conflicting EE regulations.

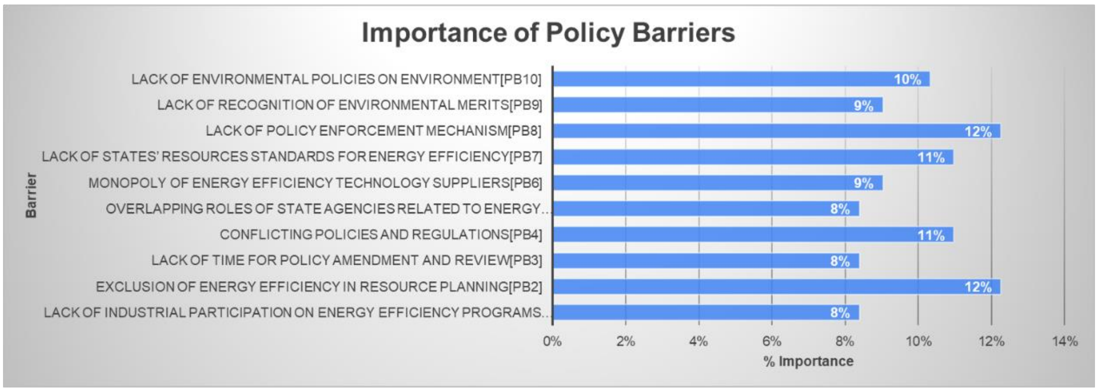
Figure 33: Policy barriers response



	Lack of industrial participation on energy efficiency programs [PB1]	Exclusion of energy efficiency in resource planning[PB2]	Lack of time for policy amendment and review[PB3]	Conflicting policies and regulations[PB4]	Overlapping roles of state agencies related to energy sector[PB5]	Monopoly of energy efficiency technology suppliers[PB6]	Lack of states' resources standards for energy efficiency[PB7]	Lack of policy enforcement mechanism[PB8]	Lack of recognition of environmental merits[PB9]	Lack of environmental policies on environment[PB10]
Very Low Importance(0)	27.3%	9.1%	18.2%	0.0%	9.1%	27.3%	0.0%	9.1%	18.2%	18.2%
Medium Importance(0.5)	27.3%	9.1%	45.5%	45.5%	63.6%	18.2%	45.5%	9.1%	36.4%	18.2%
Very High Importance(1)	45.5%	81.8%	36.4%	54.5%	27.3%	54.5%	54.5%	81.8%	45.5%	63.6%

Ports need to actively participate in EE programs as well as recognize the environmental merits in order to justify their efforts in energy efficiency. Through effective enforcement mechanisms, levelized EETs supplier standards and inclusion of energy efficiency in its resource planning, Mombasa port could realize improved energy performance.

Figure 34: Importance level of policy barriers



As shown in figure 34, effective environmental policies and associated robust enforcement mechanisms, promotes EE resource standardization, harmonization of guiding principles and procedures, and prioritization of energy efficiency in port strategic planning.

Table 15: Ranking of Policy Barriers

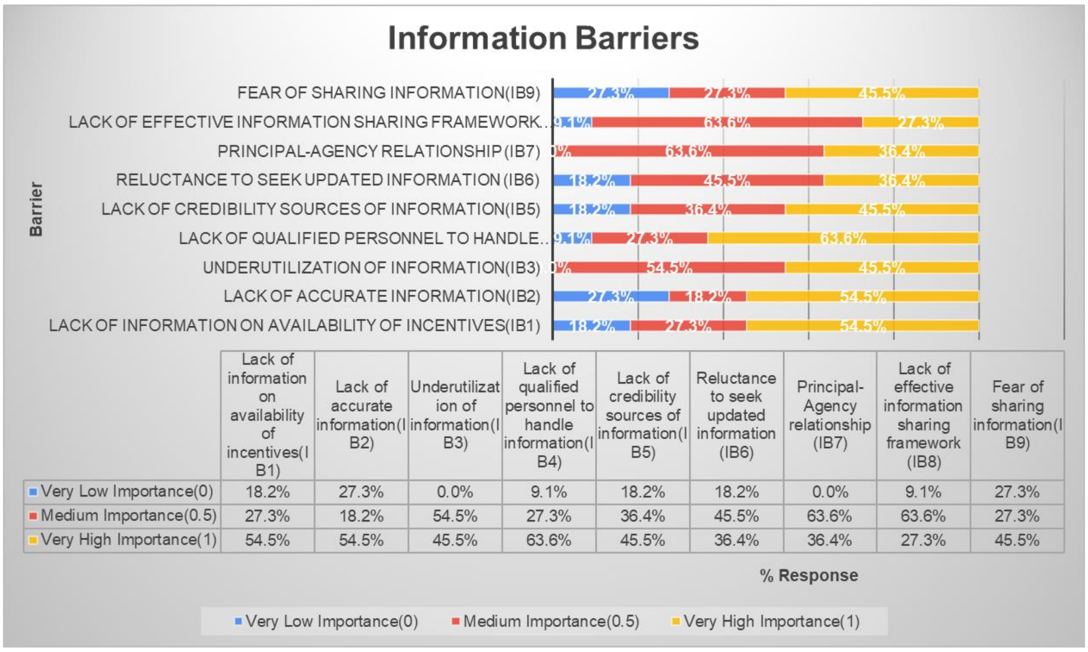
Barrier	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8	PB9	PB10
Rank	8	1	8	3	8	6	3	1	6	5

6.5.5 Information Barrier

The importance of information barriers in energy efficiency could be related to the public good of energy efficiency and consumption (Johnson & Andersson, 2014). According to the port perspective, handling of information, accuracy of information and availability of information are perceived to be significant barriers (figure 35).

Although energy efficiency investment decisions are related to economic perspective, there should be convincingly sufficient data and information to allow for verification of trustworthiness of Energy efficiency technologies' energy saving capability claims. This requires use of effective and high quality reporting and measuring systems. In addition, personnel handling energy efficiency data should be well trained and oriented on methods of inputting, retrieving and maintaining data.

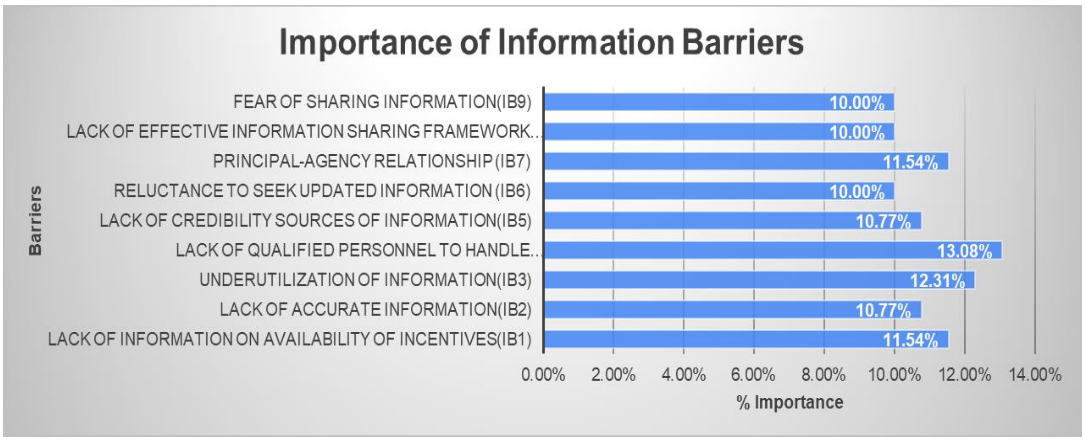
Figure 35: Information barriers response



	Lack of information on availability of incentives(IB1)	Lack of accurate information(IB2)	Underutilization of information(IB3)	Lack of qualified personnel to handle information(IB4)	Lack of credibility sources of information(IB5)	Reluctance to seek updated information (IB6)	Principal-Agency relationship (IB7)	Lack of effective information sharing framework (IB8)	Fear of sharing information(IB9)
Very Low Importance(0)	18.2%	27.3%	0.0%	9.1%	18.2%	18.2%	0.0%	9.1%	27.3%
Medium Importance(0.5)	27.3%	18.2%	54.5%	27.3%	36.4%	45.5%	63.6%	63.6%	27.3%
Very High Importance(1)	54.5%	54.5%	45.5%	63.6%	45.5%	36.4%	36.4%	27.3%	45.5%

As shown in figure 36, Information handling and utilization, availability and principal agency relationship are ranked the most important information barriers.

Figure 36: Importance level of information barriers



Moreover, credibility and accuracy of information should not be underrated. Information sharing also seems to play a crucial role in the implementability of cost-effective energy efficiency measures in ports. Information regarding projected energy prices for example could aid in forecasting on payback period and hence energy efficiency projects planning. As well, ports need to minimize the number of actors in energy efficiency services including elimination of contract agents to streamline information flow.

Table 16: Ranking of Information Barriers

Barrier	IM 1	IM 2	IM 3	IM 4	IM 5	IM 6	IM 7	IM 8
Rank	**2**	**5**	**2**	**1**	**5**	**7**	**2**	**7**

Table 17 illustrated the random ranking of information-related barriers where IM4 is the highest and IM8 the least important.

6.6 Addressing barriers in Mombasa Port

Ranking of EE measures or barriers to implementation of EE and GHG reduction measures considering their importance and priorities helps in defining implementation schemes and development of effective frameworks for overcoming existing and projected hindrances in the implementation process. Table 6.6.1 shows the overall ranking of all 47 barriers drawn from the five disciplines of barriers. Resource planning, policy enforcement value of energy efficiency and organizational structure are the most impactful barrier elements in the port. As well, training needs have manifested not only to the technical personnel but also to the management.

Lack of training seems to be a leading cause of low uptake of energy efficiency technologies due to fear of risk resulting from cost implications. The results also show that there is a strong correlation between the organization’s behavior and barriers to implementation of EE measures. Culture and practices, streamlining of logistics procedures, adequate training and information flow are the most important organization-related barriers that are also ranked high.

Table 17: *Overall ranking of barriers to energy efficiency*

Barriers to Energy Efficiency	Code	% Importance	Ranking
Exclusion of energy efficiency in resource planning	PB2	81.82%	1
Lack of policy enforcement mechanism	PB8	81.82%	2
Undervaluing and lack of interest in energy efficiency	OB2	72.73%	3
Lack of appropriate organizational structure	OB9	72.73%	4
Unwillingness to take technical risk [TB6]	TB6	63.64%	5
Lack of awareness and training[TB7]	TB7	63.64%	6
Inadequate training for technical personnel	OB8	63.64%	7
Lack of environmental policies on environment	PB10	63.64%	8
Lack of qualified personnel to handle information(IB4)	IM 4	63.64%	9
Challenges in using new EETs[TB1]	TB1	54.55%	10
Lack of trust in Energy efficiency technologies	OB1	54.55%	11
Organization culture and practices	OB3	54.55%	12
Bureaucracy in logistic procedures	OB5	54.55%	13
Lack of experience and training by management on EETs	OB7	54.55%	14
Lack of information on energy efficiency	OB10	54.55%	15
Trends/volatility of energy prices(EB1)	EB1	54.55%	16
Lack of information on energy saving benefits(EB4)	EB4	54.55%	17
Conflicting policies and regulations	PB4	54.55%	18
Monopoly of energy efficiency technology suppliers	PB6	54.55%	19
Lack of states' resources standards for energy efficiency	PB7	54.55%	20
Lack of information on availability of incentives(IB1)	IM 1	54.55%	21
Lack of accurate information(IB2)	IM 2	54.55%	22
Incompatibilities of EETs to the Port operations[TB3]	TB3	45.45%	23
Technologies require complex measures[TB5]	TB5	45.45%	24
Lack of Technical background for managers[TB8]	TB8	45.45%	25
Reluctance due to high risk of investment	OB6	45.45%	26
Limited access to /high cost of external funding(EB3)	EB3	45.45%	27
Lack of industrial participation on energy efficiency programs	PB1	45.45%	28
Lack of recognition of environmental merits	PB9	45.45%	29
Underutilization of information(IB3)	IM 3	45.45%	30
Lack of credibility sources of information(IB5)	IM 5	45.45%	31
Fear of sharing information(IB9)	IM 9	45.45%	32
Communication barriers	OB4	36.36%	33
Difficulties in amending strategic plans	OB11	36.36%	34
Intra-competition for capital (EB2)	EB2	36.36%	35
Inadequate financial incentives(EB7)	EB7	36.36%	36
Lack of time for policy amendment and review	PB3	36.36%	37
Reluctance to seek updated information (IB6)	IM 6	36.36%	38
Principal-Agency relationship (IB7)	IM 7	36.36%	39
Untrusted expertise of suppliers of EETs[TB2]	TB2	27.27%	40
Immaturity of technologies[TB4]	TB4	27.27%	41
Fear of extra hidden costs(EB5)	EB5	27.27%	42
Overlapping roles of state agencies related to energy sector	PB5	27.27%	43
Lack of effective information sharing framework (IB8)	IM 8	27.27%	44
Lack of accountability for demand response(EB6)	EB6	18.18%	45
Imperfect accounting practices(EB8)	EB8	18.18%	46
Split incentives(EB9)	EB9	18.18%	47

Split intensive, imperfect accounting and lack of accountability for demand are ranked the least significant barriers. Similarly, the role of state agencies, hidden cost, immaturity of technologies and lack of expertise of EETs suppliers is given less importance.

It could however be noted that, there is an interactive characteristic between barriers and barrier disciplines. For example, the lack of information by management could result in lack of interest in EETs as well as misinformation in energy saving benefits of Energy technologies. On the other hand, this could lead to lack of technical confidence by technicians leading to reluctance in handling technical issues without proper information technical instructions. Management's decisions also have economic influence. For example, if Energy efficiency is not factored in the annual budget plan, it is certain that there could be budgetary allocation for energy efficiency projects.

The relationships between these barriers calls for integrated solutions owing to the imbalances in importance levels of barriers disciplines that may hinder realization of energy efficiency potentials. These imbalances could be addressed through review of the port organizational structure for possible inclusion of the Energy management department under the leadership of substantive energy manager and appropriate budget allocation for energy efficiency projects. In addition, the port needs to upscale its environmental commitment by fully aligning its Green port policy to energy management system ISO14001 while embracing further efforts to implement ISO 50001 EnMS.

Staff and stakeholders' awareness and training programs also play an important role in understanding their role in the overall efficiency improvement of the port. Moreover, the port could extend its energy efficiency efforts through incentives, voluntary agreements, subsidies, and collaborations with the port city in matters such as circularity and waste-energy generation.

6.7 SWOT analysis

Although Mombasa port endeavors to improve its energy performance and environmental credibility, there exists shortcomings that need to be addressed. Thus, a compiled summary of its strengths, weaknesses, opportunities and threats is discussed in the table.

Table 18: Mombasa port EE and GHG emissions' SWOT Analysis

Strengths	**Weaknesses**
Public Port Governance Model: Privileges of environmental-friendly port. Self-control allows for promulgations of effective energy policies. Advantaged in acquisition of Government incentives, reduced cost of operation and improved energy performance	Scarce research: limited research has been conducted in energy efficiency EETs, Viability of offshore RE and Alternative fuels
Adequate space for renewable energy installation e.g. sheds at workshops, cruise terminals and Conventional cargo areas	Potential for renewable energy generation: According to global wind atlas, wind energy potential is not feasible for Mombasa port
Established transport corridors: East Africa North and Central. If effectively utilized, could reduce Port TAT and hence emissions	Inadequate Alternative fuel bunkering infrastructure
Power reticulation network: allows for improved tariffs, stabilized power, reduces energy wastage	Unreliable EETs manufacturers and suppliers. Inadequacy of local production of goods and services
Multi-agency collaboration	Challenges in administering training programs due to large number of actors that require huge investment
Opportunities	**Threats**
Port City Integration: Port and City collaboration could improve self-dependency in energy production through Waste-energy generation. Waste from the City, Ships and Industry could be used in this respect. As well, Circular economy is a potential collaboration area which has not been tapped into.	Political influences: Being a public port, Mombasa port operations and management is highly influenced by the political landscapes of the country-From hiring of top management to tendering of capital intensive services.
Green Port Policy: Alignment of the adopted GPP, with EnMS, National Climate Change Action Plan(NCCAP) and other management system could significantly improve energy efficiency and mitigate impact of port GHG emission	Unexploited marine resources such as marine energy and the potential of offshore Gas production.
Infrastructure development projects such as LAPSSET: If effectively implemented, Lamu Port South Sudan-Ethiopia Transport (LAPSSET) has the potential to significantly reduce TAT, Port and truck Congestion and as well as GHG emissions. The Port Authority also could draft proposal for inclusion of energy efficiency issues in the project plan.	Inadequate training and awareness of technical personnel and relevant stakeholders on the importance of Ports energy efficiency and GHG emission reduction
Fellowship opportunities from World Maritime University helps impart useful knowledge and skills to several Port employees and relevant stakeholders that could contribute largely in ports and maritime energy performance	Inadequate capacity to impose stricter restrictions for inefficient emitting trucks. There is imbalance between environmental requirement and economic benefits of truck transportation in the port.

Source: Author

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 Concluding discussion

Ports are faced by distinct challenges and barriers in implementing cost effective measures to reduce GHGs and improve their energy performance. In addition, factors such as lack of global standards, differentiated operational strategies, varied governance models, ports and terminal sizes and business models influence approaches for overcoming these barriers. Focusing on ports in developing economies and in particular the case of Mombasa port, this study investigated barriers hindering energy efficiency and nominated the key barriers related to ports, categorized them into five (5) disciplines and analyzed their importance and priority levels based on stakeholders' feedback. Benchmarking analysis illustrates comparative state of practices in different ports.

Turning to the applicability of port techno-operational measures, it was observed that there exists viable, mature and cost-effective EE measures exist that could potentially reduce port energy consumption as well as negative environmental impact resulting from fossil fuel combustion. The study shows that Equipment measures and Information strategies were the most highly prioritized measures in Mombasa Port. This was manifested by the port's plans to acquire modern CHEs, use of hybrid RTGs with tier 3 emissions equivalent engines, retrofitting of gantry cranes with premium efficient motors and replacement of inefficient lighting lamps with LED bulbs. Moreover, KPA has undertaken awareness and training of staff including facilitating post graduates' programs for its staff such as WMU MSc programs. Such programs improve information handling capabilities as well as bridge the skills gaps in energy and environment awareness.

Although ships and ports cannot be delinked, Mombasa port seems to play a limited role in implementing ship port interface measures. Despite initiating measures such as installation of shore boxes for tugs, optional shore power connection for HMCS and initiation of onshore power supply pilot project for berth number one, operationalization of the same is yet to be realized. On the other hand, promising operational measures such as JIT, VA and Berth allocation are still a challenge. KPA still relies on a 14 days' list and Berth/Quay allocation on arrival. Energy measures have been rated the least prioritized EE practice. Although there is evidence of partial electrification of CHE and Solar hot water systems, Renewable potential has not been fully exploited.

As illustrated, Mombasa port exhibits various barriers categorized in this study into five disciplines (Technological, Organizational. Economical, Policy and Informational). It is shown that all barriers exhibit certain levels of importance leading to varied prioritization by the port. Unwillingness to take technical risks, lack of awareness and training and challenges in using new technologies were the highest technological concerns of Mombasa port. One way to solve technology barriers is through conducting pre-tests by technology providers to ascertain EETs reliability. EETs suppliers should also provide comprehensive operational and technical information about their products and services to allow the port and operators to gauge their abilities based on product capability claims, with a view to ascertain the investment benefits. Other solutions include agreements with Technology manufacturers as well as responsibility of the port to conduct training and awareness programs to its technical staff and managers with regards to emerging technologies.

Regarding Organizational barriers, projected emission regulations and requirements such as CO2 tax and scrutiny in energy consumptions may incentivize and motivate ports investments in energy efficiency, forcing ports cultural changes. As well, Mombasa port needs to review its organizational structure with a view to integrate energy efficiency issues in its strategic planning. An energy Management department is thus crucial in planning, budgeting and implementation of action plans for energy related measures. Under the leadership of a highly skilled energy manager, the department could also facilitate skilling of staff, coordinate energy policy development, set energy key performance indicators (KPI), baselines, targets as well as advise the management on relevant energy policies.

Economic barriers cut across all other disciplines. Strong and skilled management can forecast and analyze trends and volatility of energy prices. This could improve decision-making and reduce business and external risks. The management also may render top focus on optimum budgetary allocations to relevant departments, avoiding over/or under-budgeting. This could prevent intra-departmental scramble for limited internal funding. There is a need for the management also to be trained on the energy saving benefits of the EETs. This ensures that funds allocated for energy issues are guaranteed return on investment. Further, based on the governance model, the management could engage the national government for provision on incentives such as for CHEs as well as seek support for external funding.

Information barriers on the other hand can be solved by sharing of experiences and information as well as enhancement of transparency in information dissemination among every port actor. This helps in pinpointing problems and addressing knowledge differences regarding availability of best solutions. Operators and stakeholders need continuous awareness and training on efficient use of equipment, and the benefits of energy saving. Technical personnel should be trained on how to handle and extract relevant technical information for accuracy analysis of energy efficiency gaps. All stakeholders should be encouraged to take part in information dissemination without fear through guarantee of confidentiality. The management through the Energy manager should establish confidentiality policy for energy related information.

Policy barriers were perceived to be the least important according to stakeholders' responses. However, lacking a policy enforcement mechanism, exclusion of energy efficiency in planning and environmental policies inadequacy were seen as significant in energy efficiency improvement. Bureaucracies in implementing truck emission reduction measures are as a result of inadequate policy framework to execute these measures. As well, recent trends in port expansion projects such as Kipevu oil terminal and the Lamu port projects outweighs consideration for implementation of energy measures such as CHE Electrification, OPS and other operational measures.

As an outcome of the study, complemented by benchmarking analysis from ports of Genoa and Antwerp, and the survey conducted involving human elements, ports EE barriers are subject of concern. In order to overcome these barriers, a concerted and collaborative effort is key. Financial issues are central to the implementation of cost-effective EE measures. However, Ports and governments need to devise means of securing external funds for such investments. Mombasa port also needs to explore collaborative initiatives involving multi stakeholders including Industries, Port city and Research Centres. Regional policies are also vital in shifting ports' response to GHG emissions reduction and overall sustainability.

7.2 Recommendations

Technological aspects, organizational arrangement, socio-economic, environmental requirements and policy factors influence ports' abilities to implement techno-operational practices to improve ports' energy efficiency. Designing, developing and implementing cost-effective energy efficiency measures in ports is key in achieving energy saving and environmental upgrade. However, Mombasa port efforts in implementing best practices in energy performance and GHG emission reduction are hindered by various barriers. Focusing on the outcome of this study, the following recommendations are provided:

Mombasa Port being a public port needs to abide by the highest possible national and international energy standards and regulations. The Port Authority should utilize the opportunity of its governance model, to secure Government incentives and adequate external funding for its Capital-intensive energy efficiency measures such as acquisition of efficient CHE, installation of OPS and Harnessing of RE.

The Port Authority should review its organizational structure to include a dedicated Energy and Environment Department (EED) and recruit a substantive energy manager capable of designing and reviewing effective energy policy, setting targets and KPIs, conducting energy audits and developing action plans to meet energy efficiency objectives. Furthermore, Implementing EnMS is pivotal in ensuring continuous improvement in energy efficiency practices. Thus there is a need for implementing ISO 50001 EnMS as a guiding principle for attaining ports energy efficiency.

The intersectional role of Mombasa port calls for integration of various stakeholders affected by the port operations. All stakeholders have to contribute either directly or indirectly to the cost of energy efficiency. Among the key players is the Port City. Mombasa port should involve the Mombasa City administration in finding amicable solutions for improving energy efficiency. The port could take advantage of the city waste generated in addition to waste from ships and industries to generate waste-to-Heat Energy, an emerging best practice in ports such as Gothenburg in Sweden. By promulgating proper policies, port-city integration may improve energy efficiency, eliminate waste and promote circular economy as well as create employment for hundreds of youths.

Finally, studies on Barriers to ports energy efficiency and GHG reduction are scarce. Future research is recommended that investigates the interaction between barriers to energy efficiency to provide a grounded understanding of the complexities of implementation mechanisms and allow successful formulation and adoption of energy policies and instruments.

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APPENDICES

Appendix A: Survey Questionnaire

Survey Questionnaire			
Organization: **Position:** **Contacts:**	**For organization (indicate the type e.g. shipping company, Maritime administrator, ship, Port, Ship yard etc.)**		
A. General			
1.Are you aware of IMO regulations for energy efficiency and GHG emissions in ports 2. Do you think port is doing enough in ensuring environmental credibility of Port areas and surrounding?	Yes	Not sure	No
B. Ports Energy efficiency and GHG emission reduction measures			
2. Please rate the perceived priority levels of following measures for improving port energy efficiency and reducing GHG emissions by the port Authority?	**Very Low Priority**	**Medium Priority**	**Very high Priority**
Information measures (Inventories, Monitoring, reporting)			
Equipment measures (Repair, Maintenance, replacement of Cargo handling equipment, Lighting, Air conditions)			
Energy Measures (Alternative fuels, Renewable Energy, Alternative Power systems(OPS) Energy Efficiency Measures (Energy Management systems, Energy Saving Measures, Technologies e.g. smart grids			
Operation measures(Digitalization, Green port Policy, Terminal automation, Automatic gates) Land transport measures (Intermodal transport, Truck congestion reduction)			
Ship port Interface (Onshore Power supply, Alternative fuel bunkering, Virtual arrival, Berth/Yard allocation)			

C. Barrier to implementing EE and GHG emission Measures				
Please rate the importance of the following disciplines of barriers to implementation of energy efficiency and Greenhouse gas (GHG) emissions measures in Port		No Importance	Medium Importance	High Importance
1.1	Organizational barriers (Organization structure, culture interests and priorities)			
1.2	Technological barriers(Technology adoption, risks, cost-effectiveness, Technical capabilities)			
1.3	Policy barriers (Government policies, Agreements, energy support programs, that influence organizational behavior or technological environment)			
1.4	Economic barriers(Investment decisions, Market, Capital and source of finding)			
1.5	Informational barriers(information clarity, precision, simplicity and timely as well as behavior and culture)			
C. Importance of barriers				
Please rate the importance of the following technological barriers to implementation of port energy efficiency and GHG emission measures		No Importance	Medium Importance	High importance
2.1	Challenges in using new EE technologies (Operators incapable of using new EE technology without adequate user information)			
2.2	Untrusted expertise of suppliers of EE technologies			
2.3	Incompatibilities of EE technologies to the Port operations			
2.4	Immaturity of technologies			
2.5	Technologies require complex measures			
2.6	Unwillingness to take technical risk due to high cost of EE technologies			
2.7	Lack of awareness and training			
2.8	Lack of Technical background for managers			
Please rate the importance of the following Organizational barriers to implementation of port energy efficiency and GHG emission measures		No Importance	Medium Importance	High importance
3.1	Lack of trust in Energy efficiency technologies			
3.2	Undervaluing and lack of interest in energy efficiency(Organization focus on other projects while paying less priority to energy efficiency)			
3.3	Organization culture and practices			
3.4	Communication barriers			
3.5	Bureaucracy in logistic procedures			
3.6	Reluctance due to high risk of investment			
3.7	Lack of experience and training by management on energy Technology			
3.8	Inadequate training for technical personnel			
3.9	Lack of appropriate organizational structure (No dedicated department for energy management)			
3.10	Lack of information on energy efficiency(not aware of energy saving potential of measures)			
3.11	Difficulties in amending strategic plans			
Please rate the importance of the following Economic barriers to implementation of port energy efficiency and GHG measures		No Importance	Medium Importance	High importance
4.1	Trends/volatility of energy prices (Uncertainty of changes in energy prices which may affect cost of energy efficiency technologies)			
4.2	Intra-competition for capital (Departments competing for limited capital finance)			
4.3	Limited access to (or high cost of) external funding			
4.4	Lack of information on energy saving benefits			
4.5	Fear of extra hidden costs			
4.6	Lack of accountability for demand response			
4.7	Inadequate financial incentives			
4.8	Imperfect accounting practices			
4.9	Split incentives			
Please rate the importance of the following Policy barriers to implementation of port energy efficiency and GHG measures		No Importance	Medium Importance	High importance
5.1	Lack of industrial participation on energy efficiency programs (Port management not taking part in training and awareness programs organized by Energy industry players like EPRA, IRENA)			
5.2	Exclusion of energy efficiency in resource planning			

5.3	Lack of time for policy amendment and review			
5.4	Conflicting policies and regulations			
5.5	Overlapping roles of state agencies related to energy sector			
5.6	Monopoly of energy efficiency technology suppliers			
5.7	Lack of states' resources standards for energy efficiency			
5.8	Lack of policy enforcement mechanism			
5.9	Lack of recognition of environmental merits			
5.10	Lack of environmental policies on environment			
Please rate the importance of the following Policy barriers to implementation of port energy efficiency and GHG measures		No Importance	Medium Importance	High importance
6.1	Lack of information on availability of incentives			
6.2	Lack of accurate information			
6.3	Underutilization of information			
6.4	Lack of qualified personnel to handle information			
6.5	Lack of credibility sources of information			
6.6	Reluctance to seek updated information (Use of outdated information)			
6.7	Principal-Agency relationship (Giving more powers to contractors to make sensitive decisions on behalf of the organization)			
6.8	Lack of effective information sharing framework (Managers or employees not sure of who to share energy efficiency information)			
6.9	Fear of sharing information			
D. General remarks barriers to implementing EE and GHG emission reduction measures				
10. Please provide any other information regarding Ongoing Energy projects, additional EE barriers, Perceived challenges and opportunities for implementing EE measures at the port				

Thank you for your participation

Appendix B: Coding of barriers and Barrier disciplines

Organization(OB)		Technological(TB)		Economical(EB)		Policy(PB)		Information(IB)	
Code	Barrier	**Code**	Barrier	**Code**	Barrier	**Code**	Barrier	**Code**	Barrier
OB 1	Lack of trust in EETs	**TB 1**	Challenges in using new EETs	**EB 1**	Trends/volatility of energy price	**PB 1**	Lack of industrial participation on energy efficiency programs	**IB 1**	Lack of information on availability of incentives
OB 2	Undervaluing and lack of interest energy efficiency	**TB2**	Untrusted expertise of suppliers of EETs	**EB 2**	Intra-competition for capital	**PB 2**	Exclusion of energy efficiency in resource planning	**IB 2**	Lack of accurate information
OB 3	Organization culture and practice	**TB 3**	Incompatibilities of EETs to the Port operations	**EB 3**	Limited access to /high cost of external funding	**PB 3**	Lack of time for policy amendment and review	**IB 3**	Underutilization of information
OB 4	Communication barriers	**TB 4**	Immaturity of technologies	**EB 4**	Lack of information on energy saving benefits	**PB4**	Conflicting policies and regulatior	**IB 4**	Lack of qualified personnel to handle information
OB 5	Bureaucracy in logistic procedure	**TB 5**	Technologies require complex measures	**EB 5**	Fear of extra hidden costs	**PB 5**	Overlapping roles of state agencies related to energy sector	**IB 5**	Lack of credibility sources of information
OB 6	Reluctance due to high risk of investment	**TB 6**	Unwillingness to take technical risk due to high cost of EETs	**EB 6**	Lack of accountability for demand response	**PB 6**	Monopoly of EET suppliers	**IB 6**	Reluctance to seek updated information
OB 7	Lack of experience and training by management on EETs	**TB 7**	Lack of awareness and training	**EB 7**	Inadequate financial incentives	**PB 7**	Lack of states' resources standar for energy efficiency	**IB 7**	Principal-Agency relationship
OB 8	Inadequate training for technical personnel	**TB 8**	Lack of Technical background for managers	**EB 8**	Imperfect accounting practices	**PB 8**	Lack of policy enforcement mechanism	**IB 8**	Lack of effective information sharing framework
OB 9	Lack of appropriate organizational structure			**EB 9**	Split incentives	**PB 9**	Lack of recognition of environmental merits	**IB 9**	Fear of sharing information
OB 10	Lack of information on energy efficiency					**PB10**	Lack of environmental policies on environment		
OB 11	Difficulties in amending strategic plans								

Appendix C: KPA's key Performance Indicators (KPIs)-2018-2022 strategic plan

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PERFORMANCE INDICATORS		Measure		Baseline	Target		
		2017	2018	2019	2020	2021	2022
Vessel Turnaround Time	Hours	91.2	90	86	81	78	75
Bulk Cargo Vessel Turnaround Time	Days	7.4	7.8	7.4	7	6.8	6.5
Car Carrier Vessel Turnaround Time	Days	1	1	1	1	1	1
Container Vessel Turnaround Time	Days	2.6	2.5	2.3	2	2	2
General Cargo Vessel Turnaround Time	Days	4.5	4.5	4.3	4	3.8	3.5
Roro Vessel Turnaround Time	Days	1.9	1.9	1.8	1.6	1.5	1.3
Tanker Vessel Turnaround Time	Days	4.6	4.9	4.8	4.7	4.6	4.5
Berth Productivity	Moves per ship, per hour	31	36	37	38	39	40
Average Cargo Dwell Time	Hours		96	87	78	69	60
Average Train Turnaround Time	Hours	5	4	3.9	3.8	3.65	3.5
Average Truck Port Dwelt Time	Hours		5	4.5	4	3.5	3
SGR Loading Performance	Hours		5	4.8	4.5	4.25	4
Total Demonstrated Capacity	MDWT	30.35	31.5	33.7	35.9	38.6	41.4
Total Demonstrated Container Handling Capacity	'000 TEUs	1,190	1,299	1,396	1,493	1,604	1,715
Average System Uptime	% uptime	90	90	90	90%	93%	95%
Volume of Freight Moved through Kisumu Port	MDWT	-	6,400	6,950	7,500	7852	8,204
Date Kisumu Port is Commissioned	Target Date/%	-	-	-	-	-	100
Transshipment Traffic	TEUs	81,203	83,757	86,392	89,109	91,912	94,803
Transit Traffic	DWT '000'	8,638	8,956	9,370	9,884	10,021	10,460
Ship Waiting Time	Hours	36	25	20	15	10	8.0
Customer Satisfaction Index	%	65	65	67	67	68	95
Compliance to Environmental Audits	%	-	100	100	100	100	100
Percentage of Workforce Meeting Performance Standards	%	-	100	100	100	100	100