

NIMA RESEARCH PAPER
NRP - 15-11-24
November 2024



CARBON OFFSETTING, CREDITS AND GREEN INITIATIVES: STRATEGIES FOR SUSTAINABLE SHIPPING



Authors:
Ms. Falak Naeem
Mr. Syed Khizar Askari
Mr. Ghufraan Ahmed Naeem

National Institute of Maritime Affairs (NIMA)
at Bahria University, Sector E-8, Islamabad, Pakistan

EXECUTIVE SUMMARY

Facilitating the transfer of approximately 90% of the world's goods, the global shipping sector is the foundation of international trade. Global commerce depends heavily on the shipping industry, which has approximately 110,000 vessels contributing to an annual capacity of 2.3 billion Dead Weight Tonnage (DWT). But also accounts for 2–3% of yearly worldwide emissions of Green-House Gases (GHGs), primarily carbon dioxide (CO_2). As efforts to tackle climate change around the world pick up momentum, there is growing pressure on the shipping industry to decarbonize and comply with international environmental regulations.

With the aim of cutting emissions to half from 2008 levels and reaching net-zero emissions by 2050, IMO has established a framework for cutting the emissions of carbon from shipping through its Initial GHG Strategy. With the goal to fulfil aggressive climate targets, international businesses, including shipping, must also embrace sustainable practices to comply with the Paris Agreement. To cope up with the upcoming requirements of decarbonization, PNSC, a significant participant in the national and regional maritime trade, is gearing up efforts to adopt relevant measures w.r.t its ships.

The worldwide shipping industry plays a crucial role in facilitating trade and economic growth, but its carbon-intensive activities also contribute to climate change. Along with other shipping companies, PNSC must meet its operating demands while lowering its carbon footprint. The company's fleet needs to comply with new environmental rules, especially those that control emissions of strong greenhouse gases (GHGs) like carbon, methane (CH_4), and nitrous oxide (N_2O). The key challenge is to come up with affordable ways to cut emissions without compromising effectiveness or market competitiveness.

The primary goal of the study was to determine the CO_2 emissions of PNSC's fleet by examining each vessel's fuel usage statistics for the years 2022 and 2023. To estimate emissions, the fuel consumption data was translated into standard unit and multiplied using emission factors given by the Intergovernmental Panel on Climate Change (IPCC). Various fuels, including Diesel, Marine Gas Oil (MGO), Heavy Fuel Oil (HFO), and Light Fuel Oil (LFO), were utilized throughout the fleet, each with a distinct emission factor.

The investigation showed that although the vessels' total fuel use varied, several of them managed to significantly lower their CO_2 emissions. For example, Lahore's total CO_2 emissions decreased from 24,401,731.29 kg in 2022 to 16,987,493.06 kg in 2023. The corporation was able to get carbon credits under global carbon trading schemes because of the reduction in emissions. The total number of carbon credits gained by the entire fleet was 24,794 metric tons. These credits could be sold for €1.98 million or \$2.16 million through the EU Emission Trading System (EU ETS) at a price of €80 per metric ton.

The study also provides observations at greenhouse gas emissions of N_2O , which has a GWP 298 times greater than that of CO_2 . N_2O emissions were computed utilizing fuel usage data and techniques approved by the IPCC. The findings revealed notable

discrepancies in N₂O emissions throughout the fleet, with ships like Mardan and Sargodha seeing notable rises in 2023 in contrast to 2022.

For example, N₂O emissions from Mardan rose from 94.81 kg in 2022 to 226.06 kg in 2023, while Sargodha saw an increase from 79.03 kg to 198.5 kg during the same period. The elevated N₂O levels suggest inefficiencies in combustion processes, potentially related to engine conditions, fuel quality, and operational factors such as longer voyages and port residence time. These emissions are particularly concerning because of their disproportionately large impact on global warming compared to CO₂.

The study also placed a lot of emphasis on CH₄, a powerful greenhouse gas which has a GWP 28 times greater than that of CO₂. According to the assessment, several ships, especially older Aframax tankers that are getting close to the end of their useful lives, were emitting excessive levels of methane. For example, Quetta experienced a sharp increase in its CH₄ emissions from 20.23 kg in 2022 to 103.85 kg in 2023, which may indicate inefficiencies in the fuel combustion and methane capture processes. Older engines with reduced fuel efficiency and methane slip, a phenomenon when unburned methane escapes after fuel combustion, were blamed for the increased CH₄ emissions. To gain a better understanding of methane emissions' role in global warming, CO₂ equivalent (CO₂e) values were calculated.

CO₂ emissions have decreased because of PNSC's installation of Carbon Intensity Indicator (CII) and Energy Efficiency Existing Ship Index (EEXI) systems on its ships. On the other hand, it seems that these systems are less successful in reducing emissions of N₂O and CH₄. To decrease methane, slip and increase fuel combustion efficiency, the research suggests updating the technology on board, especially for older vessels.

PNSC's decarbonization initiatives are indeed timely in line within modern dictates. However, they are faced with challenges for example inadequate funding, restricted access to cutting-edge technology, and awaited adoption of some of the most effective ways, including alternative fuels, wind propulsion and solar energy, to reduce emissions. To lessen the company's reliance on high-carbon fuels like HFO and MGO, improved fuel management procedures and investments in sustainable fuel substitutes are also required. The research recommends that to support its decarbonization measures, PNSC investigate possibilities of receiving global and local funding, such as the Green Climate Fund (GCF).

By lowering its CO₂ emissions, PNSC has achieved notable progress and gained substantial emissions credits which can be sold to finance additional carbon reduction efforts. To meet the problems presented by increased N₂O and CH₄ emissions, the company's efforts must be augmented. Owing to their increased GWP, these emissions pose a serious challenge in meeting the worldwide decarbonization targets.

CHAPTER 1

Introduction

1.1 Overview of the Global Shipping Sector:

a. The shipping sector facilitates the movement of almost 90% of the world's products, acting as the backbone of international trade. According to the United Nations Conference on Trade and Development (UNCTAD) 2023, there are around 110,000 vessels moving various commodities throughout the globe. The global shipping fleet has a total capacity of 2.3 billion deadweight tonnage and have 85% of tankers, bulk carriers, and container vessels. The industry is facing a pressing problem considering its critical role in facilitating global trade: reducing its environmental footprint. The shipping sector is accountable for around 2-3% of the world's yearly emissions of GHGs, with CO₂ being the most common pollutant (IMO, 2020). Reducing the industry's carbon footprint is under increasing pressure from stakeholders, environmental organizations, and regulatory agencies as global worries about climate change rise. As a result, for businesses involved in the industry, adhering to these environmental norms has become not just legally necessary but also morally and financially necessary.

b. The worldwide commitment to reaching net-zero emissions by 2050, a goal that is in line with the Paris Agreement's goals to keep the rise in global temperature to well below 2°C over pre-industrial levels, is a major force behind sustainability in the shipping sector. As a result, the shipping industry is embracing a wide range of sustainable practices and, like many others, is going through a considerable shift. The emphasis on increasing energy efficiency, investigating and using cleaner alternative fuels, and employing cutting-edge technology to better control and decrease emissions are key components of this change. Decarbonization initiatives have not only taken center stage in the sector, but are now essential to marine operations worldwide, signaling a clear move in the direction of a more sustainable future.

c. **Types of Ships.** According to the IMO, a ship is any vessel that operates in the marine environment. The ships discussed in this research report are by type of cargo:

(1) **Bulk Carriers.** Designed to transport unpackaged bulk cargo like coal, grain, and ores.

(2) **Tankers.** Used for transporting liquids, such as oil and chemicals. Subtypes include:

i. **Aframax.** Medium-sized tankers typically ranging from 80,000 to 120,000 DWT, often used for transporting crude oil.

ii. **Suezmax.** Larger tankers capable of transiting the Suez Canal, usually ranging from 120,000 to 200,000 DWT.

iii. **Very Large Crude Carriers (VLCC).** Huge tankers that can carry around 200,000 to 320,000 DWT of crude oil.

(3) **Container Ships.** Designed to carry standardized cargo containers. They are classified into:

i. **Feeder.** Smaller ships that transport containers to larger vessels.

ii. **Panamax.** Ships that can fit through the Panama Canal, usually around 5,000 to 10,000 (Twenty-Foot Equivalent Unit) TEU capacity.

iii. **Post-Panamax.** Larger than Panamax but cannot fit through the Panama Canal.

iv. **New Panamax (Neo-Panamax).** Ships that can pass through the expanded Panama Canal, typically carrying more than 13,000 TEU.

d. **Fuel Types**

(1) Heavy Fuel Oil (HFO):

Composition. HFO is a viscous, high-density fuel that primarily consists of long-chain hydrocarbons. Its composition can vary but generally includes:

Carbon (C)	~85-87%
Hydrogen (H)	~10-12%
Sulfur (S)	Up to 4% (can vary based on regulations)

(2) Marine Gas Oil (MGO):

Composition. MGO is a distillate fuel derived from crude oil and typically contains:

Carbon (C)	~85-87%
Hydrogen (H)	~12-14%
Sulfur (S)	Usually less than 0.5% (as per MARPOL regulations)

(3) Diesel Fuel:

Composition. Diesel is also a distillate fuel, and its composition includes:

Carbon (C)	~86-88%
Hydrogen (H)	~12-14%
Sulfur (S)	Generally, less than 0.5% in Ultra-Low Sulfur Diesel (ULSD).

(4) Light Fuel Oil (LFO):

Composition. LFO is similar to diesel but may include a broader range of lighter hydrocarbons:

Carbon (C)	~84-86%
Hydrogen (H)	~12-14%
Sulfur (S)	Varies but is typically lower than HFO.

e. **Major Global Trade Routes.** Maritime shipping routes are numerous, but the global system is relatively straightforward. At its core is a circum-equatorial corridor connecting North America, Europe, and Pacific Asia via the Suez Canal, Strait of Malacca, and Panama Canal. While these major routes handle most of the traffic, additional paths exist, particularly for coastal shipping, shaped by specific origins and destinations. Transatlantic and transpacific routes feature many ports, primarily following great circle paths, while trans-Indian Ocean traffic typically links Pacific Asia and Europe through well-defined channels.

f. Maritime routes are influenced by strategic chokepoints, natural barriers (like coasts and currents), and political boundaries. The goal is often to minimize distance by adhering to great circle routes. Core routes cater to significant shipping flows between major markets, while secondary routes connect smaller ones. Key chokepoints are vital for global trade, with two main categories:

(1) **Primary Chokepoints.** These are crucial due to limited alternative routes, such as the Panama Canal, Suez Canal, and Strait of Malacca. Disruptions here can severely affect global shipping, as seen during the Suez Canal blockage in 2021. Other critical chokepoints, like the Strait of Hormuz and the Bosphorus, also facilitate access to resource-rich areas and are essential for trade flow.

(2) **Secondary Chokepoints.** These routes have alternatives but require significant detours, including the Magellan Passage, Dover

Strait, Sunda Strait, and Taiwan Strait. While they offer options, they still pose challenges in terms of efficiency and capacity.

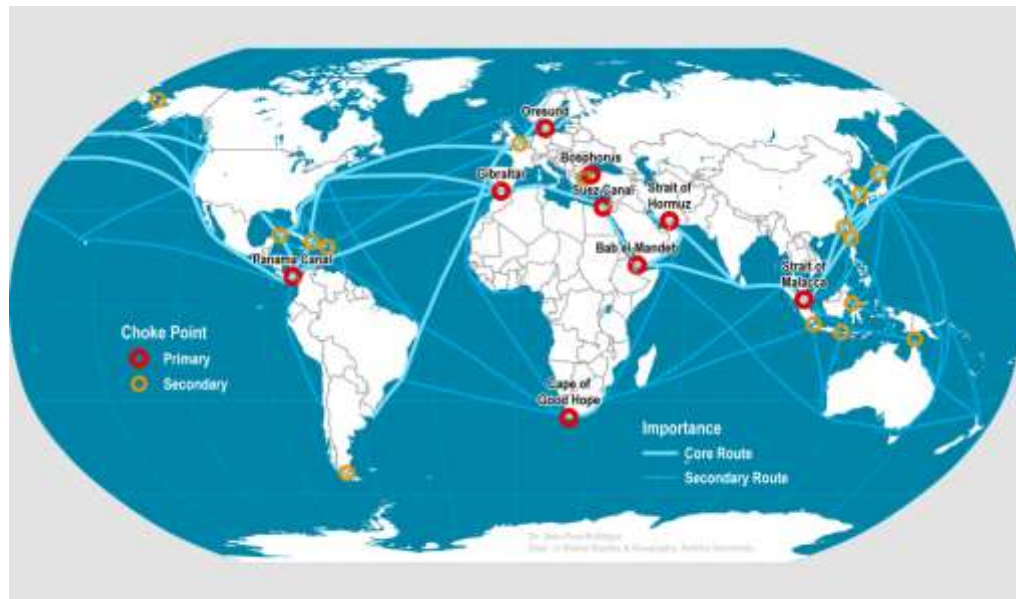


Figure 7.1: Major Trade Routes Across the Globe (Source: Port Economics, Management and Policy)

g. **Emission Control Areas (ECAs).** One of the most important aspects of international marine environmental policies is regulating ship-generated air pollution. ECAs were created by the IMO in accordance with MARPOL Annex VI to restrict harmful emissions, such as Sulfur Oxides (SO_x), Nitrogen Oxides (NO_x), and Particulate Matters (PMs). With a focus on lowering SO_x emissions through the establishment of Sulfur Emission Control Areas (SECAs), ECAs have considerably lower sulfur limitations. The fig 7.2 shows ECA regions in blue and SECA regions in lighter shade.



Figure 7.2: ECA and SECA Regions (Source: The Maritime Executive)

h. In the Baltic Sea, the first SECA was established in 1997, and it came into operation in 2005. The North Sea SECA followed this in 2006. The U.S. Caribbean ECA was put into effect in 2014, while the North American ECA, which covers the coastlines of both the United States and Canada, was established in 2010. Unlike the global limit of 0.5% m/m outside of ECAs, these zones require vessels operating within the designated areas to utilize fuels with a sulfur concentration of no more than 0.1% m/m (IMO, 2020).

i. These strict laws aim to reduce the harmful impact that shipping emissions have on human health and the environment, including respiratory disorders and acid rain. Ships in ECAs are subject to Tier III NO_x standards for engines in addition to fuel restrictions. These standards are applicable to vessels built after 2016. These regulations are a component of larger initiatives to match shipping operations with global climate goals, especially in crowded marine regions like the North and Baltic Seas (Notteboom et al., 2022).

j. With the implementation of the IMO's 0.5% sulfur cap by 2020, the global maritime industry had expanded its approach and increased the environmental advantages of ECAs. But there are still difficulties, especially for developing countries like Pakistan that have to overcome technological and financial barriers to implement these cutting-edge environmental measures (Rodrigue, 2022).

1.2 The Importance of Reducing GHG Emissions in Shipping:

a. Given its dire effects on the environment and public health, climate change is one of the most pressing issues of our day. These environmental changes have been greatly accelerated by a variety of human activities, such as the use of fossil fuels, the production of energy, urbanization, and industrial expansion (Christodolou & Cullinane, 2023; Faber et al., 2020). Shipping contributes significantly to rising greenhouse gas emissions and fossil fuel use, both of which exacerbate climate change, even though it is the most fuel-efficient form of transportation when taking tons per mile into account (Asariotis et al., 2015). Global cargo handling was estimated to be 2,265,564 tonnes as of 2023; beginning in 2024, this figure is projected to increase by more than 2.4% a year. (UNCTAD, 2023). As of right now, shipping's greenhouse gas emissions make up only 3% of all emissions worldwide. However, if maritime trade keeps growing unchecked, shipping emissions could eventually make up between 50% and 60% of all emissions (Xue et al., 2024; Tan et al., 2022; Klopott et al., 2023).

b. Emissions from shipping, particularly GHG emissions, have been found to be a significant cause of air pollution and climate change worldwide. As a result, under its MARPOL Annex VI regulations, the IMO has put in place several strict restrictions to lessen these effects. These rules set sulfur content limitations for marine fuels and create the Energy Efficient Design Index (EEDI) criteria, which promote the construction of ships with higher energy efficiency. Companies have been compelled by this regulatory framework to investigate

greener technologies and embrace alternative fuels including biofuels, hydrogen, and Liquefied Natural Gas (LNG) (IMO, 2018). But reducing emissions is more important than just following the law. A growing number of stakeholders, including as investors, governments, and consumers, are calling for increased responsibility and transparency in environmental performance. Consequently, the shipping industry's sustainability initiatives are coming under more scrutiny, which is pushing businesses to implement procedures that satisfy legal requirements while also conforming to the wider principles of ethical business practices.

c. c. The shipping industry plays a critical role in reducing greenhouse gas emissions, particularly given the pressures imposed on it by the increase of international commerce and worldwide economic growth. In the upcoming decades, shipping emissions are expected to increase significantly unless serious intervention takes place. According to the Fourth IMO GHG Study (2020), if nothing is done, these emissions would rise by as much as 130% by the year 2050. This concerning forecast emphasizes how urgent it is for governments, international organizations, and private businesses to take quick action. The difficulty lies not just in complying with regulations but also in restructuring the shipping sector to accord with global climate goals and make sure shipping plays a part in a more sustainable future.

d. d. A practical route to reaching emission reduction objectives is through the use of sustainable shipping practices, such as carbon offsetting and carbon credit schemes. Through these programs, businesses may offset their carbon emissions by funding eco-friendly projects like conservation, renewable energy, and reforestation. They also enable businesses to continue adhering to legal and regulatory frameworks. In particular, carbon credits have grown in popularity as a dual-purpose tactic that helps marine businesses in both the financial and environmental domains. Shipping companies may reduce their environmental effect and respond to stakeholder demand to adopt sustainable practices by taking part in these initiatives.

(1) Present Practices and Advancements in Green Shipping Regulations: Numerous green initiatives have been implemented in the maritime sector in response to the growing worldwide environmental concerns. Maritime countries are proactively implementing and upholding international standard-compliant policies aimed at minimizing emissions of SO_x, NO_x, PM, and carbon dioxide (CO₂). The IMO's Sulfur Cap, which was implemented in 2020, stands out among these initiatives as a crucial countermeasure to ship-related air pollution. This rule requires marine fuels to have less sulfur than 3.5% (to 0.5%); which can reduce sulfur emissions by an astounding 70% (IMO, 2020). The shipping industry's dedication to enhancing air quality and reducing its environmental effect is shown in these projects.

i. The Carbon Intensity Indicator (CII) rule, which aims to quantify and lower the operational carbon intensity of ships, was implemented by the IMO in addition to current laws. This effort

places a strong emphasis on adopting greener technology and putting energy-efficient operational measures into place. Many businesses have started implementing slow steaming methods, energy-efficient designs, and digital monitoring technologies to improve fuel economy to comply with the CII. These tactics support the larger objective of lowering the carbon footprint of the shipping sector in addition to being in compliance with legal obligations.

ii. The growing use of alternative fuels in the maritime sector is another important development. To achieve decarbonization targets, research is being done on hydrogen-based solutions, biofuels, and LNG. A number of maritime companies are also making investments in hybrid and electric ships as part of their long-term sustainability plans. Additionally gaining popularity is the retrofitting of already-built ships with energy-saving technology like rotor sails and air lubricating systems. These developments function by lowering the friction between the water and the ship's hull, which lowers fuel consumption and, in turn, lowers emissions (DNV GL, 2021). When taken as a whole, these initiatives show the industry's dedication to adopting sustainable practices and reducing its environmental effect.

e. **Air Pollution Standards and IMO Regulations.** Sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter are just a few of the pollutants that cause considerable harm to the environment and human health when they are released from ships. Air pollution from ships has long been a major problem. The cornerstone of global efforts to solve this issue is the IMO's rules under MARPOL Annex VI. These laws highlight the importance of limiting SOx and NOx emissions and provide a comprehensive worldwide framework for managing air pollution from ships. Furthermore, they concentrate on lowering new vessel energy consumption by putting the EEDI into practice (IMO, 2020). The IMO hopes to lessen the negative impacts of marine emissions and promote a more sustainable shipping sector by establishing these rules.

(1) IMO adopted the MARPOL standards to reduce ship pollution as a reaction to these issues. Under MARPOL Annex VI, these restrictions forbid the use of compounds that deplete the ozone layer and restrict the emissions of SOx and NOx from ship operations. The IMO unveiled the Initial IMO Strategy on the reduction of GHG emissions from ships in 2018 with the aim of cutting GHG emissions from international shipping by 50% by 2050 (relative to 2008 levels) (Karyoti, 2023; Wu et al., 2022; IMO, 2020).

(2) The IMO revised its greenhouse gas policy in 2023 and established a new goal of having net-zero emissions from the shipping sector by 2050. It is imperative that all vessels operating in ports

worldwide comply with these new laws (Dominioni & Englert, 2022; Issa et al., 2022; Cullinane & Yang, 2022; Coulter et al., 2007).

(3) (3) Stricter guidelines for limiting ship-source emissions have been created by the IMO, especially in ECAs where there are even stricter limits on the amounts of NO_x and SO_x. These ECAs have been recognized in specific global locations where air quality issues are particularly acute, such as the North Sea, the Baltic Sea, and sections of North America. Because high concentrations of sulfur and nitrogen compounds in the atmosphere may cause acid rain, respiratory disorders, and other major environmental concerns, reducing these pollutants is essential for protecting both human health and the ecosystem (Manzo, 2020). The IMO hopes to greatly reduce the harmful effects of marine emissions on air quality and human health by putting these regulations into effect.

f. **Decarbonization in Shipping: General Terms and Importance.** In the shipping industry, decarbonization is the methodical process of lowering carbon emissions from ships in an effort to slow down global warming. This phrase refers to a broad range of actions, such as the use of energy-efficient technology, the acceptance of alternative fuels, improvements to operations, and market-based tools like carbon offsets and credits. Decarbonization in shipping is a complex problem that calls for major changes in market dynamics in addition to technological innovation and regulatory compliance. In order to create a more sustainable marine future, it is imperative that the sector address these linked difficulties as it works to line with global climate goals.

(1) Aiming to reduce greenhouse gas emissions from ships, IMO has set aggressive decarbonization objectives in its Initial Strategy. These objectives seek to lower the carbon intensity of global shipping from 2008 levels by at least 40% by 2030 and by as much as 70% by 2050 (IMO, 2018). Coordinated efforts from the public and commercial sectors, as well as significant investments in research and development, are required to achieve these goals. With an aim to promote innovation and put into practice solutions that can lead to significant advancements in the direction of a more sustainable shipping sector, a collaborative approach is needed.

(2) Carbon credits have become an essential instrument in the efforts of governments and corporations to accomplish their decarbonization targets. Shipping firms may successfully offset their carbon emissions and help global environmental initiatives at the same time by investing in carbon offset schemes. In addition to helping the world reach its carbon reduction objectives, these programs provide financial incentives for the maritime industry to improve its sustainability initiatives. Carbon credits are therefore a useful tool for encouraging more extensive climate action and incorporating environmental responsibility into marine activities.

(3) The shipping industry is seeing an increasing desire for implementing green technology and decarbonization projects to comply with strict environmental requirements. A carbon price on emissions incentivizes transportation businesses to make strategic investments in environmentally friendly solutions. Utilizing carbon offsets, which are activities especially created to lower the total quantity of greenhouse gases in the atmosphere, is one practical approach to monetize carbon reductions through regional and worldwide initiatives. Carbon credits, which may be obtained to offset or negate a buyer's greenhouse gas emissions, are used to quantify these reductions.

(4) In terms of adhering to the new IMO policies, Pakistan's marine industry faces a dire position. Several obstacles, including financial limitations, low public awareness, and inadequate training and research, make it difficult for shippers to implement these new features. The goal of this research is to support safer methods for the shipping industry's decarbonization.

g. **Emissions Trading System (ETS).** One of the main pillars of the EU's climate policy is the EU ETS, which aims to economically reduce greenhouse gas emissions. It functions as a "cap-and-trade" system, in which the total amount of specific greenhouse gases that facilities covered by the system are allowed to emit is limited. Emission allowances are purchased or obtained by businesses, and they can exchange them with one another as needed. The system includes industries including manufacturing, aviation, and power that collectively contribute to over 40% of the emissions in the EU. By offering financial incentives to businesses who invest in greener technologies and lessen their carbon footprint, the EU ETS aims to cut emissions (European Commission, 2024). As of today, the carbon price in the EU ETS is approximately €80 per metric ton of CO₂ equivalent (mtCO₂e).

1.3 Drivers and Challenges in Sustainable Shipping:

a. Updating sustainable practices in the marine sector involves many moving parts, as recent studies have shown. Studies conducted on Norwegian offshore shipping businesses highlight the importance of consumer expectations, voluntary programs, internal initiatives, and legal requirements as major forces behind the transition to zero emissions (Hessevick, 2022). Although green shipping networks help share finance and information, they have little effect on strategic changes unless they are combined with focused advice and funding assistance for zero-emission technology. Additionally, the promotion of ecologically friendly technology, such as wind-assisted propulsion, is greatly aided by Market Based Measures (MBMs) like carbon pricing (Metzger, 2021). A mix of alternative fuels, technical advancements, and efficient regulatory enforcement becomes crucial as the sector confronts increasing pressure to satisfy strict IMO CO₂ requirements and reduce carbon intensity by 2030 (Issa et al., 2022). Together, these components highlight the necessity of internal and external cooperation in developing thorough and successful sustainable shipping plans.

b. b. With important tools like environmental levies and ETS driving the required operational and technological changes, the influence of MBMs on maritime decarbonization is becoming more widely acknowledged (Lagouvardou, 2020). Although MBMs are widely acknowledged for their significance, their practical effectiveness has been restricted. Annual emissions reductions of just 0% to 2% are achieved by carbon pricing, and carbon taxes outperform the ETS (Green, 2021). As demonstrated by a Strength-Weakness-Opportunities-Threat (SWOT) / Political-Economic-Social-Technological-Legal-Environmental (PESTLE) analysis of North European ports, the development of port energy management systems, which are essential to lowering GHG emissions in maritime transport, requires an understanding of a variety of political, economic, social, technological, legal, and environmental factors (Chirstodolou et al., 2023). In addition, the COVID-19 pandemic's continuing impacts and programs like the EU Green Deal highlight the need for flexible regulatory frameworks to achieve the IMO's aggressive emission reduction goals. All these results point to the necessity of strong, adaptable regulatory frameworks and creative funding methods to assist the marine industry's shift to a low-carbon economy.

1.4 The Role of the Pakistan National Shipping Corporation (PNSC) in Sustainable Shipping

a. **Introduction of Pakistan's National Flag Carrier.** PNSC came into being in 1979 when the NSC and PSC merged. It operates under the legal protection of the Pakistan National Shipping Corporation Ordinance No. XX, 1979 (Gazette of Pakistan, Extraordinary Part I, 29 March 1979). PNSC is managed independently by a Board of Directors and has its headquarters in Karachi. To oversee its global shipping operations, PNSC maintains an extensive network of international agents. As Pakistan's national flag carrier, its primary role is the transport of liquid and dry bulk commodities worldwide.

b. Operating under the general oversight of Pakistan's Ministry of Maritime Affairs, PNSC manages a fleet of twelve ships, various properties, and a maintenance facility. The fleet consists of double-hull Aframax tankers, Long Range (LR-1) Product tankers, and Handymax, Panamax, and Handy-size bulk carriers, with a combined capacity of 938,876 deadweight tons. PNSC transports a wide range of cargo, including iron and steel products, forest products, fertilizers, minerals, ores, alumina, cement, bauxite, and other construction materials on its Handymax and Handy-size bulk carriers. Its Panamax carriers are used for grains, coal, and iron ore, primarily supporting steel and energy production.

c. PNSC works with numerous prominent international traders and chartering companies, thereby facilitating global seaborne trade along major routes. The vessels are operated by a team of highly skilled and experienced professionals who ensure adherence to the highest safety and environmental standards. By aligning operations with stakeholder interests, PNSC strives to maximize shareholder value through effective investments and enhanced returns. Details of the shipping fleet is elaborated in table 7.1:

Table 7.1: PNSC Fleet

Tanker Vessel Name	Date of Induction	Last Operational Date	DWT
AFRAMAX TANKERS			
<i>Lahore</i>	23-Feb-2010	23-Jul-2023	107,018
<i>Mardan</i>	3-Aug-2022	27-Jul-2027	107,123
<i>Sargodha</i>	11-Aug-2022	15-Mar-2028	107,123
<i>Shalamar</i>	1-Dec-2014	8-Nov-2026	105,215
<i>Quetta</i>	10-Jul-2008	13-May-2023	107,215
LR-1 TANKERS			
<i>Bolan</i>	25-Mar-2019	18-Mar-2033	74,919
<i>Khairpur</i>	16-Apr-2019	18-Oct-2032	74,986
HANDYMAX			
<i>Chitral</i>	25-Oct-2010	9-Jun-2033	46,710
<i>Hyderabad</i>	21-Apr-2011	8-Jan-2034	52,751
<i>Multan</i>	26-Sep-2012	10-Sep-2032	50,244
HANDYSIZE			
<i>Sibi</i>	18-May-2011	18-Sep-2039	28,442
PANAMAX			
<i>Malakand</i>	27-Dec-2010	28-Oct-2034	76,830

d. Being the main shipping line in Pakistan, PNSC is vital to the marine sector of the nation. PNSC plays a crucial role in advocating for sustainable practices that conform to international norms, thereby aiding in the worldwide endeavor to alleviate environmental damage. With a fleet of contemporary ships, PNSC has implemented a number of initiatives aimed at lowering its carbon impact and improving adherence to IMO standards. By these initiatives, PNSC shows its dedication to sustainability and its key role in promoting ecologically friendly shipping methods in the area.

e. PNSC is up against issues that are similar to those that the shipping industry as a whole face, such as budgetary limits, technological barriers, and the requirement for new techniques to be accepted by society. In order for the PNSC to be in line with worldwide and national laws meant to lower emissions, these obstacles must be addressed. As of right now, PNSC's green initiatives consist of rigorous adherence to the most recent environmental requirements, expenditures in renovating older vessels, and the use of fuel-efficient technology. By putting these procedures into place, PNSC hopes to improve operational sustainability and favorably impact the larger goals of the marine sector.

f. The policies and operating processes of PNSC demonstrate the organization's commitment to sustainability, with a growing emphasis on reducing GHG emissions. PNSC does, however, face certain difficulties, such as the difficulty in obtaining money for sustainable projects and the requirement to work with other stakeholders and government organizations in order to obtain funds for carbon offset projects. In order to successfully carry out its sustainability strategy and support global and national emission reduction objectives, the PNSC must address these issues.

g. **PNSC and Its Connection with Global Shipping.** With its maritime services, PNSC makes it easier for Pakistan to participate in international trade, making it a crucial element of the global shipping scene. The following are important facets of PNSC's ties to international shipping:

(1) **Fleet and Operations.** Bulk carriers, tankers, and container ships are all part of PNSC's fleet. Transporting commodities to and from foreign markets is made easier by PNSC's diverse fleet, which allows it to participate in a number of global shipping categories.

(2) **International Partnerships.** To increase its operational capacity, PNSC works with a number of international shipping lines. Through these alliances, PNSC can provide affordable shipping services, such as containerization and cargo alliances.

(3) **Trade Facilitation.** PNSC is essential to trade facilitation because of its global linkages. It facilitates the import of necessities and gives Pakistani exporters access to global markets. Pakistan's economic influence and commercial competitiveness are improved by PNSC's participation in international shipping networks.

(4) **Participation in Global Shipping Conferences.** In order to stay up to date with worldwide shipping trends and regulations, PNSC actively participates in international maritime conferences and organizations. This involvement strengthens its position in the maritime sector by creating networking possibilities with international shipping stakeholders.

(5) **Challenges in Global Connectivity.** Although PNSC has made important ties with international shipping, it still faces obstacles like the need for technology developments and competition from commercial shipping lines. To remain relevant in the global shipping sector, it is imperative that it adjust to these problems.

h. **Pakistan's Ship Traffic and PNSC's Share:** Statistics from Karachi Port Trust (KPT) reveal, that for 2 years (2022-2024 fiscal years) 369 bulk cargo and 298 general cargo ships have been handled. Container vessels shared the largest percent with 1904 ships entering and leaving the port. The contribution from PNSC vessels is described below:

Table 7.2: Pakistan's Seaborne Trade (Source: PNSC's Annual Report 2023)
Figures in "Million Tons"

Bulk	Pakistan Seaborne Trade		PNSC's Share	
	2023	2022	2023	2022
Dry Bulk	54.13	70.72	1.57	1.316
Liquid Bulk	28.8	36.096	9.26	10.655
Total	82.95	106.8	10.83	11.97

Table 7.3: PNSC's Total Cargo (Source: PNSC's Annual Report 2023)

	Unit of Measurement	2023	2022
Dry Cargo(Bulk Carrier)	Million tons	1.574	1.316
Liquid Cargo(Tanker)	Million tons	9.26	10.655
Slot Charter			
Break Bulk	Higher of MT or CBM (W/M)	0.075	0.026
Containerized Cargo	Thousand TEUS	1.23	2.159

1.5 Research Questions and Their Relevance to PNSC's Sustainable Practices

a. As part of this research, several important questions about PNSC's role in sustainable shipping have been addressed. The main questions focus on:

- (1) **Question.** What are the current IMO regulations being followed by PNSC, and how do they impact its trading activities?

Statement. PNSC must abide by stringent rules pertaining to emissions and operational effectiveness as it works under IMO criteria. Understanding these rules is essential to determining how PNSC's trading operations are affected by them, particularly in a market that is competitive and where adherence to the rules can have an immediate impact on access to markets and profitability.

- (2) **Question.** What are PNSC's existing practices that serve as green strategies in its operations?

Statement. The procedures that PNSC now employs for waste management, emissions monitoring, and fuel management systems will all be closely examined in this investigation. We can learn a great deal about the company's sustainability efforts by recognizing these tactics.

- (3) **Question.** What modifications and different strategies can be adopted by PNSC to achieve its overall sustainability goals?

Statement. This question seeks to investigate potential avenues for PNSC to improve its operational procedures. PNSC can implement best practices that are especially designed to match its operating environment by looking at the effective tactics employed by other maritime nations.

b. In addition to these primary questions, several secondary questions will further illuminate PNSC's journey towards sustainability:

(1) **Question.** Are there existing standards for evaluating the efficiency of carbon offset systems for PNSC?

Statement. This question will investigate whether PNSC can effectively measure the impact of its carbon offset initiatives, which is essential for transparency and stakeholder confidence.

(2) **Observation.** How can PNSC enhance its investment in carbon credits and offsets to augment environmental impact within its budget?

Statement. Examining funding mechanisms and financial strategies will enable PNSC to align its operations with its sustainability objectives without compromising financial stability.

(3) **Observation.** Are there prospective incentives or government programs that can assist PNSC in offsetting its carbon footprint?

Statement. Identifying potential collaborations with governmental agencies can lead to financial support for PNSC's green initiatives, fostering a supportive environment for sustainable shipping practices.

(4) **Observation.** How can PNSC maintain accountability and transparency in its carbon credit generation and offset activities?

Statement. This question focuses on governance and reporting mechanisms that ensure PNSC's efforts in carbon offsetting are credible and verifiable.

(5) **Observation.** How can PNSC collaborate with various stakeholders to maximize its credits and offsets?

Statement. Collaborative efforts with industry partners, NGOs, and governmental bodies can enhance PNSC's sustainability initiatives and promote broader industry change.

c. By addressing these questions, this research aims to provide a comprehensive analysis of PNSC's practices, challenges, and opportunities in the context of sustainable shipping.

1.6 Research Objectives:

- a. Analysis of installed technologies, greenhouse gas emissions and credits earned by PNSC through its ships.
- b. Review of the existing international policies and regulations regarding green shipping, carbon credits and offset systems.
- c. Exploration of opportunities and challenges in upgradation of organization's functions to sustainability.
- d. Assessment of livability extent of newer green strategies with respect to prospects.

CHAPTER 2

Carbon Credits and Offsets

2.1 Introduction

a. As climate change intensifies, there is an increasing demand to reduce GHG emissions across sectors. Carbon credits and offsets have emerged as key mechanisms to address these emissions, allowing organizations to either lower their carbon footprint directly or balance their emissions by supporting projects that remove or reduce GHG emissions elsewhere. Carbon credits represent tradable permits authorizing a company to emit a certain amount of CO₂, usually quantified as one ton of CO₂ equivalent (CO₂e). Conversely, carbon offsets are reductions in emissions created through projects, such as reforestation or renewable energy, that can counterbalance emissions from high-carbon activities (Goldstein *et al.*, 2020; Dorsman, 2016).

b. In recent years, carbon credits and offsets have gained attention in the shipping industry, a sector traditionally reliant on fossil fuels and responsible for a significant portion of global CO₂ emissions, approximately 2.89% as of 2018 (IMO, 2020). The international nature of shipping makes it challenging to regulate emissions directly under one country's jurisdiction, creating a unique reliance on global agreements and market-based mechanisms like carbon credits and offsets (Faber *et al.*, 2021).

c. **Carbon Credits and Offsets as Mechanisms for Shipping Emissions.** Shipping companies have increasingly considered carbon credits and offsets to meet the IMO's 2030 and 2050 decarbonization targets, which aim to reduce carbon intensity by 40% and total GHG emissions by 50% relative to 2008 levels (IMO, 2020). These mechanisms enable companies to participate in emissions reduction indirectly by funding external projects, including reforestation, wind and solar energy generation, and CCS initiatives (Smith & Jullumstrø, 2019). For instance, Maersk, a leading global shipping company, has invested in both carbon offset projects and low-emission technologies to align with these targets (Maersk, 2022).

d. The application of carbon credits and offsets in shipping faces challenges such as verifying and ensuring the permanence of emissions reductions and managing potential market volatility. However, industry-specific certification standards, like the VCS and the Gold Standard, have helped improve transparency and reliability in offsetting initiatives (Carbon Trust, 2021). Adopting carbon credits and offsets complements technological innovations, such as fuel-efficient engines and alternative fuels, providing a multi-faceted approach to emission reduction in this traditionally hard-to-abate sector (Traut *et al.*, 2022).

2.2 Carbon Credit and Offset Registration and Verification System:

a. The carbon credit and offset registration and verification system is designed to ensure the integrity, transparency, and authenticity of emissions

reductions. This multi-step process involves developing the project, validation, ongoing monitoring, independent verification, and registration, each governed by strict standards to guarantee that the credits represent real, additional, and permanent reductions in GHGs. Elaborated below is the step-by-step procedure of carbon credit and offset registration and then verification:

b. **Project Design and Documentation (PDD)**. The initial step in the carbon credit process involves designing and documenting the project. Project developers identify a method to reduce or sequester carbon emissions, which could be through renewable energy installations, forest conservation, methane capture, or other methods. The project description and documentation step are a critical phase in the registration and verification process for carbon credits under the United Nation Framework Convention on Climate Change (UNFCCC), particularly in mechanisms like the Clean Development Mechanism (CDM). This step ensures that projects are designed to achieve credible emissions reductions and that they meet specific standards of transparency, additionality, and sustainability. The documentation submitted here forms the basis for validation, registration, and future verification of the project. Documentation includes:

c. The PDD is the cornerstone of the project description and documentation step under the UNFCCC framework. The PDD contains detailed information about the project and provides a comprehensive outline of its goals, methodology, and expected impact. It includes:

(1) **Project Description**. This section provides a general overview of the project, covering its type (e.g., renewable energy, reforestation), scale (small- or large-scale), location, technology used, and expected benefits. The description must demonstrate that the project aligns with the UNFCCC's overarching goal of mitigating climate change by reducing GHG emissions.

(2) **Baseline Scenario**. The PDD must establish a baseline scenario, which estimates the number of emissions that would occur in the absence of the project. This scenario acts as a reference point for calculating the project's emissions reductions and is key to demonstrating additionality, or the concept that the project results in reductions beyond what would occur under normal circumstances (UNFCCC, 2021).

(3) **Demonstration of Additionality**. According to the UNFCCC, additionality is crucial to proving that the emissions reductions are not part of "business-as-usual" activities. To demonstrate additionality, the PDD typically includes an analysis showing that the project faces barriers (financial, technological, or institutional) that prevent it from being implemented without the support of carbon credits (Michaelowa & Purohit, 2007). This initial documentation ensures that the project meets specific criteria and follows a recognized framework, making it eligible for validation.

d. **Methodology and Emission Reduction Calculations.** The PDD requires a detailed explanation of the methodology that will be used to quantify emissions reductions. This methodology must be approved by the UNFCCC, ensuring that emissions reductions are accurately measured and verifiable.

(1) **Selection of Approved Methodologies.** The UNFCCC provides a range of standardized methodologies for various project types (e.g., renewable energy, forestry, energy efficiency). Each methodology includes a detailed protocol for calculating baseline emissions, monitoring actual emissions, and determining the emissions reductions achieved by the project.

(2) **Quantitative Emission Reductions.** Based on the selected methodology, the PDD must include calculations estimating the total emissions reductions the project is expected to achieve. These calculations help determine the volume of carbon credits the project will generate once verified (UNFCCC, 2016).

e. **Environmental and Social Impact Assessment.** The UNFCCC mandates that the PDD include an environmental and social impact assessment. This section evaluates the potential impacts of the project on the local environment and community, ensuring that the project contributes positively to sustainable development.

(1) **Environmental Impact Assessment.** The project's impact on local ecosystems, biodiversity, and water resources is assessed, particularly for projects with significant land use (e.g., reforestation or agricultural projects).

(2) **Social Impact Assessment.** This assessment looks at the potential effects on local communities, including employment, health, and safety. The UNFCCC requires that projects provide evidence of stakeholder consultations, ensuring that affected communities are informed and able to provide feedback on the project.

f. **Monitoring Plan.** The PDD must include a comprehensive monitoring plan, detailing how emissions reductions will be tracked throughout the project's lifespan. This plan is vital for the later verification process, as it provides transparency and accountability.

(1) **Monitoring Framework.** The framework includes specifics on how emissions data will be collected, recorded, and reported. For example, a renewable energy project might track energy generation and compare it to the baseline.

(2) **Data Collection and Quality Assurance.** The monitoring plan outlines the tools, equipment, and processes for data collection, as well as quality assurance procedures to ensure data accuracy. Regular

monitoring reports must adhere to the selected methodology to avoid discrepancies in reported emissions reductions (Boyd *et al.*, 2009).

g. **Stakeholder Consultations.** The UNFCCC requires projects to conduct stakeholder consultations to gain insights from those directly or indirectly impacted by the project. This step ensures that the project aligns with local interests and minimizes potential adverse effects.

(1) **Consultation Process.** The PDD should document all consultations, including meeting dates, locations, participants, and any feedback received from stakeholders.

(2) **Feedback and Revisions.** If stakeholders raise concerns, the project developer may need to adjust the project design to address these issues before moving forward. Once the PDD is completed, it is submitted to the UNFCCC and made available for a public comment period, typically lasting 30 days. During this time, interested parties, including environmental organizations and community members, can provide feedback on the project (UNFCCC, 2011).

h. **Key Standards and Criteria for Documentation.** The UNFCCC sets specific standards for PDDs to ensure that all project documents meet strict requirements for transparency and reliability:

(1) **Transparency.** All data, assumptions, and methodologies must be clearly outlined to allow independent auditors and stakeholders to verify the project's claims.

(2) **Accuracy.** Emissions reduction calculations, baseline estimates, and additional analyses must be accurate and free from significant errors, as they form the basis for verifying credits.

(3) **Permanence and Leakage.** The PDD must address any potential risk of reversals (e.g., in forestry projects where carbon storage could be reversed by deforestation) and leakage, where emissions might inadvertently increase elsewhere due to the project (UNFCCC, 2016).

i. **Validation by Third-Party Auditors.** Before the project can start generating carbon credits, it must undergo validation by an accredited third-party auditor. The purpose of validation is to confirm the project's feasibility, adherence to chosen methodologies, and potential to deliver the anticipated emissions reductions. The third-party validation process for carbon credits and offsets under the UNFCCC framework is a significant phase that ensures a project's credibility, additionality, and ability to achieve verified emissions reductions. Validation is performed by accredited Designated Operational Entities (DOEs), which are independent third-party organizations tasked with reviewing and assessing a project's PDD. The procedure of third-party validation involves the following steps (UNFCCC, 2011):

- (1) **Step-1.** The validation process begins when the project developer submits the PDD to a DOE for review. This document is foundational, as it outlines the project's expected emissions reductions, methodologies, and alignment with UNFCCC standards.
- (2) **Step-2.** The DOE starts with a desk review of the PDD to verify the completeness, accuracy, and transparency of the information provided. This step includes the verification of methodology used in emission estimation, the baseline assessment, and the additional checks.
- (3) **Step-3.** Following the desk review, the DOE conducts an on-site assessment to verify the accuracy of the information presented in the PDD and assess the project's compliance with UNFCCC guidelines. During the on-site assessment, the inspection team assess the facility physically. They verify the installed monitoring system and data collection procedure. The DOE may also consult local stakeholders or monitoring authorities to verify that the project developer has taken their consultations before.
- (4) **Step-4.** DOEs evaluate the project's environmental and social impact assessments as documented in the PDD. This review ensures the project aligns with sustainable development goals and doesn't negatively impact local ecosystems or communities. It is confirmed in this step, that the projects hold least harm to the natural resources, biodiversity, communities, and social environment.
- (5) **Step-5.** The DOE independently verifies the project's emissions reduction calculations, reviewing the assumptions, data sources, and methodology used in the PDD to ensure accuracy. The DOE checks for consistency in baseline and emissions reduction calculations, confirming that they align with the approved methodology. The experts review each parameter used in calculations, such as energy output or fuel consumption rates, to verify they are correctly measured and reported. An uncertainty analysis is performed to account for potential variability in emissions reductions. This analysis is particularly relevant for projects like reforestation, where natural factors like growth rates can vary.
- (6) **Step-6.** The DOE undertakes a detailed assessment to confirm the project's additionally, which means the project would not have occurred without the incentives provided by carbon credits. The DOE reviews project financials to determine if the project is financially viable without carbon credit revenues. This analysis demonstrates that the project relies on the carbon market to cover its costs. The DOE evaluates potential barriers, such as technological, financial, or regulatory hurdles, that would prevent the project from proceeding without carbon credits.
- (7) **Step-7.** After completing the review and on-site assessment, the DOE prepares a detailed Validation Report summarizing its findings.

This report includes, a summary of the project and baseline scenario, results of the on-site inspection and desk review, confirmation of compliance with UNFCCC standards, validation of emissions reduction calculations, confirmation of additionally and monitoring capability, environmental and social impact finding. This report is an essential part of the documentation required for project registration with the UNFCCC.

(8) **Step-8.** Upon completion of the Validation Report, the DOE submits it along with the PDD to the UNFCCC for project registration. At this stage, the documents are also made available for public review, typically a 30-day period, during which stakeholders can submit comments or concerns.

(9) **Step-9.** After the public review, the UNFCCC considers any feedback and issues a final decision regarding the project's registration. If approved, the project is formally registered, allowing it to begin generating carbon credits through verified emissions reductions.

j. **Monitoring and Data Collection.** Once validated, the project enters the implementation phase, during which developers monitor emissions reductions over time. This step ensures that emissions reductions are accurately measured, recorded, and reported, providing the basis for verifying and issuing carbon credits. Monitoring and data collection are essential for maintaining transparency, accountability, and reliability within the carbon market. Monitoring requirements are defined by the chosen methodology and may include:

(1) **Establishment of Monitoring Plan.** Every project must have a monitoring plan embedded in its PDD, which outlines how emissions reductions will be measured and tracked. All measurable parameters necessary to calculate emissions reductions are listed, such as energy output, fuel consumption, or biomass growth, depending on the project type. The frequency of data collection for each parameter is specified, ensuring consistency. For example, some projects may require daily data collection, while others may collect data monthly or quarterly. The monitoring plan outlines standardized methods for collecting each parameter. These methods must align with approved methodologies to ensure accuracy and comparability. The plan specifies the monitoring equipment to be used (e.g., CO₂ sensors, energy meters) and calibration requirements to maintain data accuracy. By pre-defining these components, the monitoring plan acts as a blueprint for consistent and reliable data collection throughout the project's duration.

(2) **Selection of Monitoring Methodology.** The UNFCCC has approved specific methodologies for different project types (renewable energy, reforestation, waste management), each with unique parameters and data collection methods. Each methodology includes a protocol for calculating baseline emissions (emissions without the project) and project scenario emissions (emissions with the project). Methodologies specify which parameters must be measured, acceptable

measurement units, and the accuracy levels required. They also define standard emissions factors (e.g., for fuel types) and other coefficients, ensuring consistency in calculations.

(3) **Data Collection and Recording.** With the monitoring plan and methodology in place, the project team begins collecting and recording data in accordance with the specified frequency and methods. Data on emissions-relevant activities, such as energy generation or fuel use, are collected. For instance, in a renewable energy project, data on megawatt-hours of electricity generated from solar panels would be collected regularly. Other relevant data, such as weather data in reforestation projects, are gathered to help explain variations in emissions reductions. All collected data are recorded in logbooks, spreadsheets, or digital systems to ensure accurate documentation over time. Data logs must include timestamps and any relevant contextual information to facilitate later verification.

(4) **Quality Assurance and Quality Control (QA/QC).** QA/QC are vital in preventing errors and maintaining the reliability of collected data. The UNFCCC requires that each project include QC/QA measures in its monitoring plan. Technical equipment, such as meters and sensors, must be regularly calibrated to maintain accuracy. The frequency of calibration is specified in the monitoring plan. Secondary data sources, such as utility bills or external weather records, may be used to cross-check primary data. Regular data audits are conducted to detect any potential anomalies or inconsistencies, helping to identify and correct errors. Implementing QC/QA protocols ensures the quality and reliability of emissions data, which is essential for earning carbon credits.

(5) **Data Aggregation and Emissions Calculation.** Once data collection is complete for a reporting period, the project team aggregates the data to calculate total emissions reductions. Using the collected data, the project calculates its emissions under the project scenario, based on the specific methodology. The baseline emissions (what emissions would have been without the project) are calculated to determine the emissions reductions. By subtracting the project emissions from the baseline emissions, the project calculates the total emissions reductions achieved. For instance, a wind energy project would compare the emissions reductions achieved by substituting renewable energy for fossil fuels. This aggregated data forms the foundation for the emissions reduction report submitted to the UNFCCC for verification.

(6) **Preparation of Monitoring Report.** The project team compiles all collected data and calculation results into a Monitoring Report, which includes: a summary of the monitoring activities conducted, including data collection frequency and QC/QA measures, detailed calculations of baseline and project emissions, along with the resulting emissions reductions, logs, calibration certificates, and any relevant contextual information supporting the data integrity. The Monitoring Report must

adhere to the format specified by the UNFCCC and serves as the core document submitted for independent verification.

(7) **Submission for Verification.** Once the Monitoring Report is complete, it is submitted to a DOE for independent verification. The DOE reviews the report to ensure accuracy, compliance with the monitoring plan, and alignment with the chosen UNFCCC methodology. The DOE checks the consistency of collected data with the monitoring plan, ensuring no discrepancies between recorded and reported data. The DOE re-calculates emissions reductions using the collected data to confirm the accuracy of the calculations. For certain projects, DOEs may conduct on-site inspections to validate data collection procedures and equipment. Following verification, the DOE submits its findings to the UNFCCC, which then reviews and registers the emissions reductions, leading to the issuance of carbon credits.

(8) **Continuous Monitoring and Reporting.** Monitoring does not end after the first report; it is a continuous requirement throughout the project's lifespan. Regular reporting periods are established (e.g., annually), during which the project repeats the monitoring, data collection, and reporting process. This ongoing cycle ensures the project continues to achieve the projected emissions reductions over time.

(9) These data collection and monitoring processes ensure the project is achieving its intended outcomes and allow for accurate verification of emissions reductions.

k. **Verification of Emissions Reductions.** Verification is a critical step that confirms the actual emissions reductions achieved by the project. Independent third-party auditors, who were not involved in the initial validation, perform this verification.

(1) **On-Site Inspections.** Auditors may conduct site visits to physically inspect the project, review records, and assess whether the monitoring process aligns with documented methodologies.

(2) **Verification Reports.** Auditors analyze the monitoring data, confirming the quantity of emissions reductions achieved. They also evaluate data accuracy and the project's compliance with the selected standard.

(3) **Additionality and Permanence Review.** Verification confirms that reductions are additional and permanent. For example, in forestry projects, permanence is evaluated to ensure that carbon sequestration is long-term and protected against risks like deforestation.

(4) Verification reports serve as the basis for issuing carbon credits, ensuring that each credit represents a genuine reduction of one metric ton of CO₂ equivalent.

I. **Registration and Issuance of Carbon Credits.** After verification, the project is registered with a carbon registry, which issues tradable carbon credits. Registration involves several key steps:

(1) **Submission to a Registry.** The project and its verified emissions reductions are recorded in a public or private registry. Popular registries include the American Carbon Registry (ACR), Gold Standard Registry, and Verified Carbon Standard (VCS) Registry.

(2) **Issuance of Credits.** The registry issues a unique serial number for each carbon credit, ensuring traceability and preventing double-counting. This number includes project details, such as location, project type, and year of issuance.

(3) **Trading and Retirement.** Registered credits can now be sold or traded on the carbon market, allowing companies to offset their emissions. Once a credit is used to offset emissions, it is “retired” in the registry, indicating that it can no longer be traded. Registries maintain transparency and accountability, providing public records of registered projects and retired credits.

2.3 Standards and Certification Bodies in Verification and Registration

Various standards guide the entire verification and registration process, each with specific requirements:

a. **Verified Carbon Standard (VCS).** The VCS is one of the most widely used global standards for voluntary carbon offset projects. Managed by Verra, VCS provides a framework for diverse project types, including forestry, agriculture, renewable energy, and methane capture.

(1) **Methodologies.** VCS has a catalog of approved methodologies covering various project types, each providing specific guidelines for calculating emissions reductions and monitoring parameters. Projects can also propose new methodologies, which undergo a public consultation and scientific review process before approval.

(2) **Additionality and Permanence.** VCS requires projects to demonstrate additionality, meaning the emissions reductions would not have happened without the project. For carbon sequestration projects, VCS also enforces permanence requirements to ensure that stored carbon remains locked over long periods.

(3) **Monitoring and Verification.** Projects under VCS must submit regular monitoring reports verified by accredited third-party auditors. These audits verify data accuracy, methodology adherence, and emissions reductions calculations.

(4) The VCS system has issued over one billion Verified Carbon Units (VCUs), making it one of the largest voluntary carbon market registries globally (Verra, 2021).

b. **Gold Standard.** The Gold Standard was established by the WWF and other NGOs in 2003, aiming to ensure that carbon offset projects deliver high-quality emissions reductions with a positive impact on sustainable development. Gold Standard projects primarily focus on renewable energy, water management, and community-centered projects.

(1) **Sustainable Development Goals (SDGs).** Gold Standard projects must demonstrate contributions to the UN's Sustainable Development Goals, ensuring that projects benefit local communities and ecosystems.

(2) **Additionality Requirements.** Like VCS, Gold Standard mandates strict additionality criteria to ensure that the project wouldn't have happened without carbon market incentives. This is assessed through both financial and barrier analyses.

(3) **Third-Party Verification.** Gold Standard requires regular third-party verification of projects, emphasizing transparency and stakeholder consultation. Verification includes both emissions reduction confirmation and validation of co-benefits, such as improved community health or water access.

(4) The Gold Standard is recognized for its high credibility and is often preferred by organizations looking to align their offsetting efforts with broader sustainability and social impact goals (Gold Standard, 2020).

c. **Clean Development Mechanism (CDM).** The Clean Development Mechanism (CDM) is a market-based mechanism established under the Kyoto Protocol, allowing developed countries to invest in emissions reduction projects in developing countries and earn Certified Emission Reductions (CERs).

(1) **UNFCCC-Approved Methodologies.** The CDM offers a comprehensive set of methodologies covering diverse sectors, including renewable energy, waste management, and industrial processes. These methodologies specify procedures for baseline and project emissions calculations, monitoring, and data collection.

(2) **Additionality and Baseline Setting.** CDM requires rigorous additionality assessments, with project developers needing to demonstrate that projects are not financially viable without the revenue from CERs. Baseline scenarios are established to compare actual emissions reductions against what would have occurred without the project.

(3) **Accredited Independent Entities (AIEs).** Verification for CDM projects is conducted by AIEs, which are UNFCCC-accredited bodies responsible for validating emissions reductions. These entities conduct on-site inspections, review monitoring data, and evaluate project compliance.

(4) The CDM has been instrumental in supporting low-carbon development in emerging economies and has issued over 2 billion CERs to date, though it has faced challenges in recent years due to low CER prices and evolving carbon market structures (UNFCCC, 2012).

d. **Plan Vivo.** Plan Vivo is a carbon standard focusing on land-based projects, particularly those involving forestry and agroforestry in developing countries. Plan Vivo emphasizes community-led projects and sustainable development.

(1) **Community-Centric Approach.** Plan Vivo projects are designed and managed by local communities, ensuring that emissions reductions directly benefit the people who implement them. This approach *fosters* sustainable development and enhances local livelihoods.

(2) **Additionality and Permanence.** Plan Vivo requires projects to demonstrate additionality and follow strict guidelines to ensure permanence in carbon sequestration. Projects also undergo risk assessments to evaluate potential reversals.

(3) **Third-Party Verification.** Verification for Plan Vivo projects is conducted by independent third parties, who review emissions data and monitor social and environmental impacts. Credits issued under Plan Vivo are called Plan Vivo Certificates, each representing one metric ton of CO₂ equivalent.

(4) Plan Vivo's unique focus on community involvement and sustainable development makes it a valuable standard for carbon offset projects aiming to deliver social co-benefits (Plan Vivo, 2020).

(5) The registration and verification system ensures transparency, credibility, and accountability in the carbon offset market. This process assures investors and stakeholders that the offsets they purchase are backed by real and permanent emissions reductions, ultimately supporting global decarbonization efforts.

2.4 Implementation of Carbon Credit and Offset Systems:

a. Due to the drastic impacts of global environmental change, large and renowned business tycoons of the world have incorporated emission reduction goals as their social responsibility. Some of these examples are elaborated below:

b. **Microsoft Corporation.** Microsoft has been a leader in carbon offsetting and emissions reduction since 2012, when it committed to becoming carbon neutral. In 2020, the company set an ambitious goal to become carbon negative by 2030 and pledged to remove all carbon it has emitted since its founding in 1975 by 2050.

(1) **Procedure and Implementation.** Microsoft achieves this goal through several strategies, including carbon credits, nature-based offsets, and renewable energy projects. It has invested in forestry projects, soil carbon sequestration, and carbon capture technology. Microsoft uses both the Gold Standard and VCS for validating its offset projects, ensuring reliable measurement and transparency (Microsoft, 2020).

(2) **Facts and Figures.** In 2021, Microsoft removed approximately 1.3 million metric tons of carbon through offsets and achieved its 100% renewable energy target (Microsoft Sustainability Report, 2021)

c. **Google LLC.** Google became carbon-neutral in 2007 and, in 2017, matched its energy usage with 100% renewable energy. It now aims to operate entirely on carbon-free energy by 2030, an ambitious step beyond offsets, to eliminate its dependency on fossil fuels entirely.

(1) **Procedure and Implementation.** Google has invested heavily in carbon credits, renewable energy procurement, and direct reductions. It uses offsets for residual emissions and funds various offsetting projects, such as methane capture and afforestation. Its renewable energy projects are certified by the Renewable Energy Certificates (RECs), while carbon offsets adhere to the Gold Standard.

(2) **Facts and Figures.** In 2021, Google's total annual carbon emissions offset amounted to 4.9 million metric tons of Carbon Dioxide Equivalent (CO₂e), achieved through a combination of credits and renewable energy investments (Google Environmental Report, 2021).

d. **Maersk.** Maersk, one of the world's largest container shipping companies, has set ambitious targets to reach net-zero carbon emissions by 2040. Maersk's approach is a combination of offsets, alternative fuels, and efficiency improvements.

(1) **Procedure and Implementation.** Maersk began by purchasing biofuels and investing in green methanol production. It also offsets emissions by funding renewable energy projects and forest preservation initiatives. Maersk adheres to the Verified Carbon Standard and Gold Standard for offset verification.

(2) **Facts and Figures.** In 2022, Maersk operated its first carbon-neutral container ship using biofuel, resulting in a reduction of 1.5 million

metric tons of CO₂e. The company has committed to reducing its fleet's carbon intensity by 60% by 2030 (A.P. Moller - Maersk, 2022).

e. **Mediterranean Shipping Company (MSC).** MSC is another major player in the shipping industry that has committed to decarbonization. Its approach focuses on retrofitting its fleet for energy efficiency and offsetting residual emissions.

(1) **Procedure and Implementation.** MSC has adopted energy-efficient ship designs, improved propulsion systems, and uses low-carbon fuels. Additionally, it supports renewable energy projects globally to offset unavoidable emissions. MSC follows the Verified Carbon Standard and Gold Standard to ensure its offsets meet international criteria.

(2) **Facts and Figures.** MSC's investment in energy-efficient technologies and offsets resulted in a 23% reduction in CO₂ emissions per ton of cargo in 2021. The company plans to achieve a 50% carbon intensity reduction by 2030 and net-zero emissions by 2050 (MSC, 2021).

2.5 Carbon Credit Estimation Methodology for this Study:

a. Methodology on the estimation of carbon credits from ships of PNSC was adopted from the internationally described formulae by IPCC. Following steps were ensured to adhere to the methodological framework of the study:

(1) **Data Collection.** PNSC 12 ships data was collected of the year 2022 and 2023 to analyze their carbon emissions for estimation of credits generated from their technological upgrade. IMO-DCS were provided for both years consisting of the following information:

Table 7.4: IMO-DCS Parameters

Reporting year	Main engine power output (kw)
IMO number	Total rated auxiliary engine(s) power output (KW)
Ship type	Distance travelled (nm)
Gross tonnage	Hours underway (h)
Net tonnage	Total fuel consumption (MT)
Deadweight (MT)	Categories and types of various fuels with their conversion factors
EEDI (g CO ₂ /MT*nm)	Method used to measure fuel oil consumption
Total rated main propulsion power output (kW)	Flag

(2) **Data Evaluation and Compilation.** CO₂, Nitrous Oxide (N₂O) and Methane (CH₄) emissions were analyzed for years 2022 and 2023 separately through the following formulae as prescribed by IPCC. The estimates of N₂O and CH₄ were converted to their CO₂e:

- i. CO₂ emissions (MT) = Fuel consumption x Emission factor of the fuel used.
- ii. N₂O emissions (MT) = Fuel consumption x N₂O Emission factor.
- iii. CH₄ emissions (MT) = Fuel consumption x CH₄ Emission factor.
- iv. CO₂ equivalent emissions = N₂O/CH₄ emissions in MT x 298 (N₂O) or 28 (CH₄).

b. An emission factor of fuel is a coefficient that quantifies the amount of GHG emissions, specifically CO₂, emitted per unit of fuel consumed. It is typically expressed in units of kilograms or metric tons of CO₂ per unit of fuel, such as liters, gallons, kilograms, or gigajoules, depending on the fuel type and its use in specific sectors like transportation, industry, or electricity generation. Emission factors help to standardize emissions calculations, making them essential for GHG inventories, emissions reporting, and carbon accounting. After emission calculation, the credits earned from the difference of emissions were analyzed through the following formula for each vessel:

Credits earned (MT) = Baseline emissions (2022) - Reduced emissions (2023)

2.6 Gaps and Limitations:

c. The research study holds immense significance in terms of shipping sector decarbonization being the very first of its kind in the country deliberating on decarbonization measures. However, observations are being reported with a view to continuing the research in a comprehensive manner as per the international standards and practices:

(1) Emission analysis based on fuel consumption is not enough to report or register carbon credits. Accurate figures (not average values) of all processes having direct/indirect impact on the environment need to be addressed and evaluated.

(2) The data provided was of the whole year. In order to ensure the international quality, per unit emissions are to be evaluated which requires data sets of all voyages conducted in every month (distance travelled per voyage, type of fuel acquired and consumed, fuel composition, main and auxiliary engine running time, number of times ballast and wastewater treatment procedures conducted with exact

quantity, ballast water quantity acquired and released, amount of solid waste generated, amount of sludge retrieved from wastewater treatment and fuel filtration, number of times fuel filtration process had been performed, wastewater quantity etc.)

(3) Ground visit of every ship, especially observation of green technologies, its efficiency and functioning, is a necessity in studies of carbon credit/offset estimation.

(4) CII functioning and its data formulation procedure should be shown compulsorily as it is the main aspect in the reporting process.

CHAPTER 3

International Regulations and PNSC Compliance

3.1 Currently Implemented Global Regulations and Their Impacts:

a. The international shipping sector functions within a regulatory framework that aims to mitigate its ecological footprint. IMO which creates important laws like the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Initial IMO Strategy on the Reduction of GHG Emissions from Ships, is a major participant in this endeavor (Dominioni & Englert, 2022).

b. By addressing emissions such as oil, sewage, and rubbish, MARPOL creates crucial guidelines for reducing pollution from ships. Because of this convention, the quantity of garbage that enters marine habitats has decreased significantly. Shipping firms are encouraged to implement cleaner technologies and practices by abiding by MARPOL standards, which helps to maintain a healthy ocean ecology (Coulter *et al.*, 2007).

c. With a long-term objective of achieving 100% decarbonization by the end of the century, the Initial IMO Strategy sets ambitious goals to cut overall GHG emissions from shipping by 50% by 2050 compared to 2008 levels. Many nations and businesses have changed their operating procedures, invested in green technology, and increased the transparency of their emissions reporting because of this strategy's acceptance (Karyoti, 2023). In order to enable a transition toward a more sustainable maritime sector, this regulatory pressure is essential (Issa *et al.*, 2022).

d. Apart from this tactic, other laws, including the Ballast Water Management Convention, are designed to fight invasive species that are brought in by ballast water. Another important factor is the EEDI, which mandates that new ships adhere to strict energy efficiency guidelines. When combined, these laws provide shipping firms more financial and operational obligations, encouraging them to use innovative and sustainable methods in their marine operations (DNV GL, 2021).

3.2 PNSC Compliance with International Regulations and Outcomes:

a. PNSC has demonstrated its dedication to sustainability and environmental responsibility by taking major actions to bring itself into compliance with international maritime rules. The business has adopted several IMO-compliant procedures, including updating its fleet with newer, energy-efficient boats and installing waste management systems on board (PNSC, 2022).

b. The international laws ratified by Pakistan are mandatory for PNSC to abide to ensure its safe shipping operations around the globe. The shipping regulations are elaborated below as per IMO:

(1) **IMO Regulation 48.** Under the Safety Of Life At Sea (SOLAS) Convention's Chapter II-1, Part E, this regulation addresses flood protection in periodically unattended machinery spaces. It mandates that bilge wells in these spaces must be positioned and sized to detect and manage liquid accumulation effectively during normal ship conditions. Additionally, automated bilge pumps must signal when inflow surpasses capacity, while control valves for seawater or bilge systems must allow adequate response time in case of flooding. This regulation helps ensure safety by monitoring and managing liquid ingress efficiently in unattended areas.

(2) **SOLAS Protocol 47.** This protocol introduced various safety regulations aimed at enhancing the structural stability of ships, fire safety, life-saving equipment, and navigational procedures. The 1974 protocol, often referred to simply as "SOLAS 74," is widely recognized and has been updated over the years with new amendments to address evolving maritime safety challenges.

(3) **SOLAS Protocol 78.** The SOLAS Protocol 1978 was introduced as an amendment to the 1974 SOLAS Convention. It primarily focuses on improving the safety standards related to ship construction, equipment, and operation and aimed to address safety concerns around oil tankers and liquefied gas carriers, which were becoming increasingly common. Key additions included enhanced requirements for ship certification, more rigorous inspection procedures, and specific provisions to improve fire safety, life-saving appliances, and pollution prevention on tankers. This protocol further reinforced international safety and pollution prevention standards across the maritime industry.

(4) **SOLAS Protocol 88.** The SOLAS Protocol 1988 introduced amendments aimed at standardizing ship inspection and certification procedures. It introduced the Harmonized System of Survey and Certification (HSSC), allowing surveys and certificates for various international conventions (such as SOLAS, MARPOL, and Load Line Conventions) to be synchronized. This harmonization streamlined inspection schedules, minimized operational disruptions, and improved compliance consistency for vessels. By integrating survey requirements across conventions, the protocol enhanced efficiency and reduced redundancy in maritime safety and environmental protection efforts.

(5) **LOADLINES Convention 66.** The International Convention on Load Lines (ICLL) 1966, often referred to as the Load Lines Convention 66, establishes minimum standards for the safe loading of ships to prevent overloading and improve stability at sea. This convention defines load lines or "Plimsoll lines," indicating the maximum legal loading limits depending on water type, temperature, and season. It also

includes provisions for freeboard, watertight integrity, and ship stability. The convention helps enhance maritime safety by ensuring vessels maintain sufficient buoyancy and stability under varying environmental conditions.

(6) **LOADLINES Protocol 88.** International guidelines established by the Load Lines Convention of 1988, keep ships from overloading and guarantee their stability and safety while at sea. It sets minimum freeboard requirements (the distance between the main deck and the waterline) according to the size, type, and operational routes of the vessel. Along with defining geographical and seasonal loading restrictions, the convention mandates that ships modify their load lines in response to certain sea and weather conditions. Standards for structural strength guarantee that ships can endure the strain of cargo and hostile conditions. Inspections are necessary to ensure certified conformity, and vessels are issued the load line certificate required for international travel.

(7) **TONNAGE Convention 69.** The International Convention on Tonnage Measurement of Ships, 1969 (Tonnage Convention 69) established a universal system for measuring ship tonnage, which is the volume of all enclosed spaces on a vessel. The convention introduced two main tonnage measurements: GT and NT, based on the ship's overall size and cargo capacity, respectively. These measurements affect ship registration, safety regulations, port fees, and international regulations. This standardized system replaced the various national tonnage systems, promoting consistent regulatory practices across countries.

(8) **COLREG Convention 72.** The International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) establish navigation rules to avoid collisions on the water. Known as the COLREG Convention 72, it sets standards for vessel conduct, including right-of-way, safe speed, navigation lights, sound signals, and maneuvering protocols. It applies to all vessels on the high seas and navigable waters connected to the open sea and is essential for safe maritime traffic worldwide. Amendments have been added to address technological advancements and evolving maritime safety needs.

(9) **STCW Convention 78.** The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) 1978 sets global minimum standards for the training, certification, and watchkeeping of seafarers. Adopted by the IMO, STCW aims to ensure that crew members on commercial vessels are properly trained and competent in navigation, safety, and emergency procedures.

It requires uniform qualifications for roles like deck officers, engineers, and ratings.

(10) **Convention 79.** The International Convention on Maritime Search and Rescue (SAR) 1979 established a global framework to coordinate search and rescue operations for distress situations at sea. The SAR Convention divides the world's oceans into designated search and rescue regions, each with a responsible country. It also outlines procedures for organizing and operating rescue operations, training rescue personnel, and communicating effectively during emergencies. Adopted IMO, SAR 1979 aims to improve maritime safety and ensure prompt assistance for people in distress anywhere at sea.

(11) **MARPOL ANNEX I.** It addresses the prevention of pollution by oil from ships. It sets regulations for minimizing oil discharge into the marine environment during both routine operations and accidental events. Key provisions include requirements for oil discharge monitoring equipment, oily water separators, and specific operational procedures to prevent oil spills. Annex I also mandate the maintenance of an Oil Record Book and adherence to strict design standards for oil tankers, like double hulls, to reduce pollution risks.

(12) **MARPOL Annex II.** It regulates the control of pollution by NLS carried in bulk. It outlines procedures for the safe discharge, handling, and containment of chemicals classified as hazardous to marine life. Annex II requires all chemical tankers to follow strict protocols, including tank washing procedures, discharge limitations, and the maintenance of a Cargo Record Book. The substances are categorized into four pollution categories (X, Y, Z, and OS) based on their level of hazard, with Category X being the most harmful.

(13) **MARPOL Annex III.** MARPOL Annex III sets guidelines for the prevention of pollution by hazardous substances in packaged form. It applies to substances carried in containers, portable tanks, or other packaging on ships. Annex III requires proper labeling, documentation, stowage, and handling of these substances to minimize risks to marine environments in case of spills or accidents. It includes provisions for emergency response information and safeguards to protect both crew and the environment from the hazards associated with packaged dangerous goods.

(14) **MARPOL Annex IV.** It addresses the prevention of pollution by sewage from ships. It establishes regulations for the collection, treatment, and discharge of sewage to reduce its environmental impact on marine ecosystems. Under Annex IV, ships must either install sewage treatment plants, retain sewage onboard, or discharge it under specific

conditions at designated distances from shore. This annex also mandates the use of a Sewage Pollution Prevention Certificate to ensure compliance. These measures help protect coastal and marine environments from contamination and harmful pathogens associated with untreated sewage.

(15) **MARPOL Annex V.** It sets regulations to prevent pollution by garbage from ships. It prohibits the discharge of most types of garbage into the sea, including plastics, which are completely banned. Other waste types, like food waste, paper, and metal, can only be disposed of under specific conditions and distances from shore. Ships are required to follow strict garbage management practices, including holding a Garbage Record Book and creating a Garbage Management Plan. Annex V helps minimize the harmful impacts of marine debris on ocean ecosystems and wildlife.

(16) **MARPOL Annex VI.** It focuses on the prevention of air pollution from ships. It sets limits on emissions of sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter, and restricts ODS. Annex VI mandates the use of low-sulfur fuel and energy efficiency measures, such as the EEDI and the SEEMP. It also established ECAs where stricter emission standards apply, reducing the environmental and health impacts of air pollution from shipping.

c. PNSC has effectively decreased trash discharges into the ocean by adhering to MARPOL standards, helping to preserve marine habitats. Furthermore, by operating more fuel-efficient boats because of the Energy Efficiency Design Index's deployment, PNSC has been able to reduce its overall greenhouse gas emissions.

d. Even with these successes, problems still exist. Financial limitations, lack of technology assistance, and lack of knowledge about sustainable shipping best practices in Pakistan are all issues that PNSC must deal with. These barriers prevent the full advantages of compliance from being realized. Continuous training and capacity-building programs are crucial for improving PNSC's operational effectiveness and compliance requirements to overcome these obstacles.

3.3 New and Upcoming Strategies for PNSC's Shipping Activities:

a. PNSC must use fresh approaches and projects to improve sustainability and conformity with global standards even further. Integrating digital technology for real-time emissions and operational performance monitoring might be one successful strategy. PNSC would be able to better control its environmental effect and guarantee compliance with international standards by putting in place an extensive Environmental Management System (EMS) (Coulter et al., 2007).

b. For onboard power generation, investing in renewable energy sources may drastically cut down on reliance on fossil fuels. A feasible route for PNSC is to switch to biofuels or hybrid propulsion systems, which would provide them a competitive advantage in the market and be in line with the IMO's decarbonization objectives (Faber et al., 2020). Additionally, PNSC may be able to get financing possibilities and the technical know-how required to carry out green projects by cultivating cooperative partnerships with international organizations, governmental entities, and non-governmental groups. By investing in initiatives that lower greenhouse gas emissions both domestically and globally, PNSC may further strengthen its sustainability profile by taking part in global carbon offset programs (Xue et al., 2024).

CHAPTER 4

International Funding Related to Green Initiatives

4.1. Introduction to Green Financing in Maritime Decarbonization

a. One of the most important tools in the transition to a more sustainable global economy is green financing. It is essential to the decarbonization of high-emission sectors, such as shipping, which greatly increases GHG emissions worldwide. Because of its need on fossil fuels, the marine industry is well-positioned to undergo change through green finance, which will allow for investments in cleaner technology, carbon offsetting, and sustainable infrastructure. Specifically, the creation of carbon offset initiatives aids shipping firms in reducing their net emissions, enabling them to adhere to global environmental standards and support the larger effort to combat climate change (UNCTAD, 2023).

b. The need for funding green projects has increased because of global frameworks such as the IMO Initial GHG Strategy and growing awareness of the effects of climate change. The numerous national, international, and private funding sources that assist carbon offset projects are examined in this chapter, along with the procedures by which they are disbursed and the ways in which shipping firms, such as PNSC, can use them to adopt sustainable practices.

4.2 International Fundings for Carbon Offset Generation

a. With the purpose to combat climate change, international assistance is crucial for developing countries and industries like maritime transportation. This provide access to cash and promote initiatives to adopt cleaner, more sustainable technology and generate carbon offsets, a number of international financial initiatives have been established

(1) Global Initiatives and Climate Funds: The GCF, which was created to assist developing countries in financing both mitigation and adaptation projects, is one of the most prominent international funding sources for climate-related initiatives. By funding initiatives that use carbon offsets and green technologies to lower greenhouse gas emissions, shipping businesses can access GCF grants and loans (Green Climate Fund, 2023). The Global Environment Facility (GEF) has also been a major funder of emission-reduction initiatives in a number of industries, including shipping (Global Environment Facility, 2022). Furthermore, the Adaptation Fund is one of the crucial funding tools offered by the UNFCCC to assist in the execution of climate resilience initiatives. Maritime businesses can lower their carbon footprint and obtain international assistance by using the UNFCCC's carbon offsetting mechanism (UNFCCC, 2021).

(2) Bilateral and Multilateral Partnerships: Additionally, international development banks and bilateral partnerships are essential for financing green shipping projects. Numerous projects, including those related to

the maritime industry, have been started by the World Bank and the IFC to assist developing countries' transitions to renewable energy (World Bank, 2022). In a similar vein, the ADB provides grants and loans to promote sustainable growth in the maritime industry, emphasizing the implementation of carbon reduction plans by Asian nations (Asian Development Bank, 2023).

b. In addition to offering crucial financial support, these collaborations help shipping firms like PNSC navigate the challenging process of decarbonization by providing technical assistance and capacity building.

4.3 National and Private Funding on Carbon Offset Generation:

a. **National-Level Funding Mechanisms.** Many nations have established national funding systems to support green initiatives in their shipping sectors. To encourage shipowners to implement emission-reducing technologies, countries such as Norway, Japan, and Germany have established national green funds and subsidy programs. For maritime operators in nations like Pakistan, where there may not be enough money to invest in these technologies on their own, these financial resources are especially crucial (Metzger, 2022).

b. Incentives like tax breaks and grants are also provided by national development banks and government initiatives to shipowners who participate in carbon offsetting and other eco-friendly activities. This helps maritime businesses make the switch to zero-emission vessels, for example, the Norwegian Green maritime Programme offers incentives and loans (Norsk Industri, 2022).

c. **Private Investment and Corporate Funding.** The private sector's contribution to green finance has increased dramatically in the last several years. With carbon credits that may be bought, sold, or traded to offset emissions, carbon markets have given maritime businesses new avenues to make money. As part of their ESG objectives, corporations and private investors are becoming more and more interested in sustainability-linked loans and green bonds.

d. Additionally, private equity and venture capital funds are paying more attention to sustainable projects because they see the decarbonization of shipping as a lucrative prospect. Private funding is emerging as a major driver of maritime decarbonization, as evidenced by the fact that companies like as Maersk have generated money through private green bonds to support their zero-carbon ambitions (Maersk, 2023).

4.5 Funding Opportunities for PNSC's Green Initiatives:

a. Reaching its decarbonization targets requires PNSC, a significant participant in the nation's marine industry, to draw on both domestic and foreign

finance sources. By coordinating its efforts with international climate finance systems, PNSC can get the funding required to successfully execute carbon offset and green technology projects.

(1) **Global Climate Funds and Carbon Credit Markets.** By demonstrating its commitment to cutting emissions and adopting sustainable practices, PNSC can obtain money from organizations like the Global Environment Facility or the Green Climate Fund. Furthermore, PNSC has an additional way to profit from its decarbonization initiatives by participating in the carbon credit market. PNSC can generate additional revenue by selling carbon credits it generates through sustainable activities to private enterprises seeking to offset their emissions (Faber et al., 2020).

(2) **National and Regional Funds.** Pakistan might strengthen its maritime industry at the national level by establishing its own green fund or by utilizing regional financial sources, such as those provided by the Asian Development Bank's green programs. Furthermore, PNSC can consider establishing bilateral alliances with other maritime countries that are making significant investments in carbon offset and green shipping initiatives.

4.5 Challenges and Opportunities in Securing International and National Funding:

a. Despite the abundance of national and international financing options, PNSC faces a number of obstacles when trying to access them. Obtaining funds may be hampered by problems like bureaucratic roadblocks, a lack of knowledge about available funding, and adherence to international environmental regulations. Furthermore, smaller businesses are frequently deterred from applying for foreign grants and loans by the substantial upfront expenses involved in integrating green technologies. However, opportunities still exist.

b. Pakistan has several national funding opportunities to support decarbonization and carbon offset initiatives, with multiple programs aligning with its Nationally Determined Contributions (NDCs) and climate goals:

(1) **Green Climate Fund (GCF).** Pakistan is actively involved with the GCF, a key funding source for climate-related projects. The GCF supports various adaptation and mitigation initiatives in Pakistan, such as flood management, climate-resilient agriculture, and ecosystem restoration projects. For example, the "Recharge Pakistan" initiative promotes ecosystem-based adaptation to address flood risks through green infrastructure development, which aligns with decarbonization and resilience goals. Pakistan has also engaged in smaller GCF-funded projects, with the Ministry of Climate Change acting as the NDA to facilitate GCF engagement and attract further investments. Recharge Pakistan Initiative, seven-year project, focuses on building climate

resilience through ecosystem restoration, specifically by enhancing flood management and water resource conservation. It includes wetland and forest restoration, which are valuable carbon offset sources. PNSC's investment in Recharge Pakistan could help offset its carbon footprint while supporting climate adaptation efforts in flood-prone areas of Pakistan.

(2) **Voluntary Carbon Markets.** Pakistan has potential in developing voluntary carbon offset programs, which attract private sector investments in projects that reduce or capture emissions, such as afforestation, renewable energy, and waste management. Voluntary carbon markets are growing globally, and Pakistan is exploring the establishment of carbon credits for local projects, aligning with market mechanisms outlined in the Paris Agreement. Organizations like Norton Rose Fulbright have highlighted this market's growth in Pakistan, promoting private financing for low-carbon projects. PNSC can greatly augment its decarbonization goals by investing in voluntary carbon markets which are recognized widely.

(3) **World Bank and International Financial Support.** Pakistan has been receiving support from the World Bank to bolster climate resilience through programs like the PACE, focusing on clean energy transitions and energy efficiency. Such programs help reduce GHG emissions by encouraging renewable energy investments, which indirectly supports decarbonization efforts. PNSC can report its green activities and green technologies adopted for a sustainable tomorrow and can attract potential funding opportunities.

(4) **Pakistan Environment Trust (PET) Carbon Offset Initiatives.** PET is working toward establishing a carbon offset industry in Pakistan, with estimates suggesting a potential \$200 million annual market. PET focuses on low-carbon solutions across sectors, providing a potential platform for PNSC to fund projects that directly contribute to national decarbonization goals and expand Pakistan's carbon offset capacity.

CHAPTER 5

Results and Discussion

5.1 Carbon Emissions and Credits Calculation

a. The fuel consumption data of each vessel was analyzed through the formulae as defined by IPCC. After conversion, the values were multiplied by its respective emission factor (table 7.5) so that emissions can be analyzed from the amount of fuel used. The calculation is showed below for each vessel (table 7.6):

Table 7.5: Emission Factors

Fuel Type	Emission Factor (CO ₂)
Light Fuel Oil (LFO)	3.151
Heavy Fuel Oil (HFO)	3.114
Marine Gas Oil (MGO)	3.206
Diesel	3.206

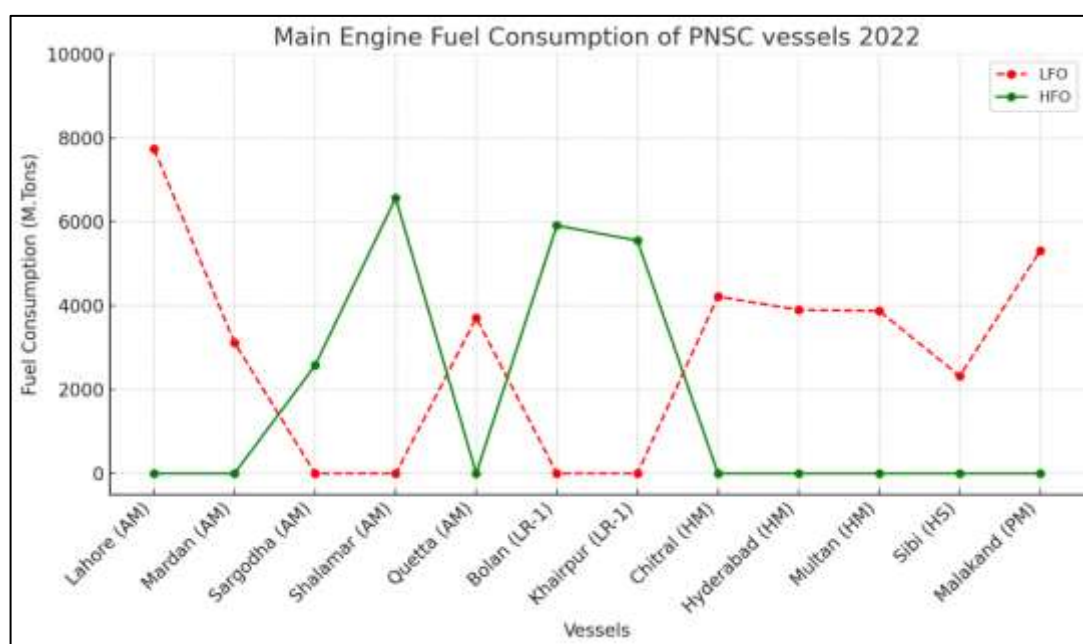


Figure 7.3: Fuel Consumption (Main Engine) of 2022.

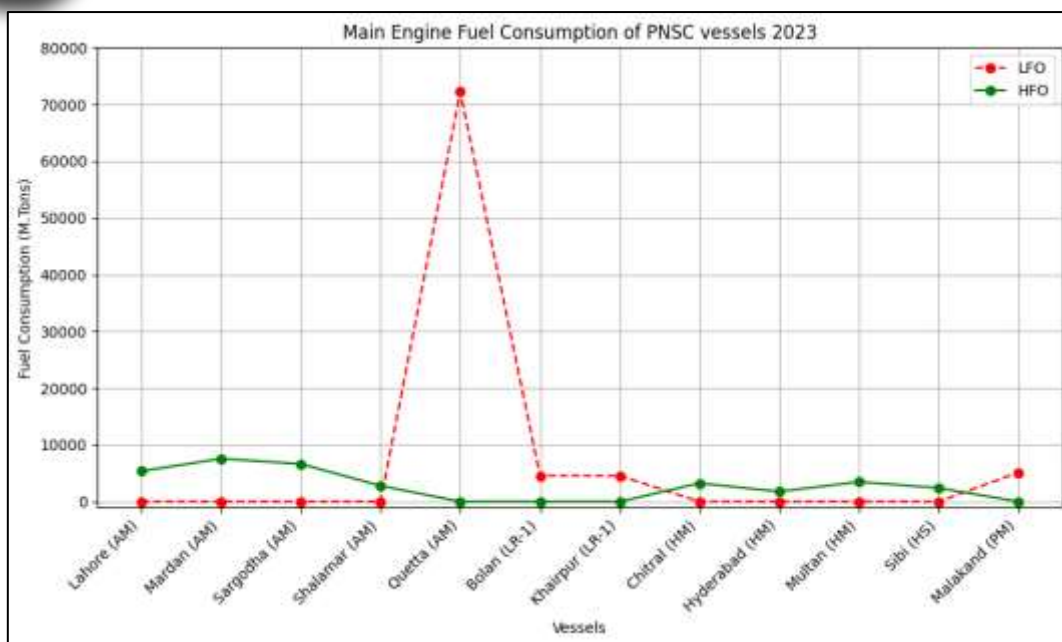


Figure 7.4: Fuel Consumption (Main Engine) of 2023.

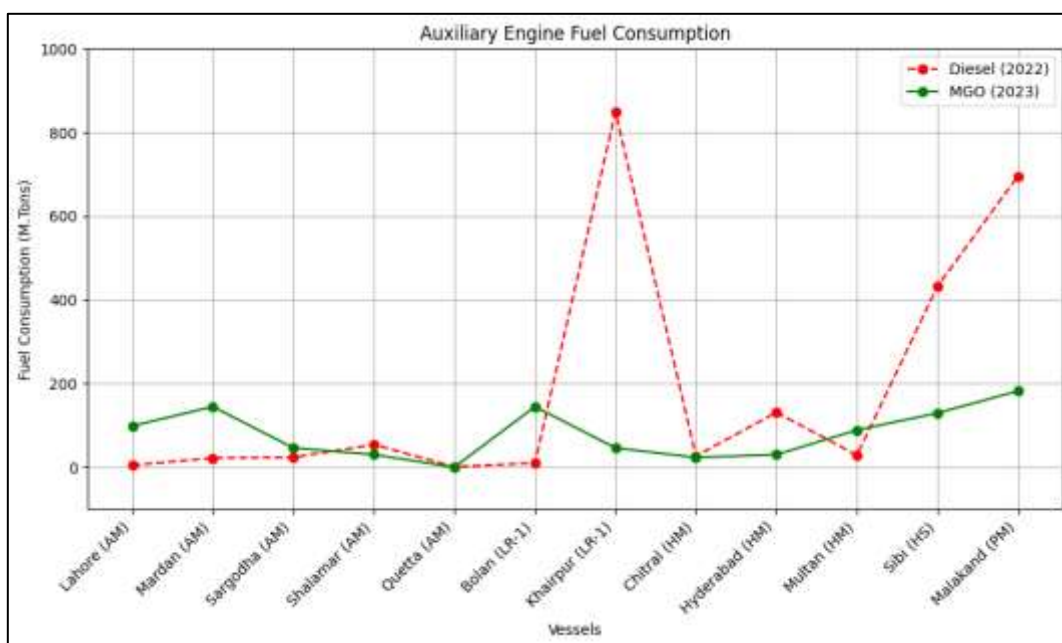


Figure 7.5: Fuel Consumption of 2022 and 2023 (Auxiliary Engine)

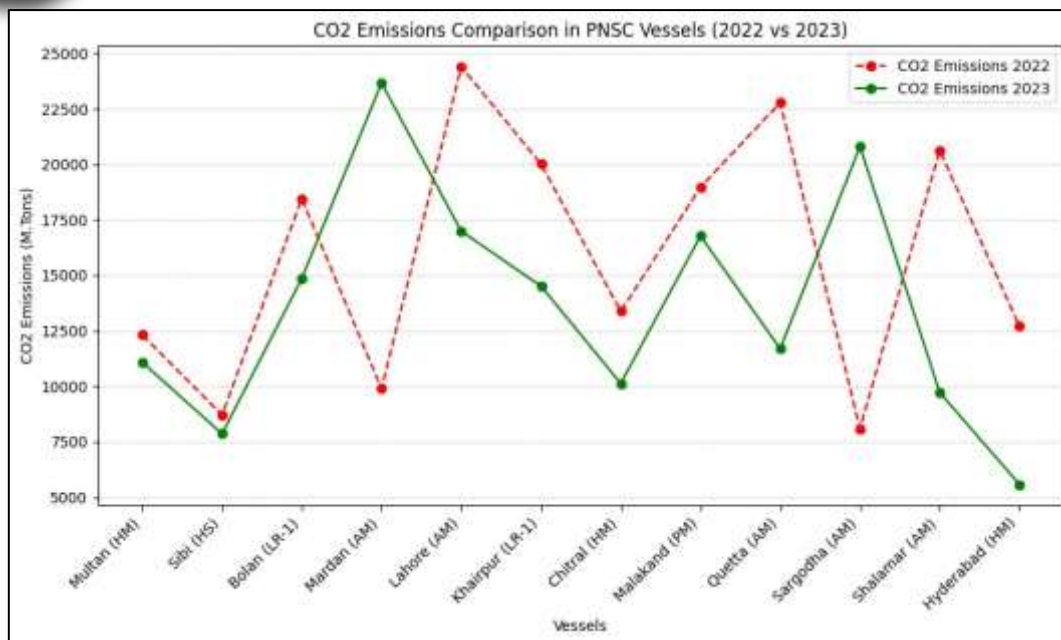


Figure 7.6: Distance travelled by PNSC ships in 2022 and 2023.

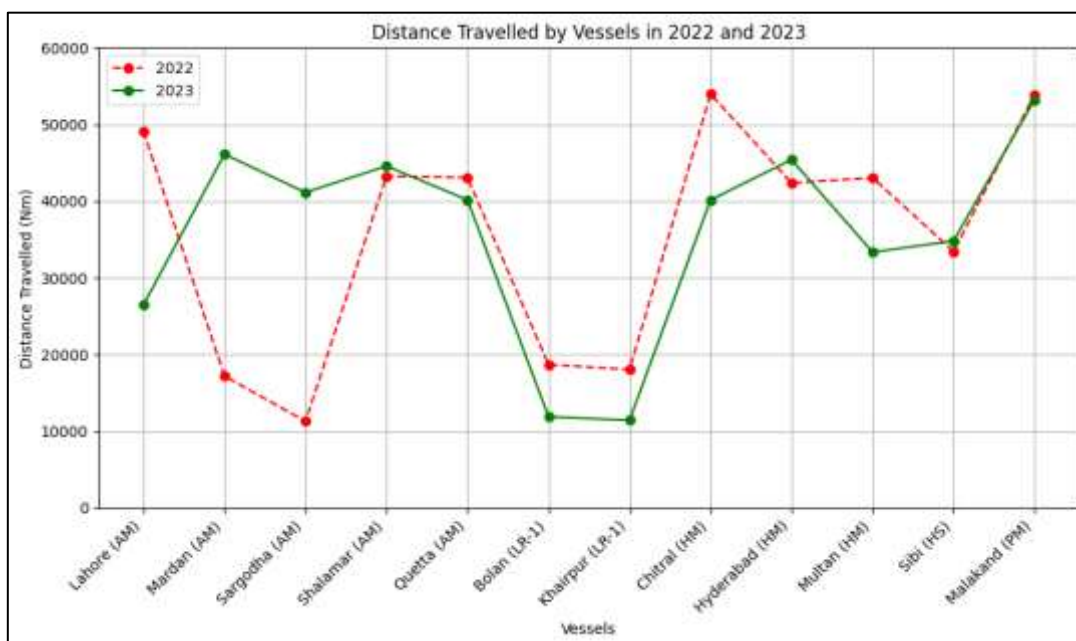


Figure 7.7: CO₂ Emissions from PNSC Fleet.

b. PNSC ships are installed with EEXI and CII to reduce various greenhouse gas emissions emitted from the ships. The graphs and tables shown above (figures 7.3 – 7.7) illustrate the amount of carbon emissions emitted from the ships during 2022 and 2023 based on fuel consumption and distance travelled. The emission concentration is witnessed in higher levels in 2023 as compared with 2022 in Aframax tankers Mardan and Sargodha. The possible reason for increase in emissions is the difference in distance travelled and the port residence time. The number of credits is determined by the difference in emissions from the previous year to the current year of assessment. Figure 7.8 and 7.9 extends the insights of credits earned from emission reduction from every PNSC vessel:

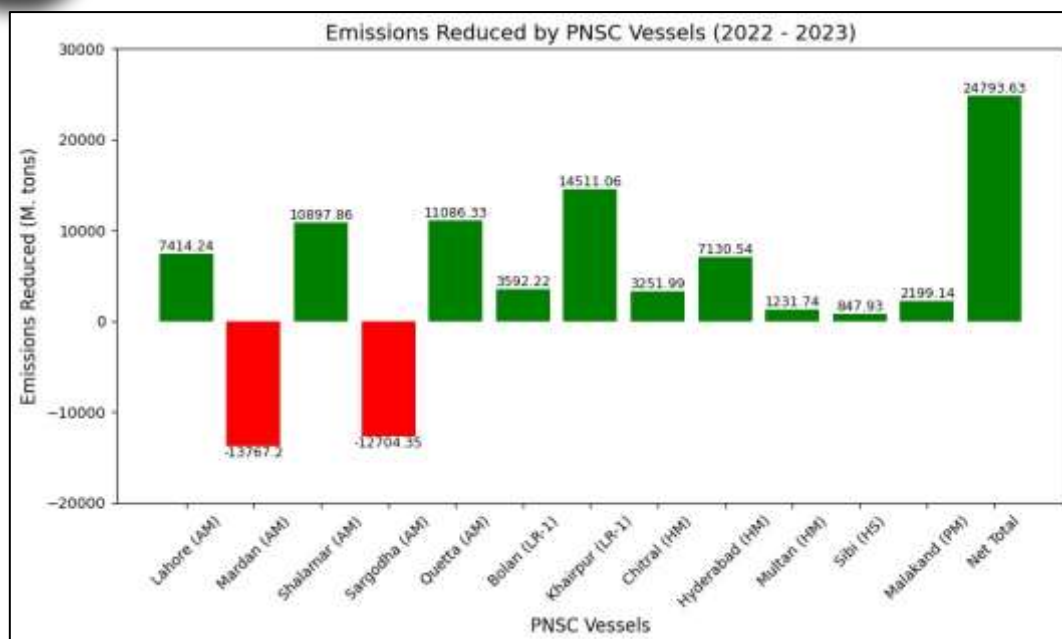


Figure 7.8: Emission reduced by PNSC fleet in 2023.

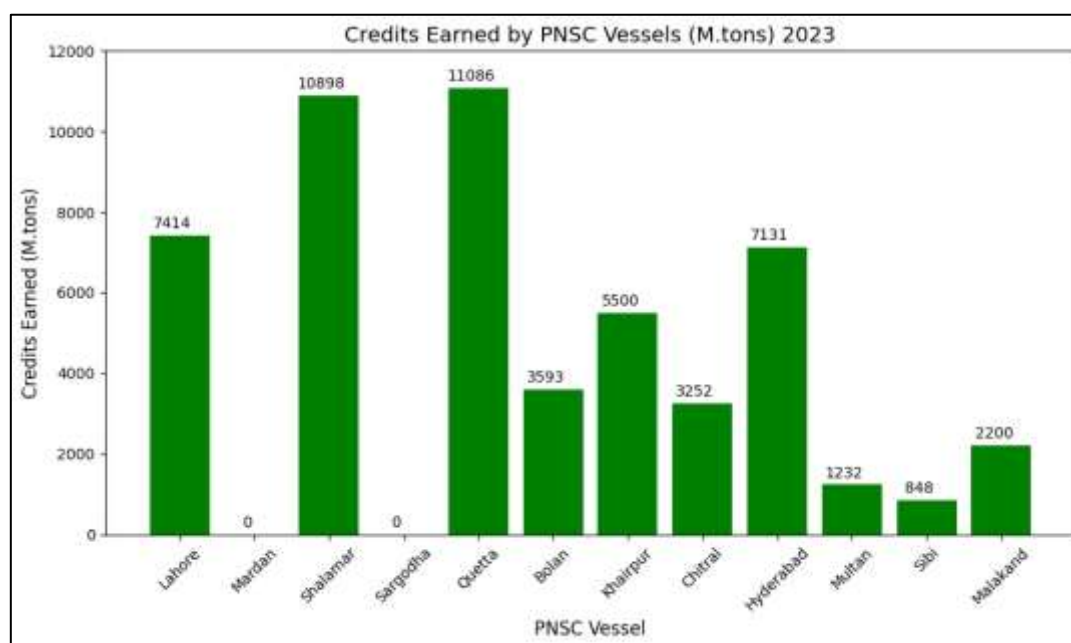


Figure 7.9: Credits earned from each vessel.

c. The net credits earned after the reductions of excessive emissions are 24794 metric tons. According to the EU-ETS, the market price of CO₂ per metric ton is EUR 80/\$87.15 as of October 2024. Hence, the total market price of the credits estimated will be:

$$\begin{aligned} \text{Credits} &= 24794 \times 80 \text{ EUR}/\$87.15 \\ \text{Credits} &= 1983520 \text{ Euros or } 2160797 \text{ Dollars} \end{aligned}$$

d. **Nitrous Oxide Emissions.** The nitrous oxide emissions were estimated from the same method as per shown in graph (figure 7.10). The results show that in 2023, Mardan and Sargodha showed emissions exceeding the values from 2022. The concentrations of N₂O found in the emissions can

cause global warming 298 times more than CO₂. This capability is known as the GWP. The amount of N₂O is also being reported in this study as equivalent to CO₂ (eCO₂ in tons) to understand the warming potential. The CO₂ equivalent values project an estimated cost of N₂O as shown in table 7.6:

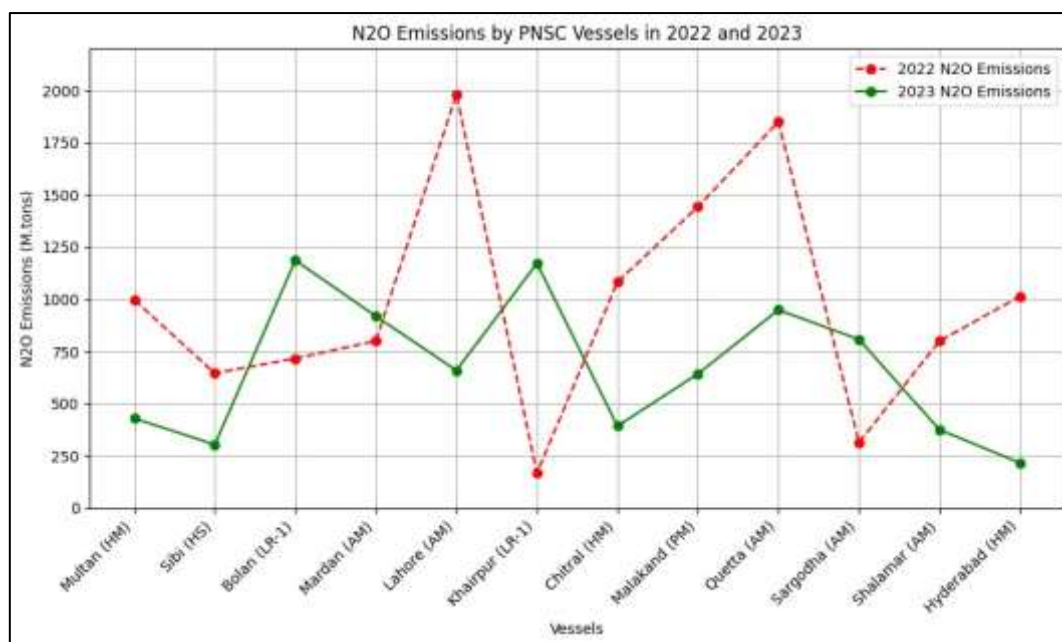


Figure 7.10: Nitrous Oxide Emissions from PNSC Fleet.

Table 7.6: Emission factors and CO₂ Equivalent Values of N₂O

Fuel Type	Emission Factor (N ₂ O)
Light Fuel Oil (LFO)	0.256
Heavy Fuel Oil (HFO)	0.121
Marine Gas Oil (MGO)	0.129
Diesel	0.129

Table 7.7

Aframax	2022 N ₂ O Emissions	2023 N ₂ O Emissions
Mardan	94.81	226.06
Lahore	231.37	161.44
Quetta	215.47	110.68
Sargodha	79.03	198.5
Shalamar	200.13	89.74
LR-1	2022 N ₂ O Emissions	2023 N ₂ O Emissions
Bolan	176.72	139.63
Khairpur	92.5	136.51
Handymax	2022 N ₂ O Emissions	2023 N ₂ O Emissions
Chitral	128.51	96.74
Hyderabad	128.19	53.01
Multan	118.7	105.65
Handysize	2022 N ₂ O Emissions	2023 N ₂ O Emissions
Sibi	107.7	73.94
Panamax	2022 N ₂ O Emissions	2023 N ₂ O Emissions

<i>Malakand</i>	220.83	156.68
Total	489751.08 tons	422762.34 tons
Emissions Reduced	489751.08 - 422762.34 = 66988.74 tons	
Credits Earned	(CO ₂ Price X CO ₂ e values of N ₂ O) 66988.74 x 80 euros= 5359099.2 Euros	

e. *Methane Emissions:* Methane (CH₄) is one of the potent greenhouse gases, known to augment the warming procedure of the planet. When quantifying the emissions in decarbonizing a particular project, methane emissions are also to be considered. In this study, the estimated methane emissions are elaborated in figure 7.11 and its carbon equivalency is presented in table 7.7. As per IPCC, methane has the tendency to accelerate the warming process 28 times more than CO₂.

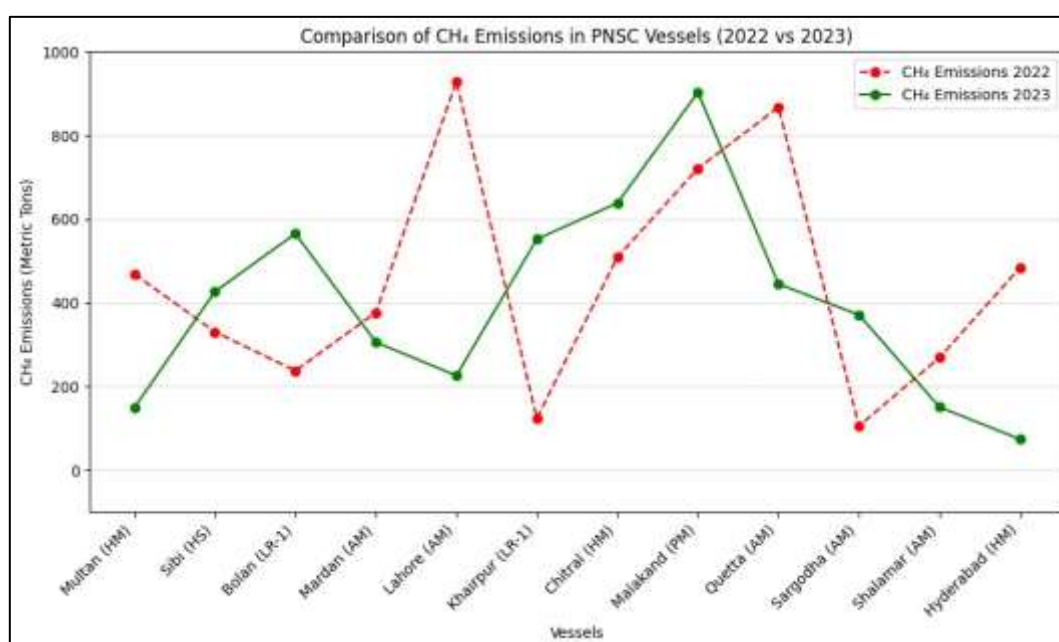


Figure 7.11: Methane Emissions from PNSC Ships.

f. As illustrated from the graph, exceeding emissions are observed from Quetta, Bolan and Khairpur. However, CO₂ and N₂O emissions from these vessels were less. This suggests that inappropriate fuel burning, extended use of a vessel reaching close to its operational deadline, less engine efficiency and methane slip due to improper methane capture through technology maybe the possible reasons for exceeding methane emissions. The CO₂e values of methane and the credits are presented in the table 7.8.

Table 7.8: Emission factors and CO₂e Methane Emission and Credit Values

Fuel Type	Emission Factor (CH₄)
<i>Light Fuel Oil (LFO)</i>	0.12
<i>Heavy Fuel Oil (HFO)</i>	0.04
<i>Marine Gas Oil (MGO)</i>	0.129
<i>Diesel</i>	0.129

Table 7.9

Aframax	2022 CH₄ Emissions	2023 CH₄ Emissions
<i>Mardan</i>	8.74	12.7
<i>Lahore</i>	21.64	9.02
<i>Quetta</i>	20.23	103.85
<i>Sargodha</i>	4.33	11.17
<i>Shalamar</i>	11.05	4.76
LR-1	2022 CH₄ Emissions	2023 CH₄ Emissions
<i>Bolan</i>	9.94	12.84
<i>Khairpur</i>	1.17	7.68
Handymax	2022 CH₄ Emissions	2023 CH₄ Emissions
<i>Chitral</i>	11.8	5.43
<i>Hyderabad</i>	10.96	2.97
<i>Multan</i>	10.85	5.85
Handysize	2022 CH₄ Emissions	2023 CH₄ Emissions
<i>Sibi</i>	6.63	4.05
Panamax	2022 CH₄ Emissions	2023 CH₄ Emissions
<i>Malakand</i>	15.09	14.46
Total	3708.04 tons	5453.84 tons
Emissions Reduced	3708.04 – 5453.84 = -1745.8 tons	
Credits Earned	(CO ₂ Price X CO ₂ e values of CH ₄) no credits earned as emissions have increased in 2023	

CHAPTER 6

Conclusion and Recommendations

m. Ninety percent of the world's commodities are moved by the global shipping industry, which is an essential component of international trade and supports global supply chains. However, there are environmental repercussions associated with this important role. In terms of its carbon footprint, the industry is estimated to contribute 2-3% yearly to world emissions of GHGs, chiefly CO₂. The Paris Agreement and other international climate commitments aim to keep global temperature increases to well below 2°C. Considering this impact, IMO and other global bodies have emphasized the urgent need for emissions reductions within the sector.

n. IMO has implemented policies and plans that encourage the maritime sector to use less energy and produce fewer emissions. Examples of these are the EEDI and the CII. By 2050, these restrictions seek to reduce greenhouse gas emissions by at least 50% from 2008 levels and by 40% from 2030 levels. As a result, shipping firms are embracing more and more environmentally friendly procedures, such as modifying their fleets, route optimization, and dedicating resources into low-carbon technologies like hydrogen, biofuels, and wind-powered propulsion.

o. PNSC is a significant entity in Pakistan's maritime sector managing the main trading activity through its 12 ships. The organization holds the 12% share in the total trade of the country. This figure can greatly enhance with inclusion of newer technologies and more ships to the current fleet. While PNSC's efforts to install EEXI and CII systems show progress toward decarbonization, still, targeted improvements in fuel quality, combustion technology, and emissions monitoring are necessary. These actions will help PNSC achieve further emissions reductions, optimize carbon credits, and align more closely with international environmental standards. In future, it is recommended for PNSC to consider following actions to improve its transition into greener shipping:

(1) In the coming years, MARPOL Annex VI regulations will be applied compulsorily to all ships. This will require PNSC to reduce other air pollutants as well such as CO_x, NO_x, SO_x, particulate matter, Ozone depleting substances etc. Fleet change to Tier-III engines and above are necessarily required.

(2) In order to make a carbon credit venture, PNSC should ensure regular monitoring and maintenance of its data from its ships and its workplace as well. PNSC need to hire qualified and expert consultants which can ensure credits generation and registration.

(3) PNSC should get verified by entities such as Verra or Gold Standard, to acquire validated and verified carbon credits from VVBs.

(4) PNSC should start working on net-zero emission goal as set by IMO by 2050. For this, a very comprehensive study to reach 40% target by 2030 should be initiated. In this perspective, PNSC data from 2008 should be analyzed to

assess the percent of emission reduction. This will assist in reshaping sustainability goals and practices for PNSC.

(5) Investment in current offset projects in collaboration will significantly assist PNSC to decarbonize its organization and reach the 40% emission reduction goal by 2030.

(6) In terms of green initiatives, PNSC can work on installation of pyrolysis technology to reduce carbon emissions. Pyrolysis is a process in which organic material is converted into simpler products through heating in the absence of oxygen. Through this process, biochar can be made, which acts as a soil fertilizer. Bio-oil can also be made which can be refined further for energy production.

(7) The Life-Cycle Assessment (LCA) methodology should be adopted by PNSC. As described by IMO, this assessment focuses on the analysis of greenhouse gas emissions from fuel production to the end-use by a ship, also known as "Well-to-Wake". It arises from the combination of two parts: "Tank-to-Wake" (sometimes called "Tank-to Propeller"), which is the part that goes from the ship's fuel reservoir to the exhaust, and "Well-to-Tank," which is the part that goes from primary production to the fuel's carriage in the tank of the ship, additionally referred to as upstream emissions.

REFERENCES

- A.P. Moller - Maersk. (2022). ESG Progress Report 2022: Accelerating Our Decarbonisation Journey. <https://www.maersk.com/about/sustainability/reports>
- Asariotis, R., Benamara, H., & Cormier, R. (2015). The role of maritime transport in global trade: A global perspective. International Transport Forum.
- Asian Development Bank. (2023). Financing for green shipping initiatives. Retrieved from <https://www.adb.org>
- Boyd, E., Corbera, E., & Estrada, M. (2009). UNFCCC land-based mitigation and the Clean Development Mechanism: A review of the literature. *Mitigation and Adaptation Strategies for Global Change*, 13(6–7), 545–569. <https://doi.org/10.1007/s11027-007-9136-4>
- Carbon Trust. (2021). Net zero: Principles and practice. The Carbon Trust. <https://www.carbontrust.com/resources/net-zero-principles-and-practice>
- Christodolou, A., & Cullinane, K. (2023). Assessing the impact of climate change on maritime transport: Challenges and opportunities. *Maritime Economics & Logistics*, 25(2), 171-188. <https://doi.org/10.1057/s41278-023-00233-3>
- Cullinane, K., & Yang, H. (2022). Sustainability in the maritime sector: Perspectives on the role of shipping. *Maritime Policy & Management*, 49(6), 789-802. <https://doi.org/10.1080/03088839.2022.2067093>
- Coulter, A., Li, S., & Wang, Y. (2007). Emission reduction in maritime shipping: International initiatives and challenges. *Journal of Cleaner Production*, 15(8), 798-807. <https://doi.org/10.1016/j.jclepro.2006.03.013>
- Davis, C. L., & Klemick, H. (2020). The impact of marine pollution regulations on shipping: A review of the evidence. *Marine Pollution Bulletin*, 151, 110774. <https://doi.org/10.1016/j.marpolbul.2019.110774>
- DNV GL. (2021). Maritime forecast to 2050: Energy transition outlook 2021. Retrieved from <https://www.dnv.com/energy-transition-outlook/>
- Dominioni, G., & Englert, J. (2022). Navigating the future: The role of policy in decarbonizing shipping. *Transport Policy*, 121, 36-45. <https://doi.org/10.1016/j.tranpol.2022.05.008>
- Dorsman, A., Westerman, W., & Karmann, A. (Eds.). (2016). *Financial Aspects in Energy: A European Perspective*. Springer.
- Faber, J., van der Ploeg, M., & K. M. (2020). Shipping and climate change: A review of the international regulations and their impacts. *Transport Reviews*, 40(3), 277-298. <https://doi.org/10.1080/01441647.2019.1605301>

- Global Environment Facility. (2022). Supporting global environmental sustainability. Retrieved from <https://www.thegef.org>
- Goldstein, A., Turner, W. R., Spawn-Lee, S. A., Anderson-Teixeira, K. J., Cook-Patton, S. C., Fargione, J., & Hole, D. G. (2020). Protecting irrecoverable carbon in Earth's ecosystems. *Nature Climate Change*, 10(4), 287–295.
- Gold Standard. (2020). Establishing Net-Zero Targets: Science-Based Approaches for Climate Action. Gold Standard Foundation. <https://www.goldstandard.org/resources/establishing-net-zero-targets>
- Google. (2021). 2021 Environmental Report: Our progress toward a more sustainable future. Google LLC. <https://sustainability.google/reports/>
- Green Climate Fund. (2023). Climate finance for low-carbon development. Retrieved from <https://www.greenclimate.fund>
- Green, J. F. (2021). Does carbon pricing reduce emissions? A review of ex-post analyses. *Environmental Research Letters*, 16(4), 043004. <https://doi.org/10.1088/1748-9326/abde8a>
- Hesdevik, A. (2022). Green shipping networks as drivers of decarbonization in offshore shipping companies. *Maritime Transport Research*, 3, 100053. <https://doi.org/10.1016/j.martra.2022.100053>
- Issa, M., Assaf, A., & Yang, H. (2022). Compliance strategies for the International Maritime Organization's GHG emission targets. *Maritime Policy & Management*, 49(1), 90-102. <https://doi.org/10.1080/03088839.2021.1934045>
- Issa, M., Ilinca, A., & Martini, F. (2022). Ship energy efficiency and maritime sector initiatives to reduce carbon emissions. *Energies*, 15(22), 7910. <https://doi.org/10.3390/en15227910>
- International Maritime Organization (IMO). (2018). Initial IMO strategy on reduction of GHG emissions from ships. Retrieved from <https://www.imo.org/en/OurWork/ClimateChange/Pages/default.aspx>
- International Maritime Organization (IMO). (2020). Fourth IMO greenhouse gas study 2020. Retrieved from <https://www.imo.org/en/OurWork/ClimateChange/Pages/default.aspx>
- Karyoti, A. (2023). Regulatory frameworks for reducing GHG emissions in shipping: An analysis of recent developments. *Journal of Cleaner Production*, 295, 126287. <https://doi.org/10.1016/j.jclepro.2021.126287>
- Klopott, S., Wanke, P., & Römer, E. (2023). The future of shipping: Trends in maritime emissions. *Environmental Science & Policy*, 134, 189-198. <https://doi.org/10.1016/j.envsci.2022.07.012>

- Lagouvardou, S., Psaraftis, H. N., & Zis, T. (2020). A literature survey on market-based measures for the decarbonization of shipping. *Sustainability*, 12(9), 3672. <https://doi.org/10.3390/su12093672>
- Maersk. (2023). Green bond program for zero-carbon shipping. Retrieved from <https://www.maersk.com>
- Maersk. (2022). A.P. Moller-Maersk Sustainability Report 2022. <https://www.maersk.com/about/sustainability/reports>
- Mediterranean Shipping Company (MSC). (2021). MSC Sustainability Report 2021: Partnering for a Better Future. <https://www.msc.com/sustainability>
- Metzger, D. (2022). Market-based measures and their impact on green shipping technologies. *WMU Journal of Maritime Affairs*, 21(1), 3-23. <https://doi.org/10.1007/s13437-022-00247-3>
- Michaelowa, A., & Purohit, P. (2007). Additionality determination of Indian CDM projects: Can Indian CDM project developers outwit the CDM Executive Board? *Climate Policy*, 7(2), 104–117. <https://doi.org/10.3763/cpol.2007.0216>
- Microsoft Corporation. (2021). 2021 Environmental Sustainability Report: A Year of Progress on the Path to Carbon Negative. <https://www.microsoft.com/en-us/sustainability/emissions-impact-dashboard>
- Norsk Industri. (2022). The Green Shipping Programme Annual Report 2022. The Federation of Norwegian Industries. <https://www.norskindustri.no/>
- Plan Vivo Foundation. (2020). The Plan Vivo Standard: Requirements for Community Land Use and Forestry Projects (2020 edition). Plan Vivo Foundation. <https://www.planvivo.org/project-certification>
- Port Economics, Management and Policy (2023), Ports and Container shipping <https://porteconomicsmanagement.org/pemp/contents/part6/ports-and-container-shipping/>
- Smith, T., & Jullumstrø, L. (2019). Environmental impacts and policy challenges in maritime carbon offsetting: A systems-based evaluation.
- Tan, Y., Wu, Z., & Zhao, X. (2022). Emission reduction strategies for the maritime sector: A review. *Sustainability*, 14(4), 2002. <https://doi.org/10.3390/su14042002>
- Traut, M., Bouman, E. A., Lindstad, H., Bows-Larkin, A., Smith, T., & Nelissen, D. (2022). Decarbonising maritime transport: The scale of the challenge and policy implications. *Transportation Research Part D: Transport and Environment*, 107, 102239. <https://doi.org/10.1016/j.trd.2022.102239>
- UNCTAD (2023), Handbook of Statistics. <https://hbs.unctad.org/merchant-fleet/>

- UNCTAD. (2023). Review of Maritime Transport 2023. United Nations Conference on Trade and Development. Retrieved from <https://unctad.org/webflyer/review-maritime-transport>
- UNFCCC. (2021). Climate resilience and funding mechanisms. Retrieved from <https://www.unfccc.int>
- UNFCCC. (2016). Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP 11). United Nations Framework Convention on Climate Change. <https://unfccc.int/documents/9581>
- UNFCCC. (2012). Benefits of the Clean Development Mechanism (CDM): 2012 update. United Nations Framework Convention on Climate Change. https://cdm.unfccc.int/about/dev_ben/index.html
- UNFCCC. (2011). Benefits of the Clean Development Mechanism (CDM). United Nations Framework Convention on Climate Change. https://cdm.unfccc.int/about/dev_ben/index.html
- Verra. (2021). Verified Carbon Standard (VCS) Program Rules and Requirements. Verra. <https://verra.org/project/vcs-program/>
- World Bank. (2022). Clean energy transitions in maritime transport. Retrieved from <https://www.worldbank.org>
- Wu, Y., Chen, H., & Liu, J. (2022). The role of the IMO in regulating maritime emissions: Progress and challenges. *Marine Policy*, 133, 104753. <https://doi.org/10.1016/j.marpol.2021.104753>
- Xue, Y., Zhang, D., & Liu, Z. (2024). The impact of maritime trade on global GHG emissions: Projections and implications. *Journal of Environmental Management*, 320, 115964. <https://doi.org/10.1016/j.jenvman.2023.115964>