INTRODUCTION TO MARPOL ANNEX VI; ADVANCEMENTS IN GREEN SHIPPING TECHNOLOGIES AND WAY FORWARD FOR PAKISTAN

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CHAPTER 1

INTRODUCTION AND CONTEXTUAL OVERVIEW

1.1 Introduction

a. Maritime transport plays an essential role in the global economy. While it is one of the most energy-efficient modes of transport, it is also a large and growing source of greenhouse gas (GHG) emissions. In 2022, international shipping alone accounted for nearly 3% of the world's greenhouse gas emissions (IEA, 2023). Despite being one of the most efficient freight options, maritime transportation emitted 1,076 Mt of GHG emissions in 2018, of which 1,056 Mt were CO_2 emissions. This is due to the shipping industry being more heavily fossilized than other industries, as oil contributed more than 99% of total energy demands historically (Deng & Mi, 2023). The shipping industry aims to align with a 1.5 degrees Celsius trajectory in accordance with the Paris Agreement and this requires that zero-emission fuels make up 5% of international shipping fuels by 2030 (UNCTAD, 2022).

b. The phrase "green shipping" is often used as a blanket term to refer to the transition shipping businesses are making towards environmentally friendly and sustainable methods.

c. Green shipping is specifically concerned with the reduction in exploitation of natural resources and energy during transport through seas, in order to preserve the global environment from GHGs and environmental pollutants generated by ships (Lee & Nam, 2017).The term green shipping encompasses a range of strategies and technologies, which all share the common goals of:

(1) Reducing carbon emissions.

(2) Minimising air and water pollution.

(3) Promoting ecological balance.

d. There are numerous definitions used for the evolving concept of green shipping.

> "*Green shipping is when people or goods are transported through ships using minimum resources and energy as possible, to protect the environment from the pollutants generated by the ships" – www.container-xchange.com/*
>
> *"The concept of 'green shipping' is a transformative approach aimed at minimizing the environmental impact of maritime operations by paving the way for a more sustainable future which prioritises the planet and its people – not just profit" - www.clarksons.com*

"Green shipping refers to the transportation of people or goods by ships with a minimal use of resources and energy in order to safeguard the environment." - International Trade Magazine

1.2 International Conventions Pertaining to Green Shipping

IMO regulates the international operating conditions in seas, which include the environmental safeguards as well, to which green shipping must comply under IMO's regulations. These conditions are described by conventions such as MARPOL 73/78, the Convention on Oil Pollution Preparedness, Response, and Co-operation regarding Hazardous and Noxious Substances (OPRC-HNS), the Anti-fouling Systems (AFS) Convention, the Ballast Water Management (BWM) Convention, and the Ship Recycling Convention. The overall purpose is to manage and monitor all harmful substances (marine pollutants and air pollutants) emitted from ships (Lee & Nam, 2017).

1.3 The International Convention for the Prevention of Pollution from Ships (MARPOL)

a. The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes.

b. The MARPOL Convention was adopted on 2 November 1973 at IMO. The Protocol of 1978 was adopted in response to a spate of tanker accidents in 1976-1977. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention, and a new Annex VI was added which entered into force on 19 May 2005. MARPOL consists of following six annexes.

(1) Annex I - **Regulations for the Prevention of Pollution by Oil** (entered into force 2 October 1983)

(2) Annex II - **Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk** (entered into force 2 October 1983, provisions took effect from 6 April 1987)

(3) Annex III **- Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form** (entered into force 1 July 1992)

(4) Annex IV - **Prevention of Pollution by Sewage from Ships** (entered into force 27 September 2003)

(5) Annex V - **Prevention of Pollution by Garbage from Ships** (entered into force 31 December 1988)

(6) Annex VI - **Prevention of Air Pollution from Ships** (entered into force 19 May 2005)

c. As of 1 November 2022, MARPOL Annex VI has 105 Parties, representing between them 96.81% of world merchant shipping by tonnage.

1.4 MARPOL Annex VI – Overview and Historical Evolution

a. Under MARPOL Annex VI, the reduction of atmospheric emissions from ships and shipping operations is the main focus. The focus has predominantly fallen on emission control under the 2015 Paris Agreement which obligates sits member states to reduce their emissions from all sectors to limit the global warming to either 1.5 °C or well below 2 °C by the end of this century.

b. The MARPOL Annex VI, which entered into force on 19 May 2005, deals with the prevention of air pollution from ships. Amendments were made to the MARPOL Annex VI on 1 November 2022, which made it mandatory for all ships to calculate their attained Energy Efficiency Existing Ship Index (EEXI) to measure their energy efficiency and to initiate the collection of data for the reporting of their annual operational carbon intensity indicator (CII) and CII rating.

c. Simultaneously, in 2018, the International Maritime Organization (IMO) set forth an initial strategy to reduce ship-generated greenhouse gas (GHG) emissions. This strategy was updated as "IMO GHG Strategy 2023" by member states, committing to achieve net-zero GHG emissions by 2050 and establishing interim reduction goals of 20% by 2030 and 70% by 2040, compared to 2008 levels (*2023 IMO Strategy on Reduction of GHG Emissions from Ships*). This enhanced strategy, while not legally binding in itself, is supported by enforceable and legally binding measures such as the EEXI and the CII under the MARPOL treaty. Countries must ensure that their fleets comply with these standards as many member countries may deny port entry to non-compliant vessels. The IMO greenhouse gas Strategy 2023 has identified some short-term measures to currently in force to reduce GHG emissions from ships by enhancing the energy efficiency of the global fleet. These regulations, adopted in 2021 and effective since 1 January 2023, require ships to measure their energy efficiency by calculating their attained Energy Efficiency Existing Ship Index (EEXI), and to continuously improve their annual operational carbon intensity indicator (CII) as defined in their CII rating (*PREVIEW: Marine Environment Protection Committee (MEPC 82), 30 September - 4 October 2024*).

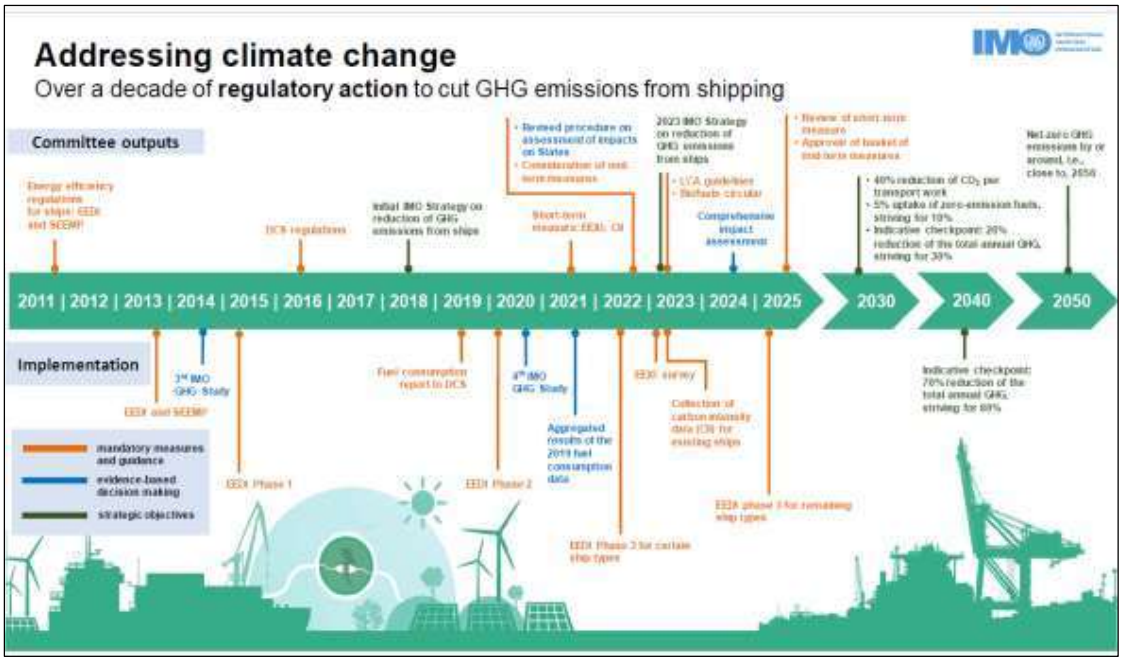

***Figure 3.1**: Timeline envisaged by IMO to reach Net Zero emissions from shipping, in line with Paris Agreement. Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx*

1.5 MARPOL Annex VI Chapters and Regulations

a. The MARPOL Annex VI has five chapters with a total of 31 Regulations. "Clause by clause analysis of MARPOL Annex VI" prepared by IMO has been annexed with this study. MARPOL Annex VI provides requirements for the control of emissions from ships such as ozone depleting substances (ODS), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM), volatile organic compounds (VOCs), greenhouse gases (GHG) and other pollutants. Further, it provides criteria and procedures in determining NOx, SOx and particulate matter (PM) emission control area to any sea area as well as to any port area as designated by IMO.

b. Table 3.1 provides a summary of the chapters and relevant regulations.

c. Chapter 3 and Chapter 4 of the Annex i.e., "Requirements for control of emissions from ships" and "Regulations on the carbon intensity of international shipping" are discussed in further detail in this report for the sake of clarity and focus.

Table 3.1

MARPOL Annex VI Chapters and Regulations	
Chapter 1 - General	▪ Regulation 1 – Application ▪ Regulation 2 – Definitions ▪ Regulation 3 – Exceptions and Exemptions ▪ Regulation 4 – Equivalents

MARPOL Annex VI Chapters and Regulations	
Chapter 2 - Survey, certification and means of control	▪ Regulation 5 – Surveys ▪ Regulation 6 – Issue or endorsement of Certificates and Statements of Compliance related to fuel oil consumption reporting and operational carbon intensity rating ▪ Regulation 7 – Issue of a Certificate by another Party ▪ Regulation 8 – Form of Certificates and Statements of Compliance related to fuel oil consumption reporting and operational carbon intensity rating ▪ Regulation 9 – Duration and validity of Certificates and Statements of Compliance related to fuel oil consumption reporting and operational carbon intensity rating ▪ Regulation 10 – Port State control on operational requirements ▪ Regulation 11 – Detection of violations and enforcement
Chapter 3 – Requirements for control of emissions from ships	▪ Regulation 12 – Ozone-depleting substances ▪ Regulation 13 – Nitrogen oxides (NOx) ▪ Regulation 14 – Sulphur oxides (SOx) and particulate matter ▪ Regulation 15 – Volatile organic compounds (VOCs) ▪ Regulation 16 – Shipboard incineration ▪ Regulation 17 – Reception facilities ▪ Regulation 18 – Fuel oil availability and quality
Chapter 4 – Regulations on the carbon intensity of international shipping	▪ Regulation 19 – Application ▪ Regulation 20 – Goals ▪ Regulation 21 – Functional requirements ▪ Regulation 22 – Attained Energy Efficiency Design Index (attained EEDI) ▪ Regulation 23 – Attained Energy Efficiency Existing Ship Index (attained EEXI) ▪ Regulation 24 – Required EEDI ▪ Regulation 24 – Required EEXI ▪ Regulation 26 – Ship Energy Efficiency Management Plan (SEEMP) ▪ Regulation 27 – Collection and reporting of ship fuel oil consumption data ▪ Regulation 28 – Operational carbon intensity ▪ Regulation 29 – Promotion of technical cooperation and transfer of technology relating to the improvement of energy efficiency of ships
Chapter 5 - Verification of compliance with the provisions of this Annex	▪ Regulation 30 – Application ▪ Regulation 31 – Verification of compliance

1.6 MARPOL Annex VI, Chapter 3 – Requirements of Reduction of Key Air Pollutants from Ships under MARPOL Annex VI and the IMO GHG Strategy

a. For over 50 years HFO (heavy fuel oil) has dominated the maritime industry. This type of fuel is much more available and cheaper, but very dirty as it contains sulfur and environmentally harmful impurities (Čampara et al., 2018). The MARPOL Annex VI deals with limiting and ultimately halting the use of fuels that release harmful substances to the sir such as Ozone Depleting Substances (ODS), NOx, Sox, Volatile Organic compounds (VOCs) and other pollutants.

(1) **Control of Ozone Depleting Substances on Board Ship**. In Regulation 12, deliberate emissions of ODS, which include halons and chlorofluorocarbons (CFCs), are prohibited. Also, new installations containing ODS are prohibited on all ships. Ozone layer depletion causes increased UV radiation levels at the Earth's surface, which is damaging to human health. Negative effects include increases in certain types of skin cancers, eye cataracts and immune deficiency disorders.

(2) **NOx Reduction**. In Regulation 13, NOx emission limits from diesel engines have been determined. The NOx Technical Code has been adopted to specify the requirements for the testing, survey and certification of marine diesel engines in order to comply with the NOx emission limits of the aforementioned Regulation. NOx emission from ships is formed from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. NOx can cause breathing problems, headaches, chronically reduced lung function, irritation and other health problems; contributes ocean acidification. NOx emission can be reduced by primary methods such as retard injection, fuel nozzle modification, change of compression ratio, water direct injection, water emulsification, exhaust gas recirculation (EGR) and secondary method such as selective catalytic reduction (SCR) (Rahman & Ahmed, 2020).

(3) **SOx Reduction**. In Regulation 14, It is intimated that the sulphur content of any fuel oil used on board ship shall not exceed to 4.5% m/m prior to 01 January 2012; 3.5% m/m on and after 01 January 2012; and 0.5% m/m on and after 01 January 2020. In emission control areas such as the Baltic sea and the North Sea, sulphur content of any fuel oil shall not exceed the stringent measures of 1.5% m/m prior to 01 July 2010; 1.0% m/m on and after 01 July 2010; and 0.10% m/m on and after 01 January 2015. SOx are formed during combustion process in the engine of the ship due to the presence of sulphur in the fuel. SOx can harm human respiratory system and make breathing difficult. Reduction of SOx can be achieved by using fuels with low sulphur content; installation of exhaust gas cleaning system (ECGS) or scrubbers; and use of alternative fuels such as LNG (US EPA, 2016).

(4) **Volatile Organic Compounds (VOCs) and incineration on ships**. In Regulation 15, provisions on emissions of VOCs from a tanker vessel may be applied if a Party intended to regulate such emissions on its ports or terminals. There are several commercially available technologies for treating VOC emissions from ship loading. These include thermal oxidation, absorption, membrane separation and cryogenic condensation (OCIMF, 2019).

(5) In Regulation 16, shipboard incineration is controlled, prohibiting burning on board such as contaminated packing materials, polychlorinated biphenyls (PCBs) and exhaust gas cleaning system residues, among others.

1.7 MARPOL Annex VI, Chapter 4 - Regulations on the carbon intensity of international shipping

a. Initial IMO GHG Strategy devised in 2018 advocates the energy efficiency activities as below:

(1) Short term measures: Are those that can be defined and finalized between 2018 and 2023.

(2) Mid-term measures are those that will be those beyond short term and for discussion by the IMO between 2023 and 2030.

(3) Long-term measures are those measures that are going to be finalized, regulated and agreed by the IMO beyond 2030.

b. These measures have also been incorporated into MARPOL Annex VI in the revised version which came into force on 1 Nov 2022. These measures are discussed in this section.

1.8 Short-term measures for reducing GHG emissions from ships

a. **Energy Efficiency Design Index (EEDI)**. The EEDI is an important technical measure aiming at promoting the use of more energy efficient equipment and engines for the design of new ships in order to make them less polluting. The EEDI requires a minimum energy efficiency level per capacity mile (e.g. tonne mile) for different ship type and size segments. The EEDI provides a specific figure for an individual ship design, expressed in grams of carbon dioxide (CO2) per ship's capacity-mile (the smaller the EEDI, the more energy efficient the ship design) and is calculated by a formula based on the technical design parameters for a given ship (*MEPC.324(75)*).

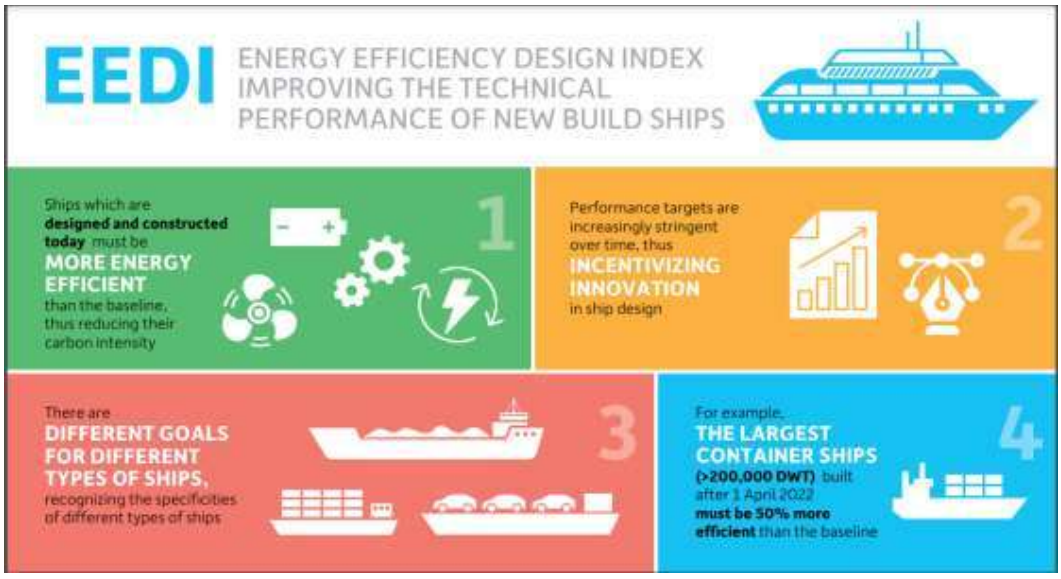

Figure *3.2*. EEDI overview. Source: https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/EEXI%20and%20CII%20Sheets/Infographic%2004_EEDI.pdf

b. **Energy Efficiency Existing Ship Index (EEXI).** A ship's attained EEXI indicates its energy efficiency compared to a baseline. The attained EEXI will then be compared to a required Energy Efficiency Existing Ship Index based on an applicable reduction factor expressed as a percentage relative to the Energy Efficiency Design Index (EEDI) baseline. It must be calculated for ships of 400 gross tonnage and above, in accordance with the different values set for ship types and size categories. The calculated attained EEXI value for each individual ship must be below the required EEXI, to ensure the ship meets a minimum energy efficiency standard.

***Figure 3.3**: EEXI overview. Source: https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/EEXI%20and%20CII%20Sheets/Infographic%2002_EEXI.pdf*

c. Ship Energy Efficiency Management Plan (SEEMP)

(1) Both new and existing ships are required to keep on board a ship-specific Ship Energy Efficiency Management Plan (SEEMP). The SEEMP establishes a mechanism to improve energy efficiency using operational measures.

(2) The SEEMP for ships of 5,000 gross tonnage and above shall include a description of the methodology that will be used to collect the data required by regulation 27.1 of MARPOL Annex VI and the processes that will be used to report the data. On or before 1 January 2023, it shall also include a description of the methodology that will be used to calculate the ship's attained annual operational carbon intensity indicator (CII), and the required annual operational CII, required by regulation 28 of MARPOL Annex VI.

d. Carbon Intensity Index (CII)

(1) This regulation applies to every ship of 5,000 gross tonnage and above and requires that each ship calculate the attained annual operational carbon intensity indicator (CII), after the end of calendar year 2023 and after the end of each following calendar year. The regulation also establishes the method of determining the required annual operational CII, and operational carbon intensity rating (A to E), taking into account the guidelines developed by the IMO2.

(2) Where a ship is found not to have achieved the required operational carbon intensity rating then it is required to develop a plan of corrective action within the ship's SEEMP, subject to verification, to achieve the required annual operational CII.

(3) From 1 January 2023 it became mandatory for all ships to calculate their attained Energy Efficiency Existing Ship Index (EEXI) to measure their energy efficiency and to initiate the collection of data for the reporting of their annual operational carbon intensity indicator (CII) and CII rating.

***Figure 3.4**: Overview of CII. Source: https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/EEXI%20and%20CII%20Sheets/Infographic%2003_CII.pdf*

How do the ratings work?

a. Based on a ship's CII, its carbon intensity is rated A, B, C, D or E (where A is the best). The rating indicates a major superior, minor superior, moderate, minor inferior, or inferior performance level. The performance level is recorded in a "Statement of Compliance" to be further elaborated in the ship's Ship Energy Efficiency Management Plan (SEEMP).

b. A ship rated D for three consecutive years, or E for one year, has to submit a corrective action plan to show how the required index of C or above will be achieved.

c. A ship run on a low-carbon fuel can clearly get a higher rating than one running on fossil fuel, but there are many things a ship can do to improve its rating, through measures such as:

(1) Hull cleaning to reduce drag;

(2) Speed and routeing optimization;

(3) Installation of low energy light bulbs; and

(4) Installation of solar/wind auxiliary power for accommodation services.

1.9 Mid-term measures for GHG reduction

A set of proposed binding “mid-term measures” for GHG reduction are currently being considered by Member States, with a view to adoption in late 2025, including:

a. A technical element, i.e., a global marine fuel standard regulating the phased reduction of a marine fuel's GHG intensity;

b. An economic element, i.e., a maritime GHG emissions pricing mechanism (UNCTAD, 2022).

CHAPTER 2

ADVANCEMENTS IN GREEN SHIPPING TECHNOLOGIES

This chapter delves on the advancements in Green Shipping technologies in compliance with the MARPOL Annex VI including Green Ship designs, international best practices and success stories and international collaborations and partnerships in the sector.

2.1 Green Design Technologies for Shipping

Among the innovative developments for green shipping, efficient systems, such as higher engine efficiency and better water cooling are foremost, which dramatically reduce environmental impact. According to a report by Marine Atlas (source: https://marine-digital.com/article_green_ship),

a. An optimized cooling system can save up to 25% of electricity and 1.5% of fuel.

b. Greener engines can minimize NOx output by up to 35% and up to zero SOx emission by using an exhaust scrubber.

b. Shipbuilders focusing on integrating solar panels on ships can save up to 20% in fuel and, accordingly, harmful emissions.

c. Newly developed propellers save up to 4% fuel. The Speed injector, which improves efficiency at high speeds, can save up to 5% fuel and new body paint technologies have been improved to reduce friction, which has a positive effect on consumption by up to 8%.

d. Fuel Optimization System can be used to collect data from sensors on the ship, satellites, and embedded trackers and process the information using machine learning algorithms to presents recommendations on the optimal route in terms of economy.

e. Slow steaming, which means slowing down the speed of the ship is not a new concept for the shipping industry. It is one of the efficient green shipping methods to reduce emission. Seas At Risk, an environmental organisation which has been requesting the curb of the ship speed limit, has conducted a study that revealed, by reducing the speed by 10% it can reduce emissions by 19%. It reduces the waiting time of the ship for port call and leans on Just-in-time arrival. Many shipping companies are already reaping the economic benefits of this method. Maersk has been slow steaming since 2007, which has helped decrease the engine load by 35% without any technical problems (*Green*

Shipping, 2019). Some other design initiatives for greener shipping are presented in figure 3.5.

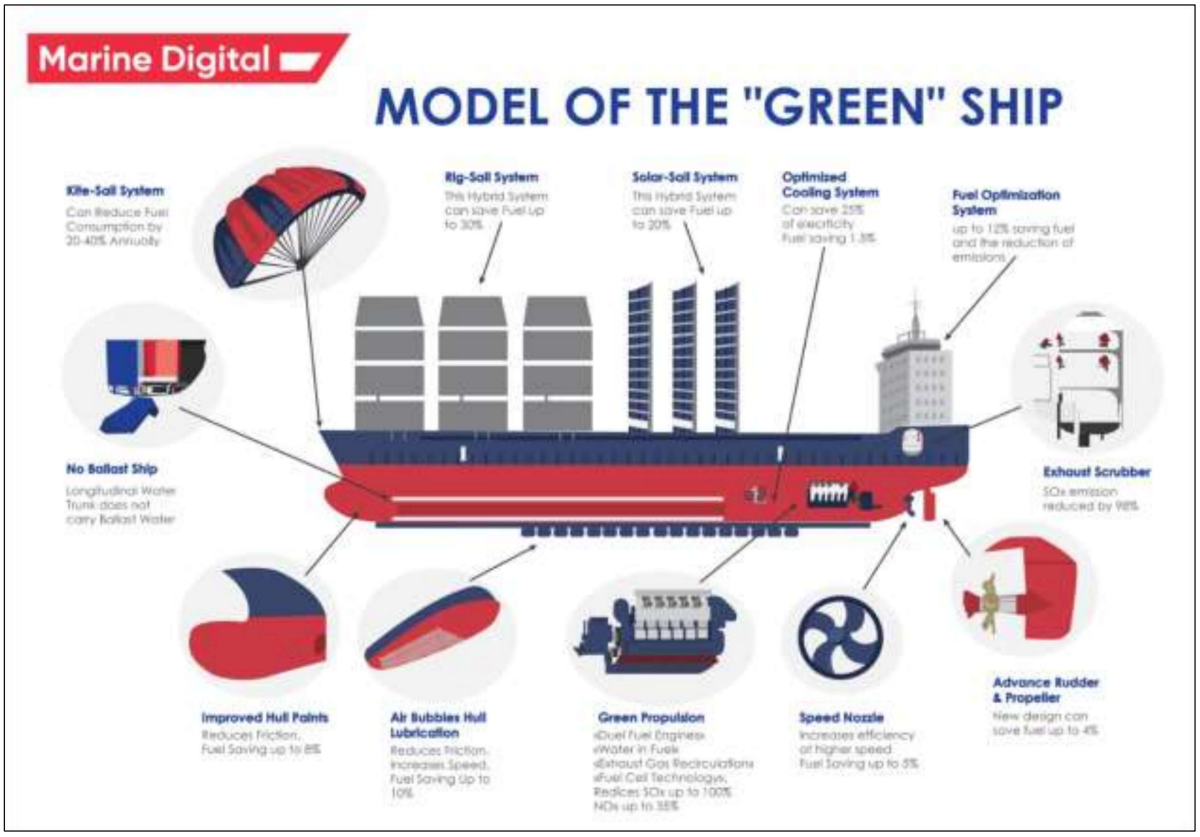

***Figure 3.5**: Model of a "Green Ship" as directed by IMO regulations. Source: https://marine-digital.com/article_green_ship*

2.2 Potential of Biofuels and other emerging fuels

Each renewable energy fuel varies in terms of benefits and challenges. The choice of fuel depends on factors such as the supply chain, engine technology, environmental impacts and production costs. The production costs of these alternative fuels and their availability will ultimately dictate the eventual deployment of renewable energy fuels. While renewable fuels production costs are currently high, in the next decades renewable fuels will become competitive (IRENA, 2021).

a. LNG as an alternate fuel:

(1) Liquified Natural Gas is an alternative fuel option for ships. But this alternative raises many safety issues. Using LNG as a fuel will reduce CO2 by 20%, along with considerably reducing SOx and NOx.

(2) Hapag-Lloyd has announced that 16 of their ships are ready to operate on LNG. These are ships they acquired from the Arab shipping company UASC that merged with Hapag-Lloyd in 2017. “Sajir”, one of their giant container ships has been running on LNG since 2015. With this new mission, they expect to save 15% to 30% on CO2 emission and reduce 90% of SOx and fine dust **(*Green Shipping*, 2019)**.

b. Advanced biofuels:

These are a viable short-term option for the shipping industry because current rules allow for fuel blends of up to 20% without engine modifications, and tests have been conducted utilising a maximum blend of 30%. In addition, important to note that 100% methanol engines are a proven technology; hence, new ships can easily rely 100% on biofuels.

c. Biomethane:

Biomethane could play a role but is likely limited. Production costs are highly dependent on feedstock availability and feedstock market price, which leads to wide cost rages, i.e. USD 25-176/MWh (IRENA, 20221). However, due to scalability and logistical issues, the role of renewable gaseous fuel may be limited, and biogas may be more effective in end-use applications other than fueling the shipping sector.

d. Electro-fuels including methanol and ammonia:

(1) Also known as **e-fuels**, are a class of synthetic fuels which function as drop-in replacement fuels for internal combustion engines. They are manufactured using captured carbon dioxide or carbon monoxide, together with hydrogen obtained from water split (Ababneh & Hameed, 2022).

(2) Renewable e-fuels, methanol and ammonia are the most promising fuels for decarbonising the shipping sector. Of the two options, ammonia is more attractive due to its null carbon content.

e. Hydrogen:

(1) The direct use of green hydrogen via fuel cells (FCs) and internal combustion engines (ICEs) is an option, but mainly for short sailings, e.g. domestic navigation. However, the indirect use of green H_2, i.e. for the subsequent production of e-fuels, will be critical for the decarbonisation of international shipping.

f. Renewable methanol, i.e. bio-methanol, renewable e-methanol and e-ammonia:

These renewable fuels require little to no engine modification and can provide significant carbon emission reductions in comparison to conventional fuels. Renewable e-methanol is of particular interest in the shipping sector. The key constraint on the production of renewable e-methanol is the availability and cost of a CO_2 supply not sourced from fossil fuels. E-ammonia looks set to be the backbone for decarbonising international shipping in the medium and long term. By 2050, production costs of e-ammonia are expected to be between USD 67-114/MWh (IRENA, 2021).

2.3 Emission Control Areas

a. To reduce the sulphur emissions from ships, the IMO (International Maritime Organization) designates Emission Control Areas (ECAs) or Sulphur Emission Control Areas. The first ECA (Baltic Sea) was adopted in 1997 and entered into force in 2005. Later, the IMO designates the other three ECAs (North Sea and English Channel, North American, US Caribbean coasts)(Sun et al., 2020). Initially this regulation was aimed at reducing sulphur oxides (SOX) and is extended in 2005 to include nitrogen oxides (NOX) for several areas. ECAs with restrictions on SOX only are sometimes referred to as SECAs. ECAs with restrictions on NOX are sometimes referred to as NECAs.

b. Ships sailing in emission control areas will have to use fuel oil on board with a sulphur content of no more than 0.10% (mass by mass). The interpretation of “fuel oil used on board” includes use in main and auxiliary engines and boilers.

c. The rules are part of the International Convention for the Prevention of Pollution form ships (MARPOL) Annex VI (Regulations for the Prevention of Air Pollution from Ships), specifically under regulation 13, which cover Nitrogen Oxides (NOx) emissions, and 14, which covers emissions of Sulphur Oxides (SOx) and particulate matter (PM) from ships. The below ECAs are currently ‘active’ according to IMO.

(1) Regulation 13 / MARPOL VI NOx control

i. Baltic Sea Area
ii. North Sea Area
iii. North American Area West
iv. North American Area East
v. Hawaii Area
vi. Unites States Caribbean Area

(2) Regulation 14 / MARPOL Annex VI (SOx and PM)

i. Baltic Sea Area
ii. North Sea Area
iii. North American Area West
iv. North American Area East
v. Hawaii Area
vi. Unites States Caribbean Area

d. IMO's 82nd session of the Marine Environment Protection Committee (MEPC), 30 September to October 4, 2024, has approved at its latest meeting two proposals for the designation of emission control areas (ECAs). The new emission control areas will provide additional protection from air emissions in Canadian Arctic waters and the Norwegian Sea by reducing emissions of sulphur oxides (SOx), particulate matter and nitrogen oxides (NOx) from international shipping.

e. The committee has also adopted a draft resolution designating the Nusa Penida and Gili Matra Islands in the Lombok Strait as a Particularly Sensitive Sea Areas (PSSAs).

f. A Particularly Sensitive Sea Area (PSSA) is a marine area that has been granted special protection due to its unique attributes and significance. By designating PSSAs, the IMO aims to safeguard these vital regions from the impacts of shipping and other maritime activities (*PREVIEW: Marine Environment Protection Committee (MEPC 82), 30 September - 4* October *2024*).

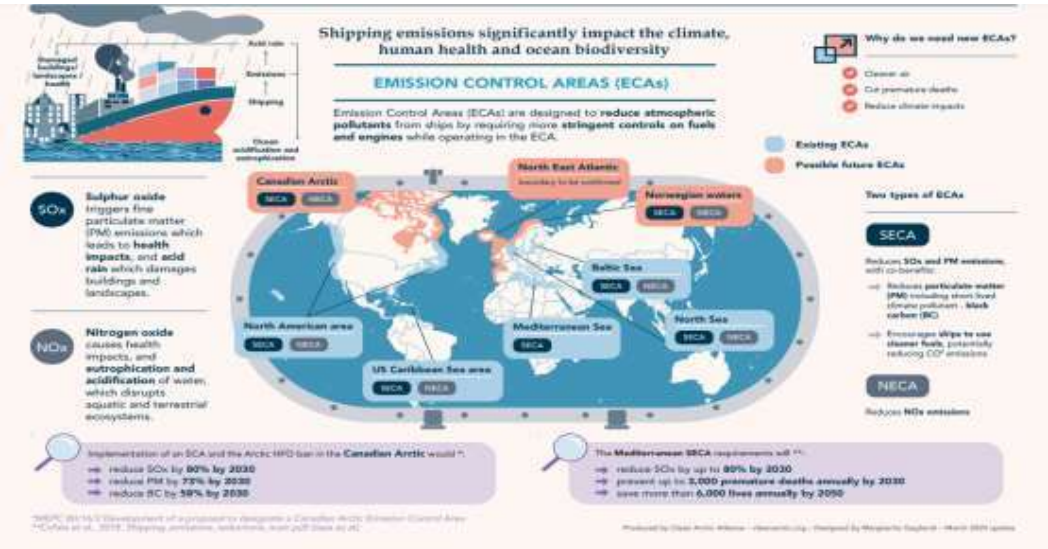

Figure *3.6*: Existing Emission Control areas.
Source: https://cleanarctic.org/2023/06/28/infographic-emission-control-areas-reducing-air-pollution-from-shipping/

2.4 International Initiatives and Partnerships for Green Shipping

a. **UN Green Shipping Challenge**. To help place the shipping sector on a pathway to align with the goal to limit global temperature rise to 1.5°, the United States and Norway organized the Green Shipping Challenge for COP27. This challenge is strongly supported by the High-Level Panel for a Sustainable Ocean Economy. The Challenge encouraged governments, ports, and companies to prepare commitments to spur the transition to green shipping. The partners included Canada, United States and Norway, ports, carriers, cargo owners, and others in the shipping value chain. This has become a regular feature at UNFCCC COP and features announcements aimed at reducing GHG emissions from shipping sector.

b. **IMO Green-Voyage 2050 program**. Green Voyage 2050 is a major technical cooperation programme initiated by the IMO to assist developing countries in reducing GHG emissions from shipping, aligning with the 2023 IMO GHG Strategy. Phase I of GreenVoyage2050 (2020-2023) supported partnering countries in developing policy frameworks and pilot projects to reduce GHG emissions from ships. Phase II (2024-2030) will continue and expand this support, leveraging substantial funding from donors including Finland, France, Germany, the Netherlands, and Norway. The technical assistance provided by the programme can be beneficial for developing countries. The key projects/announcements of the programme in the current year have been.

(1) Call for applications to the GreenVoyage2050 Accelerator: Technical assistance for pilot project feasibility studies to reduce GHG emissions from ships

(2) Call for Expressions of interest from developing countries for support to create National Action Plans (NAPs) to reduce greenhouse gas (GHG) emissions from shipping.

c. **UN Global Compact Sustainable Ocean Principles**. The United Nations Global Compact is a non-binding United Nations pact to get businesses and firms worldwide to adopt sustainable and socially responsible policies, and to report on their implementation. The UN Global Compact is the world's largest corporate sustainability and corporate social responsibility initiative, with more than 20,000 corporate participants and other stakeholders in over 167 countries. The “Practical Guidance For The UN Global Compact Sustainable Ocean Principles” provides 10 sustainable principles to transition to greener shipping practices (*UN Global Compact Sustainable Ocean Principles - Shipping 20230220.Pdf*.).

d. **Green Shipping Corridors**. Green Shipping Corridors are defined as specific trade routes where the feasibility of zero-emission shipping is catalysed by public and private action – offers the opportunity to accelerate shipping's transition to zero emissions. Green corridors are routes between two ports that offer bunkering options for vessels running on low or zero-carbon fuels to decarbonize international shipping. Key areas of focus for green shipping routes include:

(1) Fuel (zero-emissions fuels, including renewable energy for electric vessels)

(2) Ports (infrastructure development to support fuel storage and bunkering)

(3) Ships (technological development)

(4) Voyage optimisation (including Just in Time arrivals, port optimisation and advanced vessel dynamics)

e. The Clydebank Declaration was launched at COP26 in November 2021 with initial supporters including Australia, Belgium, Canada, Chile, Costa Rica, Denmark, Fiji, Finland, France, Germany, Ireland, Japan, the Republic of the Marshall Islands, the Netherlands, New Zealand, Norway, Sweden, the UK and the US. The governments of Morocco, Italy and Spain have since signed the pledge, taking the total number of signatories to 22, with more expected to join them in the near future. The signatories have committed to establish six "green corridors" by 2025 – entirely decarbonised maritime routes (including land-side infrastructure and vessels) between two or more ports – to accelerate the development of zero-emission fuels, low-carbon enabling infrastructure and effective legislation and regulation. The plan is to then scale up the six pilot corridors by creating more routes, longer routes and/or growing the number of vessels sailing through the same routes (Procter, 2022).

f. In July 2023, this first ever Green Methanol powered vessel of Maersk embarked on its maiden voyage, setting sail from Ulsan for its christening ceremony scheduled for September 14, 2023, in Copenhagen. It completed its journey through various legs to reach its destination. The important stops in its journey were the bunkering operations at East Port Said port and Port of Rotterdam, the first green bunkering operations with methanol in both ports for containership.

CHAPTER 3

PAKISTAN SHIPPING AND PORTS INDUSTRY - OVERVIEW AND READINESS FOR TRANSITION TO GREEN SHIPPING

a. The foundation of global trade and commerce is maritime transportation. More than 85% of global trade in goods is transported by sea, and this percentage is higher for the majority of developing nations[45]. The volume of goods traded globally is predicted to increase by 2.6% in 2024 and 3.3% in 2025 as the demand for traded goods recovers from a decline in 2023. After showing a 3.0% growth in 2022, the trade volume decreased by 1.2% in the previous year.

b. Initiated in January 2023, there are about 105,500 ships of more than one hundred gross tones comprising the world's merchant fleet. Approximately 56,500 of these ships have a gross tonnage greater than one thousand. The total capacity of this fleet amounts to approximately 2.3 billion deadweight tons (dwt) which is a significant increase from earlier years. The composition of the global fleet is heterogeneous, with 85% of its overall capacity being occupied by oil tankers, bulk carriers, and container ships[46]. This growth has slowed in recent years, as average annual growth rates plummeting from 7.1% between 2005-2010 to about 4.1% since then signify consolidation in shipbuilding capacity and decline in the ship financing market at large. The global fleet serves an essential purpose in international trade; it moves enormous amounts of goods across seas around the world on vessels. As of 2023, this fleet size increased in response to demands arising from greater world trade amounts with considerable shipbuilding activities occurring primarily in China, South Korea, and Japan[47].

c. Global warming and its associated environmental alterations have become one of the most pressing issues confronting the world community today. They are caused by anthropogenically enhanced levels of greenhouse gas (GHG) emissions in the atmosphere, such as concentrations of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and, in minimal amounts, fluorinated gases. These emissions have deleterious impacts on the ecosystem and human health[48]. The heating and combustion of fossil fuel in marine engines releases a variety of pollutants from the exhaust, including carbon dioxide (CO_2), particulate matter (PM), nitrogen oxides (NO_X), Sulphur oxides (SO_X), carbon monoxide (CO), and hydrocarbons (HC). These gases have

[45] Issa, M. (2020). Optimization opérationnelle, écologique et énergétique des groupes électrogènes diesel (Doctoral dissertation, Université du Québec à Rimouski).
[46] https://hbs.unctad.org/merchant-fleet/
[47] https://unctad.org/system/files/official-document/rmt2023ch2_en.pdf#:~:text=URL%3A%20https%3A%2F%2Functad.org%2Fsystem%2Ffiles%2Fofficial,100
[48] United Nations Framework Convention Climate Change (UNFCCC). Climate Change Information kit, https://unfccc.int/resource/iuckit/cckit2001en.pdf

detrimental effects on the environment and human health, and these effects worsen when ships spend more time in close proximity to populated regions.[49]

d. International shipping must cut its ecological footprint by no fewer than 70% by 2050 and by 40% by 2030 compared to 2008, according to the most recent emission goals[50]. Several technological and tactical measures can be taken to reduce CF. The best technical approach to reduce greenhouse gas emissions in the maritime industry appears to be substituting cleaner, alternative energy sources with a lower percentage of carbon for traditional fossil fuels. Most of the time, alternative fuels also contain less nitrogen and sulfur, which is crucial for ships operating in Emission Control Areas (ECAs), where local emission regulations are more stringent than international ones.

e. In the growing global maritime sector, Pakistan also plays its vital role, however the environmental alterations and stricter international regulations, has made smooth progress a challenge. Pakistan's coastline extends to 1,001 kilometers possessing huge oceanic reserves extending to its 240,000 square kilometers Exclusive Economic Zone (EEZ). The coastline stretches between two provinces: 734.5 km in Balochistan and 266.5 km in Sindh[51]. Pakistan possesses a strong geographical importance as it acts as a junction for three choke points in the main Sea Lines of Communications (SLOCs) for Asian region. These choke points include Strait of Hormuz, Strait of Malaka, and Rea Sea.

3.1 Pakistan's Shipping Sector

a. Pakistan's shipping industry had three to four vessels and was privately owned by 1947. A commercial fleet of 41 ships was in operation in 1960 and was growing steadily. National Shipping Corporation (NSC) was established as a public sector company by 1963. By 1970, NSC and other private shipping companies had grown the country's fleet to 71 ships. However, the number of ships in the fleet decreased to 57 following the privatization and division of East Pakistan in 1971. Nine privately held companies combined to form Pakistan Shipping Corporation (PSC), which has 51 ships, during the nationalization process in 1974. In 1979, PSC and NSC were combined to become PNSC. In 1992, private ship licensing was allowed once more, with 48 ships receiving licenses. Nine new ships were added to the fleet between 1993 and 1996[52].

b. Presently, Pakistan's maritime sector is mainly governed by the Ministry of Maritime Affairs (MoMA) formerly known as Ministry of Ports & Shipping. Administered under the ministry, Pakistan National Shipping Corporation

[49] Monteiro, A., Russo, M., Gama, C., & Borrego, C. (2018). How important are maritime emissions for the air quality: At European and national scale. *Environmental Pollution*, *242*, 565-575.
[50] Bouman, E. A., Lindstad, E., Rialland, A. I., & Strømman, A. H. (2017). State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping–A review. Transportation Research Part D: Transport and Environment, 52, 408-421.
[51] Government of Balochistan (2025). Balochistan sustainable fisheries and aquaculture policy 2025-2035.
[52] Shahzad, Sajid Mehmood, and Umbreen Javaid. "Development of Shipping Sector in Pakistan: Options and Proposed Strategy." *Journal of Political Studies* 23, no. 2 (2016): 537-559.

(PNSC) acts as the national flag carrier with 12 ships[53]. Pakistan like other countries around the globe, must abide by the international regulations set by the International Maritime Organization (IMO) to maintain its healthy progress in maritime sector. The country has ratified the following international conventions:

IMO Convention 48	STCW Convention 78	London Convention 72
SOLAS Protocol 74	SAR Convention 79	INTERVENTION Convention 69
SOLAS Protocol 78	MARPOL Convention 73/78 (Annex I)	INTERVENTION Protocol 73
SOLAS Protocol 88	MARPOL Convention 73/78 (Annex II)	CLC Protocol 92
LOADLINES Convention 66	MARPOL Convention 73/78 (Annex III)	SUA Convention 88
LOADLINES Protocol 88	MARPOL Convention 73/78 (Annex IV)	OPRC Convention 90
TONNAGE Convention 69	MARPOL Convention 73/78 (Annex V)	NAIROBI WRC 2007
COLREG Convention 72	MARPOL Convention (Annex VI), Regulation 14	HONG KONG Convention

Table 3.2: International Conventions Ratified by Pakistan.

3.2 Pakistan National Shipping Corporation (PNSC)

a. The National Shipping Corporation (NSC) and Pakistan Shipping Corporation (PSC) merged in 1979 to form the new organization as PNSC, which is protected by the constitution by Pakistan National Shipping Corporation Ordinance No. XX, 1979 [Gazette of Pakistan, extra-ordinary Part I, 29 March 1979]. It is run independently by the Board of Directors. Karachi is home to the Corporation's headquarters. In order to manage its global shipping operations, the Corporation also maintains a vast network of agents abroad. Transporting liquid and dry bulk commodities throughout the world is the primary function of Pakistan's national flag carrier. PNSC is an independent company that operates under the general supervision of Pakistan's Ministry of Maritime Affairs. It oversees a twelve-ship fleet, properties, and a maintenance facility. Their ship fleet, which consists of a variety of modern-vintage double-hull Aframax tankers, LR-1 Product tankers, Handymax, Panamax, and Handy size bulk carriers, can transport a combined 938,876 tons of deadweight.

b. The company ships transport practically any kind of cargo via a variety of routes that span the globe. They transport iron and steel goods, forest products, fertilizers, mineral substances, ores, alumina, cement, bauxite, and various other building supplies on their Handymax and Handysize dry bulk carriers. On the other hand, grain is transported by Panamax dry bulk carriers along with coal and iron ore for the manufacturing of steel and energy. The ships transport a variety of commodities for numerous well-known international traders and chartering companies, contributing to global seaborne trade along numerous trade routes. Professionals with a great deal of training and experience are provided with the responsibility of operating the national vessels. While making sure that the vessels meet the strictest safety and environmental regulations, PNSC strives to effectively represent the requirements of stakeholders to maximize shareholder value through extending

[53] https://www.pnsc.com.pk/about-us.html

returns on the investments. Details of PNSC vessels are elaborated in tables 3.3.

Tables 3.3: *PNSC Fleet*

Tanker Vessel Name	Type	Date of Induction	Last Operational Date	DWT
Quetta	Aframax	10-Jul-08	13-May-23	107,215
Lahore	Aframax	23-Feb-10	23-Jul-23	107,018
Shalamar	Aframax	1-Dec-14	8-Nov-26	105,215
Bolan	LR-1	25-Mar-19	18-Mar-33	74,919
Khairpur	LR-1	16-Apr-19	18-Oct-32	74,986
Mardan	Aframax	3-Aug-22	27-Jul-27	107,123
Sargodha	Aframax	11-Aug-22	15-Mar-28	107,123
Bulker Vessel Name	**Type**	**Date of Induction**	**Last Operational Date**	**DWT**
Chitral	Handymax	25-Oct-10	9-Jun-33	46,710
Malakand	Panamax	27-Dec-10	28-Oct-34	76,830
Hyderabad	Handymax	21-Apr-11	8-Jan-34	52,751
Sibi	Handysize	18-May-11	28-Sep-39	28,442
Multan	Handymax	26-Sep-12	10-Sep-32	50,244

c. After the addition to MARPOL Annexes, in 1997, the emission standards in Annex VI were commonly referred as Tier I, II and III standards. These technological modifications were made to limit Nitrogen Oxides and Sulfur Oxides emissions. The engine modification system was thought to be the most effective in capturing and lowering air polluting emissions from ships. In table 3.4, the tier system is defined:

Table 3.4: Tier Standards as set by IMO.

TIER	SHIP CONSTRUCTION DATE ON OR AFTER	n<130	n=130-1999	n≥2000
I	1 January 2000	17	45.n^(-0.2)	9.8
II	1 January 2011	14.4	44.n^(-0.23)	7.7
III	1 January 2016	3.4	9.n^(-0.2)	1.96
n= engine's rated speed (rpm)		Total weighted cycle emission limit (g/kWh)		Source: IMO

d. PNSC Ships are Tier II engines complying with regulation 14 of MARPOL Annex VI. Vessels comply with the global sulfur cap regulation. Very Low Sulfur Fuel Oil (VLSFO) is being consumed, which consists of 0.5% sulfur. PNSC provide Bunker Deliver Note (BDN), that is fuel receipt, and a lab analysis report of the purchased fuel. This is a mandatory requirement under MARPOL Annex VI. Mostly the fuel is purchased from Fujairah. The ships are equipped with Energy Efficiency Existing Ship Index (EEXI), which enhances the vessel's energy efficiency by reducing fuel consumption. In this manner, greenhouse gas emissions can be reduced significantly.

e. Secondly, the fleet is also integrated with Carbon Intensity Indicator (CII). This system helps in monitoring the carbon emissions during the entire voyage of the ship. The fleet is ranked from A-E as per the carbon emissions, showing A category as the lowest emission and E with breaching standards. Furthermore, PNSC is aimed to venture in the global carbon market by generating credits and offsets of their total releases.

f. Lloyds Register has provided advisory services for energy efficiency calculations on board currently operating ships as well as planning and data file preparation for the design and management of Engine Power Limitation (EPL) hardware. A deal has been reached with the ship's propulsion engine designer for the installation and provision of an EPL with override limitations on power for future ship docking. Ship Energy Efficiency Measurement Plans (SEEMPs) have been created and are being used for the fleet.

3.3 Karachi Shipyard & Engineering Works (KS&EW)

a. With great technological and professional qualities, KS&EW is an innovative and adaptable organization. Established in 1956, it is the only shipyard and largest engineering and manufacturing complex in Pakistan. The Ministry of Defense Production (MoDP), a branch of the Pakistani government, is currently in charge of its operations. The Chief of Naval Staff serves as the board chairman for the independent organization KS&EW, which has a board of directors.

b. KS&EW has received certification from M/s Lloyds Register, UK's Integrated Management System, which comprises:

(1) ISO 140001: 2015
(2) ISO 9001: 2015
(3) ISO 45001: 2018

c. The Karachi Shipyard has two docks and three berths and is used for both building and repairing naval vessels. Eco-friendly paints are used in the yard to reduce harmful emissions. Rust particles released by iron blasting process of ships are collected and managed to preserve air quality standards. Inspectors of air quality patrol the yard with caution. They impose restrictions on emission infractions and conduct an emission monitoring process every six months. Penalties for infractions must be paid. To maintain optimum levels of air quality within the yard boundaries, shipbuilding uses CO_2 welding, which produces fewer emissions than other gases.

3.4 Conclusion

As MARPOL Annex VI is not yet ratified by Pakistan, only its regulation 14 as issued by MoMA, is being complied by PNSC. KS&EW is only related with the building of naval ships, therefore, annex VI in production process is not given due consideration. Shifting to Tier-III engines would be required in forthcoming years, which will greatly require advancement in technological structure of the

shipbuilding and repairing industry. Due to fast transition and enhanced strictness in IMO's regulations and standards regarding greener fuels and integration of cleaner technologies, expedition of progress of shipping sector will become difficult for Pakistan with the current outdating fleet and less investment.

CHAPTER 4

RECOMMENDATIONS AND WAY FORWARD FOR PAKISTAN

a. Pakistan's shipping industry requires enhancement of ship building industry with latest green technologies to produce vessels in compliance with MARPOL Annex VI. According to the annex, engine and system modification of vessels is the basic compliance requirement. In the upcoming years, this obligation can be achieved through expanding capacity of shipbuilding and recycling industry. Currently, the outdating ship fleet of Pakistan with Tier-II engines will be required to shift to Tier-III engines to maintain its viability in the global market. Therefore, budget allocation, incentives and sustainable funding to the sector is a necessity.

4.1 Key hurdles in implementation and compliance of MARPOL Annex VI

a. Lack of institutional and human capacity for implementation and enforcement. Regulations of MARPOL Annex VI are technology and resource intensive. A developing country like Pakistan with a small international shipping fleet cannot meet the high cost linked with the technology as well as training and capacity building of the workforce.

b. Absence of relevant enabling national legislation and regulations. Countries that have ratified Annex VI are required to implement its requirements through national laws and regulations. This includes establishing systems for ship surveys, certification, and port state control inspections, among other measures.

c. Concerns about the stringent requirements of MARPOL Annex VI. Technical measures and monitoring mechanism adopted under the convention seem rigorous and stringent. Technical capacity and lack of trained personnels for managing these strict measures seems a hurdle in Pakistan.

d. Lack of coordination between stakeholders and lack of political will. The lack of political will and political will, in face of continuous political turmoil hinders the progress of Pakistan on key international fronts.

4.2 Way Forward

a. Ratification of MARPOL Annex VI as a responsible international state. As a responsible maritime nation, Pakistan must ratify and abide by the obligations under MARPOL Annex VI. In the absence of which, Pakistan might face hindered access to international ports in the future, along with penalties for not following these regulations and the missed opportunities of collaborating with international stakeholders to get on the track leading to sustainable and green shipping practices.

b. Stronger liaison and coordination with IMO to get maximum benefits from IMOs projects of technical assistance. IMO has numerous programmes to help the developing countries in transition to green shipping.

Pakistan must maintain strong liaison with IMO and benefit from international development programmes of IMO and its partners. One of the important programmes is IMO-GreenVoyage-2050 which provides technical assistance to developing countries for reducing GHG emission from shipping sector. However, these benefits can only be reaped if Pakistan adheres to international commitments like SDGs and MARPOL Annex VI.

c. **Relevant legislation to be put in place for setting the ground for MARPOL ANNEX VI implementation: Preparation of a National Action Plan (NAP) for reducing GHG emissions from shipping sector.** Many countries of the world have prepared NAPs for reducing GHG emissions from shipping sector, which advocate for a database and estimation of GHG emissions from shipping sector and designating a responsible agency for monitoring these emissions. Pakistan lacks such a plan and the arrangements which come with it, which need to be worked out in consultation with government stakeholders.

d. **Budget Allocation and capacity building of Ship Building sector**. According to the MARPOL annex VI, engine and system modification of vessels is the basic compliance requirement. In the upcoming years, this obligation can be achieved through expanding capacity of shipbuilding industry. Private partnership in the sector should be welcomed and policies should be made to attract investors in the sector.

e. **Feasibility study for Methanol production in Pakistan**. Renewable methanol is an ultra-low carbon chemical produced from sustainable biomass, often called bio-methanol, or from carbon dioxide and hydrogen produced from renewable electricity. The potential of Pakistan for producing bio-methanol can be calculated, using the considerable amount of agricultural waste produced in the country. If the potential could be harnessed, Pakistan could become a part of green corridors for international ships because of its important geostrategic location.

f. **Carbon Credit and offset scheme**. Secondly, Pakistan's gradual transition to air pollution control can be assisted with the establishment of a carbon credit and offset scheme. Formulation of policies and incentives on national level as per existing international standards can develop a two-way beneficial system which can assist in achieving sustainability with economic benefits. Furthermore, regular audits and monitoring procedures should be ensured in port vicinities to regulate and verify emission control systems and rectify technological or compliance issues on time.

g. **Regional and International Cooperation**. Promoting Emission Control Areas (ECAs) within the South Asian region through partnerships and collaborations would help achieve the international compliance measures in a broader context.

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