Towards a Greener Future: A Taxonomy of Carbon Footprint Reduction Strategies and Standards at Commercial Ports

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ABSTRACT

According to a recent health board research, pollutants from ships and seaports cause roughly 19,000 new lung cancer cases per year and result in the deaths of about 60,000 individuals. On the other hand, ship-related CO2 emissions have been steadily rising over time and are expected to make for around 2.7% of all worldwide emissions. These problems increase the importance of taking action to reduce carbon emissions in ports, a key contributor to climate change. The extensive use of energy from primary sources has increased carbon emissions. As a significant economic node, ports have financial interest priorities and must balance these economic interests with environmental issues. This study aimed to classify carbon footprint reduction strategies at commercial ports using an Environmental Impact Assessment evaluation as a scoping review to aid in and expedite future policymaking. The research methodology included a scoping review and detailed research of recent papers and resources on subjects connected to the study's topic. The findings attempted to categorize the acts in a novel and comprehensive way to make it easier for policymakers and scientific communities to analyze carbon footprint mitigation measures in seaports. Finally, in conclusion, keeping the objective of the study framework in mind, there are some suggestions for future research to enhance the development of novel techniques for seaport carbon mitigation.

Keywords: *Carbon Footprint, Seaport, Maritime Transport, Sustainable Development Goals, Climate Change.*

1. INTRODUCTION

The world's most polluting cities are near coastlines since 70% of ship emissions occur within 400 kilometres. A recent health board investigation found that seaport and ship pollution cause 19,000 lung cancer cases worldwide [1]. Moreover, seaport marine activities account for circa 3% of total carbon emissions worldwide [2], causing various initiatives to decarbonize their energy systems and make seaports smarter and more environmentally. On the other hand, climate change is addressed in Goal 13 of the Sustainable Development Goals [3], and ports, as intersection points for marine and different modes of transportation, play a critical role in mitigating global climate change. The biggest environmental impact of ports on climate change is their carbon dioxide emissions.

In 2005, the International Maritime Organization released Annexe VI of MARPOL (Maritime Pollution Regulation), a global regulation [4]; The International Association of Ports and Harbours issued by the World Ports Climate Initiative (WPCI) in 2008; the World Association for Waterborne Transport Infrastructure produced a guideline for port authorities in 2014 to promote the green port philosophy. 2020 saw the European Sea Ports Organization's European Green Deal [5], and some more can be listed as international community actions to reduce carbon emissions in ports.

Moreover, this study identifies and categorizes measures, activities, programs, and policies to eliminate C.F in seaports, which are important commerce and transportation hubs, due to their relevance in establishing standards, guidelines, normativity, key concepts, and best practices. Preventative strategies and maritime port decarbonization are also investigated.

Furthermore, it categorizes strategies and actions to minimize the Carbon Footprint (C.F) in a novel way to help policymakers better understand mitigation choices and issue better policies. However, new classifications can help scientific organizations understand many components and focus more on each class according to their research areas to provide more accurate scientific outputs.

A five-phase scoping review displays the research method in the second section. Section 3 discusses Energy Management System (EMS) basics, equipment, tools, regulations, national and international best practices, and objective standards, actions, and results. Section 4 discusses port C.F reduction efforts. Research interpretation and recommendations are covered in Section 5.

2. RESEARCH METHODOLOGY

This research used a systematic scoping review to find publications, conference papers, books, and conference reviews on practical techniques and metrics to reduce C.F generation in commercial ports worldwide between 2000 and 2021 in Science Direct,

Web of Sciences, Scopus, and IEEE. A preliminary and essential list of keywords was selected to offer a useful and pertinent perspective to address the research question.
This theoretically driven descriptive essay is based on cross-sectional research on decarbonizing maritime ports, a major marine industry carbon emissions source.
Five primary steps were taken in conducting the critical literature review:

a) Keyword search in internet databases (Science Direct, Web of Sciences, Scopus, IEEE); "Green ports", "port carbon footprint mitigation", "maritime renewable energy", "port carbon footprint reduction", and "smart seaport" were chosen to cover the study literature on greening ports, which rated top in 1261 results.
b) A preliminary refinement on the 2nd stage based on selection criteria, including the paper's title, abstract, and keywords which produced 299 results;
c) In the third stage, 236 resources were refined based on unique features, including publishing between 2000 and 2021, language requirement that all documents be in English, type of material (articles, conference papers, e-books, and conference reviews), access, and region.
d) A third abstract screening refinement and adjustment was made to account for the critical topic of 236 discovered resources and yield 126 resources.
e) The final refinement produced 70 journal publications, comprising 54 indexed journal articles, ten conference and workshop papers and reviews, 6 IEEE papers, and an additional ebook.

Figure 1 shows the refinement of the scoping review source selection process.

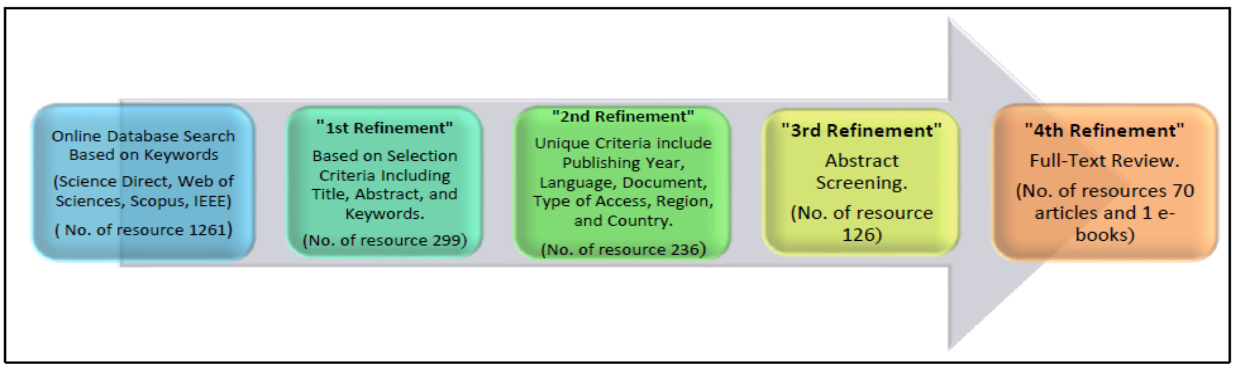

Figure 1: *Methodology Phases in the Scoping Review*

In addition, a thorough search found 14 web resources, including 11 international standards and guidelines from international organizations. The remaining web pages contained statistical data and research findings. Due to the study's main objective and scope, data, reports, international laws and recommendations will be categorized and briefly reviewed in the following sections.
The resources on lowering C.F readings at ports are classified by performance, effect, and body control in the following section.

3. FINDINGS ON REDUCING CARBON FOOTPRINT INITIATIVES IN PORTS

After designating the resources above, authors began classifying them by their activities and impacts on carbon seaports C.F. They may be divided into three primary categories: a) using EMS at ports, b) implementing infrastructure and equipment to overcome C.F in ports, and c) publishing and applying guidelines and rules that represent national and international bodies' policies to reduce C.F and mitigate climate change.

Other research combines seaport C.F mitigation with accounting procedures or renewable energy. This study's only focus on the seaport's carbon reduction goals may make it distinctive and improve future studies. Figure 2 provides a crucial conceptualization and characterization of the scoping seaports C.F findings from the synthesized technique. This study produced this framework. It proposes and leads a deeper understanding of best practices for combatting C.F at seaports internationally, so scientists, practitioners, and management can act and innovate in each area listed below.

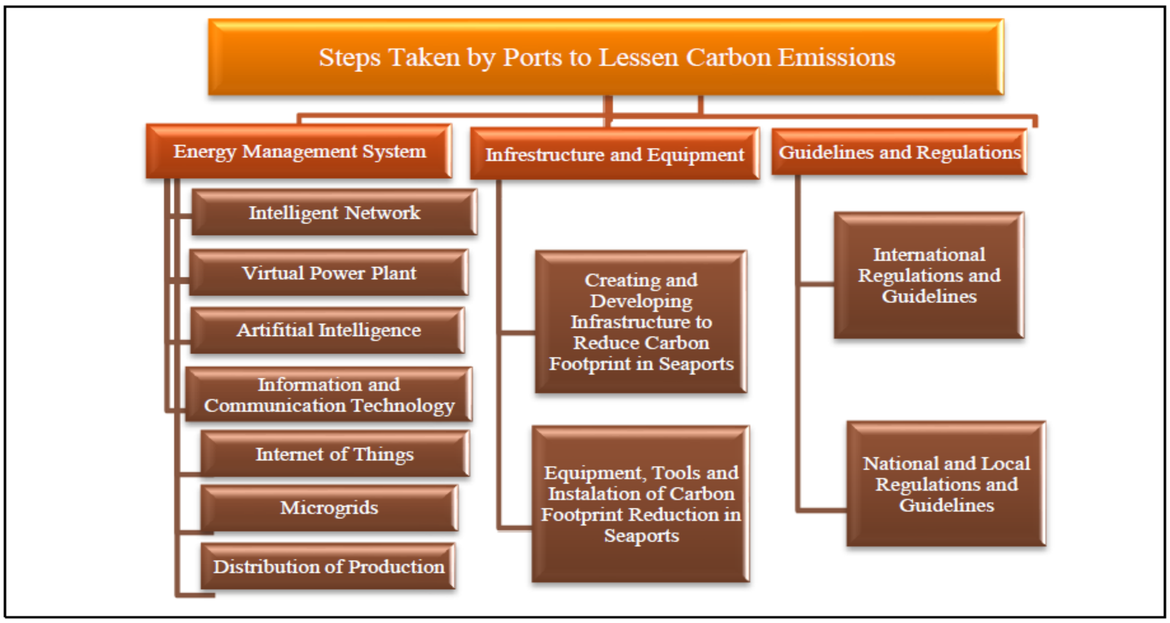

Figure 2: *Action Framework for Reducing Carbon Emissions from Seaports*

3.1. ENERGY MANAGEMENT SYSTEM

By 2040, the industry division projected a 40% increase in energy demand globally [6]. According to global energy estimates, an EMS can reduce energy consumption in fabrications and industries by applying many efficient methods and regulating the large energy demand at that time [7]. In the 1970s, rising energy prices and diminishing supplies improved energy management [8].

However, the promise of Information and Communication Technology (ICT) applications for fabrications, construction, and building automation networks has increased the viability of using intelligent energy systems in residential and commercial construction. With projected population growth and potential industrial expansion, the world's energy needs are expected to rise in the coming decades. This topic emphasizes energy generation, transport, and use's environmental impact.

Considering the above and EMS's crucial task of reducing environmental impacts while preserving energy quality and influence, Seaports have creative, efficient, safe, and cost-effective choices with modern EMS [9]. This system generates, distributes, and controls renewable energy. Energy generated in the port converts wind, solar, and wave energy into electricity. Energy distribution involves intelligent and methodical distribution to users. Energy consumption refers to port-related tasks such as cargo handling, industrial operations, logistics, and office work that utilize electricity.

However, as large ports still use fossil fuels to generate energy, authorities worldwide are concerned about optimizing their consumption.

For clarity, seaport energy consumption can be divided into a) the power needed for key port functions such as lighting, buoys, office buildings, locks, and bridges. b) port power for ships (fuel consumed and electricity provided to ships). c) Energy is needed for port-related and port-induced activities like tourism, steel and metal production, refineries, and railroads.[10].

Furthermore, ports are often located in areas that are well-suited for power generation from renewable energy sources like wind, solar, and waves (such as Rotterdam and Kitakyushu in Japan) and tide differentials (currently being researched in Dover, UK, and the Port of Digby, Nova Scotia); geothermal energy, such as Hamburg port, can use this opportunity to green.

Additionally, Ports often have large, flat surfaces like storage facilities and warehouses for solar panel installation (e.g., the Tokyo Ohi Terminal or the Port of San Diego administration buildings). Such infrastructure may only seldom be suitable for widespread solar power use. [10].

However, seaport energy management requires policy, technology, and operations.[11], National and international marine port EMS laws focus on EMS aims. As a result, various global EMS legislation is being passed, including the following:

a) Energy Management, ISO 50001.
b) Energy Management Systems, EN 16001.
c) Plans for managing port energy (PeMP).
d) Environmental Management Systems Address Energy Management (EMS).
e) Green Port Policies and Port Environmental Management Plans (PEMP).

Furthermore, following the deployment of EMS in a seaport, the following areas must be covered by measures adopted in technology and operations to boost its performance:

i. Classification of port-related activities (direct and indirect or land-based and maritime-based).
ii. Important operational metrics.

iii. Primary Technological Solutions for Vehicles and Equipment at Ports and Terminals.
iv. Energy-Saving Port Structures.
v. Additional Facilities and Infrastructure Supporting Port Energy Efficiency.

3.1.1. INTELLIGENT NETWORK

An EMS's intelligence network minimizes C.F Direct current energy and low-voltage units' power at nearby sites. Subsequently, AC grids and other devices carried energy large distances between energy units and buildings. Additionally, they are increasing the energy needed to meet people's future consumption needs [12].

The intelligent network simplifies manufacturing and storage facility selection. Moreover, a smart grid allows stakeholders and decision-makers to prioritize consumer and electrical energy operations.[13]. The public view of renewable and sustainable energy sources, population growth, and economic difficulties in developed and expanding economies affect the design of electrical energy systems. This shift emphasizes innovative, affordable, attractive, and environmentally friendly electrical system designs [14].

Furthermore, Intelligent grid technology can alleviate energy system issues by merging maritime and renewable energy sources. Figure 3 shows how an intelligent network increases seaport power efficiency and dependability. Smart systems control the energy network and logistic control signal with the central control system. It provides cargo terminals and onshore power supply (cold ironing) with transport equipment (trucks); renewable energy production systems; an energy storage system; an electrical vehicle charging station; and an intelligent grid that adjusts Alternative Current (AC) and voltage via a transformer with an intelligent meter to account for energy consumption. At central control, these components are controlled and connected.

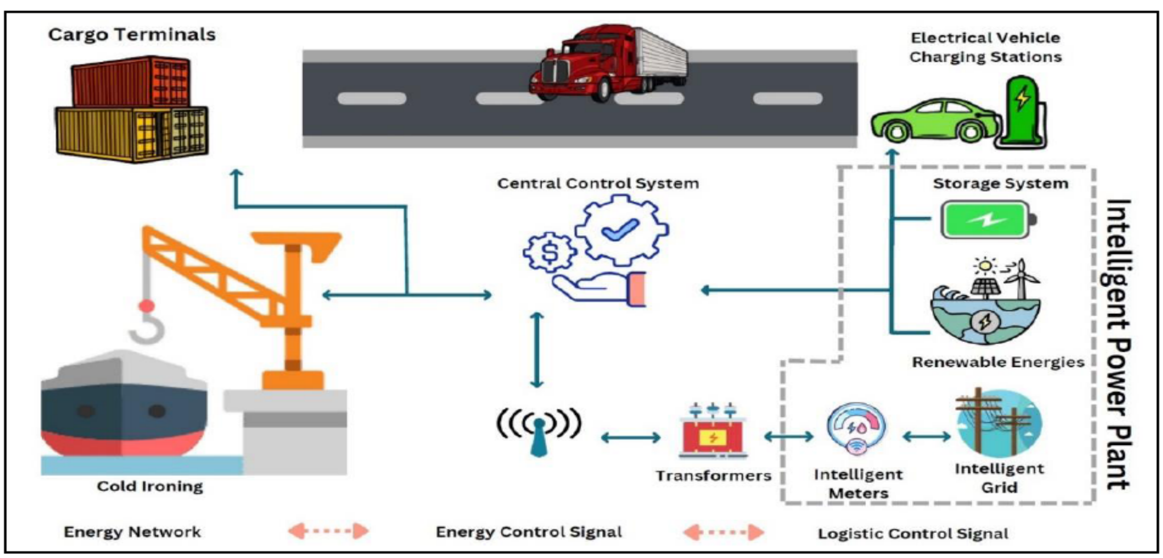

Figure 3: *Intelligent Network in Smart Seaports*

Active energy system users in an intelligent network reduce energy loss and demand. Intelligent networks save energy and make money from peak-hour energy sales, benefiting more users [15]. According to the US Department of Energy, an intelligent network uses distribution linkages to power users and more distributed products and storage sources to improve the electrical system's dependability, stability, and efficiency (both in terms of energy and economics) [16].

Intermittent renewable energy sources, including marine, solar, thermal, and wind energy make expanding intelligent electric networks difficult, especially at industrial and maritime ports [15]. Furthermore, AI can predict energy production and store or transform it. Electricity delivery is more reliable and adaptable with these technologies. After energy conversion, reapply it to meet demand. Customers can cut electrical energy expenditures and increase energy trading revenue during peak hours with the intelligent network's link to electricity energy marketplaces [17].

3.1.2. VIRTUAL POWER PLANT

Nowadays, High technology is needed to provide consumers with affordable and secure electricity when distributed production units trade traditional power plant energy. Thus, EMS virtual power plants are important [18].

Furthermore, the expansion of Distributed Generation (DG) deployment and lack of a passive stance indicate long-term investment in DG governance. VPP can help DG's energy sector involvement [19].

However, VPPs can regulate power flow between modules. It may boost system and energy efficiency [20]. Despite its description as "*a unique power plant that links, monitors, and visualizes distributed generators via ICT.*", VPP is not a power station. An aggregator-specialized software that automates capacity management- must centralize, process, and analyze data and communicate with the electrical transmission system operator [21].

VPPs monitor, control, distribute, optimize, and integrate DG and renewable energy [22]. Saboori et al. found that VPP monitors and controls user supply and demand while transmitting energy across the grid. In seaports, where energy consumption is high, and managing usage can affect cost and supply, a VPP is vital to an EMS [23].

3.1.3. INFORMATION AND COMMUNICATION TECHNOLOGY

ICT is crucial to society and EMS. "Information technology coupled with several allied technologies, particularly communication technology," says UNESCO [24]. In other words, an intelligence network's safe, flexible, and realistic communication infrastructure and protocols for real-time producer-user contact require ICT. Moreover, ICT connects different hardware in an intelligent network, and an EMS in a smart seaport's intelligent network needs it for efficient connection. ICT and Power Line Connection (PLC) are crucial in smart ports for EMS efficiency and C.F reduction [25].

3.1.4. INTERNET OF THINGS

The Internet of Things (IoT) is a new information technology sector with many principles and industrial applications. Internet protocols connect computer network-based systems for millions of users.

Due to the Internet's wide network structure, many electronic network technologies in the maritime and ecosystems industries benefit from Internet approaches [26].

Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSN) combine sensor devices and many processors to optimize decision-making to promote automation in the IoT [26]. Sarabia-Jacome, who improved a marine port data cloud that prevents stakeholder information system interoperability, recommends IoT for maritime port operations [27].

The findings confirmed that marine port data clouds assist port department decision-making. An Automatic Mooring System (AMS) that allows ships to dock and unberth without utilizing their mooring equipment can be used as an example of IoT in seaports [28].

3.1.5. MICROGRIDS

Optimizing fossil fuel-generated electricity and energy is necessary to reduce greenhouse gas emissions. A microgrid study suggested the next generation of electrical energy systems based on the energy transition era's magnitude [29].

Energy producers, power storage systems, loads, a grid control system, and Distributed Energy Resources make up a microgrid, a small local energy network (DERs). Acknowledgement systems provide communication between DERs across delivery networks in microgrids with intelligent components [30].

According to the US Department of Energy, a microgrid is "a community of interconnected loads and distributed generation at defined electrical boundaries that depend on a controllable entity connected to the grid." Since it's grid-linked and detached, a microgrid can operate alone or connected [31].

Consequently, Microgrids include renewable energy sources, management systems, consumers, and power storage. Grid-connected multigenerational systems are another alternative [32], And Renewable energy sources (RES) rely on wind and tide, weather conditions, and sporadic Photovoltaic (PV) resources [33].

However, System dependability, power needs, and disruptions must be addressed for a microgrid to work. Microgrid energy storage must handle the unexpected RES issue [34], And on the other hand, EMS performance is greatly influenced by collaboration, control, and microgrid performance [35].

DER, energy-exchanging technologies, communication connections, control units, and EMS enable effective energy management in seaport microgrids [36].

Figure 5 provides a high-level perspective of a microgrid system at a smart seaport, which includes a port with a cargo terminal including warehouses and buildings, renewable energy sources alongside a system for energy storage, cold ironing, port facilities including rail-mounted container gantry cranes and cargo load and loading facilities on the jetties including quayside cranes, etc., which whole are connected in an intelligent network and managed by a central control system.

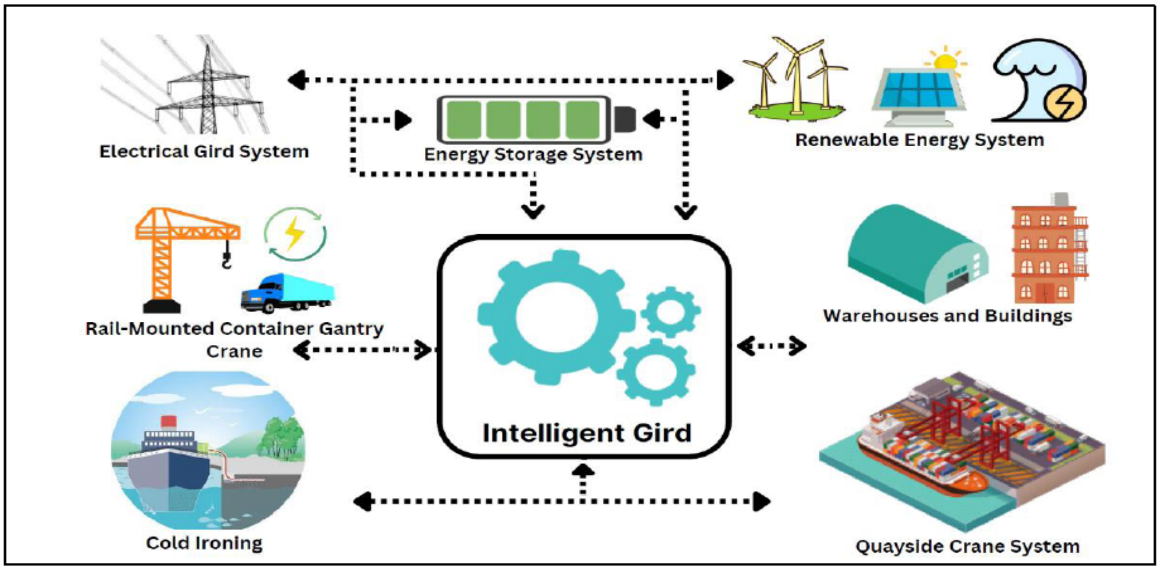

Figure 4: *Microgrid System in Smart Seaport*

3.1.6. ARTIFICIAL INTELLIGENCE

Due to Artificial Intelligence's ability to handle complicated issues, environmental modelling has increased (AI). As an industrial zone, seaports need AI for an EMS system and large-scale energy management, control, distribution, and optimization (from energy production to transmission via network and distribution to the final user).[37] AI optimizes, simulates, controls, supervises, and monitors multi-complex systems, including intelligent control, timing, optimization, and intricate mapping [38].

AI may enhance energy performance in seaports through intelligent EMS for marine ports, reducing energy demand and C.F [39]. Furthermore, an intelligent network, including an intelligent seaport network, needs AI to increase power grid security and decrease electricity prices [40].

3.1.7. DISTRIBUTION OF PRODUCTION

The last component is an EMS's energy distribution over an intelligent system. Recent energy policy has evolved due to climate change, fossil fuel shortages, and population growth. Several governments are using modest energy-producing devices to boost energy security [41]. This is known as a Distributed Generation (DG) or Decentralized Energy System (DES). DG must provide grid flexibility and security by utilizing small energy plants and more competent generations [42].

Furthermore, according to P. Paliwal and his team's study, Energy production can decentralize too quickly. RES in decentralized energy systems may minimize fossil fuel use, increase power supply security, and lower C.F [43].

However, DG restricted fixed energy storage at local power plants and local energy production capabilities. And DEC energy policies include decentralizing the energy market and comprehending climate change. As DECs are implemented, and organizations and parties compete, this is expected [44].

According to the findings of L. Mehigan and his colleagues, there are three DG classes; A) generation connected to the distribution network; B) generation connected to the user's end of the receiving device; and C) generation unconnected to the grid, and reliant on energy demand. Both conventional and unconventional manufacturing methods are included in DG [45].

In another aspect, DG consists of 2 main systems: a traditional producing system and a non-traditional producing one; Microturbines make up the traditional production system, and Non-traditional producing systems include RES, storage devices (like batteries), and electrochemical equipment (fuel cells) [46].

The second part of measuring C.F reduction in seaports has to do with equipment and facilities, which will be talked about in the sections that follow.

3.2. INFRASTRUCTURES AND EQUIPMENT

"Infrastructure and Equipment" is the second part of seaports' carbon reduction efforts. This section can be classed in many ways. The current study is divided into two primary categories: I constructing and developing infrastructure to reduce C.F in seaports and ii) using cutting-edge technology and greater efficiency to reduce energy use and C.F.

On another side, Before building new infrastructure and equipment, it should be renovated and made ecologically friendly. Yet, employing new infrastructures, tools, and applications and applying legislation requires regulations and policies, which are covered in the following Sections.

In Table 1, all of the work studies described in this chapter are tabulated by case studies for seaport infrastructures, tools, and installations: Some were existing and modified, while others were new:

Table 1: *list of all Researches on Carbon Footprint Mitigation Equipment, Tools, and Infrastructures in Seaports, Reviewed in Current Work-Study*

Infrastructure	Author	Tools	Author	Installation	Author
Smart homes for residential clients in Stockholm's Royal Harbour (IoT, ITC).	Stoll et al ,2011[47]	Use clean energy on their equipment and switch to fossil fuels during the designated period.	Hau and Wu, 2011[48]	Track and cut seaport carbon emissions.	Villalba and Gemechu, 2011 [49]
Develop a cutting-edge EMS.	Acciaro et al, 2014 [10],	An optimization model for digital twin seaport.	H. Zhang et al., 2015 [50]	Build an energy production farm.	Ramos et al, 2014[51]
Plan to manage the seaports'	Erdas et al, 2015 [52]	Ship's Automatic Mooring System (AMS).	Ortega et al, 2018 [28]	Controlling energy efficiency in the shipping industry.	Johnson and

environmental impacts.					Styher, 2015 [53],
Battery-based small crafts propulsion systems with electric power distribution for coastal areas.	Aarsaether, 2017 [54]	Simulation port-based power source to supply ships in seaports.	Yun et al., 2018 [55]	The use of an intelligent sub-grid reduces the amount of energy.	Parsie et al, 2016 [56],
EMS discrete events simulation.	Lam et al., 2018 [57]	Zero-emission seaport two scenarios for renewable energy.	Lazaroiu and Rosica, 2017 [58]	Using an AMS and Onshore Power Supply system to reduce carbon emissions at the port location.	Misra et al, 2017 [2]
Hybrid renewable energy system and architecture for seaports.	W. Wang et al, 2019 [59]	Environmentally friendly containers (tire transtainers and rail transtainers).	Y. C. Yang, 2017 [60]	Use of clean energy and reduce energy consumption.	Zhu et al., 2018 [61]
Green port project scheduling with comprehensive efficiency consideration	W. Wang et al, 2019 [59]	Multi-Agent System (MAS) in seaports to raise the voltage.	Manolis et al, 2017 [62]	Installing energy production systems and electric vehicles for transportation.	Arena et al, 2018 [63]
Intelligent network (ITC) in a seaport and intelligent management in smart ports.	Molavi et al, 2020 [64]	Ship's Automatic Mooring System (AMS).	Ortega Piris et al, 2018 [28]	Use of consumption and emission inventories.	Haibo et al, 2019 [65]
Plans for seaport locations and implementing green practices.	Twrdy and Zanne, 2020 [66]	Simulation port-based power source to supply ships in seaports.	Yun et al., 2018 [55]	The output-direction distance boundary.	Tovar and Wall, 2019 [67]
		Electric Rubber Tire Gantry (E-RTG)	Fahdi et al, 2019 [68]	Ports Container Distribution (PCD) method for computing carbon emissions.	L. Wang et al, 2020 [69],
		Onshore Power Supply (OPS)	Gutierrez- Romero et al, 2019 [70]		
		Intelligent microgrid for fishing seaports using Photovoltaic (PV) electricity generated on-site.	Alzahrani et al, 2019 [71]		

3.2.1. CREATING AND DEVELOPING INFRASTRUCTURES TO REDUCE SEAPORT CARBON FOOTPRINT

The second group starts with Seaport C.F reduction infrastructure. Upgrading existing infrastructure for environmental impact and developing new infrastructure to combat climate change are its main measures C.F. The following actions are notable and unique. In a study by Stoll et al., Stockholm's Royal Harbour's smart residences used an innovative design. The port's intelligent network can communicate with these residents' homes' Internet of Things and wireless equipment. Energy use is managed to reduce CO2 emissions [47].

Also, the research of the project done in the north of Europe, Norway, by Aarsaether and Karl, a project to reduce carbon emissions using battery-based small crafts propulsion systems with electric power distribution for coastal areas, was undertaken, and the results were positive. The batteries could be charged via electricity generated from renewable energies, significantly mitigating CO2 emission in the overall port scale [54].

Another study by Yun et al. illustrates the effects of using a port-based power source to serve ships in seaports while removing the impact of action techniques on emissions through simulation, a quantitative carbon emission model. The same study found similar carbon emissions from port activities and container terminal transport. This study found that reducing a ship's speed in waterways channels from 24 to 8 knots can cut carbon emissions by 32.9 per cent, which can be utilized as practical legislation to limit speed in ports access channels and prevent ship manoeuvring accidents by utilizing safe and regulated ship speed [55].

In an additional pertinent study by Wang et al., A two-stage framework is recommended as the optimal architecture for a hybrid renewable energy system for seaports. This method can help create a "green harbour" container terminal that drastically cuts carbon emissions and can be used to deploy an ecologically friendly container port to combat climate change [59].

Added research by Molavi et al concerning the consequences of establishing an intelligent network in a seaport was investigated using a two-stage programming technique in the intelligent management of smart ports. This study showed how a port's intelligent network might drastically reduce energy consumption and carbon emissions. This intelligent network shows how efficient infrastructure, standards, and policies integrate with the EMS system to reduce climate change through C.F mitigation and achieve sustainability [64].

On the other hand, in the study by Wang et al., An economical and environmental seaport in southern China with five jetties container terminal may cut coal consumption for power generation by 6527 tons per year, CO2 emissions by 40,875 tons per year and savings of 49 million yuans. This study presented a green port design approach for seaport construction to maximize port greening. It said the money saved might pay for the greening project in six years [59].

The following section will briefly outline the new tools and equipment utilized in seaports to minimize C.F.

3.2.2. EQUIPMENT, TOOLS, AND INSTALLATIONS OF CARBON FOOTPRINT REDUCTION IN SEAPORTS

The second section of 2nd category of C.F reduction measures in seaports examines the effects of applying equipment and tools and installation in Seaports, one of which is as follows:

According to Fahdi et al., E-RTGs are more effective than Rubber Tire Gantries (RTG).using a combination of E-RTG and green port rules in Singapore's case study port lowered carbon emissions by 67.79% and energy by 86.6 per cent. This analysis indicates that energy savings can quickly save the port authority money and replace E-RTGs [68]. Furthermore, Gutierrez-Romero et al. found that modern sources can power Onshore Power Supply (OPS) for ships berthed in Spain's Cartagena port. It claimed that energy-efficient systems were generated on land instead of ship generators, which were two-stroke and less efficient, and that the OPS system could reduce 10000 tons of CO2 each year in the port [70].

According to Peiris and colleagues' technical studies, a ship's Automated Mooring System (AMS) can lower Santander's seaport's carbon emissions by 76.78 per cent. This technology replaces ship generator-powered winches and drums. Two-stroke ship generators run on diesel or heavy fuel oil. Port-powered AMS controls energy use and CO2 emissions [28].

Lam et al. evaluated seaport "EMS" implementation in another study. This discrete events simulation study gave seaport authorities important financial and environmental benefits from their emissions. This sector installs EMS equipment, but research uses it. Finally, this teamwork reduces Seaport C.F [57].

Meanwhile, in research by Al-Zahrani et al., A nearby port was used to validate an intelligent fishing seaport microgrid. The results reveal that offices and enterprises near ports may meet their local electricity needs using on-site photovoltaic (PV) electricity and considerably reduce CO2 emissions and their repercussions. Port C.F optimization suffers [71].

According to Heng et al., research's An optimization model for twin sea port coordination has been presented for ship terminal coordination. This page covers fuel-efficient port group berth allocation. The Twin Ports' Coordinated Optimisation (TPCO) and Single Port Berth Allocation (SPBA) techniques were evaluated by combining the weekly baseline berth plan and reassignment procedure and modelling their one-year operations. The simulation results show that by exchanging information and collectively forming the twin ports berth plan, the TPCO technique may cut fuel consumption and optimize waiting time and ship departure delay time better than the SPBA strategy. Ship hoteling time optimization helps reduce CO2 emissions. Port activities reduced C.F [50].

In the other research by Haibo and colleagues, Researchers looked at energy use and carbon emissions in seaports using consumption and emission inventories. The study advises adopting solar-powered cold ironing in Qingdao Port, China, to cut carbon emissions and energy use [65].

Moreover, the research of Lazaroiu et al., An investigation into the idea of a zero-emission seaport, was done in Italy. His study examines two renewable energy possibilities for Naples, Italy: ocean, wave, and tidal. Due to their renewable nature, both were valuable in the study [58].

Meanwhile, Zhu et al. discussed how to meet the electrical needs of the Chinese seaport of Ningbo using renewable energy sources. This analysis demonstrates that sustainable energy can minimize EMS energy use and seaport carbon emissions [61].
Another related research was done by Wang et al. the C.F amounts in 30 Chinese ports are examined in the work mentioned. The authors suggested the Ports Container Distribution (PCD) method for computing carbon emissions, verified this method and got positive results in CO2 reductions [69].
Additionally, The Erdas et al. study introduced a plan to manage the environmental impacts of seaports by considering ecological footprints applied by ISO 14000 standards in the port of Limassol in Cyprus that requires some facilities and can be used as an excellent example in this category of using tools for CO2 mitigation actions in seaports [52].
In addition, an article by Tovar and Wall estimated the ecological efficiency of 28 seaport organizations in Spain using the output-direction distance boundary with low output and extreme carbon emissions. The study suggested that port officials might reduce carbon emissions by 63% by improving environmental efficiency [67].
On the other hand, in another study, Arena et al. Examine the possibility of utilizing and installing energy production systems in seaports that can harness the force of the ocean's waves and use electric vehicles for transportation inside the ports and resultant argue for a significant reduction of CO2 emissions [63].
In the study conducted by Johnson and Styhre, researchers looked into the rise in energy efficiency in the shipping industry, particularly at seaports, by shortening the time that ships spend in ports and defined as “ship hotelling time”. The research's location in the north and baltic seas revealed a 2–8% decrease in energy consumption in those ports, directly reducing carbon dioxide gas emissions [53].
However, Yang's research indicates, Utilizing research on the C.F and grey relationships, the carbon dioxide emissions in two different terminals of Taiwan's Kaoshiung port (tire transtainers based and rail transtainers based) have been examined. This study demonstrated that environmentally friendly containers must be constructed to balance their operations with those of container ports [60].
Ramos et al. investigated whether it is feasible to build an energy production farm that converts mechanical energy produced by tides into electrical energy to supply the seaport in Spain's "Ribadeo port" with the energy it needs. The study found that 25 turbines might cover the port's electrical needs while lowering carbon emissions [51].
In addition, in another research by Hua Wu's study, Taiwan's Existing data on the energy consumption of Taiwanese fishing vessels were used to examine those vessels' energy efficiency to find ways to reduce these vessels' daily emissions. According to the author's final conclusion, the fisheries organization should employ subsidies to encourage fishing vessel owners to use clean energy on their equipment and switch to fossil fuels during the allocated period. Fishing vessels need updated connectors to utilize port energy [48].

In the meantime, studies conducted by Acciaro et al. show That port authorities have been required to develop cutting-edge EMS to lessen the adverse environmental effects of using fossil fuels at ports. This article stated that ports' energy efficiency would reduce carbon emissions and energy costs. Hamburg and Genoa ports administrations, which used inventive energy management measures, supported this claim [10].

Over and above-mentioned paragraphs, In the study of Paris et al., Technical-economic and statistical analysis based on data from long beach ports in California, USA, is used to investigate the use of new energy and renewable energy, as well as energy storage for ships and efforts to upgrade the energy network so that it can exchange electricity with the network's slow, ageing, and inefficient components. This paper claims that an intelligent sub-grid can dramatically cut port energy use and C.F [56].

Also, the study by Manolis et al discussed the importance of using a Multi-Agent System (MAS) to implement a distributed demand response technique in seaports to raise the voltage [62].

Additionally, in a study work of Misra et al., the carbon emissions from Chennai, India's port, were calculated using the World Sea Port Climate Initiative (WPCI) and the Intergovernmental Panel on Climate Change (IPCC) recommendations and totalled 280,558 tons of CO2. The author suggests reducing port carbon emissions with an AMS and Onshore Power Supply (OPS) system. In another study, the same authors proposed port authorities employ clean energy to cut carbon emissions [2].

In contrast, Twardy et al. research was done on the state of the port of Koper in the north Adriatic Sea of Slovenia and the management perspective on the sustainability of logistics in seaports. To reduce port carbon emissions, the authors offered seaport placement designs and Koper port green practices [66].

Finally, a study by Villalba and Gemechu contributed to developing metrics to measure GreenHouse Gas (GHG) emissions from port operations, helping to track and cut seaport carbon emissions in the port of Barcelona. The author suggested these metrics could help municipal governments minimize carbon emissions. Related research found that seaports are using more renewable energy, and Barcelona port's geographical location allows it to generate power from renewable resources that require particular equipment according to the port authority's greening agenda [49].

All installed facilities described above are updated and discussed in the second part of the seaports C.F reduction measures. They can be employed if the policies and regulations allow them to be used properly and in collaboration with the smart EMS from earlier chapters. However, the following criteria are essential to link successful management and appropriate and focused consumption.

3.3. REGULATIONS AND GUIDELINES FOR TO MITIGATE CARBON FOOTPRINT IN SEAPORTS

3.4. The 7th, 9th, 11th, and 13th goals of the Goal of Sustainable Development (SDG) are related to affordable, clean, and sustainable energy, sustainable industries, innovation and infrastructures, sustainable cities, and climate change mitigation [72]. On the other hand, the concept of a "green port," closely related to environmental integration, states that the port's management, operations, and operations should all be in harmony with the environment [73].

Subsequently, different criteria can be stated to count the actions to implement the green port concept, such as using renewable energies and policies to help reduce carbon emissions from the port's activities.

In the third section of this work study on seaport CO2 reduction initiatives, suitable laws, standards, and regulations enable appropriate policies to connect equipment and facilities with energy management in all generation, distribution, and consumption stages.

A summary of significant studies for applications in the previous field is reviewed in two primary strategies: i) there are international guidelines and regulations; ii) national, local, and domestic guidelines and rules that are prepared and issued following the regional capabilities and seaports.

3.4.1. INTERNATIONAL REGULATIONS AND GUIDELINES

Concerning international standards, Table 1 below lists the most significant laws enacted from 2005 to 2020; however, most of these laws have historical backgrounds dating back to earlier years, and their reviews and implementation are ongoing.

As shown in the table below, this list includes the most well-known international rules to reduce C.F and, in the long run, stop climate change in commercial ports:

Table 2: *An International Perspective on Efforts to Mitigate Climate Change and Cut Carbon Emissions in the Maritime Sector*

No	Name of Regulation	Year	Approving Organization	Summary of Performance
1	Maritime Pollution Regulation (MARPOL).	2005	International Maritime Organization (IMO).	By adding Annex VI to MARPOL in 1997, these rules were introduced to limit air pollution from ships. [4]
2	WPCI (World Ports Climate Initiative).	2010	International Association of Ports and Harbours (IAPH).	This created a framework to help ports mitigate climate change. It also created the World Ports Climate Initiative (WPCI), designed to increase awareness in the port and maritime communities about the need for GHG emission reductions.[74]
3	Toolbox for Port Clean Air Programs.	2011	International Association of Ports and Harbours (IAPH).	The "IAPH Toolbox for Port Clean Air Programs" Web-based guideline aims to give all ports worldwide, and all stakeholders involved easy access to information, choices, and tools that may be utilized to start the planning process to address port-related air quality challenges while fostering commercial growth. [75]
4	Ship Energy Efficiency Regulations and Related Guidelines.	2011	International Maritime Organization (IMO).	The most crucial technological measure for new ships is the EEDI, which promotes using more energy-efficient (lower polluting) equipment and engines. [76]

5	PIANC Sustainable Port Guideline.	2014	The World Association for Waterborne Transport Infrastructure (PIANC).	This provided a guideline for port authorities to raise awareness about the green port philosophy.[77]
6	Clean Cargo Working Group Carbon Emissions Accounting Methodology.	2015	The Clean Cargo Working Group (CCWG).	This project created tools for calculating the CO2 footprint of a single or entire approach in the logistics chain.[78]
7	IMO strategy to reduce greenhouse gas emissions from ships.	2018	Marine Environment Protection Committee (MEPC 72).	This is the IMO strategy for reducing GHG emissions from ships adopted.[79]
8	Carbon Management for Port and Navigation Infrastructure.	2019	PIANC's Working Group 188.	Including dredged material management, this looked into the C.F of port infrastructure and navigation channels activities. [80]
9	World Ports Climate Action Program (WPCAP).	2019	The World Ports Sustainability Program (WPSP).	This vowed to demonstrate port leadership in CO2 reduction by port membership in the Paris Agreement. [81]
10	IMO, strategy to cut GHG emissions from shipping.	2019	The Green Ship Technology Conference.	This endorsed the IMO plan to cut shipping's GHG emissions by 50% until 2050.[82]
11	Climate Change Adaptation Planning for Ports and Inland Waterways.	2020	PIANC's Working Group 178.	This produced a technical guidance document to aid in adapting sea transportation to climate change.[80]
12	ESPO's Roadmap to implement. The European Green Deal objectives in ports.	2020	European Sea Ports Organization (ESPO).	The European Green Deal calls for a reduction in CO2 emissions from ships at anchor and in ports by at least 50% across all maritime segments by 2030. [83]

Although a brief explanation of how each legislation and set of recommendations is to be followed is included in the table, most ports worldwide also have methods for achieving environmental sustainability utilizing the local and domestic criteria specific to their particular port.

3.4.2. NATIONAL AND LOCAL REGULATIONS AND GUIDELINES

To understand policy implementation, this section will assess municipal and national essential policies and standards and their effects on seaport C.F reduction.

The studies of Fahdi et al. [68] showed that Singapore ports' work on replacing rubber cranes with electric propulsion systems to reduce energy usage and carbon emissions might be an excellent local example.

Additionally, Another study found that Stockholm City Royal Seaport's usage of green energy and active home architecture minimize energy consumption and carbon emissions [47].

Meanwhile, another research conducted by Wang et al. presented a hybrid renewable energy framework for seaports, notably wind energy, and a new policy for generating and storing energy in a terminal port in southern China. This research found that port authorities must construct infrastructure for renewable electricity generation, which is expensive. However, controlled scheduling and activity will minimize fossil fuel consumption and pay for these infrastructures [40].

In other studies, Haibo et al. presented an energy usage inventory in China's Qingdao Port utilizing the "green port" concept and many carbon emission reduction measures. This investigation showed that other seaports could use this strategy [65].

Furthermore, the article by Zhu et al. examined seaport carbon emissions reduction via renewable energy technologies. Liquid Natural Gas (LNG) reduces CO_2 and SO_2 at seaports while increasing energy consumption, yet several Chinese seaports recommend use to minimize air pollution. Regional seaport strategies are shown in this Ningbo research [61].

Aside from that, Twrdy et al evaluated Koper port, a Slovenian green port certificate holder, as a local port in the northern Adriatic sea to assess port logistical sustainability and the current situation. This study demonstrated that green ports society requirements could dramatically reduce seaport CO_2 emissions [66]; In another study by Pavlic et al. [84], In the same port, proposals for applying the green port principles have been examined and characterized as effective model for the local rules that both mentioned can be used as examples of local legislation.

Moreover, Al-Zahrani et al. provided a great example of intelligent microgrids for fishing ports, which would minimize carbon emissions by reducing energy consumption and boosting renewable energy sources. Green harbour practices research covers values, regulations, and conventions that help individuals apply green harbour ideals. Local implementation can lower seaport C.F in certain locations [71].

Another innovative and cutting-edge approach was made by Azarkmand et al, which established and studied carbon emission measuring standardized to monitor integrated and defined criteria and reduce seaport carbon emissions. It examines how implementing a specific standard can help a port authority with multiple ports or some separate port authorities develop appropriate policies to mitigate C.F due to an integrated accounting system. These are very useful national standards that can also be used internationally [85].

Last but not least, Misra et al demonstrated the effects of GHG mitigation techniques such as replacing lighting equipment, installing an automated mooring system, and using biodiesel on port infrastructure in Chennai, India. It was also observed that Chennai's container port's capabilities required adapting the technology to local norms [2].

4. DISCUSSION

This study supports the efforts of several international organizations and port authorities to reduce CO_2 emissions to address climate change.

IMO, IAPH and PIANC programs aim to reduce port GHG emissions. The World Ports Climate Initiative (WPCI) working group, MARPOL Annex VI guidelines for ship-borne air pollution and a framework to help ports mitigate climate change are examples.

These illustrate that many ports have started calculating and sharing their C.F in recent years, which is good for greening ports. There's room for growth.

As mentioned, the measurements and actions can be divided into three independents but linked sections.: utilizing energy management systems, deploying new or updating infrastructure and equipment, and regulations and guidelines (standards and policies).

As indicated in Figure 4, these three components are interrelated and can only be accomplished independently with the help of others.

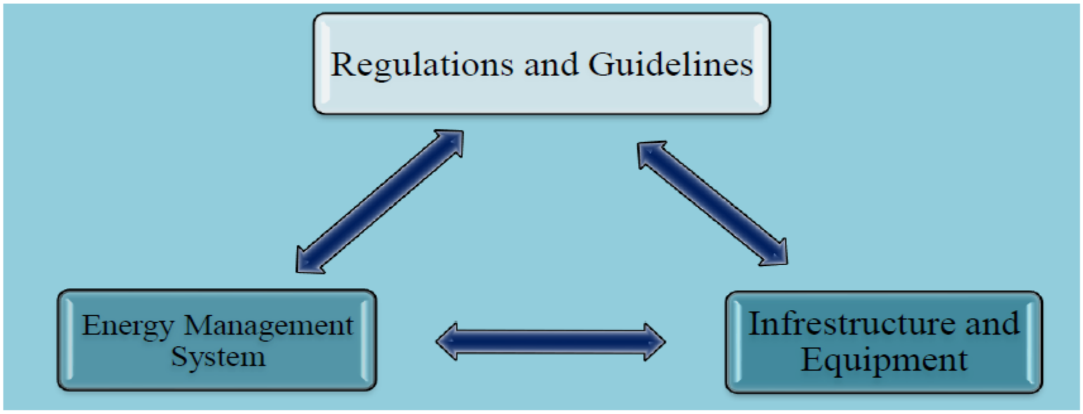

Figure 4: *Interrelation of Different Categories of Seaport's Carbon Footprint Mitigation Actions.*

Furthermore, from two views, EMS and C.F. mitigation in ports are related. EMS is used in smart seaports. This EMS must implement a smart energy network to regulate and optimize energy usage utilizing monitoring systems with hardware and software to reduce C.F. in seaports. The port authority can invest in new C.F. mitigation technologies within the port's boundaries due to cost savings from lower power demand, as shown in Figure 5.

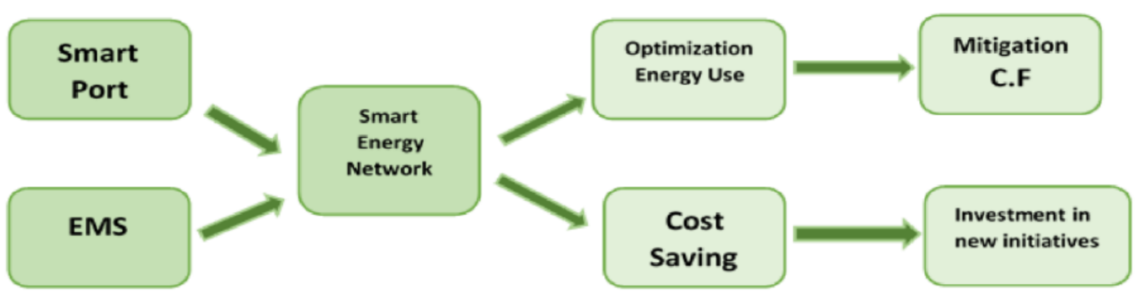

Figure 5: *Smart Network System and Mitigation C.F. Relationship.*

However, after closely evaluating the efforts taken by governments, port authorities, and international agencies to minimize carbon emissions in seaports, the research revealed the following issues:

a) For port equipment and facilities, land-based ship energy may reduce carbon emissions. EMS is being deployed. However, using fossil-fuel-based land-based energy does not reduce carbon emissions.

b) Additionally, supporting infrastructure is needed to employ the right equipment in ports. With the correct economic and environmental policies, the port management may afford these high costs, such as installing AMS in Chennai port in India. Limiting greenhouse gas emissions and carbon footprints should be suited to the port's infrastructure and equipment (Singapore port E-RTG deployment scenario).

c) To reduce C.F., seaport systems and equipment should be evaluated based on port efficiency, traffic, cargo kinds, and ship numbers. LNG ships, tankers, and bulk carriers emit the greatest carbon and greenhouse gases in ports due to their internal pumps, cranes, and facilities, which require their internal generators, which port authorities cannot control to comply with environmental rules.[86]. First, regulations to shorten these ships' hotelling in ports and then loading/discharging cargo facilities and equipment for port services operations must be addressed.

However, Ships need easier access to the docks' energy origin. Land-side receipt facilities must get consent from ship owners and public finance legislation before creating a network. To use port energy, all port authorities must address this issue. Additionally, ships and other operators should be regulated or indirectly controlled to control carbon emissions. After that, evaluate these steps. Studies suggest using port equipment instead of ship equipment, which has shown potential in preliminary experiments. Because they only generate energy when needed, Automatic Mooring Systems (AMS) and onshore energy systems (cold ironing) are more efficient. Extra energy can be stored, but ships don't have the technology.

d) Before analyzing macro-reduction measures, carbon must be quantified using the Life Cycle Approach (LCA) to better understand the causes driving the ongoing development of C.F in ports.

e) Port management systems can perform routine inspections based on port infrastructure, vehicles, and equipment. Several ports have tested these processes to reduce carbon emissions using municipal, national, and international regulations.

This study also found a correlation between the EMS and global air pollution from seaport energy management. This relationship is stronger on bigger sizes, such as industrial sites, because per capita energy consumption is more important than activity and geographic area for service and industrial production performance.

Finally, many ports are industrial and service zones. EMS effectiveness in a seaport influences energy consumption and product and service performance; Thus, less energy used in its service and production activities means less air pollution. Energy consumption produces air pollutants, including carbon (76 per cent) (Centre for Climate and Energy Solutions n.d.); as a result, the growing EMS's full potential minimizes air pollution and C.F.

5. CONCLUSION

Nowadays, to reduce or stop global climate change, all relevant factors must be examined. GHG (C.F) is a key contributor. This study examines this attempt.

These aspects are classified into three separate aspects as mentioned as follows: utilizing EMS, tools and infrastructures, and standards and legislations.

Concerning utilizing EMS, The EMS manages energy generation, transfers, and consumption and employs the storage system or direct connection between production and consumption to balance them.

However, remember that 71% of the world's energy comes from fossil fuels. It will take time to replace fossil fuels with renewable energy. EMS must boost energy generation, transmission, and consumption productivity and efficiency [46]. The EMS uses smart energy networks to balance energy supply and demand in ports with effective renewable energy production. If smart ports' energy demand exceeds the renewable energy supply, the excess will be stored for later use.

Finally, it can be proved that the energy produced by fossil fuels will be compensated for by implementing smart energy networks and management systems and that the amount of energy produced by fossil fuels will be reduced.

On the other hand, regarding the infrastructure and facilities that will be used in seaports, the more money the port authority spends, the more cutting-edge facilities can be deployed, and the more advanced tools and infrastructure, the more effective actions against climate change and C.F can be made. As a result, the viability of success depends on the policies and the volume of investments authorized by such policies.

In addition, the executive guarantee demands time, attention, monitoring, and oversight as government agencies, organizations, and authorities adopt rules, norms, and guidelines. This analysis found adequate laws and regulations; therefore, they must be enforced.

The research raises the question of “are seaports successful in effectively mitigating their C.F?” The short answer is "No" because, as long as ports are the country's and region's economic hubs, they will always come first. Port C.F reduction requires strategy, infrastructure, and equipment. Regional, national, and international institutions are at risk until the globe is green.

The study is limited because it was conducted before 2021. However, the COVID-19 pandemic and global trade limits have affected several features and approaches. Create tools and methods to overcome these limits in future reviews.

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