11-3-2020

Using hybrid renewable energy system for electricity generation to reduce cost and greenhouse gas emission : case study Banjul Port

Bakary L. Camara

WORLD MARITIME UNIVERSITY

Malmo- Sweden

USING HYBRID RENEWABLE ENERGY SYSTEM FOR ELECTRICITY GENERATION TO REDUCE COST AND GREENHOUSE GAS EMISSION- CASE STUDY BANJUL PORT

Submitted by: BAKARY L CAMARA

(A dissertation submitted to World Maritime University in partial fulfillment of the requirements for the award of)

MASTER OF SCIENCE

IN

MARITIME AFFAIRS

(MARITIME ENERGY MANAGEMENT)

Year of Graduation: 2020

DECLARATION

I certify that all the materials 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 content of this dissertation reflect my own personal views and are not necessarily endorsed by the university.

(Signature): ....

(Date): **22nd September 2020**

Supervise by: **Dr. Fabio Ballini (PhD)**

Lecturer

Maritime Energy Management Specialization

World Maritime University

ACKNOWLEDGEMENT

I wish to extend my heartfelt appreciation to my WMU donors, the Norwegian Government, who made it possible for me to embark on this fourteen-month academic journey. My utmost gratitude goes to my supervisor, Fabio Ballini, for his tolerance and perseverance, his insightful guidance and support, especially his relentless effort in sourcing and directing me for research materials and academic advice.

I am also grateful to WMU faculty and staff, library assistance and their support team for providing a conducive leaning environment and avenues for relevant information. Many thanks to the MEM Family, headed by professor O. Aykut and his able team Professor Ballini, professor Sorbhorn, Professor Kitada and my course mates.

Special thanks to my wife, for her endurance to take care of the family during these difficult times. I Sincerely appreciate the effort of my employer, Gambia Port Authority, Ferries, for granting me 14-month study leave coupled with all the necessary material and moral support throughout this journey. I will sincerely thank the Director of Technical Service –Ferries and his team for their relentless support and all the departments involved in one way or the other for retrieving necessary information.

ABSTRACT

***Tittle of the Dissertation* : USING HYBRID RENEWABLE ENERGY SYSTEM FOR ELECTRICITY GENERATION TO REDUCE COST AND GREENHOUSE GAS EMISSION-CASE STUDY –BANJUL PORT.**

Degree: ***Master of Science (MSc)***

The upsurge increase in global fleet volume as a result of exponential increase in world trade and population, is the primary influencing factor for ports all over the world to improve and modernize their energy infrastructure. This is as a result of continuous pursuant within the maritime domain for optimum cargo handling and other ports operations in order to respond to the increasing energy demand and to cope with the market trend.

Investment in energy infrastructure with the aim of environmental protection and cost reduction, have become prerequisite and prompted ports to lean towards atomization of terminal operations and introduce modern cargo handling equipment to facilitate quick cargo movement and fast turnaround time of ships.

The erratic nature of transmission and frequent power outage, causes substantial economic loss to many ports in sub-Saharan Africa, which compelled many prominent stakeholders, involved in port operations to divert their businesses in more lucrative and sustainable areas. Energy security has been a challenge in so many port operations. Many ports, especially African regions, depends mainly on the national Grid for electricity supply. Many energy generation platforms in Africa are dependent on fossil fuels for continuous power generations which has an adverse effect on the operating cost and contributes immensely to emission of GHG in Ports. The growing international pressure for policy change towards better environmental protection is giving relevance to energy transition from fossil fuel to renewable energy technologies to enhance public environmental awareness, focus on energy efficiency, industrial revolution and more technological innovation in Ports.

In lieu of the afore mentioned, this dissertation intends to make a case study to ascertain the feasibility of introducing a hybrid renewable energy system (Wind and Solar) for electricity production in Banjul Ports to reduce cost and the emission of GHG.

Keywords: *Hybrid renewable energy system, energy transition, renewable energy technologies, GHG emission.*

Table of Contents

List of Tables

List of Figures

LIST OF ABBREVIATIONS

BCC	Banjul City Council
CCCC	China Communications Construction Company
ECA	Emission Control Area
ECOWAS	Economic Community of West African States
EnB	Energy Baseline
ENMS	Energy Management system
EPA	Environmental Protection Agency
ESPO	European Seaport Organization
GCCI	Gambia Chamber of Commerce and Industry
GHG	Green House Gas
GMA	Gambia Maritime Administration
GPA	Gambia Ports Authority
HPA	Hamburg Port Authority
HRES	Hybrid Renewable Energy System
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
KVA	Kilo Volts Ampere
KW	Kilo Watt
KWh	Kilo Watt Hour
LED	Light Emitting Diode
MARPOL	International Convention for the Protection of Pollution from Ships
MDGs	Millennium Development Goals
MEM	Maritime Energy Management
MW	Mega Watts

NAWEC	National Water and Electricity Company
NOx	Nitrogen Oxides
PDCA	Plan –Do-Check and Act
PEMP	Port Energy Management Plan
PERS	Port Environmental Review System
PM	Particulate Matters
PURA	Public Utility Regulatory Authority
PV	Photovoltaic
PWD	Public Works Department
RTG	Rubber –Tyred Gantry
SDG	Sustainable Development Goals
Sox	Sulphur Oxides
TW	Thera Watts
UN	United Nation
UNCTAD	United Nation Conference on Trade and Development
UNFCCC	United Nation Framework Convention on Climate Change
VOC	Volatile Organic Matter
WAPP	West African Power Pool
WB	World Bank

1. CHAPTER ONE: INTRODUCTION

Ports all over the world play a pivotal role in the global production and distribution system. They form a major intermodal transport hub, linking the sea and the land (Carpenter & Lozano, 2020). In pursuant to ensure a sustainable and continued economic viability, ports face increasing pressure and challenges to become more environmentally friendly, socially conscious and more cost effective. Sustainable and cost effective energy generation, coupled with good connectivity to the hinterland and healthy environmental response within her proximity are always instrumental for the ports in their operations.

The efficiency of any port is heavily dependent on its traffic flow to the hinterland (Dalaklis, et al., 2019). From the historical context, many cities are in proximity by the coastal line and therefore grew up along ports, thereby gaining economic benefits from the flow of goods and the movement of people seeking jobs and good living standards. Port cities are predominantly the most economically strong and competitive cities in the world (Carpenter & Lozano, 2020). These developments and economic trends prompted many ports to pursue expansion projects and strive for more digitized well equipped smart ports.

In lieu of the aforementioned, the innovative improvement in technologies, and global energy demand has increased considerably with its associated impact on the environments and greenhouse gas emission (GHG).

In pursuant of sustainability and meeting the challenges of complexity in the maritime industry, there is a growing trend of competition among ports to implement sustainable energy efficiency strategies including green ports policy, energy management plan, Port environmental energy management plan which are certified oriented. Maritime Energy Management Program is adopted by many ports to delve into the management of the overall energy chain within the maritime domain (Port and Shipping) to achieve cost reduction and overall system improvement (Drewniak, Dalaklis, Kitada, Ölçer, & Ballini, 2018). Sporadic and erratic electricity supply with volatile fuel prices, coupled with some negative environmental impact is the order of the day. Therefore, there is an urgent need for all stakeholders and players in the industry to effectively and efficiently utilize the energy and adopt cost effective regulations to curb the situation.

From its reports on the renewable energy readiness assessment of the Gambia, The International Renewable Energy Agency (IRENA) indicates that Utilization of renewable energy systems and energy efficiency measures could provide consistency in the energy sector improvement and efficiency (IRENA, 2018).

However, in order to achieve a substantial emission reduction within the ports and their proximities, the potential application of technologies which have a universal renewable energy resource on large scale is required. Its effective and more efficient usage to minimize operational cost and to mitigate the emission of greenhouse gas needs to be investigated.

For the past five decades, The Gambia faces and still facing energy security challenges due to reliance on importation of fossil fuel for energy generation. As a result, electricity generated is inadequate and characterized by frequent shortage and erratic supply chain. With regards to the fluctuating price and frequent shortage of petroleum, the situation affords The Gambia the inability to satisfy the electricity demand of the nation. The situation trickles down to the Port of Banjul, drastically affects port operations, and makes her less competitive within the sub region. Due to ineffective cargo handling, caused by poor port infrastructure and inadequate electricity supply, compelled most shipping agencies to divert their cargo delivery service to neighboring ports of Senegal.

The Gambia is one of the smallest countries in West Africa with 70 percent of her population living below the poverty line. With these trajectories, The Gambia is one of the countries in West Africa with the highest electricity tariff 0.5 Dollars w/h (IRENA, 2018). Due to heavy reliance on imported fossil fuel for electricity generation, coupled with less utilization of renewable energy, the Port of Banjul which is also annexed with three important national maritime oriented institutions (Ferry Service, Banjul shipyard, and Fisheries Jetty) rely on diesel driven cargo handling equipment like forklift, and trailers and uses diesel generators to supply electricity to the offices, warehouses, high mast lightning, reefer stations and other important installations in the absence of national grid.

This research focused on investigating the potential of Solar photovoltaic and wind energy in hybrid, to be use in Banjul Port for electricity generation. The result of the research can be used to guide the port management or decision makers to introduce such a facility in their drive for port expansion.

1.1. Problem Statement

The upsurge in global fleet volume as a result of growth in world trade and population is influencing ports all over the world to improve and modernize their energy infrastructure for atomization in cargo handling and other ports operation in response to increased demand and competition. 90 percent of the electricity used in Banjul ports today is relying on the national electricity generated by the only electricity generating company in the country, National Water and Electricity Company (NAWEC). In totality, NAWEC produces less than 150MW of electricity and is further characterized by unreliable low generating capacity, aging machines and primitive mode of transmission. The investment on the in-house electricity generation is huge and less cost effective due to high dependence on imported fossil fuel which is also less environmentally friendly. Consequently, the emission of greenhouse gas in Banjul Port and her proximity is on the increase.

The erratic nature of transmission and frequent power outage, causes substantial economic loss to the port and other prominent stakeholders involved in port operations. In view of aforementioned problems, coupled with the Government's desire to harness more avenues for economic expansion, this research topic is selected and Banjul ports is chosen for the case study.

IMO Sulphur cap 2020 is another influential factor that prompts the choice of this topic, thus, if alternative measures are not put in place, will cause some serious consequences in ports operations. Up to date, there is no proper and formidable structure in place to prepare the ports for this IMO Sulphur cap, which was recently implemented and may turn into another dimension in a very near future. Hence there should be proper and applicable alternative measures such as cold Ironing for adequate power generation. That will enable the port to utilize the greater economies of scale to compete in the upsurge increase of seaborne trade. Renewable energy is the possible answer.

The International Renewable Energy Agency (IRENA) aims to assist its members in planning for the transition to an energy system that makes maximum use of environmentally friendly and fossil free renewable energy technologies. West African Power Pool (WAPP)'s share of renewable energy technologies in the region could potentially increase from 22 percent of electricity generation at the time (2010 Base year) to as much as 52 percent in 2030 (Miketa, & Merven, , 2013). This projection according to IRENA, is in line with the Paris agreement which in their renewable energy electricity development policy targets a more extensive deployment of 7.7 TW (Schwerhoff & Schwerhoff, 2019). (The United Nations (UN) SDGs adopted in 2015, provided a framework assisting links between global warming of 1.50 or 2 degrees Celsius and development goals including poverty eradication and reducing inequalities (IPCC, 2018). SDG 7 which calls for access to affordable, reliable sustainable and modern energy for all 2030 has a strong connection with majority of SDGs illustrating how energy is central in fostering the pathways necessary to keep the world well below 2 degrees Celsius of warming and meet a wide range of SDGs targets (IRENA, 2019).

1.2. Research Objectives

The main aim of the research is the application of hybrid renewable energy for electricity production in Banjul Ports to reduce the operational cost, to enable ports infrastructural expansion and to reduce greenhouse gas emission.

Within the main port premises, there is urgent need to expand the shore to sea electrical supply (cold ironing) to reduce GHG emission from both international and domestic fleet, and to expand the jetty with ship to shore gantries, Rail mounted Gantries operation and other cargo handling equipment as well as improving the lightening of the main yard and buildings.

To attain the aforementioned goals, the following objectives will form the core of this research:

1. Quantifying and critically analyzing the total electricity consumption in Banjul ports and all its annexed institutions, both from the national grid and domestic generation.
2. Compare the energy consumption data obtained from the similar establishment from energy efficient ports in the developed and more industrialized countries.
3. Compare and contrast the technologies and guiding policies adopted by these ports with that of Banjul ports
4. Formulate and analyze the application of EnMs at the port of Banjul.

,

1.3. Research question

The relevant question that needs to be answered in this research includes what is the current energy profile for the Gambia and Banjul ports. Is there any political, economic capacity in place to implement such a project? Is the environment conducive for it? In the process, the following research questions will be address:

1. What is the energy profile of Banjul Port?
2. How can we use hybrid renewable energy to produce electricity for Banjul port to reduce operational cost and the emission of greenhouse gas?
3. Based on the current technical and environmental challenges, did Banjul Ports have the capacity to introduce Hybrid renewable energy systems?
4. With the prevailing economic condition, and with the available national avenues, can the port of Banjul afford to venture into such an investment?

1.4. Methodology

The study intends to follow basically a quantitative analytic approach to address the problems outlined above. The aim is to obtain relevant information from the Port of Banjul and all its annexed institutions. The electricity generation from the national grid is aimed to be obtained from the National Water and Electricity company (NAWEC) and Public Utility Regulation Authority (PURA).

The source of electricity in Banjul Port is mainly dependent on the fossil fuel, thus discharge huge quantity of harmful gases in port and port proximity. With the available infrastructure in Banjul Port, photovoltaic(PV) in hybrid with Wind energy, is more suitable. Solar PV are used in the off-grid applications e.g., aid to navigation buoys, and remote locations while the wind energy plant will be a complement to the national grid to offset the electricity deficiency. Solar panels are built in open fields if land is free, on roof tops of Cruise terminals, buildings, warehouse and a cold storage warehouse which shall be demonstrated in the proposed solar power projects. In view of the above, a proposal shall be made for both solar and Wind energy plant and use the levelized cost analysis to assess the feasibility of its implementation and its economic viability.

The parameters below are meant to describe the procedure to gauge the feasibility of renewable energy technologies and levelised cost of energy and subsequently ascertain the establishment of Hybrid Renewable Energy technologies.

As per the procedures of the World Energy Council, the under listed parameters are used:

- Cost of Energy (LCOE)
- Capital expenditure (CAPEX)
- Operating Expenditure (OPEX)

The levelized cost of electricity (LCOE) is the price that must be received per units of output as payment for producing power in order to reach the specified financial return.

FORMULA= $\frac{Life\ cycle\ cost\ (\$)}{2a\ Life\ Time\ Production}$

It will also help to compare different technologies with different project size, life time, different capital cost, return, risk and capacities.

NPV Calculation for the proposed Wind Power

In order to achieve the most important economic benefit of the wind turbine, is to reduce the exposure of our economies to fuel price instability. The less volatility this trend, justifies a larger share of wind energy in most European countries even though wind were more expensive per KWh than other forms of power generation.

The conducive avenue provided by the University in accessing the external lectures from mainly Genoa, Gothenburg and Hamburg Ports enable the research to obtain relevant information and data that could be utilized in benchmarking and to determine the feasibility of the project in Banjul port.
Other useful information that will be relevant to this research will be obtained from class lectures, peer review journals, periodical conference papers, reports and books published by renowned scholars in the Energy field. Other international institutions having affiliation to energy generations and academia. The World Bank (WB), International Renewable Energy Agency (IRENA), International Energy Agency (IEA), West African Power Pool (WAPP), European Sea Port Organization (ESPO) amongst others will also be tapped for information and data. Other

sources of information relevant to this study will be obtain by sending questionnaires to relevant sectors and departments, online interviews, direct research from the internet etc.

1.5. The scope of the research

This research aims to look into the feasibility of electricity generation through renewable energy technology with the possible introduction of Hybrid renewable energy System of Solar photovoltaic and wind power to reduce cost and mitigate greenhouse gas emission. The influence of certain externalities regarding port operation are also factored out. However, the city of Banjul which embodied the proximity of the port and other stakeholders that take part in the discharge of port operation are all inclusive. The current mode of power generation, employed to sustain the daily operation, in a more cost effective manner.

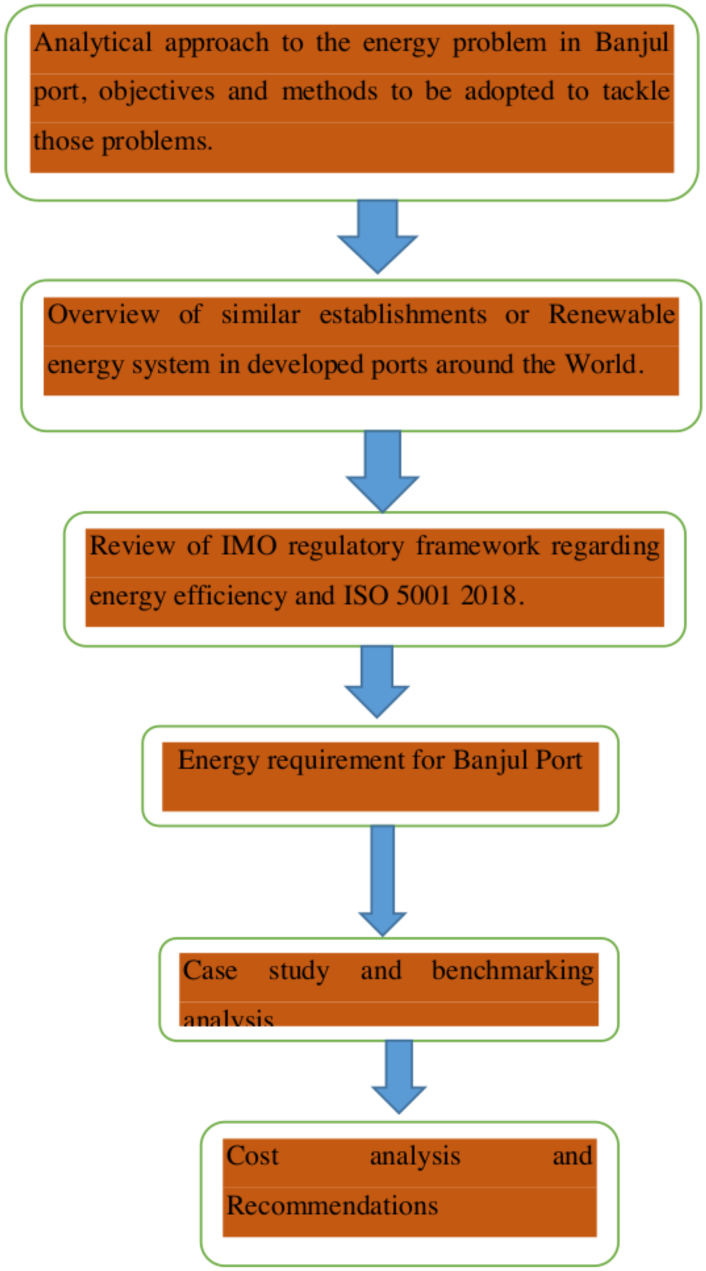
The dissertation will also focus on the human operational aspect with regards to the annexed institutions (Banjul Shipyard, Ferry Service, and Fisheries Jetty) in relation to their energy efficiency and management. The environmental factor, human factor, regulatory framework will be the guiding principles of this technological concept and its implementation.

1.6. Research Outline

Chapter one of this dissertation delves into the problems outlined, Objectives of the research, methods to be adopted, to carry out the research, and the research scope as well. Chapter two contains extensive literature review, overview of similar energy generation systems in different ports, overview of ports Banjul and its energy consumption assessment and the energy management system thereof, with Barriers and challenges affecting the system.

Chapter three contains mainly regulatory framework encompassing I MO's regulatory framework regarding energy efficiency and the ISO certification 2018. Chapter four deals with mainly the energy requirements of the ports and the amount of energy needed in the port expansion process. Chapter five looks at the relationship between the Gambia ports Authority and the National Electricity Company (NAWEC) in terms of power generation, a case study for the establishment of Hybrid renewable energy systems and the levelized cost analyses. Chapter six and seven concludes the dissertation and gives recommendation.

The Study intends to follow the task as per flow chart in the figure below:



2. CHAPTER TWO: LITERATURE REVIEW

Ports all over the world are characterized by the geographical concentrations of high energy demand and supply activities because of their proximity to power generation facilities and metropolitan areas, and their functions as a central hub in the transport of raw materials (Acciaro, Ghiara, et al., 2014). The need for better understanding and to monitor energy related activities taking place near and far within the ports and port proximities is now more apparent. This is due to the growing relevance of energy trade, public environmental awareness and focus on energy efficiency to enhance bigger industrial revolution and technological innovations in ports.

In pursuant of innovative technologies such as onshore power supplies, alternative fuels, such as LNG, and increasing development in ports areas, port managements around the world are now paying more attention to the energy matters. Renewable energy plays a pivotal role within ports as they are often located in areas that are particularly suitable for power generation from wind and Solar (Acciaro, Ghiara, et al., 2014).

Global warming is a foremost challenge on earth, and maritime transport plays a critical role in greenhouse gas emission (GHG) (Alamoush et al., 2020). Ports and terminals are essentials nodes in the maritime transport network. However, this trend has made ports a frontier for pollution with various anthropogenic inputs owing to their large consumption of fossil fuel and being inevitable source of concentrated maritime transport emission.

2.1. Overview of Port energy generation systems.

The changing energy landscape in Europe, marked with development of the energy union in 2015, had a profound impact on the European port sector. Energy consumption has naturally risen into top environmental priority for Port Authorities in Europe.

Within the frame work of green port policy, and in their pursuant to this obligations, some port authorities in Europe have recently introduce energy transition process. For example, Port of Rotterdam , where the proposed request for concession contract of its Maasvlate 2 container terminal to ensure better environmental and energy performance (Sdoukopoulos et al., 2019). During the peak hours, the sun even provides so much power that the company can supply to the grid. They have 11000 solar panels, mainly generate solar power, and during hot days, lots of electricity is used to cool ware houses (Sdoukopoulos et al., 2019). Developing other forms Renewable energy and appropriate technologies to make them work since the beginning of the 19^{th}

Century is a priority in Norway. They have generated most of its electricity from renewable source and (Infield & Freris, 2020) still active in research and development in other forms of renewables. Scarlet solar has developed, a container used solar power solution to overcome the financial and technical challenges of traditional installations. This effort will ease the barriers and entrance flexibility in the contract durations (Sdoukopoulos et al., 2019). In such technology, the existing power infrastructure (solar) and hybrid battery solutions can be integrated, thus mitigate the financial risk and liabilities. Through the global value chain, smaller economies, especially in the developing countries, can immensely benefit from such technological innovations in their port.

At the port of Rotterdam, "Renewable energy such as wind and solar power is crucial in marking the ports more sustainable. In lieu of the advantages provided by the renewable energy technologies, this philosophy could be vehemently substantiated, if ports in the developing countries especially African ports are advice to introduce solar and wind powers which have the potential to easily and efficiently facilitate the drive for green and smart ports initiatives. The exponential increase in the world seaborne trade, primarily through bulk cargo and containerization is subjecting the African and other developing countries to exorbitant pressure for expansion, and are yet to tap emerging economies of scale and potentials of renewable energy, thus, still facing the problem of awareness and importance of energy efficient infrastructure.

Continuous research within the maritime industry have shown that, replacement of diesel powered terminal equipment minimized energy consumptions and CO2 emission, hence, triggered Port of Valencia to retrofitting of RTG cranes diesel driven generators set as measures of reducing the emission GHG by 43 percent (Alamoush et al., 2020).

In a similar vein, San Pedro Bay Port clean air action plan chose to replace some older CHEs with new clean engines over a specific period (Acciaro, Ghiara, et al., 2014). New York and New jersey (NYNJ) container terminal operators systematically replaces yard tractors with a brand new ones after working for five years as a strategy to minimize their CO_2 emission. Also all the locomotives and older diesel powered gantry cranes will be retrofitted with features that utilizes regenerative electrical capabilities to support strong competitive businesses (Alamoush et al., 2020).

Port of Amsterdam, Tokyo, Antwerp, Felixstowe, San Diego and Genoa exploit PV energy (Acciaro & Serra, 2013). Studies have shown the benefits of utilizing Solar PV and Wind Power generation in different ports, example Ukrainian ports, Port of Damietta-Egypt, and other Egyptian ports, and as a result, considerable emission reductions are registered.

Existing examples of wind generators can be found in Ports of NYNJ, San Diego, San Francisco, Baltimore, Long beach, Hamburg and Zeebruge while large wind investment can be found in the port of Rotterdam (200MW).
The role of Ports in climate change mitigation, is very crucial, hence has been receiving significant attention because of increasing pressure to improve environmental credibility. The most significant strategy in this strides, is reduction of GHG particularly carbon emissions and has been driven by many factors:

One factor is national Regulation of Air quality and climate change mitigation which pertains to port authorities, operations tenants and inland transportation (Alamoush et al., 2020).

A second factor is regional regulations an example is the EU Renewable energy directives 2009 aiming to reduce EU GHG 20 percent below 1990 levels by 2020 (Alamoush et al., 2020).

Clean power transport directives 2014/94/EU which require port to provide Liquefied Natural Gas (LNG) refueling points and shore side electricity (ESPO, 2020).

Location of Banjul port is optimal to harness RE, Solar and Wind. With regards to the much anticipated port expansion project, the interest of port in utilizing RE to supply energy needs has risen significantly. For widening the scope of the RE utilization, port invest heavily in the Cooperate Service and Social Responsibility (CSSR) to collaborate more with the Banjul City Council (BCC) and other important stakeholders to ensure quality service delivery.

Hatchel's investigation in 2018 have shown that RE cooperatives can be expanded in port of Rotterdam and as a result, EU- projects E-harbors studied the potential utilization of RE in EU ports, hence energy consumption and CO_2 emissions are significantly reduced (Alamoush et al., 2020).

In Norway for example, CO_2 abatement potential is 99.5 percent (Hydroelectric power, 85 percent in France (Nuclear power) and only 9.4 percent in the US (Alamoush et al., 2020). Studies conducted by Michele & Serra (2014) have shown that provision of OPS can reduce ships' CO_2 by 48-70 percent but predicted different emission reduction in various ports.

2. 1. 1. Port of Antwerp

Port of Antwerp is currently embarking on energy transition from fossil fuel to renewables. Waste heat is captured and use as energy in chemical industrial processes in the city. 69 wind turbines, concentrated solar PVs, powered with reliable and resilient energy generation mechanisms, to reduce energy consumptions, thus, lower cost and mitigate emission of greenhouse gas (GHG) as well. From the trajectories of port activities, it is clearly evidenced that the application of renewable energy coupled with the wide range of innovative technical solutions and operational measures implementation in European ports, immensely improve their current energy performance. This effort is further giving more priorities to energy concerns resulting in wider exploitation of renewable energy resources such as wind energy, solar and other different forms of ocean energy (Wave and tidal energy). These effort lead to higher decree of automation within the European port network. E.g. Rotterdam, especially its Maaslakte 2 Terminal, Port of Hamburg, Antwerp Barcelona, Algeciras, Liverpool just to name a few.

Fully automated or semi-automated terminals contributes immensely towards more sustainable operation in various ways (Kohls, Hoogstraal, & Clifford, 2019). It enhances the achievement of greater optimization of container flows, through proper cargo handling and improved turnaround time for international fleet.

Numerous projections have shown that global energy consumptions in 2040 will be about 30 percent higher than the one in 2010 and in 2040, Electricity generation will be more than 40 percent of global consumption. In this context, the renewable energy development plays a pivotal role.

Global shipping account for 256 million tons of fuel per year (fossil fuel) (Aronietis et al., 2016), thus, its combustion therefore increases the concentration of CO_2 in the atmosphere which has negative on climate change.

In view of the above, the international maritime organization (IMO), and the European Barge Industry raised concern and planned to impose strict standard aimed at mitigating the emission of CO_2 and other pollutant in the atmosphere. The only attainable and appropriate measures in Europe is the transition from fossil fuel to renewable energy. In pursuant of these strategies, Antwerp port played a leading role in the strive to green fuel transition, thus, aimed to become multi fuel Ports by 2025. The first key targeted strategy is the transition to renewable source of Energy.

Reference to Paris agreement in 2015, MDGs and SDGs (SDG 7 in particular) International Maritime Organization (IMO), in 2018 decided to adopt a target that, shipping industry would have to reduce the emission of GHG to half with respect to the 2008 level by 2050 (Germond & Ha, 2019). The European barge industry went further to target a complete neutral within same period. With regards to the air quality, IMO has decreed a regulations Sulphur cap 2020 (usage of 0.5 percent for the Sulphur content of marine fuel and enforced to be complied with strictly by January 2020.

As the second largest port in Europe, the port of Antwerp is a critical intersection of water ways (Cottini, 2018). Thus, her drive to spearhead this green port revolution is a wakeup call and exemplary motivation towards the global climate change effort. Thanks to their unique combination of logistics, industrial and transshipment companies (Cottini, 2018).

2. 1. 2. Port of Hamburg

Hamburg's port is centrally located in the heart of the city (Bernt & Holm, 2005). It is rather fascinating and ground breaking strides for energy industry, to see the shipping world on the right track of energy transition. On the Elbe beach, one can watch and observe the frequency of passing container ships from around the world justifying the quick turnaround time in Hamburg ports as a result of smart cargo handling infrastructure which emanates from reliable energy supply.

Against this impressive backdrop, Hamburg ports are enabled to achieve these important energy strides by installing three wind turbines of Nordex (a North German Manufacturer) which substantiate German's stance for their ongoing energy transition.

The container terminal operators, Eurogate has operate its own wind turbine generating 2-4 MW with a power output of 8 million kilowatt hour. These wind turbines are visible proofs for German's ongoing transition from fossil fuel to renewable energy resource.

"Two third of power consumption at the Hamburg terminal are already been met through CHP, Solar energy and wind power (Mr Friza), Beside power generation, the strategy includes Eurogate's environmental strategy and resource conservation coupled with increased energy efficiency.

2. 1. 3. Banjul ports

Banjul Ports is operating under the ministry of Works, transport and infrastructure of the government of The Gambia. As a service port, the Authority's core mandate is the management and operation of the Port and other smaller maritime oriented facilities like, the Ferry service, Banjul ship yard, fisheries Getty, and the inland ferry stations along the River Gambia. The core business and mandate of Banjul Ports is to provide Marine services, including Towage, Dry docking, Pilotage, Maintenance of the channel (dredging) and turning buoys, provision of navigation aids, Stevedoring and shore handling services like cargo handling services both for containers, general cargo, dry bulk and bulk liquids, and reception of the vessels (World Port Source, 2020).

Reference from the renewable energy trajectories mentioned in various ports, it is vital and timely to consider establishing a Hybrid Renewable energy system in Banjul port. From the afore mentioned scenarios in terms of renewable energy development in various ports in Europe, it is clearly evidenced that the exemplary strides demonstrated in electricity generation leading to the various decrees of automation, enhanced the European ports to achieve a better cargo handling infrastructure resulting to improved turnaround time for international fleets, thus positioning these ports at a vantage point in the international shipping arena and the global value chain. With regards to sustainable agenda, EU ports are meticulously monitoring energy consumption which indicate 65 percent increase from 15 percent in 2013 thus, attaching great importance to energy transition issue. Among the environmental priorities, EU ports ranked energy consumption in second position (Lam & Notteboom, 2017).

In West African countries, due to deficiency in institutional and market arrangement, many ports focused more on availability rather than conservation in terms of energy policies. However, the sub regional, Economic Community of West African States (ECOWAS) has come up with a policy document in 2013 aiming to ensure efficient use of the region's resource and drive towards energy transition (ECOWAS, 2013).

2.2. Energy management system in Ports

Maritime Energy Management (MEM) is a study of overall energy system- Supply, conversion, production, use and consumption in the maritime domain (ships, ports and Shipyards) to achieve utilization and cost reduction, thus improvements in environmental profiles, through effective measures (Ölçer et al., 2018). In this vein, energy transition, coupled with the proper implementation of energy efficiency programs have potentials to reduce the energy cost by 30 percent. Reduction in energy consumption as a direct result of low fuel consumption in ports due to various fuel saving measures, enhanced reduction in externality cost, like medical bills due to respiratory diseases arising as a result of air pollution in Ports (Ballini & Bozzo, 2015).

With respect to energy reduction effort, through energy transition, it is essential to introduce resolute energy awareness campaign with the proper implementation of vibrant energy management system. It is important that all employee and other ports stakeholders utilized awareness and proper monitoring energy use in saving cost (Acciaro M. , 2014). There is a deficiency of awareness in energy efficient infrastructure as many ports in developing countries began embarking on energy efficient and energy transition technologies in their operations. Energy awareness campaign in port operations should be frequently promulgated among port stakeholders for easy implementation of energy efficiency and management strategies.

Energy management system entails plans that implement various measures, e.g. electrifications, automations, hybridization, and utilization of alternative fuel and Renewable energy to more energy complex energy management technologies such as energy storage system, smart grid micro grids, virtual power plants (VPP) and smart load management.

Energy management plan (EMPs) is a functions of planning and management all transactions between the producers of energy (supply) and energy consumers(Demand) (Acciaro, Ghiara, et al., 2014). See the same study for the same study for the role of Hamburg and Genoa Port Authorities in Energy management.

Ships would connect to OPS provided by a local port grid, while their auxiliary engines and boilers are shutdown. The Ops potential to reduce GHGs is high but depends on the source of electricity (Alamoush et al., 2020) the best result is when the the grid depends on RE or LNG (Solar and wind).

3. CHAPTER THREE - PORTS ENERGY EFFICIENCY AND REGULATORY FRAMEWORK

Ports are the interfaces between land and Sea, hence, play a pivotal role in the international trade. In many ports in Europe, due to sophisticated cargo handling infrastructure, improve turnaround time and energy transition from fossil fuel to renewable energy, ships emission contribution, is relatively insignificant as regards to global shipping emission. However, for the shake of environmental sustainability in ports industry is of growing concern for ports authorities, policy makers, port users and local communities (Acciaro, Vanelslander, et al., 2014). There can be a serious environmental effects especially in the coastal regions in Europe, Asia, and North America which have dense seaports and busy shipping activities. Most of these shipping related environmental impact are brought by explicit routine operations such as in-port ship activities.

Research and scientific evidence have shown that emission produce by shipping, can affect significant climate (GHG emission), air quality, (NOx, and SOx), acidification NOx on eutrophication and atmospheric ozone formation, public health and eco-system (causing malfunctioning of lungs or lung cancers, allergies and Asthma) (Bailey & Solomon, 2004).

In lieu of the grave environmental risk, emission of GHG mostly from Anthrophonic activities (including port areas), IPCC, UNFCCC, and other international agencies highlighted the significance of imperative energy management and efficiency coupled with the utilization of international conventions and guidelines to reduce energy consumption.

From the Paris agreement in 2015 where Sustainable Development Goals (especially SDG7) which imply providing accessible, affordable and modern energy for all, set by UN, aiming at strategizing agendas that includes, challenging Port Authorities, Port cities and shipping community at large to develop an interface that will strategically improve productivity through economic, social and environmental means.

From maritime and management context, formulating energy strategy requires the adoption of vibrant energy management and efficient measures that reduces greater energy consumptions, lower the operational cost considerably. This is achievable through implementation of proper port energy management plan that contributes significantly towards reliable energy service that couples with the reducing emission from port related operations.

3.1. International legal framework IMO Regulation on GHG emission (MARPOL Annex VI and 2020 Sulphur cap)

Environmental sustainability in ports industry is of growing concern for ports authorities, policy makers, port users and local communities (Acciaro, Ghiara, et al., 2014). In view of the complexity in the maritime industry, and in relation to what type of technological innovation can be appropriate in ensuring environmental sustainability, there is a need to adopt more advance conceptual framework.

The situation in some of the leading ports in Europe and Asia, for example Singapore, Shanghai, Antwerp and Rotterdam are matured in exercising environmental standard regulations which reveal that the enforcement approach is more eminent in their endeavors towards implementing more energy efficient strategies (Lam & Notteboom , 2014). According to UNCTAD, international shipping industry carries over 80 percent of the global trade volume which is more than 70 percent of the global trade volume through seaport worldwide (UNCTAD, 2017).

From the current shipping trajectories, World merchant fleet stands at 42,486 ships with a combined dwt 1.76 million in 2017. This implies that, the global merchant fleet tonnage has been double in 15 years (Beliën et al., 2020). This trend is a clear manifestation that shipping is considered to be the most proficient and economic international transportation medium for all kinds of goods due to the low cost and its potential to ease commerce.

On October 2016, international Maritime Organization (IMO) announced enforcement of its revised Annexed VI regulation known as IMO Sulphur cap 2020 to be implemented from January 2020 (Topali & Psaraftis, 2019). The regulation was amended for strengthening the effort to drastically reduced the air pollution from the ships, especially emission of (Sox) Sulphur.

Stipulated in the regulation is that, ships will have to use marine fuels with Sulphur content of not more than 0.5 percent m/m (mass by mass) against the current existing limits of 3.5 percent m/m for outside(ECA) and 0.1s m/m content for the emission control areas(ECA) will remain as 2015 standard.

Ports as a central hub for transportation of goods and predominantly found in metropolitan areas, thus, international regulations are essential, drivers and instrumental in reducing emission at the open sea and within the ports and terminals. Implementation of such regulations has brought in so many important strides in the improvement and cementing the cordial relation between the regulators and stakeholders in the maritime industry. MARPOL Annex VI is the most important IMO instrument, designed to mitigate air pollution, while its chapter 3 stipulates the requirement for control of emission ozone depletion substances SOx, NOx, Volatile Organic Compound, and Particulate Matters, chapter 4 entails GHG emission prevention through energy efficiency strategies on ships.

3.2. EU vs National Energy Policies and Regional Regulatory framework

Policy interest in Europe are increasingly focusing on ports, seas and oceans. This phenomenon is triggered due to the derive to manage and protect the marine environment which raises concern as to whether such activities are geared towards developing sustainable management of the seas.

Sustainable management of ports, seas, and oceans calls for an integrated and cross-sectional approach in order to protect bio-diversity and other land based activities. From the European context, Seaborne transportation is generally considered as less harmful compared to road and air transport. However, this does not justify paying less attention to the discharge of pollutant like NOx, SOx, and Particulate Matters by marine transport sector. The major concern in Europe is mainly centered on illegal discharge of oil and waste, atmospheric emission of Nitrogen dioxide (NOx), Sulphur oxide (SOx), noise, particulate matters and accidental discharge of hazardous substances'.

Ports state controls in Europe institute mechanism to improve compliance monitoring system some of which includes ensuring European ports to have reception facilities for ships generated waste and cargo residue (Köck, 2004).

Beside the Sulphur cap 2020, IMO further used its most prominent preventive mechanism International Convention for the Prevention of Pollution from the ship to prescribed 4.5 percent limits for Sulphur content in heavy fuels used in shipping and further designate Sox emission control areas and ships plying those areas should use fuel below 1.5 percent Sulphur content. (European commission 2005). Atmospheric emission from shipping have triggered air quality problem in many European ports and has prompted European communities, to promulgate the need for expansion and include all European waters in already designated areas.

In view of their regulatory frameworks against energy efficiency and with reference to the climate change trajectories, Banjul Port is far from ready to make any positive strides due to their inability for Energy transition.

3.3. Voluntary Certification framework

Among the top environmental priorities of European port sector, energy consumption has received increasing attention, thus ranked 7th in 2009 (Sdoukopoulos et al., 2019). In pursuant for the effort of addressing this environmental concern and energy efficiency, Ports authorities in Europe have been working tirelessly towards setting up appropriate policies aiming for action plan and establishing proper management framework.

In an effort to evaluate and reflect the different level of commitment, individual ports authorities in Europe undertake, to improve their energy efficiencies, policies, strategies and standards. International Standard Organization (ISO) introduce an effective tool (ISO 50001 for supporting energy managers on meeting energy consumption reduction goals which follows the conventional Plan –Do-Check – Act (PDCA) improvement cycle which will be discuss in details in Chapter 4.

The Eco Ports, Port Environmental Review System (PERS) is the only port sector specific environmental management standard which is independently certified. In 2016. ESPO undertook Port environmental review aiming to update the top 10 environmental priorities of European Ports and produce further bench marks figures in key areas of port environment management . (ESPO, ESPO Port Environmental Review, 2016)Their effort was mainly focus on redefining the environmental priorities of European port sector. The results gathered, identified the high priority environmental issues on which ports are working and set the framework guidance and initiative to be taken by ESPO and Eco Ports.

The table below provides the list of EU Countries represented in and the number of participating ports for each country. Spain and United Kingdom have the highest number of Port representation (12 each), followed by France (10).

Figure 1 Number of contributing Ports per country

Country	Number of contributing ports
Spain	12
United Kingdom	12
France	10
Netherlands	9
Denmark	8
Germany	6
Greece	5
Sweden	5
Italy	4
Norway	4
Croatia	3
Ireland	3
Finland	2
Latvia	2
Belgium	1
Cyprus	1
Romania	1
Estonia	1
Lithuania	1
Portugal	1

Source: (ESPO, 2016).

4. CHAPTER FOUR - PORT ENERGY REQUIREMENTS

To achieve quality energy management system, that strive on full DE carbonizations and leads to reduction of the greenhouse gas emission, technical and operation efficiencies should consider transition from the use of fossil fuel to renewable energies. Greenhouse gas emission from ships at berth and from the domestic energy production system or even from the national power grid, is generated during combustion process in engines, hence a vibrant energy management system will drastically reduce the menace (Ölçer et al., 2017). The efficiency of every port is heavily dependent on its traffic flow to hinterland (Ölçer et al., 2018). Port connectivity to interlard and its environmental response with the proximity is very instrumental for ports energy profile. In this view, port energy requirements should be determined by the port ability to ensure reduction in operational cost, and be more environmental friendly, thus investment in energy efficiency technologies with efficient operational management, reduction of noise, mitigating air pollution, and sustainability should be adopted to achieve these objectives. The port connectivity to interland and its environmental response with the proximity is very instrumental for ports energy profile. In this view, port energy requirements should be determined by the port ability to ensure reduction in operational cost, and be more environmental friendly, thus investment in energy efficiency technologies with efficient operational management, reduction of noise, mitigating air pollution, and sustainability should be adopted to achieve these objectives.

Port authorities are set to actively pursue the energy management system based on the following fundamental requirements:

- Resilience
- Availability
- Reliability
- Efficiency and cost effective
- Sustainability

Based on the above fundamental managerial pillars, there should be an effort in place to have an applicable energy management plan. In this view, Port Authorities pay more premium to energy policy ISO 50001 which is discussed in detail in the subsequent chapters.

4.1. Port energy management strategy port expansion plan and priority areas.

The aim of port energy management Strategy, is to formulate process and strategies towards realizing appropriate energy saving through cost reduction and consolidation of gains for profit maximizations in ports (Ölçer et al., 2018). To improve a port energy profile for an optimum port infrastructural development in order to earn a better competitive posture in the maritime transportation, attainable and better energy management system is the core. Energy transition to renewable energy technologies, which aims to reduce the operational cost and to make the ports and its proximity more environmentally friendly, is a primary factor for enforcing energy efficiency and improvement. Transition from carbon intensive port industry (dependent on fossil fuel) to low carbon port model through harnessing renewable, and energy alternative fuel (LNG hydrogen, biofuel), ensure more credible and reliable power distribution system.

Generally, Ports, especially container ports have some major functional areas targeted for huge energy consumption, thus, prioritized for energy efficiency management. These include mainly quay side, ship yards, and land side. For the case in Banjul Port, major operational areas that needs efficient management system are the main port premises including the main buildings, old and the new Wharfs, container terminals including the sheds, reefers stations and workshops as well as the four main institutions annexed to the port (Ferry Service, Ship yard, Fisheries jetty and Banjul shipyard).

There are numerous technological solutions that can enhanced energy efficiency and reduce greenhouse gas emission in ports but the one that is apt for Banjul port, with regards to this research, is the use of Hybrid renewable energy system for producing electricity. This kind of energy system will therefore enhance:

- Cold ironing – to facilitate shore to ship electricity supply and reduce GHG emissions from the domestic and international fleet during berthing.
- Electrification of cargo handling equipment to improve turnaround time for international fleet and reduce the maintenance cost on current equipment in use (fork lift, trailers etc.) and mitigating the emission of greenhouse gas.
- Ensure the use autonomous vehicles and automation of cargo handling facilities for speed and cost reduction.
- Energy storage device.

- Reefer cooling technologies- to facilitate re-export trade for Agricultural and perishable goods.

4.2. Developing a new energy management plan

Energy management system consist of Energy demand planning, energy supply planning and smart energy management. For port authorities to efficiently implement proper energy management system, ports should be measured in terms of energy consumption, establish the appropriate energy requirement and strategies. For Banjul Port, these standards are mostly aim to address energy issues in the priority areas that are afore mentioned, thus impacted strongly on their energy consumption.

ISO 50001 Energy Management System standard was designed to encourage organization especially port authorities to establish system and process that gradually improve the energy efficiency and measure energy consumption (Iris, Ç, & Lam, 2019).

From the literature of Port energy trajectories, the following major ports in Europe have been certified with the ISO 50001:

- Hamburg Port Authority in Germany
- Port of Antwerp in Belgium
- Noatum container terminal – Valentia in Spain.
- Port of Felixstowe in the UK
- Port of Africa in Chile
- Baltic container terminal in Poland.

In the same vein, and with regards to their authority's desire to have cooperate policy and energy management plan, in order to establish framework for energy efficiency, Banjul port will delve into ISO 5001 Energy management standard.

Energy Policy ISO 50001:2018

The ISO standard 50001 -2018 enable ports authorities and other relevant institutions to achieve a sustainable energy reduction by systematic energy controlling, documentation and raising awareness of all personnel and stakeholders (Van Heerden, 2014). An energy management system in Banjul port, shall be designed to achieve maximum energy saving performance in the energy transition project. It will provide a framework for the project, drivers, engineers and other relevant port users during and after the project implementation. The Paln –Do-Check-Act (PDCA) cycle will be applied throughout and follow the basic step recommended by the standard. It will put more premium on the concept of continual improvement to enable sustainable increase in Electricity savings.

1. Implement and respect existing energy policies and regulations especially those that are maritime related.

2. Established and manage an energy team, composed of an energy manager as the head of the team and representative from each centre or department that partake or with an important share of energy consumption.

3. Each centre or department, with an important share in energy consumption or saving potential, shall be obliged to adjust the energy saving process annually.

- These processes outlined below, describe the systematic planning, implementation and assessment of energy-saving measures that will lead the Port of Banjul to achieve the energy savings and improvements during and after the implementation of energy transition project. It will improve the energy efficiency of its own fleet, (Harbour craft, Tugboats, pilot boats, mooring boats, etc.), so that by the end of the targeted period, their energy consumption will absolutely decrease by a certain percentage that maybe prescribe in base line.
- Attainment of the prescribed percentage of the total energy savings by switching from fossil fuel to the use of renewable energy source.
- Maintain and further develop the energy monitoring system for ensuring appropriate evaluation and analysing the energy flows.

4. During this period, assessment of new investments in energy sector, the team shall continue to include the energy efficiency aspect in the decision-making process.

5. Further stimulate the energy awareness through frequent training and periodic sensitization of every employee and port users.

6. Provide adequate logistical support, and sufficient human resources, through which the proposed actions can be carried out within the specified time frame.

4.3. Port energy performance tracking and monitoring

Energy performance is a key element which is related to energy efficiency, energy use and energy consumption (Peter, O, & Mbohwa, 2018). Therefore, port energy performance tracking and monitoring is basically focus on routine improvement of energy performance in provision of requirements for systematic date driven and fact base process. The fundamental framework, which is the guiding principles in the afore mentioned context is based on PDCA concept. This will incorporate the existing energy management system in place in Banjul port.

Figure 2: Plan Do Check Act Diagram

Source: (Bushell, 1992)

The objectives of monitoring and progress review process are to measure and compare energy consumption with the company's goals or with general energy consumption standard and regulations. A PEMP is a strategic tool for port authorities and maritime administrations that are used to address energy savings and environmental objectives by obtaining structures and detail analysis of the current status of energy environments in ports areas and subsequently to set up a potential direction (Ölçer et al., 2017).

4.4. Benchmarking and case studies.

In order to encourage the authorities in Banjul Port, to consider establishing a hybrid renewable energy system for electricity generation, it is important to reference other developed ports (especially in Europe) that have already established similar facilities. In this research, Port of Hamburg, Genoa, and Gothenburg have made a significant stride in energy transition from fossil fuel to renewable energy.

4.5. Port of Genoa

The Port of Genoa is spread over an area of about 700 hectare of land plus 500 hectares of sea along a coastal strip that extend for a length of about 22 km, protected from the open sea by a system of breakwaters (Balini, 2017). Through efficient study, and adoption of Port Environmental Energy Plan (PEAP), Genoa port places a particular emphasis on renewable energy resources with the primary aim of reducing the impact of the operational activities in port areas and to achieve more efficient use of energy.

According to the PEAP guidelines, Genoa Port, through their energy transition process embark on the following renewable energy technologies.

- Onshore wind energy resources
- Solar Thermal and photovoltaic energy biomass energy
- Geothermal and hydrothermal energy wave power.
- In addition to renewable energy technologies, ports registered improvements on energy efficiency of buildings.
- Improvement of energy efficiency of public lightening.
- Improvement of efficiency of cargo transport.

Genoa Port Authority (GPA) has developed a port energy Environmental Plan (PEEP) for its ports with the scope of stimulating and developing the activities linked to the production of energy from renewable resource. The Port is also proceeding towards the electrification of parts of its quay and transformation of cabins which is currently underway in the industrial area of the ports (Acciaro, Vanelslander, et al., 2014)

Figure 3: Location of Port of Genoa

Source: (Port of Genoa, 2020)

The trend of energy demand and the energy management trajectories in Genoa ports outlined in the table 1 below, shows that, each terminal operator is responsible for monitoring and reporting terminal's total energy consumptions rates without providing specific disaggregated data on the share.

Port of Genoa is also embarking on the process of expanding its capacity with two major infrastructural developments of (Derma and Bettino quays), with a projection of 7,500,000 KWh a year for total overall consumption (Acciaro, Vanelslander, et al., 2014). The prominent inspirational idea behind this case study and served as a motivation is using Banjul port (the country's No. 1 gateway) as an energy reservoir for the whole country with a small population of (Two million people) almost equals to the population of Genoa port city.

Table 1: Energy consumption for Container Terminal in Genoa port

TERMINAL	CONSUMPTION /YEAR IN KWh
VTE (50% reefer)	19,000,000
SECH	4,500,000
Messina	5,000,000
Fruit Terminal	4,600,000
Stazione Marittima	6,300,000
Oil terminal	2,500,000
Dry bulk terminal 5	,000,000
Other	49,900,000

Source:(Compiled by the authors on Port of Genoa data).

4.6. Port of Gothenburg

From the Swedish trade statistics, Gothenburg is the second largest metropolitan area in Sweden, Covering 13 municipalities and with a total population of 0.95 million (Kalmykova et al., 2018). Literature have shown that Gothenburg had one of the highest growth rate in Europe between 2002 and 2007 and has the largest Port in Scandinavia. 30 percent of the Swedish foreign trade passes through this port (42 and 22.2 million tons of freight and oil respectively), while the passenger traffic amounts to 1.7 million passengers per year (Kalmykova et al., 2018).

Figure 4: Image of Port of Gothenburg

Source: (Port of Gothenburg, 2020)

From the shipping trajectory analysis, Port of Gothenburg receives between 10,000 and 12000 calls per year including almost all types of ships (Winnes et al., 2015). Additionally between 1000 to 2000 ships to and from ports upstream the river Gota Alv (Gibbs et al., 2014). Thus, this trajectory above makes the port the largest cargo ports in Scandinavia.

In their pursuant to the environmental challenges, the port has initiated an environmentally differentiated dues to reward ship operators with high environmental performance. The port offers connections to the onshore power grid (Renewable energy source) at six RoRO berths and has installed a windmill that supports the electricity supply that correspond to the ships power needs.

The table below depicts the impact of energy transition from the use of fossil fuel to Renewable energy resource technology according to movement of ships in their categories and size in port of Gothenburg. From the shipping trajectories in the table below, the first row indicates the number of ships calling including those passing the port of Gothenburg in 2010. From the second row depict the amount GHG emission from the ship calling the port.
From the statistics below, the significant increase registered in the reduction of GHG emission is as a result of onshore power supply and design improvement on ships. With reference to Banjul, the trajectories stipulated in table 2 indicates that energy transition is the appropriate technology for mitigating GHG emission and reducing the operational cost.

Table 2: Number of ship movements of different ship categories and their CO2-e emissions in Port of Gothenburg 2010

TYPES OF SHIPS CALLING	Ferry /RoRo	Container	Dry and liquid bulk	Cruise	General cargo	Bunker ships	Others	Total
Number of ship calls including passing ships	4297	1211	3007	41	1343	1343	3600	13,676
Emissions of CO2-equivalents (tons), 2010	85,800	30,200	79,800	1450	4360	9330	3600	210,000

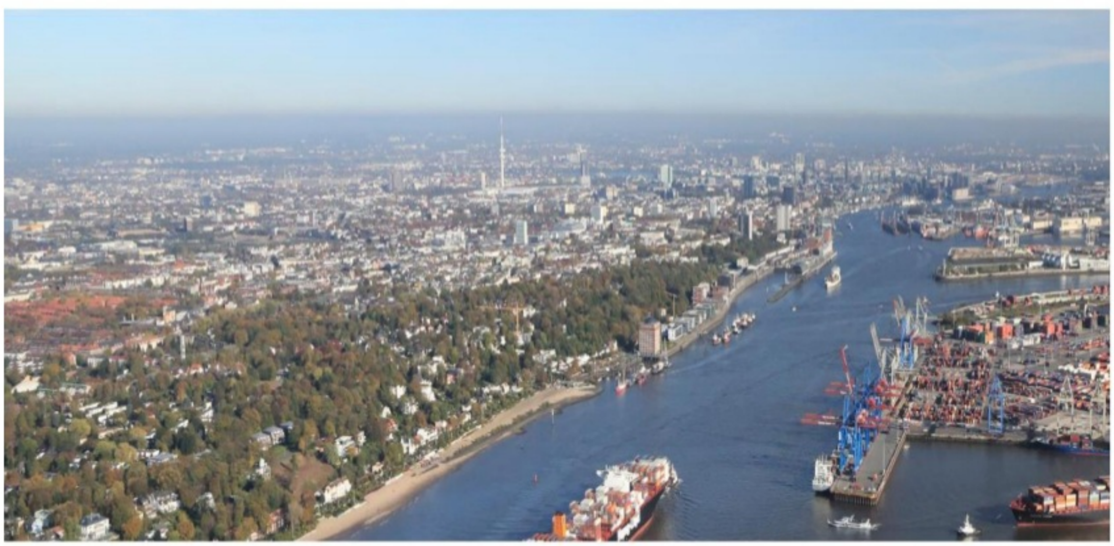
CO2- emissions from ships b5000 GT, (%)	0	2%	16%	1%	69%	100%	30%	12%
CO2-emissions from ships 5000–30,000 GT, (%	65%	54%	53%	23 %	31%	0%	27%	55%
CO2- emissions from ships N30,000 GT, (%)	35%	45%	31%	76 %	0	0	43%	33%

Source: (Port of Gothenburg, 2020)

4.7. Port of Hamburg.

From the literature, and the European port trajectories, Sustainability through proper energy management system, plays an important role in the port of Hamburg as the proximity of the port areas to city and the sensitivity of the Elbe river ecosystem require particular attention to sustainability issues in the port development.

Figure 5: Image of Port of Hamburg



Source: Port of Hamburg-2019

From 2011 HPA in partnership with German Chamber of commerce and Hamburg city with other important players in port operations, formulates a strategies that aims at improving the ecological balance within the city of Hamburg and strengthen the correlation between protecting the environment and the success of the business environment and in the same vein, together with state ministry of Economic affairs, Transport and Innovation developed a project call “smart port project” (Merk & Hesse, 2012).

The largest terminal operator in Hamburg HHLA has an approximate energy demand of 120MWh per year which is relatively small compared to the steel mill operated by Mittal in the range of GWh or a rolling mill (Europe’s largest copper producer) operated by Norsk hydro that requires 2GWh.

In view of the energy gap outline above, the largest terminal operator in Hamburg ports Hafen und Logistik (HHLA) 70 percent state owned has been pioneering energy efficient measures within ports in addition to solar installations and other renewable energy resources mentioned above.

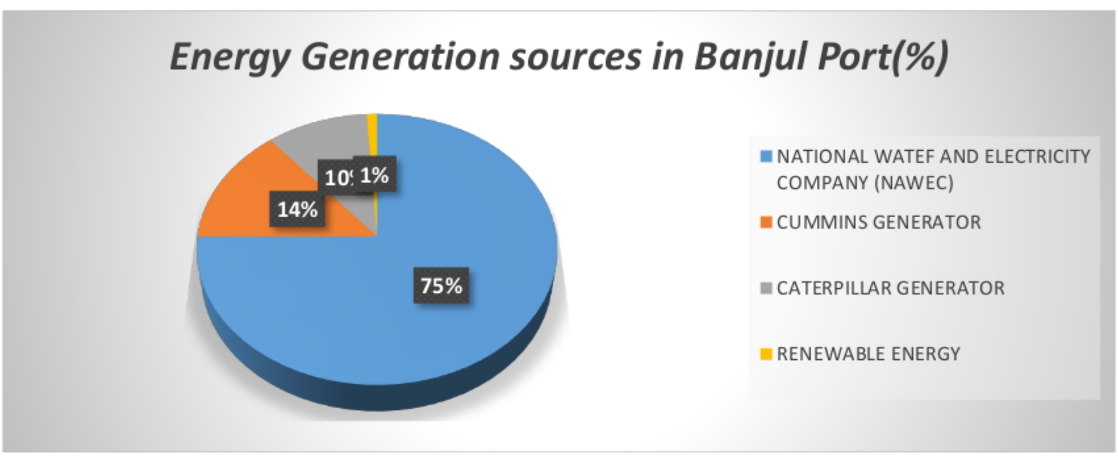
5. CHAPTER FIVE - CASE STUDY FOR THE ESTABLISHMENT OF HYBRID RENEWABLE ENERGY SYSTEM IN BANJUL PORT

Energy generation in the Gambia is under the purview of the ministry of energy and petroleum. Administratively, the sector operates under the directorates of National Water and Electricity Company (NAWEC). Although the sector is predominantly occupied by public players (Government bodies), there are few private independent producers (Both indigenes and external), who are involved in electricity generation.

Banjul port, is the only port in the country that connects The Gambia and the international world for seaborne trade through shipping (import and export). The divergence of the administrative portfolio outlined above, depicts the complexity in this study. However, there is a common regulatory body, the Public Utilities Regulatory Authority (PURA), which is also established through an act of Parliament in 2001, mandated to safeguard the interest of the citizenry in terms of public utilities but more significantly the consumers as per electricity act 2005. Power transmission in Banjul Port is exclusively undertaken by three main sources:

1. From the National grid, control by National Water and Electricity Company(NAWEC)
2. Local Power generation within the port through two standby generators, 750kva (Cummins) and 500KVA (Caterpillar) respectively, which collectively supply 24 percent of the electricity to the port.
3. Renewable energy generations are only 2 percent.

Figure 6: Energy Generation sources in Banjul Port



Source: (Banjul Port 2020)

With the expected port expansion program, which aims to improve the port, is projected to experience sharp upsurge in demand for electricity consumption in the coming decades. In this view, there is a need to optimized the energy usage and redesigned to introduce cost effective energy management measures that will be resilient, reliable and sustainably implemented. Hence, the introduction of Hybrid renewable energy management system.

5.1. Gambia National Energy Grid

The Gambia is one of the smallest West African Country, located along the West coast of Africa bounded by Senegal on three sides, and narrow Atlantic coastline at the west. The Gambia is a Sub- Tropical country, a narrow strip of land on either side of the River Gambia, 48km wide at the west point. It has an estimated population of 2,4 million, annual GDP 1.40 billion. GDP growth of 4.6 percent, Land area of 10, 689 Square km stretching 450 km along River Gambia (Blimpo, Carneiro, & Lahire, 2016).

Figure 7 Map of the Gambia

Source: (Sisawo, 2018)

The Gambia has a population annual growth rate of 2.2 per annum and the population density 120'/KM^2 (One of the highest in Africa (IRENA, 2017). With regards to the Gambia's renewable, readiness assessment report 2013, the progress is retarded by inappropriate decentralization, as the country is undergoing a rapid rate of urbanization with a share urban population increasing by 37 percent in 1993 to about 55 percent today (World Bank, 2013).

With reference to the economic trend highlighted in the energy system trajectories, the Gambia needs to scale up its energy services both in quality and quantity in order to meet the country's socio-economic developments.

The ministry of energy and petroleum is the sole government body mandated to oversee the entire energy matters in the country. National water and Electricity company (NAWEC) is overseeing the responsibilities for the generation, transitions and distribution of electricity in the country. The few Independent Power Producers (IPP) includes: GAM WIND (Operating -150 Kwa wind turbine), Global Electrical Company (GEC-operating a thermal Plant), KARPOWER, (operating shipboard plant hired from Turkey).

In view of the energy trajectories outlined in table 3 below, the average Gambian citizen are among the lowest electricity consumers in the World. More than 90 percent of Gambian house holds rely heavily on traditional biomass to meet their basic energy demand (Schiffer, 2016).

Two major stations Brikama and Kotu comprising 17 substations which represent 90 percent of total generating capacity of the entire urban settlement and the remaining 10 percent is for public and private Independent producers (IPPs). The substations are mainly run with smaller and medium size diesel generators with an average capacity of 5 MW. As they all operate on fossil fuel, their operation and maintenance posed a huge challenge to the utility company NAWEC thus, resulting in poor maintenance, instability and inefficiency of the entire energy system. However, with available IPPs in the sector, KARPOWER and imported electricity from Senegal, serve as supplementary to partially alleviate the situation, yet quality and quantity remains a problem.

Gambia is currently generating 123.1 MW and the available capacity of 125.7 MW and 2 MW from neighboring Senegal (PURA, 2018) as indicated in the table below:

Table 3 State of electricity generation in the Gambia (2020)

	PROJECT	INSTALLED CAPACITY (MW)	AVAILABLE POWER (MW)	STATUS QUO	REMARKS
Stations in Brikama	Brikama G 1	5	5	Running	OK
	Brikama G 2	5	5	Running	OK
	Brikama G 3	5	5	Running	OK
	Brikama G 4	5	5	Running	OK
	Brikama G 5	5	5	Running	OK
	Brikama G 6			Overhauled	In advance state
	Brikama G 7			Overhauled	Work in Progress
Stations in Kotu	Kotu G 1	3	2.8	Overhauled	Work in Progress
	Kotu G 2	3	3	Overhauled	Work in progress
	Kotu G 3	3	2	Running	OK
	Kotu G 4	4.4	4	Running	OK
	Kotu G 6	6.4	6	Running	OK
	Kotu G 7	4.4	4.3	Running	OK
	Kotu G 8	4.5	4.4	Running	OK
	Kotu G 9			Running	
Stations funded by International communities	BADEA OFID			New	
	Wart Silla (B2) (WB)	6	5.8	New	OK

	Brikama (20 MW) IDB	20	19.8	Running	OK
	Power Rental Karpower	30	30	Running	OK
Imported Power	Senegal-Farafenni (30MW)	6	6	Running New	Imported
	Senegal-Farafenni	10	10	Running New	Imported
	Senegal-Base	0	0	Running	Work in Progress
	OMVG	0	0	Running	Work in Progress
TOTAL		**125.7 MW**	**123.1 MW**		

Source: (The Author)

5.2. Energy profile of Banjul Port.

Considering the expansion project in Banjul port, which is expected to begin in a very near future, energy use is considered to increase considerably. As mentioned in the previous chapters, modernization of ports operation through introduction of electric cranes, cold ironing and atomization of some operational activities, can only be optimize with a transition from using fossil fuel for energy generation to renewable energy technologies.

The operation trajectories coupled with the maintenance challenges, depict in the table 4 below, substantiate the urgent necessity for energy transition from the use of fossil fuel to the use of renewable technologies. These domestic generators supply 25 percent of the total electricity need of Banjul Port, thus, their four hours of operation can cost the Port 500 dollars. This is not cost effective by virtue of the mode operations in the port and the fluctuating market trend.

Table 4 The domestic electricity generating capacity within the Port

GENERATOR	CAPACITY	CONSUMPTION	DIESEL COST AT USD/ liter
CATERPILLAR	500 KVA	100 liters/hour	106/hour
CUMMINS	750 KVA	120 liters/hour	127.2/hour
TOTAL	1250 KVA	220 liters/hour	233.2/hour

Source: (GPA 2020)

From the critical analysis in the table 5 and pie chart below, the energy consumption trajectories reveal the importance of consistency in electricity supply, and hence shows the most sensitive and important areas that bear the highest percentage of electricity consumption.

Head office for example, consumed 20 percent caused by the high presence of standalone air conditioning units to enhance the busy transactions thereof. This is followed by reefer station 18 percent, where recent huge investment in Agriculture and Fisheries boosted export in fish products and other perishable goods, hence, accounts for electricity consumption.

Table 5 Sectional electricity consumption in Banjul port.

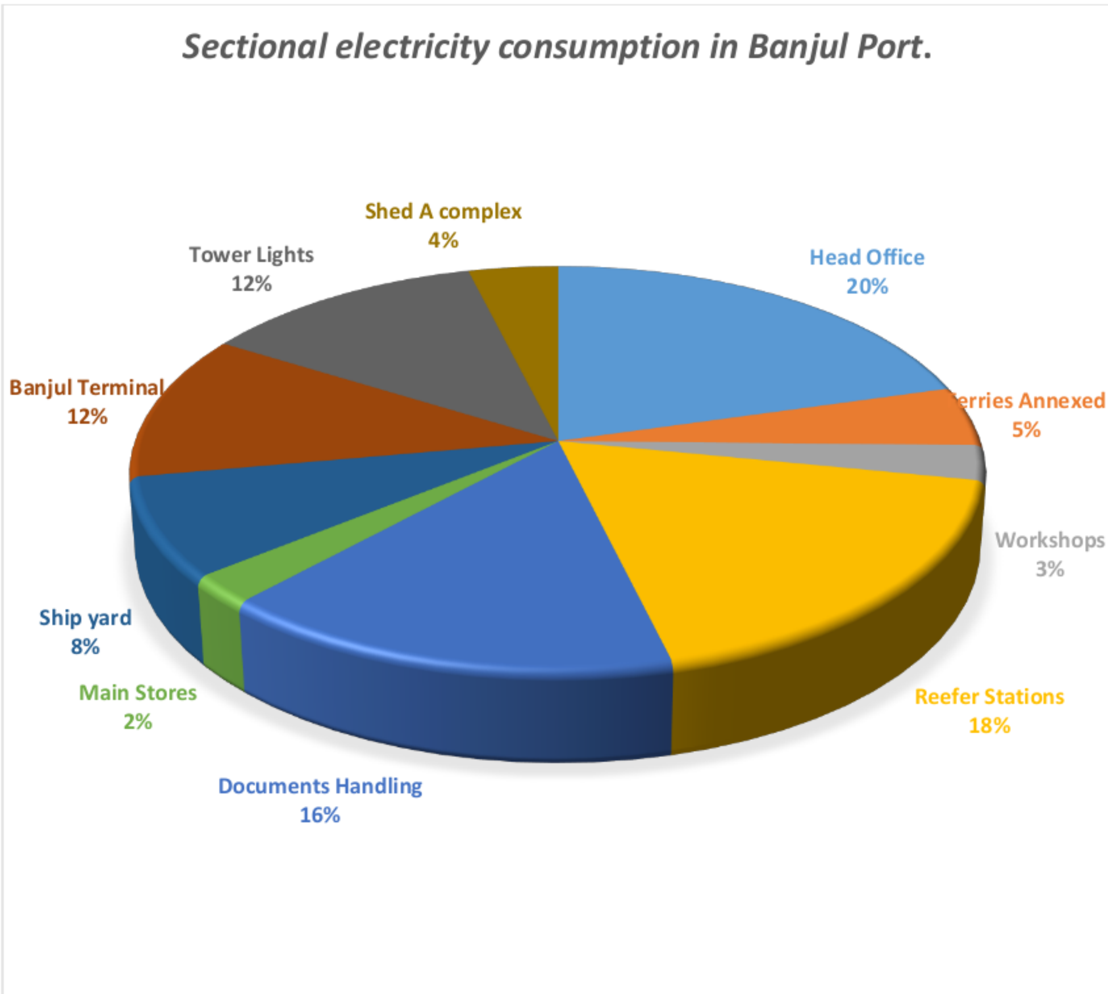
No	Section	Apparent power(va)	Real power(kw)	Remarks
1	Head Office	133,770VA	119.055	Air conditioning and IT gadgets account for higher consumption
2	Ferries Annexed	30,870VA	27.4743	Air conditioning and IT gadgets account for higher consumption
3	Workshops	18,130VA	16.1357	Compressors, turning machines etc., accounts for bulk of the consumption.
4	Reefer Stations	117,600VA	104.664	Export for fish and other perishable goods increased ,thus increased use of compressors for reefer containers

5	Documents Handling	101,920**VA**	90.7088	Lightening system and IT gadgets
6	Main Stores	16,170**VA**	13.3913	Lightening system and IT gadgets
7	Ship yard	47,485**VA**	46.2617	Capacity deficiency and the use of inefficient machinery account for higher consumption.
8	Banjul Terminal	75,605**VA**	67.2885	Ticketing and other commercial activities account for more electricity consumption
9	Tower Lights	80,000**VA**	71.2	Located in some very busy areas and HPS lightning system are used causing major consumption
10	Shed A complex	25,235**VA**	22.4592	HPS lightning system are used causing major consumption

Source: (The Author)

The high consumption rate at ship yard is as a result of old machines being used there in a very bad shape and inefficient. The use of high pressure sodium lights for high mast lights, is also increased in the two Jetties and hence accounts for high consumption thereof. This trend is aggravated by wrong electrical cabling and switch gear which at times causes frequent blackouts.

Figure 8: Pie Chart Presentation of Energy Consumption of Banjul Port



Source: (PURA, 2018)**.**

The world market price for fossil fuel is always subjected to frequent fluctuations and instability as depicted in the table 6 below. For the period under review, the peak consumption is normally observed in year 2018 which is attributed to increase in the oil price at the World market.

Table 6: Electricity generation(kwh) trajectory and consumption between the period 2016-2020

YEAR	Total number of running hours	Total fuel consumption (in liters)	Average consumption (liters/hour)
2016	875	38980	44.55
2017	2552	109820	43
2018	1043	48925	46.9
2019	826	34175	41.37
2020	763	33200	43.5
TOTAL	6059	265100	219.32

Source: (GPA, 2020)

5.3. Overview of Gambia Ports Authority

The Gambia Port Authority (GPA) was established by an act of parliament in 1972. The Port is located on the Latitude 13.4423 and Longitude- 16.5765 along the Atlantic Ocean. Aside being the country's cargo hub for seaborne trade, GPA also engaged in transshipment trade to neighboring countries in West Africa, more specifically Mali which is landlocked country. The vantage location of the port accords her that positive externality but yet to be guided by a good transport network and connectivity, with a sound and vibrant energy generation system, which this study seeks to establish.

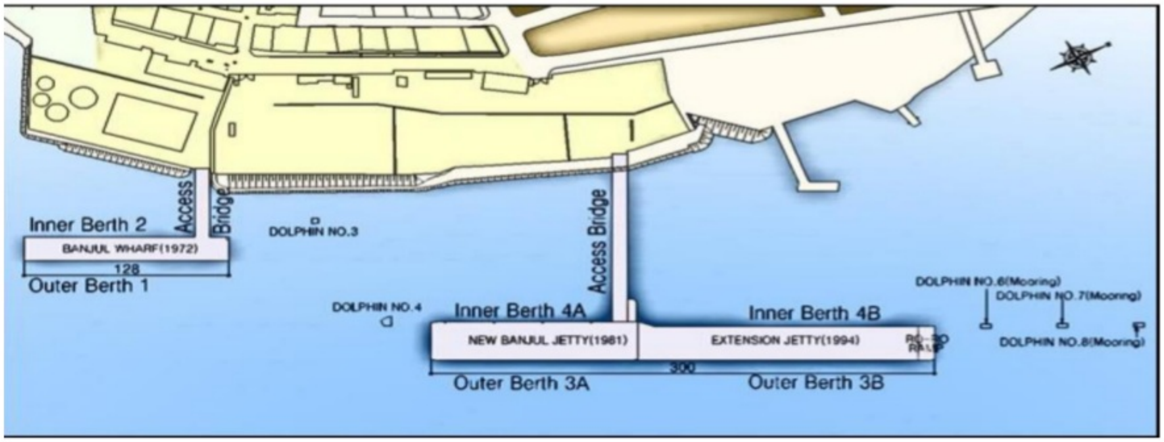
According the projections from GPA website, the BLGCC (Belgian/Luxembourg) companies that the Gambia government will soon be seeking competitive bids from third party investors and contractors to support the expansion of the Port of Banjul (GCCI, 2020). The Gambia's Finance Ministry in collaboration with Gambia Public Procurement Authority are currently interest to explore potential public private partnership opportunities with Belgian/Luxembourg companies including Port operations.

Figure 9 Location of the port of Banjul

Source: (Nations Online, 2020)

As a service port, and 100 percent state own, GPA has overall responsibility of harbors and rivers, that takes care of both domestic and international fleet), Ferry Service including all inland Ferry stations, Banjul Shipyard, Banjul fisheries Jetty, Gambia Maritime Administration (GMA) -serves as a regulatory body who is responsible for ensuring the safety of Navigation and compliance to the international maritime regulations.

Figure 10: Map of Banjul Port



Source: (GPA, 2020)

The cargo area is about 69,600m^2 comprising north and south terminal with an area of 20,000m2 and 8,000m$_2$ respectively. PWD which is annexed with a car park is 19,000M2, while the new terminal is 22,000m2.

As depicts from the figure above, GPA is currently having two jetties, Banjul Warf (Old Warf) 120m length and 6.0m draught, built in 1972, while the outer berth is 120m length and 9.0m draught with an access bridge of 45mX9m, which is equipped with network of pipelines for liquid bulk cargo.

The new Banjul Warf was constructed in 1981 and was extended in 1994. It has a length of 300m with 12m draught for an outer berth and the inner berth is 120 X 6m draught, also with and access bridge of 120mX9m. The extension is 177mX 25.5m, equipped with RoRo facilities with several dolphins and bollards.

As a public cooperation, and a service port, GPA has a core mandate of provision of marine and maritime services that includes pilotage, improving and maintaining the approach channels within the territorial waters for appropriate water depth(dredging), Maintaining the landing facilities for Ferries, Dry docking of domestic crafts, fishing boats, military crafts and some pleasure boats. Due to the limited capacity of the ship yard and energy generation deficiency, its operation is confined to the categories of crafts afore mentioned. Their mandate includes towing, provision and maintaining of navigational aids, stevedoring and handling of vessels.

Figure 11 Pictorial View of Banjul Port.

Source: (GPA, 2020)

Other marine related institutions were annexed to GPA, further to its mandate as a public cooperation. This has widened her energy demand to ensure cost effective operations.

Naturally Gambia is divided into North and south by River Gambia and until recently, there has not been many bridges across this river, thus, the only means of communication from the north to south is by ferry crossing. GPA operates a fleets of ferries both in the territorial and inland waters linking north and south. By virtue of Gambia's geographical location into Senegal, these crossing point equally links Senegal's North and South making them a very lucrative trade centers and energy consumption demanding.

Figure 12: Ferry Service in Banjul Port

Source: (GPA, 2020)

GPA owns a small domestic fleet of, two tugboats, a dredger, pilot boat, and a mooring boat all operates on diesel engines with very limited cold ironing facilities. With the limited capacity of Banjul Shipyard, it is always challenging and costly to maintain these fleet in an operating standard.

5.4. Energy requirement for Banjul port expansion project

A contract to expand the Port of Banjul has received a 140- million euros bid from a subsidiary of the state-owned China Communications Construction Company (CCCC). A French Shipping Company, Bollore Group has also submitted an offer to develop the Port with millions of dollars to a standard at which the officials hope, will make the port competing with neighboring port of Senegal (Bieringer et al., 2017).

Space constrain at the ports, for example due to space limitation in Berthing, cargo ships often have to wait at anchorage before entering. Loading and offloading cargo have to take unnecessary longer hours, thanks to poor cargo handling infrastructure and inconsistency of the electricity generation. These afore mentioned and other major bottlenecks are things the redevelopment and major expansion works will address.

Accessibility with the requisite depth of berth in Banjul is a fundamental factor that needs to be tackle in this aspiring port expansion project. Deep maritime access is a facility that will enable ships with large draught to berth and facilitate improved traffic flow and make transshipment possible. Banjul port is currently experiencing some draught restrictions at the entrance channel, and berthing points which all debars with big ships. These and other similar restrictions deterred port's ability to gain any competitive advantage.

5.5. Banjul Port Energy and environmental impact

Over the years, there has been a complete paradigm shift towards increase awareness in the maritime industry worldwide about the role of seaport in the sustainable environment. In view of the numerous global climatic challenge, Gambia Port Authority have now attached more premium to energy efficiency and the use of renewable energy in electricity generation.

The threat of climate change, which is regarded as the most defining challenges in the 21st century, improving on energy related sustainability in ports should be linked to the mitigation GHG emission in logistics. The transport sector as a whole account for one-fifth of GHG emission worldwide (Schmid, 2019) thus any project that aims' at greening the ports and terminals is considered significant as it contributes to reducing the emission of GHG and mitigate climate change.

Like many ports in Europe and elsewhere, the Authorities in Banjul Port should consider making more stringent laws in the future for port operation to achieve a reduction in emission as enshrined in the Paris Agreement.

5.6. Barriers and challenges.

There cannot be any meaningful port infrastructural expansion without a robust and well-functioning energy management system, that can better handle energy conversion, usage and conservation. The statuesque in Banjul port in terms of electricity generation is characterized by inconsistency, inefficient and very costly.

75 percent of electricity used in Banjul ports today is relying on the national electricity grid owned by National Water and Electricity Company(NAWEC), which in totality, produce less that 100MW and further characterized by unreliable low generating capacity, ageing machines and primitive mode of transmission. The cost of in-house electricity generation is exorbitant due to high cost of imported fuel and maintenance challenges (GPA, 2018). Being predominantly fossil fuel, it is not environmentally friendly, thus contributes to greenhouse gas emission (GHG). Frequent power outages, cause substantial economic loses to both ports and other stake holders involve in port operation.

The current statuesque in Banjul Port indicates that there are no proper and formidable strategies in place to tackle IMO's 2020 Sulphur cap, which is recently implemented and there are no alternative measures for adequate power generation for international fleet especially during berth. In this respect, energy transition, is the possible solution. With the adoption of these initiative, it will create avenues for energy efficient technologies and create effective energy management strategies that will be more cost effective and mitigate the emission of Greenhouse gas from port and port operations. Port operation will also be cost effective and the negative externalities within the port and its proximities will be drastically reduced.

6. CHAPTER SIX: Analysis and Discussion

6.1. Discussion on hybrid renewable energy performance

Under this chapter, we critically analyze the current status quo, with regards to the energy generation situation in the country as a whole, and Banjul Port in particular. The analysis involves critically looking at the different mode of energy generation, the individual capacity at which they are operating, the operational cost, and the level of carbon emission within the port proximity. The analysis will also map out the feasibilities of measures that needs to be taken, considering the externality factors of establishing a Hybrid Renewable Energy Generation System in Banjul Port.

As aforementioned in the earlier chapters, 95 percent of power generation in the Gambia depends on the use of fossil fuel, subsequently causing unbearable and unsustainable operational cost as well as increase in the emission of GHG. Banjul Port in Particular, tap 75 percent of its electricity supply from the national grid which is meagre and faced with different challenges. The establishment of hybrid Renewable energy generation system required a complete paradigm shift to uphold a sustainable energy transition from the use of fossil fuel to renewable energy system.

6.2. Proposed Solar and Wind Power generation in Banjul Port

Energy demand across the globe is increasing in many fold due to technological advancement, rapid industrial growth and increase in house hold demand (Goel & Sharma, 2017). Under this chapter, a comparative performance of introducing Hybrid Renewable Energy system, comprising Wind and Solar in the energy generation system of Banjul Port is highlighted.

The most important advantage about Hybrid Renewable Energy System (HRES) is to make best use of the renewable power generation technology operating characteristics, and to obtain efficiency that is higher than that could be obtain from the single power source (Aznan et al., 2015). It can also address the challenges and limitations attached to fuel flexibility, efficiency and reliability, GHG emission and economic aspects.

As mentioned extensively in previous chapters, the source of electricity in Banjul Port is mainly dependent on the fossil fuel, thus discharge huge quantity of harmful gases in port and port proximity. Solar energy production is either photovoltaic (PV) or Solar water. With the available infrastructure in Banjul Port, photovoltaic(PV) is more suitable. The production is poor in winter and excellent in summer. For the tropic regions like Gambia, is raining season against Dry season. PV are used in the off-grid applications e.g., aid to navigation buoys, and remote locations. Solar panels are built in open fields if land is free, on roof tops of Cruise terminals, buildings, warehouses and a cold storage warehouses as demonstrated in the proposed solar power projects.

This initiative had prompted this case study to subsequently recommend to the authorities in Banjul Port to establish a similar facilities described in this chapter

Table 7 Proposed Solar PV in Banjul Port.

LOCATION	**LENGTH X BREATH**	**DIMENSIONS(M2)**	**SOLAR POWER GENERATION POTENTIALS (Based on 150Wp/M2 in MWh/Year)**
Cargo Area, North and South Terminals	15 x 30	450	150
PWD Terminal	20 x 25	500	250
Car park Area	20 x 20	400	230
Banjul Warf Jetty	30 x 30	900	350
New Warf Jetty	20 x 15	300	200
Reefer station	40 x 35	1400	350
Ferry Terminal/Banjul Barra& provincial stations	100 x 50	5000	1900
Banjul Ship Yard	30 x 29	870	240
Fisheries Jetty	30 x 21	630	190
Harbors Department	24 x 22	528	165
TOTAL		**10978**	**4025**

6.3. LCOE Calculator for Hybrid Renewable Energy (Wind Energy).

The proposed wind power in Banjul port

Over the past decades, wind power capacity has developed very rapidly, on an average by 25-30 percent per year. Literatures have shown that the total wind capacity doubles approximately every three or four years (Moné et al., 2015).

The parameters below are meant to gauge the feasibility of renewable energy technologies and levelised cost of energy and subsequently ascertain the establishment of Hybrid Renewable Energy technologies.

As per the procedures of the World Energy Council, the under listed parameters are used:

- Cost of Energy (LCOE)
- Capital expenditure (CAPEX)
- Operating Expenditure (OPEX)

The levelized cost of electricity (LCOE) is the price that must be received per units of output as payment for producing power in order to reach the specified financial return.

FORMULA= $\frac{Life\ cycle\ cost\ (\$)}{2a\ Life\ Time\ Production}$

It also helps to compare different technologies with different project size, life time, different capital cost, return, risk and capacities. In this context, it can be regarded as a minimum cost at which electricity must be sold in order to achieve a break even.

NPV Calculation for the proposed Wind Power

One of the most important economic benefit of the wind turbine is to reduces the exposure of our economies to fuel price instability. The less volatility this trend justifies a larger share of wind energy in most European countries even though wind were more expensive per KWh than other forms of power generation.

The information in table 8 below, stipulates the methodology and the assumptions used in this LCOE calculations. The initial cost of the building and operating as per one megawatt power is Initial investment and O&M cost respectively. The proposed project will last for ten years as stipulated in the table.

The capital cost of wind energy projects is normally dominated by the cost of the turbine itself. The table below shows the typical cost structure.

The average Turbine installed in Europe has a total investment cost of 1.23 million per MW but as benchmarked from the similar structures or establishments in Europe and due to proximity deficiency, the total investment cost in this case will 1.5 million per WW. The table below indicates the size of the proposed Plant.

Table 8: Proposed Wind Power Plant in Banjul Port

PROPOSED WIND POWER PLANT IN BANJUL PORT		
Size of the Plant	10000	KW
Initial investment	1500000	$
O& M Growth rate	2.00%	%
Operations and Maintenance Cost	100000	$
Annual Electricity Output	3000000	kwh
Project lifespan	10	Years
Discount Rate	0.08	%
Entry Date	31/12/2021	

SOURCE:(The Author)

Levelized Cost Analysis

The levelized cost of energy (LCOE), is a measurement used to assess and compare alternative methods of energy production (2021 to 2030 CFI Education Inc.). It is the average total cost of building and operating the asset, per unit of total electricity generated over an assumed period of time.

This analysis below provides a systematic framework for the economic dimension of wind energy Plant and of the energy policy when comparing the economic benefit of it. From the business context, the NPV as depicted below is positive which implies that venturing in to such a project in Banjul port with this size described below is feasible in the technical point of view and economically viable as well

Table 9: Total Cost Analysis

Date	**Year**	**Initial Investment**	**O&M Costs**	**Discount factor**	**Present Value of Costs**	
31/12/2021		1500000		0.08	1500000	
31/12/2022	1		100000	0.925925926	92592.59259	
31/12/2023	2		102000	0.85733882	87448.55967	
31/12/2024	3		104040	0.793832241	82590.30636	
31/12/2025	4		106120.8	0.735029853	78001.956	
31/12/2026	5		108243.216	0.680583197	73668.514	
31/12/2027	6		110408.0803	0.630169627	69575.81878	
31/12/2028	7		112616.2419	0.583490395	65710.49551	
31/12/2029	8		114868.5668	0.540268885	62059.91243	
31/12/2030	9		117165.9381	0.500248967	58612.13952	

31/12/2031	10		119509.2569	0.463193488	55355.90954	
					2225616.204	NPV of cost
					£2,225,616.20	

SOURCE:(The Author)

The system size proposed in table of energy output below, is supposed to generate 10MW, which is equivalent to 10,000 kwh. In the European standard, to produce I MW of Wind power is approximately $1.23 million but due to proximity challenges and importation of equipment and expertise, I assumed to be $1.5 million for Banjul Port. Therefore, the total initial cost is amounting to $1,500,000 Million. It helps to determine the cost effectiveness of the project when successfully implemented and how much it can mitigate the GHG emission.

Table 10 Total energy output for the proposed wind power plant

Total entry output	Yearly output	Discount Factor	Present Value of Cost	
1	3000000	0.925925926	2777777.778	
2	3000000	0.85733882	2572016.461	
3	3000000	0.793832241	2381496.723	
4	3000000	0.735029853	2205089.558	
5	3000000	0.680583197	2041749.591	
6	3000000	0.630169627	1890508.881	
7	3000000	0.583490395	1750471.186	
8	3000000	0.540268885	1620806.654	

9	3000000	0.500248967	1500746.901	
10	3000000	0.463193488	1389580.464	
			20130244.2	NPV output
			£20,130,244.20	

SOURCE:(The Author)

In the result table below, it is quite evident that using Wind power technology for generating electricity in Banjul port would be a lucrative venture. From the analysis in the table above, using renewable energy for power generation will save the company **$11683176.00 in ten years** and most importantly the port will be save from emitting **1200 tons of CO_2** under the same period.

Table 11 LCOE RESULTS

Port consumption/year	3000000	kwh
WG (3) production/year	3000000	kwh
price of kwh grid	0.5	$
LCOE	0.11	$
cost of electricity consumption/year grid	1500000	$
Cost of electricity production/ year WG	331682	$
Saving ($) yearly	1168318	
Saving ($) in ten years	11683176	
CO2 emission grid/year/ton	1200	
CO2 emission WG /year/ton	0	

Saving (CO2) ton/year	1200	
in ten years	12000	

Source: (The Author)

Gap analysis

This chapter involves the critical analysis of levelized cost in terms of the feasibilities of the benchmarked and the proposed projects outlined above, compare it to the status quo in the port of Banjul especially with regards to energy generation situation. The analysis will therefore determine, the mode of port operations, different technologies applied, different policies governing the energy sector as well as international standardizations.

Table 12 Development strides (2016-2020) Energy and environmental management at Banjul Port

ASPECT	THE STATUS QUO	REMARKS
Port Energy Policy	Attained 2016	Port has make good strides to improve on the energy efficiency and management.
Green Port Policy	Proposed in 2017	It is at an embryonic state and yet to be fully implemented.
ISO 500001-2011 Cooperate Social Responsibility.	Great improvement achieved from the beginning of 2019	The authority starts a fruitful collaboration with the Banjul City Council (BCC) to bear sensitive responsibilities regarding environmental issues.
ISO 50001 Management System	Proposed but yet to be implemented	
Emission control measures on vehicles, cargo handling	Proposal for control strategies are underway but yet to be fully implemented	A deliberate policy to fully govern and bar the emission limit is yet to be formulated.

equipment operating within the Port premises.		
Just in time arrivals	There is a policy for vessels to give two weeks' pre-arrival notice through shipping agents. Due to limited berthing space, bulk carriers will always give chance to container vessels during the time of congestion.	The two weeks' notice policy is flexible as per weather condition and cargo handling situation.
Renewable energy Technology (Solar PV)	So far as at now, limited capacity of solar PV are installed at certain strategic locations within the port premises and ferry terminal where the electricity supply is sporadic.	The installation of Solar PVs is more common at the provincial Ferry stations where there are no form of electricity supply at all or with a very limited capacity.
Alternative fuel & Low Sulphur fuel	Not in existence within the port, not with the domestic fleets and Port annexed areas.	With the energy transition, from fossil fuel to renewable energy, strategies can be put in place.
Automation in the Port operations, Tugboats ,pilot boats , and mooring boats.	Certain type of operations in these vessels are automated but generally the full atomization strategy with regards to port operations is yet to be adopted.	With green port policy, this will be fully implemented in the expected Port expansion project.
Electrification of cargo handling equipment	Mostly carried out by diesel powered equipment like fork lift trailers etc.	Electrification of cargo handling equipment is the most important focal point after the energy transition.

		This as a result, will reduce the turnaround time , mitigate the emission of GHG, reduce energy consumption and increase operation efficiency.
Importance of proper energy management measures	Not yet attained to an optimum state.	The energy management team should endeavor to sensitize staffs and port users , the new energy policies and proper energy management measures.
Training and Education on renewable energy technologies and efficient energy management measures.	Attainment of this strategy is quite challenging due to the limited capacity and proximity deficiency to proper learning institution like WMU. However, the management is trying to send more personnel to WMU and similar institutions to learn more about energy efficiency management.	Proper implementation of energy policies and strategies is only possible with more energy expert and more marine oriented personnel who are aware of the environmental impact in Port operations

Source: *(GPA, 2020)*

7. CHAPTER: CONCLUSION AND RECOMMENDATIONS.

7.1. Conclusion

The primary objective of this research is to examine the feasibility of establishing a hybrid renewable energy system (solar PV and wind) in Banjul port for optimum operational cost and mitigation of greenhouse gas emission. A critical analysis is conducted, ranging from the energy system to electricity generation trajectories of Banjul port and the country as a whole, to the management policy of the Port Authority and institutional framework, capacity awareness of the staff with regards to the technical and operational measures.

From the analysis and in view of the trend in the electricity demand in the country, Banjul port needs a befitting and attainable energy transition from depending on the fossil fuel to the use of renewable energy technologies. This will boost the overall productivity and competitiveness' of the port and increase the awareness of the citizenry with regards to the energy consumption as well as improving the green image of the Port. It will also pave the way for a vibrant and attainable industrial revolution.

To this end, with regards to the energy generation system in the Gambia, a proposal guided by levelized cost analysis is made and to be instituted in Banjul port energy generation strategies.

The feasibility of these effort required a strong political commitment and sound economic policies from the Government through which, the Gambia Port Authority (GPA) can coordinate effectively at their level to the best advantage of their operation.

Adherence to the international instrument, conventions and national laws regarding energy generations and maritime affairs, should be a guiding principles for the authorities in Banjul port for a successful implementation. Regulatory framework from PURA and NEA (responsible for environmental affairs) needs to be strengthen to avoid capacity deficiency.

It has been observed that in the energy generation system the country is long been confined to one mode of energy transmission and direction, despite the numerous challenges, no diversifications were made. Electricity generation was substantially based on the national grid depending on the fossil fuel for their operation. With the increasing environmental pressure and the need for competitive port operations, energy efficiency and proper energy management system is required.

For a global supply chain to be successful, there ought to be a vibrant communication and infrastructure network in port operations. This reserve has shown a considerable deficiency in that trend base on the wide gap in reliability, efficiency sustainability and resilience in energy generation system.

The environmental management system in the port of Banjul and its proximity had made some good strides of improvement in the last two years. The authority's collaboration with the Banjul City Council (BCC) for environmental protection strategies, is a good step in the right direction and should be nurtured to lay a proper foundation for a robust and formidable environmental protection system. Deficiency in the energy sector, coupled with the inconsistency in the electricity supply are the primary challenges to the progress in this sector.

With the Port of Banjul projecting a massive expansion project which constitute replacing over 150 units of 1500W HPS high mast lights with 600 led, smart gantry cranes, and cold ironing, there will be some percentage saving of energy but upsurge increase in the demand of electricity is expected.

With reference to the policy implications, this study has observed that measures that are often applied by large ports of developed countries, are relevant to all ports regardless of size or management model. The strategies to mitigate climate change should begin with identification of areas (scopes) including the source of emission. Banjul port should conduct energy and emission inventories that will highlight the greatest emitters within the ports and its proximities and build a baseline for it.

In view of the urgent need to address climate change, measures identified in this study, have the capacity to reduce GHG emissions. However, their abatement potential is different in terms of capital and operational cost, thus evaluation and feasibility studies are required to develop the best strategy approach in project implementation (port expansion) and to earn highest environmental benefits and GHG emission.

Changing the port infrastructure, to a modernized and smart system, will pave the way to bring them to the tune of current competitive trend in port operations.

With successful energy transition, Banjul port stand the chance of improve energy performance, lower operational cost and enhance consistency in electricity generation. If the project is diligently pursued, and properly implemented, the problem of human, economic, political and infrastructural barriers will be overcome. Furthermore, proper energy efficiency and environmental protection will be ensured in the port proximity and its annexed institutions.

7.2. Recommendation

In the pursuant of addressing climate change challenges, the Authorities in Banjul Port need to contribute immensely to strengthen their Corporate Social Responsibilities(CSR), maintain their license to operate and respond to public pressure by local communities and nongovernmental organizations (NGOs) to divest out the effect of fossil fuel and to improve on their effort towards energy transition for amicable green reputation and good image for wider customer network. From the world Port climate initiative perspective, GHG emission reduction and energy efficiency are considered to be one of the important pillars to achieve green and sustainable Port.

In view of the above, and reference to the cornerstone of this case study, the authorities of Banjul port should be encouraging to undertake the challenges and be more proactive with measures to tackle its energy problem to reduce the cost, enhance competitiveness and take the lead in global climate change mitigation struggle. Prominent among the measures that can be undertaken and help to reduce energy related greenhouse gas emission and drastically reduce the operational cost is the energy transition from the fossil fuel to renewable energy technologies. This, if well implemented can lieu the authorities to replace some of the operating ferries with electric driven ones to save the company from the colossal sum of money spent on the fossil fuel importation every year.

This can be achieved through several means: Political commitment from the central government, coupled with the systematic and proper management system backed by capacity building and awareness creation among its employees, proper monitoring and auditing and timely reporting of energy use and consumption, application of feasible and cost effective technologies as well as creating avenues for effective procurement strategies to enhance improved energy performance for better service delivery.

The outcome of the study recommends that port of Banjul should consider reform programs regarding environmental program to be in tandem with international standard the ISO 5001-2018 supported by a vibrant port energy management plan.

By virtue of the serious congestion within the city of Banjul, the authority should engage the Banjul City Council through Corporate Social Responsibilities (CRC) to revisit the location of the electricity generation point (proposed solar and wind plant) to acquire a better and safe vantage point outside the city.

Upon successful implementation of proposed wind and solar energy project, which aimed at producing more than 10MW (unprecedented in annals of the country's energy system) will not only safe the port to mitigate the negative externalities, that emanates from the use of fossil fuel, but will serve as a supplement to the country's long term energy struggle.

References

Acciaro, M. (2013). Trade, Supply Chain Activities and Transpor. *Contemporary Logistics and Maritime Issues, 14*.

Acciaro, M., & Ghiara, H. (2014). Energy Policy. *Energy management in seaports: A new role for port authorities*.

Acciaro, M., & Serra, P. (2013). *Maritime Supply Chain Security: A Critical Review*.

Acciaro, M., Ghiara, H., & Cusano, M. I. (2014). Energy management in seaports: A new role for port authorities. *Energy Policy*, *71*, 4–12. https://doi.org/10.1016/j.enpol.2014.04.013

Acciaro, M., Vanelslander, T., Sys, C., Ferrari, C., Roumboutsos, A., Giuliano, G., Lam, J. S. L., & Kapros, S. (2014). Environmental sustainability in seaports: a framework for successful innovation. *Maritime Policy and Management*, *41*(5), 480–500. https://doi.org/10.1080/03088839.2014.932926

Alamoush, A., Ballini, F., & Ölçer, A. (2020). Ports' technical and operational measures to reduce greenhouse gas emission and improve energy efficiency: A review. *Marine Pollution Bulletin*, *160*, 111508. https://doi.org/10.1016/j.marpolbul.2020.111508

Aronietis, R., Sys, C., van Hassel, E., & Vanelslander, T. (2016). Forecasting port-level demand for LNG as a ship fuel: the case of the port of Antwerp. *Journal of Shipping and Trade*, *1*. https://doi.org/10.1186/s41072-016-0007-1

AUTHORITY, G. P. (2019 , 2007). GPA SERVICE RULE. *SERVICE RULE*.

AWEA. (2013). American Wind Energy Association. *U.S. wind industry first quarter*.

Awuor, C. B., Orindi, V. A., & Ochieng Adwera, A. (2008). Climate change and coastal cities: The case of Mombasa, Kenya. *Environment and Urbanization*, *20*(1), 231–242. https://doi.org/10.1177/0956247808089158

Aykut, Olce, Rapheal, B., Fabio, B., & Momoko, K. (2017). *Marine Energy Management*.

Aznan, A. S., Musirin, I., Mohd Saleh, S. A., & Rahmat, N. A. (2015). Optimization of Hybrid Renewable Energy System (HRES) using Modified Evolutionary Strategy for Cost Minimization. *Applied Mechanics and Materials*, *785*, 546–550.

Bailey, D., & Solomon, G. (2004). Clearing the air. Environmental impact assessment review. . *Pollution prevention at ports*.

Balini, F. (2017). *Marine Energy Management*. Malmo.

Ballini, F., & Bozzo, R. (2015). Air pollution from ships in ports: and socio-economic benefit of cold-ironing technology. *T. Research in Transportation Business & Management*.

Bauriedl , a., & Grossmann. (2008). Grossmann.

Beliën, J., Boute, R., Creemers, S., Bruecker, P. De, Gijsbrechts, J., Tinoco, S. V. P., & Verheyen, W. (2020). *Collaborative shipping: Logistics in the sharing economy - INFORMS*. Informs. https://www.informs.org/ORMS-Today/Public-Articles/April-Volume-44-Number-2/Collaborative-shipping-Logistics-in-the-sharing-economy

Bernt, M., & Holm, A. (2005). Gentrification in a Global Context: The new urban colonialism. *Exploring the substance and style of gentrification*.

Bieringer, P. E., Young, G. S., Rodriguez, L. M., Annunzio, A. J., Vandenberghe, F., & Haupt, S. E. (2017). Paradigms and commonalities in atmospheric source term estimation methods. *Atmospheric Environment*, *156*, 102–112.

Blimpo, M., Carneiro, P., & Lahire, N. (2016). *Experimental Evidence from the Gambia. Working paper*. Banjul.

Bogliolo, A. B.-f., Bogliolo , A., Berntzen , B., & Michel Diaz. (2013). International Journal on Advances in Internet Technology Volume 6, Number 3 & 4, 2013.

Bushell, S. (1992). Implementing plan, do, check and act. *The Journal for Quality and Participation*, *15*(5), 58.

Cagatay, Irins, J., & Siulee, L. (2019). Renewable energy and sustainable energy review.

Carpenter, A., & Lozano, R. (2020). European Port Cities in Transition. *Springer International Publishing*.

Carpenter, A., & Lozano, R. (2020). *Proposing a Framework for Anchoring Sustainability Relationships Between Ports and Cities*. 37–51. https://doi.org/10.1007/978-3-030-36464-9_3

Cottini, L. (2018). The Art of Objects: The Birth of Italian Industrial Culture. *University of Toronto Press*.

Dalaklis, D., Kitada, M., Ölçer, A., Schönborn, A., Canepa, M., & Ballini, F. (2019). Expanding the Use of Liquefied Natural Gas in the Baltic Sea Region via Tailor-made Training Activities. In *Policy and Energy*.

Drewniak, M., Dalaklis, D., Kitada, M., Ölçer, A., & Ballini, F. (2018). Geopolitics of Arctic shipping: the state of icebreakers and future needs. *Polar geography, 41*(2), 107-125.

ECOWAS. (2013). *Renewable Energy Resource*. Ghana: Website of ECOWAS.

El-Amary. (2018).

Eleftherios s , Seloukopoulos, , Maria Boile , & Alkiviadi. (2019). Sdoukopoulos, E., Boile, M., Tromaras, A., & Anastasiadis, Energy Efficiency in European Ports: State-Of-Practice and Insights on the Way Forward. Sustainability.

ESPO. (2012).

ESPO. (2020). *ESPO proposes a two-step approach on the new EU Transport Strategy*. Website. https://www.espo.be/views/espo-proposes-a-two-step-approach-on-the-new-eu-tr

Esteve Pérez,, J., & Gutiérrez Romero, J. (2015). *Renewable energy supply to ships at port. Instrumentation viewpoint, (18), 66-66*.

G. J., Beliën, J., Boute, R., Creemers , S., & De Bruecker,. (n.d.). Collaborative shipping: logistics in the sharing econom. *ORMS Today*.

Germond, B., & Ha, F. (2019). Climate change and maritime security narrative: the case of the international maritime organisation. *Journal of environmental studies and sciences,* .

Gibbs, D., Rigot-Muller, P., Mangan, J., & Lalwani, C. (2014). The role of sea ports in end-to-end maritime transport chain emissions. *Energy Policy*, *64*, 337–348.

Goel, S., & Sharma, R. (2017). Performance evaluation of stand alone, grid connected and hybrid renewable energy systems for rural application: A comparative review. *Renewable and Sustainable Energy Reviews*, *78*, 1378–1389.

GPA. (2018). *ANNUAL POWER ACCESSMENT REPORT OF GPA*. Banjul: cooperate department.

GPA. (2020). *Gambia Ports Authority*. Homepage of Gambian Port Authority. https://www.gambiaports.gm/

Haupt, S. E., Bieringer, P. E., Young M., ,. G., Rodriguez, L., & Vandenberghe, F. (2017). Paradigms and commonalities in atmospheric source term estimation methods.

Heitmann, N., & Khalilian, S. (2011). *Accounting for carbon dioxide emissions from international shipping:Burden sharing under different UNFCCC allocation options and regime scenarios. Marine Policy*. .

IEA. (2012). *Energy Policy*.

Ines, M., & cusano. (2014). Energy Efficiency in Ports.

Infield, D., & Freris, L. (2020). Renewable Energy in Power Systems. In *Wiley* (Second Edi). https://www.wiley.com/en-us/Renewable+Energy+in+Power+Systems%2C+2nd+Editionp-9781118649930

IRENA, & Schiffer, A. (2016). *Unveiling issues of energy access inequality and resource dependency in The Gambia*. *Energy Research & Social Science*.

IRENA. (2018). *IRENA Planning and prospects for renewable power: West Africa*. Abu Dhabi: International Renewable Energy Agency.

Iris, Ç, & Lam, J. (2019). Operational strategies, technologies and energy management systems. Renewable and Sustainable Energy Reviews. *A review of energy efficiency in ports*.

JOURNAL, G. (2019). FACTS ABOUT BANJUL PORTS.

Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular economy–From review of theories and practices to development of implementation tools. *Resources, Conservation and Recycling*, *135*, 190–201.

Köck, W. (2004). Governance in der Umweltpolitik. UFZ.

Kohls, G., Hoogstraal, H., & Clifford, C. (2019). *Redescription and New World records and resurrection*.

l, Hulda , W., Linda , S., & Erik, F. (2015). *Reducing GHG emissions from ships in port areas*.

Lam , & Notteboom. (2017). *ESPO, 2017*. ESPO, 2017,.

Lam, J., & Notteboom , S. (2014). a comparison of port management tools used by leading ports in Asia and Europe. *The greening of ports: . Transport Reviews*.

Machele, A., Thierry , V., & Christa , S. (2014). Maritime policy and management.

Mariska , V., Heerden, M., Kleingeld , J., & Janc, v. (2018). improving project implementation and sustainability through ISO.

Merk, O., & Hesse, M. (2012). The competitiveness of global port-cities. *The case of Hamburg, Germany*.

Michele Acciaro , Hilda Gharia, Maria, & Ines casi. (2018). A new role for the ports authority,.

Michele, A., & Serra, P. (2014). Strategic determinants of terminal operating system choice: An empirical approach using multinomial analysis. *Transportation Research Procedia*, *3*(July), 592–601. https://doi.org/10.1016/j.trpro.2014.10.038

Miketa, , A., & Merven, , B. (2013). *Planning and prospects for renewable energy*. *IRENA, Abu Dhabi*. West African power pool:.

Moné, C., Hand, M., Bolinger, M., Rand, J., Heimiller, D., & Ho, J. (2015). Cost of Wind Energy Review: 2015. *Nrel*, *May*. https://doi.org/NREL/TP-5000-52920

Motazdi, A., A, N., & N.K.M. (2013). Optimization of of Hybrid Renewable Energy System (HRES). *The Mediterranean Green Energy Forum*.

Nations Online. (2020). *Map of Banjul, The Gambia - Nations Online Project*. Homepage. https://www.nationsonline.org/oneworld/map/google_map_Banjul.htm

Ölçer, A. I., Ballini, F., Kitada, M., & Dalaklis, D. (2017). Development of a Holistic Maritime Energy Management Programme At the Postgraduate Level: the Case of Wmu. *INTED2017 Proceedings*, *1*, 1426–1432. https://doi.org/10.21125/inted.2017.0474

Ölçer, A. I., Kitada, M., Dalaklis, D., & Ballini, F. (2018). *Editorial Conclusion BT - Trends and Challenges in Maritime Energy Management* (A. I. Ölçer, M. Kitada, D. Dalaklis, & F. Ballini (Eds.); pp. 527–531). Springer International Publishing. https://doi.org/10.1007/978-3-319-74576-3_36

Onna , H., Jonathan, H., Christopher, m., & Maureen, M. (2015). *Bakery National Renewable Laboratory*.

Peter, O, & Mbohwa. (2018). The Interlink Between Sustainable Supply Chain Management and Technology Development in Industry. *In Proceedings of the International Conference on Industrial Engineering and Operations Management*.

Port of Genoa. (2020, June 12). Homepage of Port of Genoa. https://www.portsofgenoa.com/en/

Port of Gothenburg. (2020). *Container volumes rise at Scandinavia's largest port*. https://www.portofgothenburg.com/news-room/press-releases/container-volumes-rise-at-scandinavias-largest-port/

PURA. (2018). *Public Utility Regullatory Authority*. Banjul, Gambia.

Schiffer, A. (2016). Empowered, excited, or disenfranchised? Unveiling issues of energy access inequality and resource dependency in The Gambia. *Energy Research & Social Science*, *18*, 50–61. https://doi.org/https://doi.org/10.1016/j.erss.2016.04.011

Schmid, D. J. (2019). HPC Hamburg Port Consulting GmbH.

Schwerhoff, & Schwerhoff, G. (2019). *Developing Africa's energy mix. Climate policy, 19(1), 108-124*. IRENA.

Sdoukopoulos, E., Boile, M., Tromaras, A., & Anastasiadis, N. (2019). Energy efficiency in European ports: State-of-practice and insights on the way forward. *Sustainability (Switzerland)*, *11*(18). https://doi.org/10.3390/su11184952

Sdoukopoulos, E., Boilet, M., Tromaras, A., & Anas. (2019). State-Of-Practice and Insights on the Way Forward. Sustainability,. *Energy Efficiency in European Ports*.

SeeK., J., & Chew , P. (2004). Glaucoma in Singapore. J. *Journal of glaucoma,*.

Sisawo, A. (2018). *Adopting port energy efficiency and management plan: the Port of Banjul in consideration*.

Sonali , G., & Renu , S. (2017). *Performance evaluation of standalone, grid connection and Hybrid renewable energy system for Rural Electrification*.

Sonali, Goel, & Renu , S. (2917). *Anusaishai University, Bhubaneswar, India 2017)*.

Sons., I. J. (2020). Renewable energy in power systems.

Topali, D., & Psaraftis, H. (2019). Maritime Business Review. *The enforcement of the global sulfur cap in maritime transport.*.

UNCTAD. (2017). *Foreign direct investment: Inward and outward flows and stock, annual, 1970-2016*.

Van Heerden, M. (2014). *Improving DSM project implementation and sustainability through ISO standards*.

Winnes, H., Styhre, L., & Fridell, E. (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management*, *17*, 73–82. https://doi.org/https://doi.org/10.1016/j.rtbm.2015.10.008

Winnes., H., Styhre, L., & ridell, E. (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management*.

World Bank. (2013). The Gambia: Migration in Africa's' Smiling Coast'. *The Online Journal of the Migration Policy Institute*.

World Port Source. (2020, June). *WPS - Port of Banjul contact information*. Homepage of the Website. http://www.worldportsource.com/ports/GMB_Port_of_Banjul_1715.php

yarova. (2017).

Yuliya , K., Leonardo , R., & Joao. (2018). *Energy policy in Sweden*. Department of Civil and Environmental Engineering,.

Yuliya , K., Leonardo, R., & Joao , P. (2015). *Environmental Science and Technology*.

Zhukova, N., Ramaswamy, V., Remke, M., & Pfaff, E. (2014). mutation in medulloblastoma. Journal of Clinical Oncology, 31(23), 2927. *Subgroup-specific prognostic implications of TP53*