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IMO Sulphur Cap 2020: case study of the environmental impacts in the selected sea-ports

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IMO SULPHUR CAP 2020:

Case Study of the Environmental Impacts in the Selected Sea-ports

By

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Liberia

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me. The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: ………………………………

Date: ………………..18-SEP- 2020…………………..

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Keywords:

IMO Sulphur Cap 2020, Emission, Greenhouse Gas, Sustainability, Sulphur Oxide, Nitrogen Oxide, Greenport, Renewable,

Abstract:

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The research through a literature review studied the Greenport methodology / technology use by the selected ports (Port of Hamburg, Port of Antwerp and Port of Shanghai) as measure to respond to environmental regulations to reduce the negative externalities on

the port cities; especially those emitted by ships auxiliary engines while at berth. The use of LNG, Renewable sources and discounts for ships with environmentally friendly technology and propulsion in addition to EU regulation for the use of 0.1% Sulphur fuel by ships at berth in EU seaports were observed at the two EU ports mentioned above. The both selected EU ports make efforts to transform the transport sector by gradually replacing the ports diesel cars with electric cars and replacing high emission lamp with LED lamp for the lighting system. The Port of Shanghai that is identify as the weak port by the researcher grants incentives to ships with environmental friendly propulsion in an effort to meet the Greenport regulation. Quantitative data was collected during the literature review from sources such as Reports, WMU Library, PA Review Journey, Seminars, Google Scholar, Science Direct, Internet sources, International Organizations like IMO, ESPO, OECD, etc.

The researcher through the literature review use the SWOT analysis to identify the strengths, weaknesses, opportunities and threats from using the Greenport technologies adopted from the SWOT analyses of national energy sector for sustainable energy development. In addition to the SWOT analysis, the PESTEL analysis tool was used to ascertain the political, economic, social, technological, environmental and legal aspects adopted from The Governance of Multi-Use Platforms at Sea for Energy Production and Aquaculture: Challenges for Policy Makers in European Seas.

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List of Abbreviations and Acronyms

AAPA	American Association of Port Authorities
AMP	Alternative Maritime Power
ASEAN	Association of Southeast Asian Nations
CARB	California Air Resource Board
CHE	CO_2 Human Emissions
CLINSH	Clean Inland Shipping
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CP	Cleaner Production
ECAs	Emission Control Areas

EEA	European Environmental Agency
EEDI	Energy Efficiency Design Index
EMS	Environmental Management System
EnMS	Energy Management System
ESI	Environmental Ship Index
ESPO	European Sea Ports Organization
EU	European Union
GERIAP	Greenhouse Gas Emission Reduction from Industry in Asia and the Pacific
GHG	Greenhouse Gas
GPS	Global Positioning System
GTL	Gas – to - Liquids
HHLA	Hamburger Hafen und Logistik AG
HPA	Hamburg Port Authority
IAPH	International Association of Ports and Harbours
IARC	International Association of Cancer Research
ICCT	International Council on Clean Transportation
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LSF	Low Sulphur Fuel
NOx	Nitrogen Oxide
OCS	Operation Clean Sweep
OECD	Organization for Economic Co-operation and Development
PESTEL	Political, Economic, Social, Technological, Environmental and Legal

PIANC	World Association for Water-borne Transport Infrastructure
RES	Renewable Energy Sources
SECAs	Sulphur Emission Control Areas
SEEMP	Ship Energy Efficiency Management Plan
SOx	Sulphur Oxide
SWOT	Strengths, Weaknesses, Opportunities and Threats
TEU	Twenty-Foot Container
UN	United Nations
UNCLOS	United Nations Convention for the Law of the Sea
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
WPCI	World Ports Climate Initiative

1.0 Introduction

1.1 Background

The International Maritime Organization (IMO) is a specialized agency of the United Nations with the responsibility to provide safety, security and prevention of pollution with in the Maritime Industry.

The Third IMO GHG Study 2014 estimated that GHG emissions from international shipping in 2012 accounted for 2.2% of anthropogenic CO_2 emissions and this could increase by 50% to 250% by 2050 (ICCT, 2018; IMO, 2018b). The Paris Agreement to Climate Change by maintaining, the global temperature increase to well below 2^0C above pre-industrial levels and an efforts to limit the temperature increase to 1.5^0C above pre-industrial levels (The IPCC's Special Report on Climate Change at 1.5^0C) need the IMO positive response to reduce GHG emissions.

The Marine Environmental Protection Committee (MEPC), one of IMO's standing committees beginning with its 73/78 MARPOL Convention has implemented rules and regulations regarding marine pollution. In 1997, the MARPOL Annex VI was first adopted with the main aim to prevent pollution. To limit the air pollutants contained in ships exhaust gas including Sulphur oxides (SOx), Nitrous oxides (NOx), Particulate Matter (PM), and prohibits deliberate emissions of the ozone depleting substances (ODS). On May 19, 2005, the MARPOL Annex VI entered into force. In July 2005, the MEPC at its 53rd session agreed to revised the MARPOL Annex VI with the aim to strengthen the emissions limits. In October 2008, MEPC 58 adopted the revised MARPOL Annex VI with the main changes to reduce globally emissions from of SOx, NOx, PM and the introduction of emission control areas (ECAs). Under the revised MARPOL Annex VI, the aim is to reduce the Sulphur limits in marine fuels from 3.50% to 0.50% effective on January 1, 2020 outside the ECAs.

1.2 Problem Statement

Prior to the 1970s, the pollution from the shipping industry was not regarded as issues. As a result, there have been serious health issues and premature deaths worldwide especially those living in port cities and coasts. By the year 2000, the air pollutant emissions from shipping in the North Sea and the Baltic Sea were responsible for annual health damage in Europe valued at €22 billion (AirClim). Poor air quality due to international shipping accounts for approximately 400,000 premature deaths per year worldwide at an annual cost to society of more than €58 billion according to recent scientific studies (Transport & Environment). The emissions continue to affects the health of marine species and coastal inhabitants today. In addition, this will continue to increase as shipping increases on the world seaborne trade.

The dissertation focuses on the emissions and air pollutants from the selected seaports (Ports of Antwerp, Hamburg and Shanghai). The impact of these emissions and air pollutants on the environment, global warming and health threat to the port cities population.

The introduction of MARPOL 73/78, especially the adoption of MARPOL Annex VI will addressed some of the major health issues today by the reductions of pollutants from air emissions from the shipping industry; by reducing the Sulphur content in marine fuels, reducing the emissions from NOx, and PM. The EU Green Deal to Make the EU climate-neutral by 2050, address soil pollution with 50% chemical reduction by 2030, and the EU Sulphur Directive 2012/33/EU on the sulphur content, Directive 2014/94/EU on the development of alternative fuels infrastructure are regulatory framework to reduce the environmental hazards caused by EU ports and Ships operations.

1.3 The Dissertation

The research is the holistic approach to IMO Sulphur Cap 2020. The negative effects of Sulphur emissions / emissions from shipping on marine species, human health, environmental, society and economic. A case study is conducted in the selected European Sea-ports and recommendations are made with the aim to reduce the negative externalities in the port regions and the environment in addition to the IMO regulations on the GHG reduction strategic.

1.3.1 Dissertation Objectives

The key objectives of the dissertation include the following:

- To identify the strengths and weaknesses of the selected EU Seaports greening methods.
- To identify and analyze the key factors arising from the air pollutants from shipping in addition to the prevailing problems
- To reduce the premature deaths cause by the GHG emissions from shipping
- To improve health issues associated with air quality and to improve/reduce the negative externalities caused by shipping on the environment

1.4 Research Questions

The following questions must be answered in order to properly address this research objectives.

a. What are the negative impacts of GHG emissions and Air pollutants on the environment and the human life?
b. How to reduce the GHG emissions and Air pollutants and which methods are involved?
c. What are the costs and implications of the technologies used?
d. How the GHG emissions reductions benefit the environment?

1.5 Research Limitations

The research herein is based on a literature review that focuses on the emissions and air pollutants from the selected seaports (Ports of Antwerp ‘Belgium’, Hamburg ‘Germany’ and Shanghai ‘China’). The impact of these emissions and air pollutants on the environment, global warming and health threat to the port cities population. The study only focus on the emissions from the selected ports and not all global emissions.

However, there are mitigation measures put in place by the ports under review. During the literacy review from Reports, Books, Library sources, Sciencedirect, Google Scholar, PA Review Journey and International Organizations (IMO, OECD, ESPO, etc.), the researcher identified that the EU ports, specifically the Ports of Antwerp and Hamburg have put emissions reduction measures in place such as the use of LNG tanks, electrical cars, LED lights, onshore power supply, use of low-sulphur content fuels by berthed ships, incentives for ships with environmental friendly propulsion among others. The Port of Shanghai is barely managing to adopt the use of Alternative Maritime Power (AMP), but have put some measure in place like the use of low-sulphur content fuels. The study covers the period between 2005 and 2020.

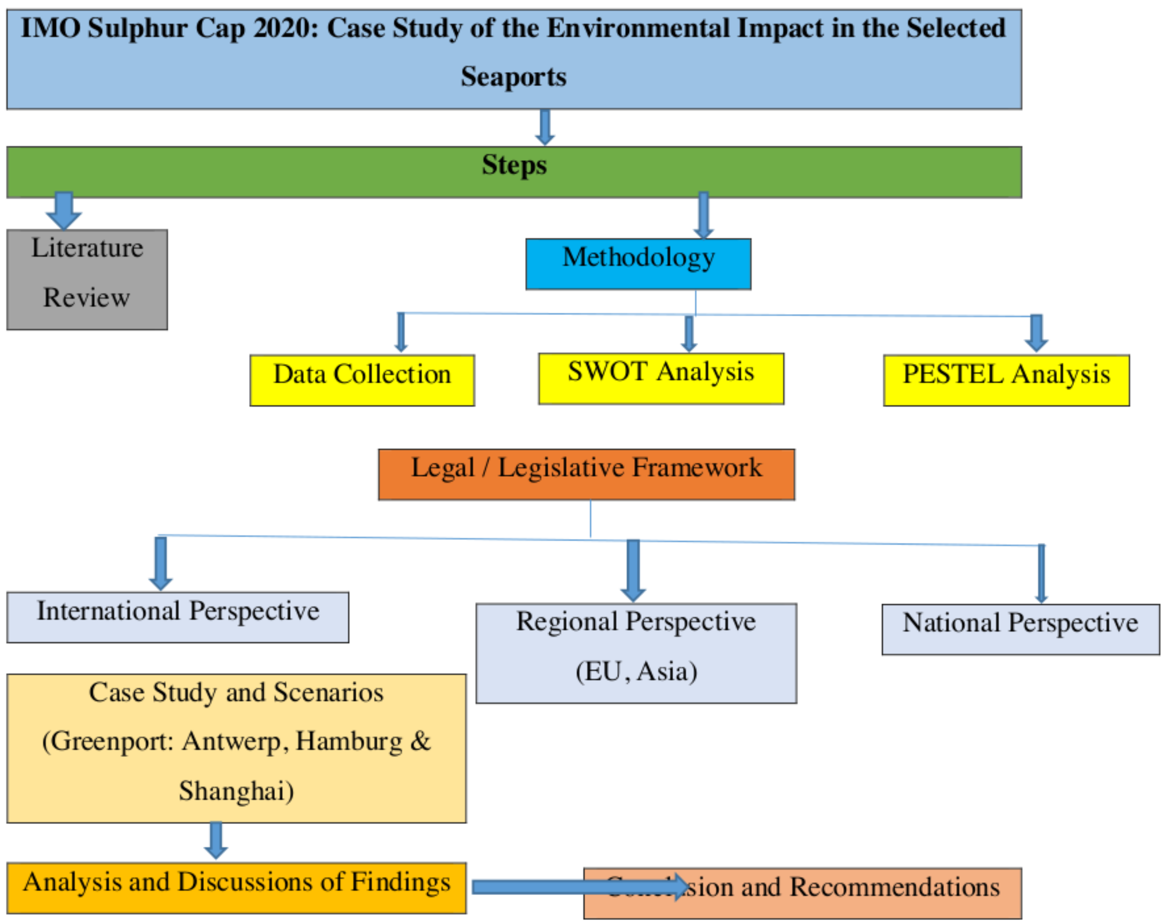
1.6 Research Methods

The various methods and techniques were used during the research. These include the SWOT analysis (the strength, weaknesses, opportunities and threats); PESTEL or PEST analysis (political, economic, social, technological, environmental and legal). It is also base on Quantitative research using primary data collected from broad databases, i.e. internet and library sources. Data was obtained from International Seminars, PA Review Journey, IMO official website, Science Direct, Google Scholar, visiting faculty, International Organizations websites (ESPO), course modules, library materials, and other relevant articles and magazines. The search for data was restricted from year 2005 to year 2020 in a peer-reviewed literature only in English language.

1.7 Dissertation outline

Chapter 1 contains the introduction / background of the dissertation, the problem statement, the dissertation, the objectives of the dissertation and the research limitations. Chapter 2 covers the literature aspect; chapter 3 includes the methodology and technology used during the research. Chapter 4 looks at the legislative framework; chapter 5 illustrates the greening of EU Seaports and the port of Shanghai, GHG emission and other air pollutants reduction technology. Benefits and challenges of GHG emissions reduction, and best practices. Chapter 6 demonstrates the case study and chapter 7 consists of the recommendations and conclusion.

1.8 Dissertation Flowchart



2.0 Literature review

The GHG, carbon dioxide (CO_2) and other air pollutants from the shipping industry and ports have caused negative externalities on the environment including climate change, ocean acidification, premature deaths, diseases like lung cancer, asthma, stroke, etc. The following problems have put pressure on the shipping industry and ports cities to put in place efficient operational measures to obtain sustainable and cleaner shipping industry.

The globalization of industrial and agricultural processes makes maritime transport a fundamental sector of the world economy (UNCTAD, 2017; EEA, 2017a). Currently, over 80% of the world trade is carried by sea (e.g., Cullinane et al., 2014; UNCTAD, 2017). The majority (95%) of the world's shipping fleet runs on diesel engines (Deniz et al., 2010), and it is expected that shipping energy use and emissions will keep growing in the near future (Buhaug et al., 2009; Eyring et al., 2010; UNCTAD, 2017). Diesel engines are strong emitters of both primary and secondary PM (Winnes and Fridell, 2009, Lack and Corbett, 2012). Diesel emissions as a whole have been defined a "carcinogenic through genotoxicity" by the International Association of Cancer Research (IARC, Benbrahim-Tallaa et al., 2012). BC, component of diesel PM emissions, is also reported as robust indicator (more than PM_{10} or $PM_{2.5}$ metrics) of PM-induced mortality and morbidity (WHO, 2012). NO_2, another component of ship diesels emission is known to bear adverse health consequences for humans (WHO, 2013). In 2007, global mortality caused by ship emissions was estimated at 60,000 per year, with an expected growth of 40% by 2012 (Corbett et al., 2007). In fact, Sofiev et al., (2018) estimate the 2020 global mortality due to shipping emissions will grow to about 250,000. The Mediterranean region and the Italian coast are one of the world hotspots in terms of shipping pollution and consequent health effects (Winebrake et al., 2009; Sofiev et al., 2018). Therefore, emissions from shipping are expected to have increasing impact on inland air quality (Viana et al., 2014; Aksoyoglu et al., 2016). Due to maneuvering, fueling and hoteling phases, ship-generated air pollution can be rather large in port areas (Barregard et al., 2014; Murena et al., 2018).

With non-optimal engine loads, maneuvering can generate much more pollution (3-6 Times) than cruising and hoteling phases (Petzold et. Al., 2010; Moldanova et. Al., 2013; Lack and Corbett, 2012). Most ships supply their services by means of auxiliary diesel engines while at berth. Depending on the ship type, the energy needed during hoteling ranges between 30% and 50% of the one employed at cruising (Tzannatos, 2010). Overall, in-port emissions of NOx and SO_2 represent 5 - 6% of the total generated by ships in all their navigation phases (Whall et al., 2002). All these elements point out that in both port areas and port cities, important fractions of air pollutants can originate from ships (Tzannatos, 2010; Cullinane et al., 2014; Viana et al., 2014). Recently, a new epidemiological study confirmed a 31% increase in mortality due to lung cancer and 51% increase in due to neurological diseases for the people residing within 500 m from the port area (Bauleo et al. 2018).

According to research, the emissions from ships in ports originates from the burning of fossil fuels by ships auxiliary engines, boilers, ships propulsion engines mainly by tankers and containerships. From building electricity and heat, ports transports system etc.

According to the “Third IMO GHG Study 2014”, about 796 million tonnes of CO_2 was emitted by international shipping in 2012; accounting for approximately 2.2% of the total global anthropogenic CO_2 emissions for that year, and those emissions from international shipping could grow between 50% and 250% by 2050 (IMO, 2018b) due to the growth of the world maritime trade.

As ships transport about 90% of the world transportation in volume, the shipping sector cannot be underestimated. In 2017, over 80% of global trade by volume and more than 70% of its value was carried by ships and handled by seaports worldwide (UN, 2017).

However, environmental concerns have risen and have some impacts on the development of the shipping industry. As emissions from shipping have a negative effect on air quality in seaport areas, and global warming (OECD, 2014; UN, 2017). Most of the emissions from shipping take place at sea yet the noticeable one takes place in the port areas and post health threat to the local residents. International organizations, national government, shipping companies and port authorities are now in charge of mitigating the emissions and obtain sustainable shipping industry and seaports. In ports and surrounding areas, the air pollution has an indirect effect regionally that leads to grave degradation of ambient air quality. For instance, about 70% of particulate emissions from shipping occur within 400 km of the coast; as ship emissions is a major source of urban pollution around port cities, the operations of the ports share does not exceed 15% (OECD, Chang, C; Wang, C.). The emissions in a port depends on the size of the port and the city including the character of the city such as industrialization level (OECD). Sulphur oxides emissions affect human health by reducing lung functions and causing asthma [European Environment Agency (EEA)]. About 15% and 13% of global emissions from anthropogenic sources from shipping air pollution derive from nitrogen and Sulphur oxides respectively (IPCC, 2014).

To reduce emissions from the shipping industry, the International Maritime Organization (IMO), the United Nations Convention on the Law of the Sea (UNCLOS) and the United Nations Framework Convention on Climate Change (UNFCCC) are vital to the regulation of ships emissions [Bodansky, D. Regulating Greenhouse Emissions from Ships]. The IMO as UN specialized agency, is responsible to create a regulatory framework for the shipping industry that covers safety, security and prevention of pollution by ships (IMO: http://www.imo.org). To minimize emission / pollution from shipping, the IMO introduced Emission Control Areas (ECAs) in 1997 in designated sea areas that include the Baltic Sea in effect 2006, North Sea in effect 2007, North American Coasts, in effect 2012 and the United States Caribbean Sea in effect 2014; with Sulphur limits of 0.1% m/m. The EU require all ships at berth in EU seaports to use low-Sulphur fuel (0.1%) from January 1, 2010. [OECD]. Furthermore, IMO introduced a regulation to reduce the sulphur content in marine fuel from 3.5% m/m to 0.5% m/m outside the ECAs as of January 1, 2020. In January 2011, IMO introduced the Energy Efficiency Design Index (EEDI) for the new ships and Ship Energy Efficiency Management Plan (SEEMP) for existing ships with the aim to obtain energy efficient shipping industry (IMO). The energy consumption and CO_2 emissions for newly-built ships may be reduced up to 60% by 2050 via waste heat recovery, innovations in engine and transmission technologies, aerodynamics, electronically controlled engine systems designed for fuel efficiency and speed, and auxiliary power systems (IPCC, 2014). If the biggest ships continue to speed up, the GHG emissions emitted per unit of transport supply will equalize or even rise [International Council on Clean Transportation (ICCT)]. There are voluntary initiatives by international organizations such as World Port Climate Initiative (WPCI), Environmental Ship Index (ESI) launched in 2010 with the aim to reduce emissions from nitrogen and Sulphur oxide, as well as CO_2 in the long-term by encouraging ports to grant discounts for shipping companies on ports dues for ships that are certified with ESI certificate. In 2017, there was a total of 6,857 ships with a valid ESI score, representing more than 7% of the world's commercial fleet of seagoing ships; 52 ports globally, 38 of which are located in Europe [United Nations (UN): Review of Maritime Transport 2017, World Ports Climate Initiative (WPCI): Environmental Ship Index (ESI)].

Ports are important area of transportation and play a crucial role in international trade (Aregall et al., 2008). However, the high-energy consumption and high pollution from the increasing port production and trade volumes have environmental impacts on the ocean, drive climate change and threaten human health (Van Breemen, 2008). To address these issues, the "Green Port" strategy initiative was officially proposed at the 2009 United Nations Climate Change Conference (Wu and Ji, 2013; von Bargen & Kramer 2009). The Greenport strategy involves many aspects such as using renewable sources, reducing the emissions of harmful gases from ports and ships (Pettit et al., 2008). The green port practice was first implemented in the US Port of Long Beach that applied the "San Pedro Bay Ports Clean Air Action Plan" from seven aspects (Gupta et al., 2005). Port activities can influence GHG emissions reduction from ships by supporting systems, technologies and implementation of incentive programmes that facilitate fuel savings within the port area (Acciaro, Ghiara, & Cusano, 2014). Speed reduction at sea due to shorter time in port is one of the measures deemed to contribute to large reductions in emissions at limited costs (Eide et al., 2011). Faber et al. (2009) have estimated that up to 10% GHG emission reduction is possible, and Bazari and Longva (2011) determined that the potential ranged from approximately 10-20% depending on the vessel type and size.

Measures to reduce portside emissions: "Technical and Operational Measures Overview"

1. Information measures are essential for ports that include energy inventory and emission, monitoring and reporting. After conducting emissions inventory and energy consumption, ports determine an emission baseline, and then continue the data on emission, tracking emissions and reporting then over the years. The port information measure was referred to as one the environmental measures the help in the reduction of emissions of ports (Acciaro et al., 2014b; Lam and Notteboom, 2014; OECD, 2014; Woo et al., 2018), ships (Christodoulou et al., 2019), and the hinterland transport (trucks) (Gonzalez-Aregall et al., 2018). Monitoring of air pollution is essential to implement environmental measures (Darbra, et al., 2009), to control external effects of port activities (Acciaro et al., 2014b), to internalize port emissions (Tichavska and Tovar, 2015a) and to account for the external cost of shipping emissions (Tichavska and Tovar, 2017), thus improving the port's green image (Kang and Kim, 2017; Lam and Notteboom, 2014).

2. Equipment measures involve the physical change or replacement of older equipment of port emission sources with cleaner and newer energy-efficient technologies, example include harbour craft such as tugs, CHE, and buildings' lights and air conditioning (I2S2, 2013; IAPH, 2008; IMO, 2018a, 2018b, 2015). The equipment measures can implemented by purchasing new equipment, replacement older equipment with cleaner and more energy efficient equipment, repower by changing old engines by new ones and by retrofitting that adds emission control technology. The replacement of diesel power terminal equipment

minimizes energy consumption and CO_2 emissions (Geerlings and van Duin, 2011). Martinez-Moya et al. (2019) suggested retrofitting of RTG cranes' gen-sets as a measure to reduce emissions in the Port of Valencia container terminal, which could reduce the RTGs' CO_2 emissions by 40%. The terminal operators retrofit locomotives and invest in the replacement of older diesel-power gantry cranes with features that utilize regenerative electric capabilities, supported by a strong business case (IAPH, 2017). Nevertheless, the replacement and repowering programs are cost intensive for the CHE, as well as difficulty and long duration for manufacturing and transfer to the ports facilities (Zhong et al., 2019).

3. Energy measures involve the use of cleaner energy consumption in ports, such as alternative cleaner fuels, and others renewable sources. Ports could adopt the use of alternative fuels for their power supply such as the LNG which could provide an approximate energy efficiency 10% higher than conventional fuel per kilometer, and produce 25% less CO_2 (Yun et al., 2018). However, LNG has 25 times more warming potential than CO_2. Hence, it is recommended that LNG be used in gas turbines rather than piston engines to overcome this issue. LNG is use to power equipment and craft, in the Port of Rotterdam, the evaporated LNG that cools big LNG tanks is used fuel barges (PIANC, 2019). Methanol is another alternative fuel that generates less CO_2 emissions, and at low loads, it does not have the methane slip (APEC, 2014). Ports could also source or generate and use hydrogen and ammonia as clean marine fuels (Bicer and Dincer, 2017). Hydrogen can be considered as renewable fuel if generated from renewable electricity. The use of hydrogen was investigated in the Port of Hamburg via the e-harbours project (E-Harbours Electric, 2012). Ports can utilize biomass generation. Biofuel development is an opportunity for many ports (Acciaro, et al., 2014a), although biofuel is limited (Winnes et al., 2015). Biofuel can be blended with other fossil fuels, for vehicles (CARB/EPA, 2015c). Biodiesel, as a blend can lower GHG emissions (Misra et al., 2017). CO2 emissions of CHE could fall by 30% if the blending of 30% biofuels with diesel is realized by 2050 (Geerlings and van Duin, 2011). Hybrid port equipment can be

fuel-electric hybrids (engine and battery), plug-in electric hybrids (a rechargeable battery, e.g. in vehicles), and diesel-hydraulic hybrid where the hydraulic power accumulated drives the motor and the wheels (CARB/EPA, 2015a).

4. Energy efficiency measures include technical and operational measures to reduce port energy consumption and shift toward the use of renewable energy (Acciaro et al., 2014b), thus by reducing GHG and CO2 emissions, which are directly proportional to the amount of fuel combusted (Styhre et al., 2017). Port operation energy consumption is divided between necessary and wasted energy. Energy consumption "efficiency" was rated second after air pollutants in EU environmental priorities in 2018 (ESPO, 2018). Fifty-seven (57%) of EU ports developed energy efficiency programs, and 20% adopted measures to utilize renewable energy. Energy saving was recognized as one of the green port indicators (Chen and Pak, 2017). Many studies proposed measures to improve port energy saving, e.g. (Boile et al., 2016; He, 2016; Martinez-Moya et al., 2019; Schmidt, 2019). The use of light emitting diode (LED) lights in buildings, docks, yards, storages, warehouses, and tugs is rather simple, but efficient measure that is widely implemented in many ports. It saved 70-90% of energy in Port of Venice (Hippinen and Federley, 2014). Automatic lighting controls and sensors are used in Finnish ports and in Port of Felixstowe (ESPO, 2012a) among others.

In order to achieve the greening of EU Seaports, ports authorities collaborated closely with public authorities and energy suppliers to build liquefied natural gas (LNG) infrastructures, extend shore connections to reduce GHG emissions and air pollution in addressing future uncertainties regarding future propulsions and onshore-based power supply. The seaports should develop an efficient energy management practices such as the use of the ISO 50001 Energy Management System (EnMS) and the ISO 14001 Environmental Management System (EMS). All ships at berth or doing ports operations should use low Sulphur fuel such as LNG, Scrubbers etc. The use of cool ironing to provide electrical power for ships at berth while the auxiliary and main engines are turn off is essential in the reduction of emissions in ports.

3.0 Methodology

To answer the research questions and to achieve the objectives of the research, quantitative data collection was carry out in a literature review. The collected data was analyzed using the SWOT analysis (W. M. Chen, H. Kim, H. Yamaguchi, 2014) and the PESTEL analysis (M. Stuiver, K. Soma, P. Koundouri, et al., 2016). The researcher take into account the Greenport technology of the selected Seaports allowing various scenarios that include the strengths, weaknesses, opportunities and threats; also the political, economic, social, technological, environmental and legal aspects as well.

3.1 Data Collection

The researcher gathered the information doing a literature review for the selected ports via international seminars, visiting faculty, course modules, library sources, internet sources, Reports, PA Review Journey and relevant international organizations websites (IMO, ESPO, OECD). The collected data consisted of ports emissions from the use of diesel fuels by ships auxiliary engines at berth, ports trucks and cars. The emitted components included NOx, SOx, PM, CO2, GHG and other related air pollutants. The data were used to analyze the associated impacts on the environment and the related human health issues. The data between 2005 and 2020, with the negative externalities exerted on the port cities, port authorities and environmental regulations help to mitigate the emissions. Like the use of LNG tanks, and shore-based power in Port Antwerp and Port Hamburg; with the EU regulatory framework on GHG emissions reduction and the EU Directives.

3.2 Description of the Quantitative Data

The researcher use literature review in his approach to the objectives of the research. The collected data will help the administrators / decision makers of the selected Seaports to improve the identified weaknesses and the negative impacts of the GHG emissions on the port cities. The cost of the greening of the ports and the future uncertainties associated with the emissions reduction strategy. The data was gathered from Reports, relevant websites, PA Review Journey among others. The collected data help the researcher to identify the strengths, weaknesses, opportunities, threats, political aspects, economic, social, technological, environmental and legal issues of the selected seaports.

3.3 Data Analysis

The researcher use SWOT and PESTEL analysis tools from the literature review to analyze the collected data and performance of the selected Seaports methodology. The study combine the SWOT and PESTEL analyses tools to demonstrate the strengths, weaknesses, opportunities and threats for the SWOT analysis. This analysis was used to illustrate the political, economic, social, technological, environmental and legal aspect in the PESTEL analysis tool.

Cold ironing, though environmentally beneficial in improving air quality and reducing noise but yet the standardization electricity and the huge electrical infrastructure that is needed onshore is a major challenge for some ports. Development of the port energy management system using the ISO 50001 and environmental management system using ISO 14001 standard in the selected ports are good alternative in achieving the objectives of the research. Since the cost associated with the installation of the cold ironing electricity infrastructure is a challenge, another alternative would be the use of low Sulphur content marine fuel of 0.1% m/m by ships auxiliary engine and main engine while at berth.

3.4 SWOT and PESTEL Analysis Overview

The combination of the SWOT and PESTEL analyses tools were used to address the external and internal factors of the green port technology. The PESTEL analysis was use to look at the external factors and how these factors influence the internal factors via scenarios across Europe and Asia in the literature review. The SWOT analysis included both internal and external factors. Strengths and weaknesses (internal), opportunities and threats (external). The researcher combined both tools to identify the internal and external factors in the selected ports using different scenarios. The external factor influence affects the effectiveness of the internal factor such as the political influence (corruption), economic power (finance), and the legislative power (legal) among others.

The SWOT analysis is a method widely used in strategy development, strategic planning, and decision making (Wang et al., 2020). It involves comprehensive factors influencing specific objective (ArshadiKhamseh and Fazayeli, 2013) such as agricultural development (Mansour et al., 2019) and sustainable agriculture (Emami et al., 2018). The SWOT stands for ‘Strengths’, ‘Weakness’, ‘Opportunities’ and ‘Threats’ (Gurel and Tat, 2017). The strengths and weaknesses are known as internal factors and opportunities and threats are external factors (Arsic et al., 2017). The strengths and weaknesses factors are identified through assessing the internal system environment, while the opportunities and threats factors are recognized via evaluating the external environment (Khan, 2018). Hence, SWOT analysis provides a list of strengths, weaknesses, opportunities and threats associated with the internal and external environment affecting the system. The internal factors are combined with the external ones (Christodoulou and Cullinane, 2019) in a framework SWOT matrix to formulate four types of strategies.

PESTEL is a widely used framework for the analysis of the external environment of a company. It focuses on the developments in the political, economic, social-demographic, technological, ecological/environmental, and legal factors that shape the macro-environmental context in which a company operates (Marrison, 2018). These factors provide opportunities that managers can utilize or create threats for which they must be prepared to face. The result is used to identify the threats and weaknesses that are used in the SWOT analysis tool.

4.0 Legal / Legislative Framework

Shipping though indispensable to the world, have drawn environmental attention as the result of the negative externalities. The GHG emissions reduction is now a priority on national, regional and international level due to the effect on climate change and health threat. The emissions in ports is now a major concern owing to the health damage it cause for the port cities inhabitants. International, regional and national authorities are tasked with the responsibilities for regulating emissions from the shipping sector with IMO at the heart of the responsibility. The regulations and guidelines on the Greenport and emissions of GHG, SOx, NOx, and PM are review below.

Ports are hermetic places that are difficult for local people to access. They can be an obstacle to access the sea (Martorell et al., 1998). According to Ravesteijn et al. (2014), port and other infrastructure projects directly relate to citizen interests and values in terms of employment and welfare, but also, because of the expropriation of agricultural and otherwise used land. Alemany (2005, 22-27) openly criticizes the privatization of coastal and port areas when he refers to a large number of marines that had saturated some of the coast. The construction and maintenance of marines (Alemany, 2014) has caused strong environmental impacts and they have occupied some ecological valuable coastal areas. These port projects cannot be developed without the consideration of citizens and all stakeholders in general.

The port-city interface was first introduced by Hayuth (1982), who believes that the emerging port-city interface is derived from spatial and functional trends caused by the changing coexistence of seaport and port cities regarding new developments in maritime transport and modern port operations. Hoyle (1989) added that any development in the port-city interface should achieve a balance between technological changes and ecological restraints, and between maritime viewpoints and urban planning conceptions. In the case of developing countries, the interface shows more conflicts as compared to developed countries. The reason is that in the mature economics, port authorities perceive containerization and intermodal services as an efficient way to connect ports to inland cities. In contrast, port authorities in developing countries (mainly in Asia) struggle more on developing and improving the function of ports and inland cities symbiotically (Ducruet, 2006). Unlike mature economics in which policy preferences and political borders are less significant, developing countries struggle more with the centrality of the port to the city (Ng and Gujar, 2009). The positive impacts of port expansion range from employment opportunities, port cities benefit mostly from the industrial clusters in the port area, the plausible economics of scale and knowledge transfer (Merk, 2013; OECD, 2013). The negative impacts is the consequences of the environmental impacts (e.g. air emissions, water quality, waste, loss of biodiversity, etc.).

4.1 International Perspectives

Global warming is a foremost challenge on earth and maritime transport plays a critical role in Greenhouse Gas (GHG) emissions (Gu et al., 2019). The emissions from international shipping is now a global, regional and national concern due to the associated negative health issues and climate change impacts. The Third IMO GHG Study 2014 estimated that GHG emissions from international shipping in 2012 accounted for 2.2% of anthropogenic CO_2 emissions and this could increase by 50% to 250% by 2050 (ICCT, 2018; Smith et al., 2014 Google Scholar; IMO, 2018b) if reduction measures / regulations are not put in place.

In accordance with the Paris Agreement to Climate Change by maintaining, the global temperature increase to well below 2^0C above pre-industrial levels and strive to limit the temperature increase to 1.5^0C above pre-industrial levels (The IPCC's Special Report on Climate Change at 1.5^0C), the IMO adopted on 13 April 2018 at the MEPC 72nd Section

“RESOLUTION MEPC.304(72)” Initial IMO Strategy on Reduction of GHG Emissions from international shipping in response (IMO, 2018c). In relation with timelines, the IMO Initial GHG Emission Strategy consisted of Short-term measures, Mid-term measures and Long-terms measures. The short-term measures could be finalized and agreed by the Committee between 2018 and 2023; the mid-term measures could be finalized and agreed by the Committee between 2023 and 2030; and the long-term measures could be finalized and agreed by the Committee beyond 2030 (ICCT, 2018).

Table 1: Candidate measures included in IMO’s Initial GHG Reduction Strategy

Type	Years	Measure	Target	Current Status
Short-term	2018-2023	New Energy Efficiency Design Index (EEDI) phases	New vessels	-10% in 2015 -20% in 2020 -30% in 2025
		Operational efficiency measures (e.g. SEEMP, operational efficiency standard)	In-service vessels	SEEMP planning required
		Existing fleet improvement program	In-service vessels	-----
		Speed reduction	In-service vessels	-----
		Measures to address methane and VOC emissions	Engines and fugitive emissions	-----
		Alternative low-carbon and zero-carbon fuels implementation program	Fuels/new and in-service vessels	-----

Mid-term	2023-2030	Further operational efficiency measures (e.g. SEEMP, operational efficiency standard)	In-service vessels	SEEMP planning required
		Market-based Measures (MBMs)	In-service vessels/fuels	-----
Long-term	2030+	Development and provision of zero-carbon or fossil-free fuels	Fuels/new and in-service vessels	-----

Adapted from the (ICCT, 2018) Report: International Maritime Organization's initial GHG Emissions Reduction Strategy

As emissions from ports are now a significant concern, pressure on ports authorities are driven by several factors. These factors include; the national regulation of air quality and climate change mitigation, which pertains to port authorities, operators, tenants, and inland transportation (Poulsen et al., 2018). The regional regulation, such as the California Air Resource Board (CARB) regulations, the EU regulations. An example is the EU Renewable Energy Directive/2009, which aims to reduce EU GHGs 20% below 1990 levels by 2020, in addition to the EU Energy Efficiency Directive/2012, and Clean Power Transport Directive 2014/94EU which requires core ports to provide Liquefied Natural Gas (LNG) refulling points and shore-side electricity (ESPO, 2012a). Green effort project (Green Efforts, 2014); environmental reports (ESPO, 2018); and USA San Pedro Bay Ports reports (CARB/EPA, 2015a; CARB, 2015; DNV GL 2016; SCAQMD/CARB, 2015). International regulation, those introduced by the IMO (IMO, 2018b; 2018a, 2015), the International Association of Ports and Harbours (IAPH) (IAPH, 2008, 2007), World Port Climate Initiative (WPCI, 2010), the International Institute for Sustainable Seaports (I2S2, 2013) and the Association for Water-borne Transport Infrastructure (PIANC) (PIANC, 2019).

In the EU, MARPOL Sulphur regulations were first implemented in the Sulphur Directive (1999/32/EC) as currently amended Directive (2012/33/EU). In Europe, the Baltic Sea, the English Channel and the North Sea were declared SECAs in an amending directive (2005/33/EC). In the Sulphur Emission Control Areas (SECAs) the limit for fuel Sulphur content has been and is stricter: 1.5%S between 6/2006-6/2010, 1.0%S from 7/2010-12/2014 and 0.1%S as of 1/2015 (ELSEVIER: Sciencedirect). The study by Bosch et al. (2009) indicates positive net benefits for Europe. The 2018 recast of the Renewable Energy Directive (EU) 2018/2001 already set a 2030 target of 40% reduction in GHG emissions, together with 32% share of renewable energy in gross final energy consumption. In 2020, the European Green Deal Communicat (2019), the new European Commission 2019-2024 declared its aim "to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50% and toward 55% compared with 1990 levels in a responsible way" by mid-2020, and to achieve climate neutrality by 2050. The proposed European Climate Law 'European Commission, Brussels, Belgium (2020) sets out a legal framework for this. Between 2010 and 2019, solar PV electricity generation capacity in the EU increased from 1.9 GW to over 133 GW, exceeding previous expectations. In 2019 new PV capacity of 16.5 GW was installed and further market growth is expected for 2020 (A. Jager-Waldau, PV status report 2019).

In 1097, the IMO defined and introduced special Emission Control Areas (ECAs) to minimize pollution in designated sea areas (IMO). There are two facets of ECAs that set limits on Sulphur oxide and nitrogen oxide emissions. Sulphur Emission Control Areas (SECAs) and Nitrogen Emission Control Areas (NECAs). The below figures illustrates the existing SECAs and NECAs, and the likely future designated areas.

Figure 1: Existing and possible future ECAs (Source: DVNKL, DNV.GL)

Figure 2: Existing ECAs (Source: DVNKL, DNV.GL)

The requirements in SECAs which current include the Baltic Sea, in effect from 2006; the North Sea, in effect from 2007; the North America coasts, in effect from 2012; and the United States Caribbean Sea in effect from 2014 are stricter than the general requirements and laws. All ships spending energy by using fuel at berth in EU ports are required to use low-sulphur fuel 0.1% from 1 January 2010. European ports have far fewer emissions of Sulphur oxide 5% and particulate matter 7% than their share of port calls 70% (OECD, 2014). Moreover, all ships driving in the North Sea, Baltic Sea, North America, and the United States Caribbean Sea were required to use fuel with sulphur content not exceeding 1.0%, thereby implementing the revised Annex VI of the International Convention for Prevention of Pollution from Ships (MARPOL Annex VI), which entered into force on 1 June 2010 (IMO, 2008). As illustrated in the table below, as of 1 January 2012, the current global limit of ships' fuel using sulphur content is 3.5% m/m. Within SECAs, the maximum permissible sulphur content in marine fuels was lowered to 0.1% in January

2015. The same year, the sulphur content of fuels used in SECAs decreased substantially. The Sulphur Directive (Directive 2012/33 /EU) implemented SECA requirements into European law on 21 November 2012. From 2015, ships operating in SECAs have to adopt clean technologies such as scrubber systems or LNG for their primary propulsion. However, in their current state, ships will unlikely achieve such ambitious sustainability goals. In Europe, the introduction of SECAs has already proved effective, resulting in a 50-66% decrease in sulphur oxide emissions (Colette, A., Degraeuwe, B., De Vlieger, I., Hammingh, P., Van Aardenne, J., Viana M., Querol, X, 2014).

Table 2: Fuel quality requirements to limit SOx emissions

Fuel Sulphur Content	2008	2010	2012	2015	2020/2025
SECAs: Baltic Sea (2006) North Sea (2007) U. S. Caribbean Sea (2014)	1.5%	1.0%		0.1%	
Worldwide	4.5%		3.5%		0.5%

Source: Adapted from WPCI Reports

Nitrogen oxide emissions from shipping are regulated by mandatory limits on the emissions of newly-built engines. These regulations entered into force in 2005. MARPOL established the first nitrogen oxide regulations with three tiers (IMO). Firstly, marine diesel installed on ships constructed between 1 January 2000 and 1 January 2011 are required to comply with Tier I emission limits. Secondly, Tier II emission limits for engines installed on ships apply to ships built after 1 January 2011; this corresponds to approximately a 15-25% reduction compared to Tier I. Thirdly, Tier III requirements comprise installed marine diesel engines on ships constructed on or after 1 January 2016 and which are intended for operation in NECAs, the relative reductions are 80% below Tier I emission standards. Today, there are two NECAs, both in North America. One

NECA is along the coasts of Canada and U. S. and a second NECA is along the Caribbean portion of the U. S. coastline (Elgohary, M., Seddiek, 2014). Table … illustrate regulations that apply to diesel engines with an output of over 130KW and to ships with length over 24 meters.

Table 3: Mandatory limits for NOx emissions of newly-built ships

	Entry into Force	Diesel Engines Installed on Ships	NOx Limit in g/kWh	Regions
Tier I	2005	1 Jan 2000 – 1 Jan 2011	9.8-17.0	Worldwide
Tier II	2011	After 1 Jan 2011	7.7-14.4	Worldwide
Tier III	2016	After 1 Jan 2016 only operating in NECAs	2.0-3.4	NECAs: North American Coasts U.S. Caribbean Coastline

Source: Adapted from WPCI Reports

Taking environmental concerns and the manipulation of competition within European ports into account, the IMO designated the North Sea and Baltic Sea as NECAs starting from 1 January 2021 (IMO). Based on available emission scenarios, the European Monitoring and Evaluation Programme estimates that the annual reduction in total nitrogen deposits into the Baltic and North Sea will be around 22,000 tonnes compared to a non-NECA scenario (Ahdour, S., Faber, 2016)

4.1.1 EU vs Asia Perspectives

Both the European Union (EU) and the Asian countries, specifically the Association of Southeast Asian Nations (ASEAN) have striven to improve air quality and mitigation of climate change by regulatory framework for the use of environmentally friendly energy.

For the past years, the EU and ASEAN countries have adopted regulations for ships emissions at international level.

The EU have adopted directives in accordance with the reversed MARPOL Annex VI prevention of pollution from ships. These include, the Council Directive 1999/32/EC amended by Directive 2005/33/EC and Directive 2012/33/EU to align with MARPOL revisions (1997 & 2008 changes). The Sulphur content limit in marine fuels use by ships at berth in the EU seaports of 0.1% (DNV-GL, 2016). This exclude ships at berth for less than two hours and ships that use cold ironing at berth. Another milestone is the DFI Directive 2014/94/EU mobility for the development of alternative fuels infrastructure implemented via national policy framework. Additional is the Directive 2008/50/EU under the Air Quality Directive to limit the levels of SOx, NOx and PM (IMO, 2015). Furthermore, EU27 develop a proposal for Directive on the promotion of the use of energy from renewable sources (RES) that establishes an overall binding target of a 20% share of renewable energy sources in the gross final energy consumption and a 10% binding minimum target for biofuels, or other renewable fuels in transport to be achieved by each Member State and binding the national targets by 2020 in line with the overall EU targets of 20% (EU, 2008; RES2020, 2009b).

In an effort to reduce GHG emissions, the ASEAN are not as efficient as the EU. The project Greenhouse Gas Emission Reduction from Industry in Asia and the Pacific (GERIAP) help the Asian companies to become more energy and cost efficient via the use of Cleaner Production (CP), which China is a member. The project was funded by the Swedish International Development Cooperation Agency (Sida) under the United Nations Environmental Programme (UNEP). The project serve as regulations to GHG emission reduction through the implementation together with national focal points by nine countries (GERIAP, 2005).

Table 4: EU Vs Asia Regulatory Framework on Emission & Air Pollution

Regions	Regulatory Frameworks on Emissions & Air Pollution
EU	- Directive 1999/32/EC, amended by Directive 2005/33/EC & 2012/33/EU – on marine fuel Sulphur content limit - Directive DFI 2014/94/EU – mobility for alternative fuels infrastructure development. - Directive 2008/94/EU – Air quality - EU27- promotion of the use of renewable energy sources (RES)
Asia	- GERIAP – use cleaner production (CP)

Noted: Adapted from Asia and EU Regulatory Framework (Author: 2020)

4.2 Barriers and Drivers: Discussions

Green ports maintain a good balance between environmental impact and economic benefit. This involves many aspects including reducing the emissions of harmful gases from ports and ships, which is also the most prominent factor (Pettit et al., 2018). Port pollution is mainly from ships, about 70% of exhaust gas discharge from ships happens in areas neighboring ports, and out of which 60% to 90% occurs during ships' docking (Ballini and Bozzo, 2015). To date, the reduction of emissions from ports and ships have been primarily achieved by connecting Alternative Maritime Power (AMP), using LNG and reducing speed (Winkel et al., 2016; Sciberras et al., 2015; Styhre et al., 2017; Winnes et al., 2015). The Port of Goteborg in Sweden designed and installed the world's first high voltage AMP system in the early 2000, which reduced pollutant emissions from berthed ships by 94% to 97% (Corbett et al., 2007). However, there are barriers and restrictions in using AMP sources. Some barriers include but not limited to the following:

- Technical application: The technical problems applies to the matching of port and ship power supply systems, when using the AMP, it is important to ensure the matching of voltages and frequencies, and the compatible current phase [Peterson et al. (2007); Paul and Haddadian (2005)]. Direct power supply from the grid, to achieve the direct power supply to berthed ships, technical problems solving include high power electricity frequency-conversion, equipment cooling, electromagnetic compatibility and harmonic wave control (Paul and Haddadian, 2005; Pettit et al., 2018). Power supply quality, that include problems of voltage stability of port power supply and seamless switch between ship and port power supplies for reducing the loss of ship-borne electrical equipment (Ericsen, 2008; Kherson sky et al., 2005).
- Economic cost: The economic cost include the cost for port infrastructure construction and renovation, this includes the cost of installing power supply equipment at newly built ports, renovating existing terminals and ports, and building safety channels of ship-borne cables [Bao et al. (2010); Sciberras et al. (2015). The cost for installing ship-use power receiving facilities, it includes the cost for installing power receiving facilities of newly built ships, renovating existing ships, and installing and renovating ship-borne electric power monitoring equipment (Peterson et al., 2007). Cost for operation and management, this includes the cost for manpower, management and maintenance of power supply and power-use equipment in the use of the AMP (Bao et al., 2010).
- Operation and management: Equipment maintenance for ship and port, it refers to the establishment and improvement of AMP management measures, safety maintenance of cable and prevention of ship-port collaboration failure among others (Lam and Notteboom, 2014). Determination of accident responsibility refers to the establishment of ruling institutions for AMP accident and the improvement of accident determination system (Zis et al., 2014; Lam and

Notteboom, 2014). Coordination of ship-port power supply, it includes the coordination of ports and local power grids, the balance of stakeholders' interests and determination of power supply charge standards (Shigematsu et al., 2007; Arduino et al., 2011).

- Policy system: The policies and supporting systems, it includes safety agreement between ships and ports, policies on port financial subsidy and tax reduction or exemption, and AMP implementation scheme or guiding opinions promulgated by government departments (Ferrara et al., 2011; Styhre et al., 2017). AMP construction standard, it includes power supply and power use standards, relevant construction engineering quality standard, and appraisal and acceptance standard for AMP engineering facilities (Tan et al., 2017). System for laws, rules and regulations, it includes legislation of environmental protection, determination of sales qualification for the port AMP, formulation and promulgation of local technical laws and regulations, issuance of legitimate invoices, and legitimate tax payment (Tan et al., 2017; Ballini and Bozzo, 2015).

The four above aspects summarizes twelve restrictions / barriers of AMP application. They barriers were observed in the Port of Antwerp, Port of Hamburg and the Port of Shanghai in their efforts to establish green port technology.

The drivers on the other hand illustrates the important of stakeholders' involvement. The literature classify various stakeholders in four categories, the market players, public policy makers, internal stakeholders and community.

❖ Market players: The fundamental function of a port is the connection or "interface" point where market players transact and interact. Ports authorities need to collaborate with their major customers that is, shipping companies in reducing air pollution and greenhouse gases. The use of low-Sulphur fuel by ships to reduce GHG emissions was adopted. One of the programs implemented by LA/LB called Green Flag Speed Reduction Program (Port of LB, 2009) is cost-effective for shipping companies. By slowing down the ships speed, ships can reduce emissions and ship-owners in return get discount fees the following year as an incentive, hence this combines environmental protection and economic benefits.

- Public policy makers: The involvement of public policy makers representing the government and public agencies act as central party in the decision-making. The involvement of public policy makers will ensure that the government strategy is implemented and a better chance to sustain.
- Internal stakeholders: The employees are considered as the major internal stakeholders of a port. The employees' knowledge and understanding toward the green ports have an impact on the port development. Training and awareness are essential aspect. LA pursues employee involvement and provided various training programmes to over 900 employees at the Harbor Departments (Port of LA/2011). The improvement of internal communication will play a crucial role. The internal communication officer was appointed in 2010 in the Port Authority (Port of Antwerp, 2010). Practical measures such as proposed green port projects are discussed across various functions by internal communication.
- Community: The environmental conservation is a public issue. The involvement of NGOs and the public when building green ports is not only necessary but also beneficial for port image and sustainable development.

The above-mentioned drivers and scenarios were observed during the literature review of the selected ports green port implementations.

5.0 Case Study: IMO Sulphur Cap 2020: Environmental Impacts in the Selected Seaports

5.1 Introduction

The case study is conducted in the selected ports, with the researcher aim to identify the mechanisms put in place by the selected ports to achieve the research objectives

(Greenport). The environment impacts from the air pollutants and GHG emissions caused by the selected ports operations. Their strengths, weaknesses, political difference, economic factors, geographical locations, technology among others.

The selected three seaports are ideally located and served as transportation hub for the various countries. The Port of Hamburg is the largest port in Germany and third largest in Europe, and often referred to as the "Gateway to the World". The Port of Antwerp is the second largest seaport in Europe after Port Rotterdam. The port is the largest seaport in Belgium located in the center of Europe that makes it one of the best convenient places for transshipment. The Port of Antwerp can now host the world largest ships with capacity over 20 thousand TEU. The Port of Shanghai is the world's busiest and largest seaport located in Shanghai, China at the mouth of the Yangtze River. The three ports A, B & C are selected because of their geographical and strategic locations, the environmental policy of the countries, their efforts and compliance to achieve green ports in the world, port energy policy among others.

5.2 Port of Hamburg "Germany" Overview

The Port of Hamburg was founded on 7 May 1189 almost as old as the city itself. Based on international trade, the port enable Hamburg to strengthen its position in Central Europe and to develop a prosperous economy. Today, Hamburg is one of the world's largest and busiest ports which hosts a wide range of shipping activities. The Port of Hamburg handles around 9,000 sea going ship calls per year Table 5 and is served by more than 2,300 freight trains per week, of which 1,300 are destined for the hinterland. The Port has 280 berths for seagoing ships, three cruise terminals, four state-of-the-art container terminals, and about 7,300 logistics companies within the city limits (Hamburg Port Authority). In term of seaborne cargo throughput, its main trading partners are China, Russia and Brazil. The port main trading partners regarding only container throughput are China, Singapore and Russia. As the nation's gateway, the Port of Hamburg is the largest seaport in Germany, the third largest container port in Europe and the seventeenth in the world (American Association of Port Authorities (AAPA): Port Industry Statistics). The port covers an area of 7,105 hectares, of which 4,258 are on land and is the country's second largest inland port. About 166,000 jobs are directly and indirectly dependent on the Port activities [Port of Hamburg]. To achieve a sustainable symbiosis of port activity and environmental concerns, the port is highly aware of the need for new technology and innovative approaches in ensuring maximum efficiency and economy in all areas the port infrastructure (Hamburg Port Authority). The below table illustrates the total calls at Port Hamburg for the period 2016 to 2018.

Table 5: Total calls at Port Hamburg: 2016-2018

2016	2017	2018
8,719	8,088	8,044

Source: Statistische Landesamt Hamburg und Schleswig-Holstein (2019)

5.2.1 Port Incentives

To achieve more environmentally friendly technologies and propulsion, the Port of Hamburg has taken a variety of actions to push shipping companies. In accordance with the Air Pollution Control Plan passed by the Hamburg Senate, a new fee rating system featuring an environmental component is being introduced in 2018 (City of Hamburg, Luftreinhalteplan fur Hamburg). Seagoing ships will be granted a discount on port dues up to 10%. Ships with an ESI score between 20 and 24 will be given a discount of 0.5%, up to a maximum of 250 EUR, those with a score between 25 and 34 will received a discount of 1%, up to a maximum of 500 EUR, those with a score between 35 and 49, a discount of 5% up to a maximum of 1,000 EUR; and those a score of 50 or more, a discount of 10% up to a maximum of 1,500 EUR. In 2016, ships registered with an ESI score made more than 15% of the ship calls and 18% of all calls were far cleaner than the required law. In 2016, nearly one of every three ESI-registered ships had more than 35 ESI points, an increase by 41% as compared to 2015 (Hamburg Port Authority).

The discount increases even more in terms of environmental financial incentives. All ships with the Green Award certificate are granted an additional discount of 3% and ships with a Blue Angel Award can receive a discount of 2% on port dues. A special discount of 15% was provided for ships with an exclusively LNG propulsion system until 31 December 2018. Ships without exclusively LNG propulsion but do hold an ESI score above 0 or Green Award can receive a discount of 15% on port dues, up to a maximum of 2,000 EUR if they predominantly use an onshore based power supply. The introduction of a nitrogen oxide based tariff system is in progress [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen and City of Hamburg: Luftreinhalteplan fur Hamburg].

5.2.2 Infrastructure Deployment

Since 2015, the LNG Hybrid Barge Hummel, the world's first environmentally friendly hybrid LNG barge, complements fueling via truck-to-ship. The Hummel silently supplies low-emission electric power to ships at berth. The LNG Hybrid Barge reduced CO_2 emissions by 20% and nitrogen emissions by 80%, with no particulates or Sulphur oxide emissions. During the winter season, the 76 meter LNG Hybrid Barge is classified as a seagoing ship and operates as a heat plant and floating power plant [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen & Becker Marine Systems].

The mobile LNG PowerPacs are alternatively use to minimize air emissions within the port of Hamburg that consists of containers equipped with gas engines placed onboard ships. The system can be quickly implemented to provide a high degree of operational flexibility. A PowerPac is the size of two 40-foot containers and combines a gas-fired generator with an LNG tank [Port of Hamburg and Becker Marine Systems].

The Port of Hamburg seeks to provide proper infrastructure for onshore-based power supply for inland and seagoing ships, especially cruise ships to promote the use of environmentally friendly fuels. Today, shore power is produced entirely from solar panels and wind parks, and thus is 100% renewable. However, it is also roughly four times more expensive than auxiliary engines. In 2017, shore connection was used by just one cruise ship (City of Hamburg: Luftreinhalteplan fur Hamburg and WPCI, Onshore Power Supply).

5.2.3 Port-owned Efforts

The Port of Hamburg promotes the use of low-emissions, energy-efficient machinery, and equipment to reduce it carbon footprint. Its created a smartPORT philosophy that promises digital intelligence and guarantees sustainable economic growth with the aid of the T-Systems and SAP. The port's smartPORT Logistics covers approximately 20 projects and focus on optimizing three sub-sectors that include traffic flows, infrastructure, and flow of goods. Its also boosts environmentally friendly mobility and accounts for reduced energy consumption with three focuses that consist of renewable energy, energy efficiency, and clean mobility [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen].

5.2.3.1 Sustainable Mobility / Traffic Relocation

Within its smartPORT energy strategy, the Port of Hamburg has a carpool of 248 vehicles, 13 of which have CNG (Compressed Natural Gas) propulsion and 18, which drive electrically. Hamburger Hafen und Logistik AG (HHLA), awarded as the best green container terminal operator ordered a fleet of 64 all electric cars, the largest fleet of electric owned by a European port operator. They cover about 475,000 km each year, reducing CO_2 emissions by 148 tonnes. HHLA also purchased two new straddle carriers [Port of Hamburg and Hamburg Hafen und Logistik AG (HHLA)]. Engines with soot particle filters to prevent particulate emissions are encourage by a discount since 2011. Over 50% of railways are electrified [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen and Hamburg Hafen und Logistik AG (HHLA)]. The port subsidiary rail company Metrans with 272 km trucks has acquired two new hybrid locomotives for heavy-duty shunting reducing harmful substances such as particulate emissions by up to 70%. 38 out of 231 shunting locomotives in the port were equipped with particle filters [City of Hamburg: Luftreinhalteplan fur Hamburg]. Most of the port-owned ship fleet has switched to fuel gas liquid (Gas-to-Liquids: GTL) that emits less nitrogen oxide and particulates compared to diesel [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen].

5.2.3.2 Logistics Systems

Digital solutions like real-time navigation, mobile GPS all-purpose sensors and smart maintenance increase the flow of goods help ensure an efficient, intermodal and sustainable transport system within the port. Computer aided optimization reduce both energy consumption and noise and mitigates the distance travelled by transport equipment. To ensure effective and traceable improvements, the smartPORT Logistics strategy facilities the interactions between sensor technology and analysis, information and forecasting systems [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen].

5.2.3.3 Energy Saving

Both the Pintsch-Aben and the Port of Hamburg installed a geothermic switch-point heating for 880 switch along the railway, reducing external power supplies and saving energy in accordance with the smartPORT Energy Project. The port real-time information system monitors the condition of rails and switches via sensors. The utilization and efficient planning of port rail infrastructure is improve by early warnings on the traffic conditions and malfunctions [Hamburg Port Authority (HPA): smartPORT – der intelligente Hafen and Pintsch Aben B. V., Pilotprojekt bei der Hamburger Hafenbahn]. The HHLA terminal is one of the first northern range ports that completely adopted LED lamps for lighting terminal areas and outfitted all container cranes with LED lighting. The LED lights automatically turn off when unneeded. HHLA estimates electricity savings of more than 95% for the lighting of its block storage facilities. About 50-container gantry cranes have been fitted with energy recovery systems, that have saved around 20 to 25% of the energy used [Hamburg Hafen und Logistik AG (HHLA)].

5.2.3.4 Renewable Sources

By 2015, the HHLA terminal installed a widespread photovoltaic system and seven wind turbines to receive environmentally produced electricity [Hamburg Hafen und Logistik AG (HHLA)]. Eurogate on the other hand strive to be the first port terminal in Hamburg that covers its own electricity demand by self-owned renewable sources. At the beginning of 2015, the company installed a wind turbine on one of its container terminals generating its needed electricity. The terminal and wind turbines save 9,000 tonnes of CO2 emissions per year. Almost two-thirds of power consumption at the Eurogate terminal is provided by solar energy combined with heat, power plant, and wind power [EUROGATE GmbH & Co. KGaA, KG: Unser Engagement fur die Umwelt].

In addition to the above mentioned, the use of the ISO 50001 Energy Management System, ISO 14001 Environmental Management System standards and the installation of Cold Ironing are highly essential in achieving the greening of seaports when implemented.

5.3 Port of Antwerp "Belgium" Overview

The Port of Antwerp was first mentioned in the 12th century and developed into an export point for wine from Germany to England, as well as a port for passengers travelling to the Netherlands or England. The 16th century was Antwerp's golden age, when exports of wool, textiles, and paintings produced in the provinces of South Netherlands boomed. Today, the Port of Antwerp is not only the largest port in Belgium, with a size of 12,068 hectares (or about 20,000 football fields), but also the largest port area in the world, ranking 14th worldwide in container traffic volume [American Association of Port Authorities (AAPA): Port Industry Statistics & Port of Antwerp]. 40 docks, 86 terminals, and 7 locks produce smooth transfer of traffic within the port area. About 900 private companies are active, employing no less than 150,000 people. The Port of Antwerp has 85 European and more than 500 direct destinations all over the world [Port of Antwerp].

Since 2012, there has been an upward trend in the volume of shipping freight handle in the Port of Antwerp. In 2015, the port's freight volume passed 200 million tonnes and the port handle 14,500 seagoing ship calls. This naturally has both positive and negative impacts on economic and environmental issues in and around the port's surrounding [Port of Antwerp]. The beneath table highlight the calls for three years trend but to one avail (2016).

Table 6: Total Calls at Port Antwerp: 2016-2018

2016	2017	2018
14,473	-	-

Source: Port of Antwerp

5.3.1 Incentives

The Port of Antwerp grants a discount on port dues for ships with a good ESI score. In 2017, a new graduated system was introduced, in which ships with a score between 31 and 50 were given a discount of 5%, those with a score between 50 and 70 a discount of 10%, and those with a score of 70 and or more a discount of 15% on port dues. The number of ships with such characteristics increased over the years from 462 calls in 2012 to 1,137 calls in 2016 as a result. While the total number of calls at the Port of Antwerp also decreased. In 2016, the Port of Antwerp granted ESI discounts for about one in 13 calls, whereas roughly one in every 40 ships calling at the Port of Antwerp had emission-reducing technology such as scrubber systems [Port of Antwerp].

5.3.2 Infrastructure Deployment

From 2011 to 2016, the Port of Antwerp worked to make LNG available as an alternative fuel for inland and seagoing ships. Even though the bunkering volumes remain small, they have been increasing from year to year, ranging from 68 tonnes in 2013 to 468 tonnes in 2016. In 2016, the port signed a 30-year concession with the energy company ENGIE to develop and operate an alternative energy hub to supplement truck-to-ship and ship-to-ship LNG fueling [Port of Antwerp & Engie Electrabel: Alternative Electric Hub]. This first shore-to-ship multifunctional LNG bunkering and LNG fueling facility in Europe consists primarily of an LNG bunkering station for inland barges and short sea ships. It will also feature an LNG and CNG filling station for trucks, buses, and cars. The multifunctional alternative energy hub will have fast charging facilities for electric vehicles. The storage tank with inputs from the LNG boil-off will produce the CNG. It is to become a local zero-emission facility [Engie Electrabel: Alternative Electric Hub].

In 2017, the Port of Antwerp installed seven new shore connections to avoid active auxiliary engines at berth in an efforts combat air pollution. The connections reduce CO2 emissions and other harmful pollutants including nitrogen oxide and particulates, its also mitigate noise nuisance for people living nearby the port. The onshore electricity is mainly produced by port-owned wind parks within the port area [Port of Antwerp].

The Port of Antwerp and various partners jointly support the Clean Inland Shipping (CLINSH) project, a two-year demonstration project that assesses the effectiveness of alternative fuels, emissions control technology, and onshore-based power supply collecting data during regular operations. To develop a smart and sustainable inland shipping sector, valuable information about the ecological performance and operating costs of the monitored ships will aid [Port of Antwerp].

5.3.3 Port-owned Efforts

The Port efforts included the below.

5.3.3.1 Sustainable Transport / Traffic Relocation

The Port of Antwerp implemented both alternative and sustainable transport possibilities accordingly. For the workforce of nearly 60,000 employees commuting to and from the port every day, the port installed park and ride car parks, the Port of Antwerp shuttle bus, and a special waterbus for bicyclists. The port and its partners introduced a campaign to encourage privates companies to invest in sustainable transport with reference to trucks and private cars. The port set a good example for other to invest in environmentally friendly traffic by replacing diesel-engine straddle carriers with hybrid versions. The Port issued a call for proposals to make transport more efficient and sustainable in and around the Port of Antwerp. Seven projects, ranging from innovations in barge transport to shifts in rails were selected and each received financial support up to a maximum of 200,000 EUR spread over a period of three years. The projects are to relieve the streets by up to 250,000 truck trips annually [Port of Antwerp].

5.3.3.2 Renewable Sources

In 2016, roughly one-fifth of the installed capacity was produced by renewable sources such as wind power, solar panels, and biogas. The Port expects to double its production of sustainable energy in the coming years [Port of Antwerp].

5.3.3.3 Gas Venting

Highly aware of its environmental impact, the Port of Antwerp is preparing to implement a ban on the free venting of gases. Electronic detectors, including so-called iNoses (devices for monitoring the air quality) and infrared cameras will be installed around the port to identify and prevent the release of hazardous and noxious substances [Port of Antwerp].

5.3.3.4 Pilot Projects / International Initiatives

As the main polymer hub in Europe for the production, handling and distribution of plastic pallets, the Port of Antwerp recently became the first port to officially join Operation Clean Sweep (OCS), aimed at keeping plastic out of the sea [Port of Antwerp].

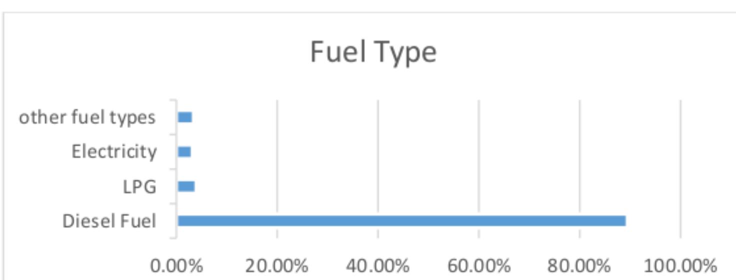
5.4 Port of Shanghai "China" Overview

The Port of Shanghai is the world's busiest and the world's largest container port. It is located in the middle of the Chinese mainland coastline at the Yangtze River estuary. The port is the transportation hub on the east coast of China. The largest terminal in the Port of Shanghai is the Waigaoqiao terminal on the southern bank south port channel of the Yangtze River estuary and has held the first position in global ranking of annual cargo throughput. Other large terminals include the Wusong Ferry Terminal, the Luojing Ore Terminal, the Yangshan deep-water port etc.

5.4.1 Port Emissions

According to study conducted in the Port of Shanghai in 2015, the use of diesel fuel by internal and external port related container trucks, and in-port machineries released various air pollutants. The port terminals are close to residential area. The emission inventory conducted in the port of Shanghai in 2015 indicated that the consumption of diesel fuel dominated the fuel type of machines and cargo delivery trucks [Sustainability 2020, 12(10), 4162; https://doi.org/10.3390/su1204162].

Figure 3: Fuel Types use in Port Shanghai 2015



Source: Sustainability 2020, 12(10), 4162

The use of diesel fuel dominated with 89.46% followed by LPG 3.96%, electricity 3.17%, and other fuel types of 3.41% including LNG, Gasoline among others.

5.5 SWOT Analysis: Case study application

The use of shore-based energy in ports are driven by environmental regulations. The installation of shore power has many challenges for ports authorities and ship owners due to the electrical power require by the ports infrastructures. Shore-based power has benefits for both the environment and ship owners. Environmental benefits are improvement in the health sector, climate change mitigation. The ship owners on the other hand have incentives for ships with Green Award, discounts for ships with environmentally friendly awards (Green Award 2017). The researcher doing the literacy review take into consideration the SWOT Analysis; the strength, weaknesses, opportunities and threats in the selected sea ports as illustrated in the below table…[W.M. Chen, H. Kim, H. Yamaguchi; Energy Pol., 74(2014), pp. 313-329; N. Markovska, V. Taseska, J. Pop-Jordanov; Energy, 34(2009), pp. 752-756]. The selected ports and ship owners should take advantage of the opportunities to strengthen their environmentally friendly energy supply in the various ports.

Table 7: SWOT Analysis of Ports A, B, & C

Strengths	Weaknesses
❖ Improve the health benefits for the port cities inhabitants, the port workers and the ship's crew. ❖ Improve the environmental impacts by reducing the negative	❖ High cost of investments for port authorities for the electricity demand by shore power supply infrastructures. ❖ High capital cost for ships owners for the use of low Sulphur fuel

externalities emitted from the ports operations. ❖ Contribute to the mitigation of climate change if produce from coal. ❖ Reduce the emissions of GHG and air pollutants from the use of diesel fuel by ships auxiliary engines while at berth. ❖ The use of shore base power by ships at berth will reduce the emissions of SOx, NOx, CO_2 and PM.	(0.1%) by ships for power supply at berth. ❖ The high maintenance cost of the shore base power supply. ❖ The use of LNG tank to supply ships at berth are cost intensive. ❖ The use of renewable energy sources to supply the port infrastructures including buildings, cargo-handling equipment, transportation, require energy by ships at berth are high capital cost for port authorities. ❖ Political factors (corruption)
Opportunities	Threats
❖ Discounts on port dues for ships that meet the ESI requirements in the EU ports. ❖ EU Ports grant discounts on port dues for ships with the Green Awards. ❖ All ships with environmental friendly certificates are given incentives by EU ports such as reductions in port dues. ❖ The use of shore power supply by ships at berth can be an alternative	❖ The risk of high investments due to future uncertainties. ❖ On shore power supply are usually expensive than the power produce by auxiliary engines.

for ships owners because of the increase in fuel oil price (Low Sulphur Fuel) required by port authorities for vessels at berth.	

Adapted from the Literature Review in the Research (Source: Author 2020)

SWOT Analysis Findings

In the SWOT analysis, the researcher mainly focused on the strengths and weaknesses of the selected ports. For example, the Port of Hamburg have the strengths to install on shore power infrastructures for ships at berth in addition to the EU Sulphur limit 0.1% regulation for ships at berth in the EU seaports. The port also have LNG tanks, electric cars and LED lamps among others. However, were also influence politically by the stakeholders representing the Central Government. The political influence could include corruptions, stakeholders' decisions without taking into account the future uncertainties associated with these Green infrastructures but only focuses on the environmental regulations. The Port of Antwerp also demonstrated their strength in installing the LNG tanks, shore electrical power, but the huge capital investment became a challenge. The EU play a crucial role to mitigate port emissions via the EU green deal and the EU directive.

5.6 PESTEL Analysis: Case study application

In addition to the SWOT analysis, the researcher also use the PESTEL Analysis in the literature review to address the research objective through the political, economic, social, technological, environmental and legal aspects [M. Stuiver, K. Soma, P. Koundouri, et al.; Sustainability, 8(4)(2016), p. 333]. The local government plays a critical role in regulatory framework in greener economic (Apollo Alliance, 2008). The legislative is a key political factor of green infrastructure development; the local policy makers play an important role in removing the barriers that hinder the growth of greener environment (Workplace Research Central, 2007).

Table 8: PESTEL Analysis of Ports A, B & C

POLITICAL	
Internal Factors	**External Factors**
▪ The port management specific plan of operation. ▪ The port energy management policy, targets and objectives of Greenport. ▪ Incentives / discounts for ships with environmental friendly certificates (eg. ESI, Green Award) on port dues.	▪ The stakeholders influence, the stakeholders have an influence on the port specific plan. ▪ Government energy management policy. ▪ The Central Government tariffs for seaports remain unchanged. ▪ The level of corruption in the Government have negative influence.
ECONOMIC	
Internal Factors	**External Factors**
▪ High cost of shore power for ships owners. ▪ High capital investment for port authorities to install shore power supply	▪ The need of additional funds to supply the required power demand by the ports. ▪ The commitment to sustainable development by national authorities.
SOCIAL	
Internal Factors	**External Factors**
▪ The training of staffs	▪ The health effect on the society.

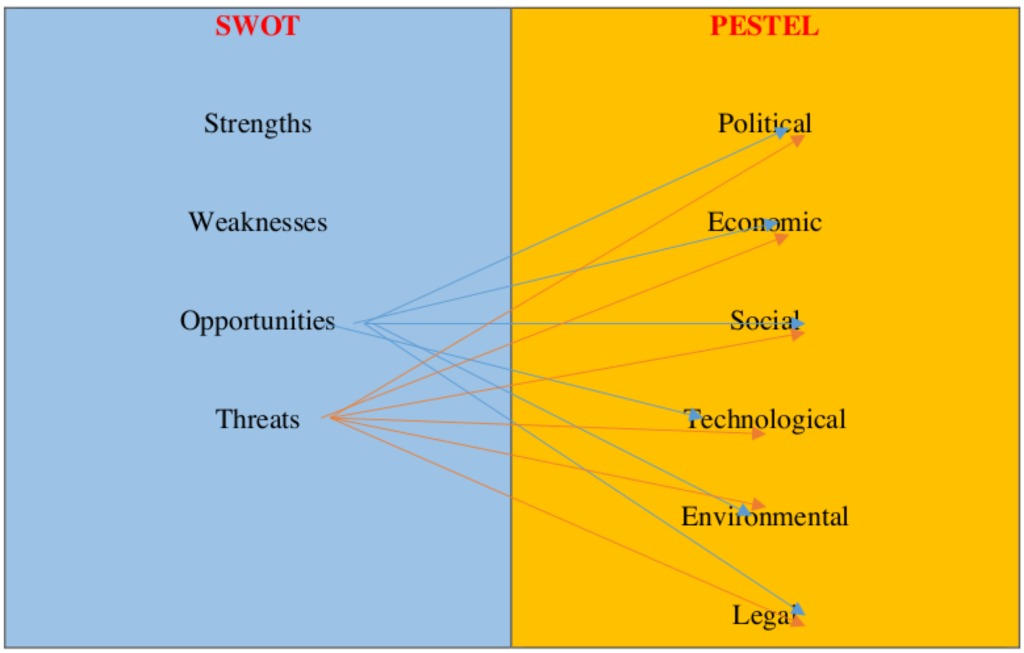
▪ The use of clean energy / renewable energy sources awareness.	▪ The cultural difference between the ports authorities and the Central Government.
TECHNOLOGICAL	
Internal Factors	**External Factors**
▪ Top management should carry out technological awareness. ▪ To identify and put in place energy efficient measures for ports energy management system.	▪ The invention of new energy efficient technologies via innovations.
ENVIRONMENTAL	
Internal Factors	**External Factors**
▪ Reduction of emissions from the use of energy. ▪ The use of clean energy to improve the health of port workers ▪ Installation of renewable energy sources for port energy activities.	▪ To reduce the environment impact of air pollutants from ports on human health. ▪ To contribute to the mitigation of climate change. ▪ To improve the health of the port cities inhabitants.
LEGAL	
Internal Factors	**External Factors**
▪ To comply with the existing energy policy.	▪ To meet the future energy-related regulations (2014/94/EU).

Adapted from the literature review during the research (Source: Author 2020)

PESTEL Analysis Findings

Representatives from the governmental sector influenced the Port of Antwerp, Port of Hamburg and Port of Shanghai. These stakeholders in formulating the Greenport regulatory framework did not take into consideration the future uncertainties involved in the huge capital investment to achieve these infrastructures by the ports authorities. Instead, they were only focus on negative externalities exerted on the environmental from the ports operations.

Table 9: SWOT Analysis vs PESTEL Analysis



Adapted from literature review (Source: Author 2020)

Discussions

In combination, the SWOT and PESTEL analyses address external and internal factors in the selected ports been researched. The strengths and weaknesses are internal factors; for example, the Port of Antwerp illustrated their strengths in the installation of LNG tanks, yet with a weakness of the huge capital cost and future uncertainties. The opportunities and threats are influence by external factors such as the political influence, future uncertainties, stakeholders decisions etc. affected the selected port authorities. The SWOT-PESTEL refers to the combination of SWOT (Strengths, Weaknesses, Opportunities and Threats) and PESTEL (Political, Economic, Social, Technological, Environmental and Legal) analyses use by business / organizations during planning. The PESTEL sometime call STEEP is by firms to get details overview of what external factors determine the trends. The SWOT is the traditional tool use by firms to identify how the external factors influence the business.

Table 10: Summary of Combination "SWOT-PESTEL" Analysis

Futures	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**
Political	Protect scale of services	Lake of physical data control	Supporting the continuities of service	Ignoring the arguments
Economic	Low cost of maintenance	High cost for securing communication network	Being a new service	Industrial and economic sanctions
Social	Interoperability with other data	Rapid changes in technology	Using support of other provider resources	Cultural invasion
Technical	Continuity of service delivery	Data transfer bottlenecks	Offering worldwide services	Weak communication infrastructure
Environmental	Protecting the environment	Negative effect of environments	Saving the energy	Vast resources
Legal	Improve the quality of services to achieve the SLA	Lake of proper law	Define the qualified data center services	Lack of legal law

Adapted from a literacy review (Source: Google Scholar, Author 2020)

Table 10 highlight few relationships from the combination of the both tools (SWOT-PESTEL).

5.7 Analysis and Discussions of Findings (Selected Ports Green Technology)

With the research objectives to achieve a Greenport and reduce the negative externalities from port emissions for the port cities, the researcher has suggested the use of cleaner energy for ports related operations in the future for the selected ports. However, the ports under review have put some measures in place to reduce the emissions of GHG and other air pollutants like the use of low Sulphur fuel of 0.1% by ships while at berth, LNG tanks etc. in the Ports of Antwerp and Hamburg. The use of cold ironing and on shore electricity by ships at berth need improvement. The use of renewable energy sources such as solar power, wind turbine, tidal energy, hydro energy, biomass, geothermal energy for the selected ports energy usage for electricity, heating, transportation, ships at berth, buildings, need to be increased.

The researcher identify the Port of Shanghai as the weak port in the study. The port needs to put in place the use of clean energy such as the use of LNG, electricity for its operational activities like Cargo-handling equipment. The use of diesel fuel by the port equipment dominated in 2015. The use of diesel fuel for the port related activities continue today, causing negative environmental impacts for the residential community.

The use of diesel fuel for the selected ports transportation should be converted to hybrid and electric cars and trucks. The emissions from the selected ports transportations and buildings power usage need improvement. The use of pure electricity for the ports buildings and transport system need to be increase.

5.8 Analysis and Conclusion of Findings

The research indicated the high emissions of GHG by container ships and tanker ships; even though the container ships spend, a short time in the ports yet emitted the highest emissions. The use of renewable energy sources in the selected ports is less and should be improve. The Port of Shanghai that is identify as the weak port need to convert the energy sources to environmental friendly energy such as the use of renewable energy sources for its port transportations, buildings and cargo-handling equipment.

The Port of Antwerp and the Port of Hamburg have both make great efforts for the past years in establishing efficient energy ports operations. However, there is a need to improve the infrastructures and transport system to complete renewable sources. The use of cold ironing and pure electricity by ships at berth are essential for the selected ports highlighted in this research.

6.0 Conclusion and Recommendations

6.1 Conclusion

The findings indicate that Greenport technology has been implemented in the EU seaports some years ago and very few Asian countries. The Port of Antwerp and the Port of Hamburg adopted the use of LNG tank, electric cars for ports operation, and the use of shore power by ships at berth including incentives for ships with environmental friendly propulsion system like ESI, Green Award to implement the Greenport strategy. The Port of Shanghai has also make efforts to adopt the environmentally friendly regulations on ports operation yet limited due to the capital investment to meet the requirements.

The objective of the research was to identify the implementation level of the Greenport technology in the selected ports. The researcher during the literature review used the SWOT and PESTEL analyses tools for the findings. The technology has many environmental benefits yet the capital investment is a challenge for ports authorities and the operational investment is a huge challenge for ships operators / owners. For instance, the Port of Antwerp as a landlord port demonstrated their strengths by the use of LNG, few electric cars, and replacing the lighting system with LED lamp. Installed on shore power supply for ships at berth and give incentives / discount to vessels with environmental friendly propulsion system. However, though a proprietor port, still face challenges from stakeholders (political influence), the capital cost to install and maintain the Alternative Maritime Power (AMP). The ship operators on the other hand benefits from the discounts yet the operational cost is a challenge given that the use of LNG and others onshore power supply is more capital intensive than the use of marine diesel fuel.

6.2 Recommendations

With the challenges in adopting a Greenport infrastructure, the benefits of Greenport is essential to the human health and the environmental. For the selected ports under review, Port of Antwerp, Port of Hamburg and Port of Shanghai, the researcher recommend the following for timely considerations.

I. The use of ISO 50001 Energy Management System standard in the selected ports to meet environmental regulatory framework.

II. The use of LNG and onshore power supply by ships at berth in the ports mentioned above.

III. To reduce the time ships spend at berth will greatly reduce the emissions for the ports under the research.

IV. The IMO with others International, Regional and National authorities have put in place regulations to reduce greenhouse gases and air pollutants. However, there is yet no regulations for the reduction of CO_2 emissions; hence, this research recommend the relevant authorities to develop regulations for the emissions of CO_2 in the selected ports.

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