OCCASIONAL PAPER

The role of mangroves in supporting shipping industry commitments to environmental protection and sustainable development

Pham Thu Thuy
Nguyen Thi Van Anh
Nguyen Thi Thuy Anh
Tang Thi Kim Hong
Dang Hai Phuong
Nguyen Thi Kieu Nuong
Dang Le Hoa
Pham Thi Thuyen
Hoang Tuan Long

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Pham Thu Thuy
CIFOR

Nguyen Thi Van Anh
VNU

Nguyen Thi Thuy Anh
DAV

Tang Thi Kim Hong
NLU

Dang Hai Phuong
NLU

Nguyen Thi Kieu Nuong
NLU

Dang Le Hoa
NLU

Pham Thi Thuyen
NLU

Hoang Tuan Long
CIFOR

Center for International Forestry Research (CIFOR)

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Nong Lam University.
Tan Cang – Cai Mep International Terminal and Can Gio Mangrove Biosphere Reserve.

CIFOR
Jl. CIFOR, Situ Gede
Bogor Barat 16115
Indonesia

T +62 (251) 8622-622
F +62 (251) 8622-100
E cifor@cgiar.org

cifor.org

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List of acronyms

CRP-FTA	CGIAR Research Program on Forests, Trees and Agroforestry
CC	Clean Cargo
CSR	Corporate social responsibility
DPF	Diesel particulate filter
EC	European Commission
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EU	European Union
EU-ETS	EU Emissions Trading System
HFO	Heavy fuel oil
GHG	Greenhouse gas
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil
SEEMP	Ship energy efficiency management plan
TEU	Twenty-foot Equivalent Unit
USAID	United States Agency for International Development

Summary overview

Due to the increasing speed and impacts of climate change, the United Nations Framework Convention on Climate Change (UNFCCC) and countries around the world are calling for active participation from all sectors in helping to resolve global environmental problems. The shipping industry, which plays a leading role in world commerce by transporting 90% of goods globally, has the potential to contribute significantly in the battle to adapt to and mitigate the impacts of climate change.

This report explores shipping industry contributions to Vietnamese and global economic development, analyses the environmental impacts shipping activities can cause, and reviews upcoming solutions for tackling environmental risks in Vietnam and globally. At the same time, the report reviews the role of mangroves in supporting shipping industry commitments to environmental protection and sustainable development.

The report shows that shipping plays important roles in creating jobs and increasing global gross domestic product (GDP). However, shipping business activities can cause air pollution, water pollution, noise pollution, oil spills, coastal erosion and subsidence and detrimental effects to human health. To address and prevent these risks, the international community, and nations including Vietnam have developed and implemented many policies and international initiatives as well as technical solutions and technology innovations. Over the last 15 years, policies have developed from focusing only on technical issues to combining technical, financial, social, policy and ecological solutions. As proposed solutions have both advantages and limitations, combinations of different solutions will help the transport industry improve the effectiveness of its environmental protection commitments, reduce operating costs and establish environmentally friendly models to meet market and customer requirements.

Recognized as some of the world's largest carbon sinks, mangrove ecosystems are receiving more attention as potential ecological solutions for supporting shipping industry commitments to environmental protection and sustainable development. However, the importance of mangroves to shipping industry operations has yet to be popularized to many shipping companies. Research on financial mechanisms for the shipping industry to contribute to mangrove conservation remains limited. Therefore, it is necessary for new scientific research and policies for a sustainable financial mechanism that can promote and enhance contributions from sectors, including the shipping industry, for protecting and expanding mangroves.

1 Introduction

With the whole world participating actively in the fight against climate change, and in response to increasing pressure from customers for environmentally friendly services, the international and Vietnamese shipping industries have built and implemented many solutions for environmental protection and sustainable development over the last 5 years (Bowers 2021a). The international community, the private sector and donors are also aiming at eco-solutions to support the transport industry in reducing emissions and fulfilling its commitments to sustainable development. More specifically, developing countries, including Vietnam are emphasizing linkages and interactions between the maritime transport industry and mangrove ecosystems, and the role of mangroves in reducing global warming (Ocean Economist 2021), and helping the shipping industry achieve emissions reduction goals, reduce dredging costs, store heavy metals in water, beautify landscapes, lessen wave impacts and minimize noise pollution (Pham et al. 2019). New policies such as the Green Port and Payments for Forest Environmental Services (PFES) schemes confirm central and local government interest in sustainable development and ensuring the shipping industry achieves its dual objectives of economic development and environmental protection.

While most reports focus on analysing lessons learned from applying technical solutions for helping the shipping industry achieve its environmental protection and sustainable development goals, this report reviews other solutions proposed by stakeholders, including those based on mangrove ecosystems, and analyses the advantages and disadvantages of implementing such solutions. The authors hope this report will provide useful inputs for the Ministry of Transport in the process of implementing and diversifying the solutions proposed in the Green Port project, and for the Ministry of Agriculture and Rural Development in the process of formulating policy for applying PFES to mangrove forests.

2 Research methods

This report is based on a literature review. The research team reviewed annual and periodic reports of global shipping companies and the International Maritime Organization (IMO), regulations and policies on climate change from many countries, as well as scientific reports from Vietnam and abroad to answer the four following questions:

i. How has the shipping industry been contributing to global economic development and to Vietnam?
ii. What impacts does the shipping industry have on the environment and society?
iii. What policies, solutions and initiatives have been, are being or will be developed and implemented to help the shipping industry address existing environmental problems and commit to effective sustainable development? What are the advantages and disadvantages of implementing such policies, solutions and initiatives?
iv. What roles do mangroves play in supporting shipping industry commitments to environmental protection and sustainable development?

The research team discusses each of these questions in the sections below.

3 Shipping industry roles and contributions to economic development

The shipping industry plays a key role in the global economy as 90% of the world's goods are transported by sea (Selin and Cowing 2018). In 2019, the total value of the world shipping trade reached more than USD 14 trillion (International Chamber of Shipping 2019). Over the past 20 years, the shipping industry's contribution to global GDP has increased by 73% (Goodwin 2016), while creating hundreds of millions of jobs worldwide. In Europe, the shipping industry accounts for 75% of EU external trade and 36% of intra-EU trade flows, transports more than 400 million passengers a year (Defour and Afonso 2020) and supports approximately 2.1 million jobs (Government Europa 2020). Asia has become home to more than 50% of the global shipping trade. In 2019, Asia accounted for 41% of exports and 62% of imports handled and transported by sea (United Nations 2020).

In Vietnam, the shipping industry plays an important role in the overall economic development of the country (Truong 2000; Nguyen 2016). The output value of the shipping industry, port services and shipbuilding increased steadily by an average 22% per year during the 2007–2010 period, and 13% annually from 2011 to 2015 (Ministry of Natural Resources and Environment 2020). By 2017, the volume of total goods through Vietnam's seaports had increased sixfold compared to 2000 from 73 million to 442 million metric tons, while container cargo increased more than twelvefold from 1.1 million Twenty-foot Equivalent units (TEU) to 14.4 million TEU (PetroVietnam 2019). Despite being affected by the Covid-19 pandemic, shipping has continued to grow. In the first four months of 2020, the volume of goods unloaded through Vietnam's seaport system was more than 215.3 million metric tons, up 4% on the same period in 2019, of which container cargo was approximately 6.78 million metric tons, an increase of around 12% on the same period in 2019 (Nguyen 2020). Export turnover through maritime transport reached USD 264,273 million in 2019; around USD 102,208 million higher than in 2015. Most goods were exported to the US market with turnover reaching USD 61,404 million, followed by the Chinese market at USD 41,434 million, and other markets such as Japan, Korea and Hong Kong at around USD 47,318 million (UNCTAD 2020).

4 Shipping industry impacts on the environment and society

Although the shipping industry has brought significant economic benefits as described above, its activities give rise to many environmental and social impacts (Figure 1).

Air pollution: Compared to other modes of transport, maritime transport is often considered economical and less emissions intensive. In Europe, for example, maritime transport emissions are only 80% of those from aviation (international and domestic) and only 15% of those from road transport (Shell Global 2020). However, maritime transport remains a huge source of GHG emissions and air pollution with detrimental effects on the environment and human health.

Maritime transport generates three main types of emissions: (i) carbon dioxide; (ii) black carbon, which is generated from the combustion of shipping fuels, accounts for 21% of CO_2-equivalent emissions from ships, and is second only to CO_2 in terms of impacts on the marine air environment (Europe Oceana 2020); and (iii) other emissions.

CO_2 emissions from worldwide shipping increased from 962 million metric tons or 2.76% of total emissions in 2012 to 2.89% (1,056 million metric tons) in 2018, and 3.1% in 2020 (EC 2013; Reynolds 2019; Saul 2020; Bowers 2021c). CO_2 emissions from EU-related shipping reached 144 million metric tons in 2019 (Defour and Afonso 2020). CO_2 emissions depend on a number of factors, including engineering parameters (e.g., hydrodynamics, machinery age and size) and operating parameters (e.g., distance travelled, speed, cargo transported, fuel used and weather conditions) (EC 2020; Faber et al. 2021). Different types of cargo ships, which currently account for 55% of all shipping industry CO_2 emissions, have different emissions levels (Table 1). Seven types of ships: bulk carriers, oil tankers, container ships, chemical tankers, liquefied gas carriers, general cargo ships and cryogenic bulk carriers, account for around 88% of global maritime transport CO_2 emissions (Faber et al. 2021).

Black carbon has serious effects on human health, can cause respiratory and cardiovascular diseases and cancer, and is a carrier of various toxic chemicals into the human body. Black carbon emissions in the Arctic have been found to increase surface temperatures there nearly five times more than they do in mid latitudes (Reynolds 2019). Reducing machine speed without adjusting engine combustion, can increase black carbon emissions

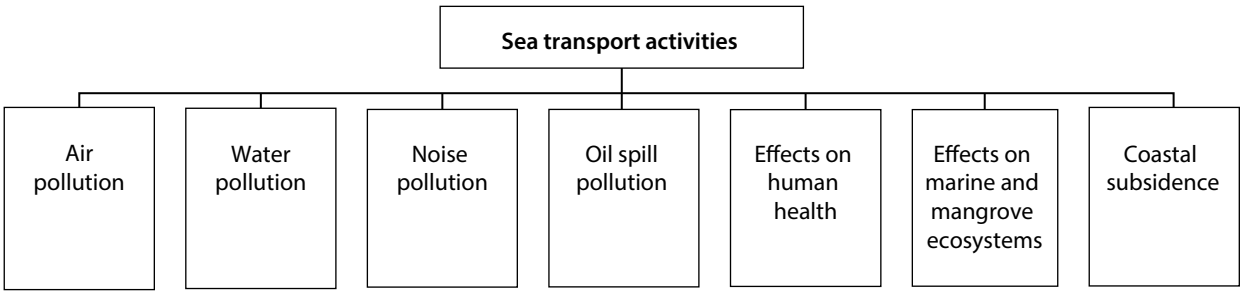

Figure 1. Shipping industry impacts on the environment and society

Table 1. Cargo density densities and emissions levels of for different types of cargo ships

Type of transport	Weight of goods to ship tonnage (%)	CO_2 emissions generated as % of total transport sector CO_2 emissions
Dry bulk carriers transporting iron ore, coal, grain and similar goods	42.5	13%–19%[a]
Crude oil tankers (oil tankers)	29.2	13
Container ships	13.1	23%–30%[b] CO_2 emissions from 17 of the world's largest container carriers, accounting for around 85% of global container shipping (AP Møller - Mærsk, CMA CGM Group, COSCO Shipping Lines Ltd., Evergreen Line, Hapag-Lloyd, Hyundai MM, MSC, ONE (Ocean Network Express) and Yang Ming Marine Transport Corp) continued to fall in 2019. Average CO_2 emissions per container per km fell by 5.6% and 2.5%, respectively for dry and cold (refrigerated) goods indices (CC 2019). Improvements in CO_2 indices were seen mainly in shipping lanes: • from Northern Europe to Asia with a fall of 3% • from the west coast and northeast coast of North America to Asia with a fall of 6% • from the Middle East/India to Asia with a fall of 12% • from the Mediterranean/Black Sea to Asia with a fall of 12%

a Distance travelled of approximately 55 million nautical miles
b 1,742 ships sailing over 70 million nautical miles

Sources: CC 2019; EC 2020; Healy and Graichen 2019; Reynolds 2019; Ovcina 2020.

due to inefficient combustion. Black carbon emissions will need to be reduced by at least 35% from 2010 levels to limit global warming to 1.5°C by 2050 (IPCC 2018; Reynolds 2019).

The shipping industry not only generates 3% of global CO_2 emissions, but was also responsible for a 150% increase in methane emissions from 2012 to 2018 (Bowers 2020b), contributing around 15% of global nitrogen oxide (NOx) emissions, and 5–8% of sulphur oxide (SOx) emissions (Frese 2019; Trimmer and Godar 2019) leading to crop damage, reducing the lifespan of buildings, causing environmental problems and increasing the risk of respiratory tract infections and cardiovascular diseases (Vidal 2009). The world's largest on-board diesel engines typically operate for around 280 days a year, generating approximately 5,200 metric tons of SOx (Vidal 2009).

At current growth and emissions rates, the shipping industry could be responsible for 10% of total global emissions by 2030 (Abbasov 2020) and a 50% increase between now and 2050 if there are no effective measures to prevent this happening (Defour and Afonso 2020). With the emissions generated, the shipping industry will be a major source of air pollution, which is likely to affect people in countries along shipping routes, as most emissions are emitted within 400 km of the coast (Trimmer and Godar 2019).

Maritime transport requires around 300 million metric tons of dirty fuel and thus has a carbon footprint equivalent to that of Germany (Selin and Cowing 2018). In fact, if the global maritime shipping industry were a country, then that country would be the world's sixth largest GHG emitter (Europe Oceana 2020). The fifteen largest ships alone cause as much pollution as all 760 million cars worldwide (Europe Oceana 2020; Helms 2013). Panama (15%), China (11%) and Liberia (9%) are the world's largest shipping industry emitters (Frese 2019).

Although there are many international and regional regulations to control emissions from the maritime shipping industry, maritime shipping emissions have been largely ignored in discussions on mitigating climate change and on sustainable production and consumption (Trimmer and Godar 2019; Europe Oceana 2020; Defour and Afonso 2020). Tracking and monitoring shipping industry emissions is not easy given the lack of reliable data on emissions being released into the environment and controversy over assigning responsibility for those emissions to the different countries, traders, manufacturers, consumers and transportation companies involved (Trimmer and Godar 2019). It is customary to estimate emissions per commodity based on a commodity's transaction volume, ignoring specific factors such as the weight and bulkiness of goods and how they are transported. Ship type, for example, can have a significant effect on the scale of emissions (Trimmer and Godar 2019). In addition, because shipping plays an important role in the world economy, policy formulation encounters many obstacles from stakeholders. Many scholars argue that it is difficult to predict future CO_2 emissions from shipping as they are highly dependent on international shipping demands, and the availability and effectiveness of technical solutions and developments in markets for alternative fuels, as well as the costs and benefits of these solutions (Fenhann 2017).

Noise pollution: Many studies have shown water transport creates noise pollution that affects the health of communities living near waterways. In addition, the international community and countries have expressed increasing concern over water transport, especially the operations of ocean crossing ships, causing significant damage to marine ecosystems on a global scale. These operations have led to reduced numbers and fertility in many marine animals (dolphins, whales and endangered marine species) (Simpson et al. 2010).

Water pollution: Pham et al. (2020) have shown that shipbuilding activities and ship wastewater discharges have caused serious seawater pollution, and in many places pollution has exceeded permitted levels stipulated by national and international regulations (Frese 2019; Abbasov 2020).

Oil spill pollution: Shipping lines and port management boards worldwide have recorded negative impacts on the environment from oil spills. As a result, many technological innovations and oil spill over insurance models have been introduced globally (Reynolds 2019).

Effects on human health: In 2015, pollution from cargo ships around the world resulted in 90,000 deaths and incurred costs of USD 330 billion to treat lung and cardiovascular diseases (Vidal 2009). In Denmark, pollution from water transport costs the country almost GBP 5 billion a year, mainly for treatment of cancer and heart problems, and 1,000 people in the country die prematurely each year as a result of pollution from maritime transportation (Vidal 2009).

Effects on marine and mangrove ecosystems: Pham et al. (2019, 2020) have shown the construction of seaports and impacts of waterway transport activities have reduced the quantity, quality and area of mangrove ecosystems worldwide and in Vietnam. Mangroves can be damaged by ship cleaning and remediation activities (Beyer et al. 2016). Oil adhering to tree roots can cause mangrove trees to lose their leaves or even die, leading to loss of forest cover (Tam et al. 2005). The rapid spread of oil on the surface of the water, some of which dissolves in the water and sinks to the bottom, leads to sediment pollution and greatly affects biota (Beyer et al. 2016). Levings et al. (1997) suggested that oil in sediments at concentrations above 100 μg g-1 dry weight would cause sublethal effects on mangroves.

Coastal erosion and subsidence: Commercial shipping activities and regular dredging operations to keep channels in estuaries open for large ships have led to coastal erosion and subsidence in Vietnam (Anthony et al. 2015). In this context, protecting and replanting mangroves are always considered priority measures (Vietnam Academy of Science and Technology 2020).

5 Solutions and proposals for supporting the shipping industry reduce emissions, protect the environment, and develop sustainably

The international community, UNFCCC, IMO and countries have proposed many solutions to help the shipping industry reduce environmental and societal risks and impacts. (Figure 2)

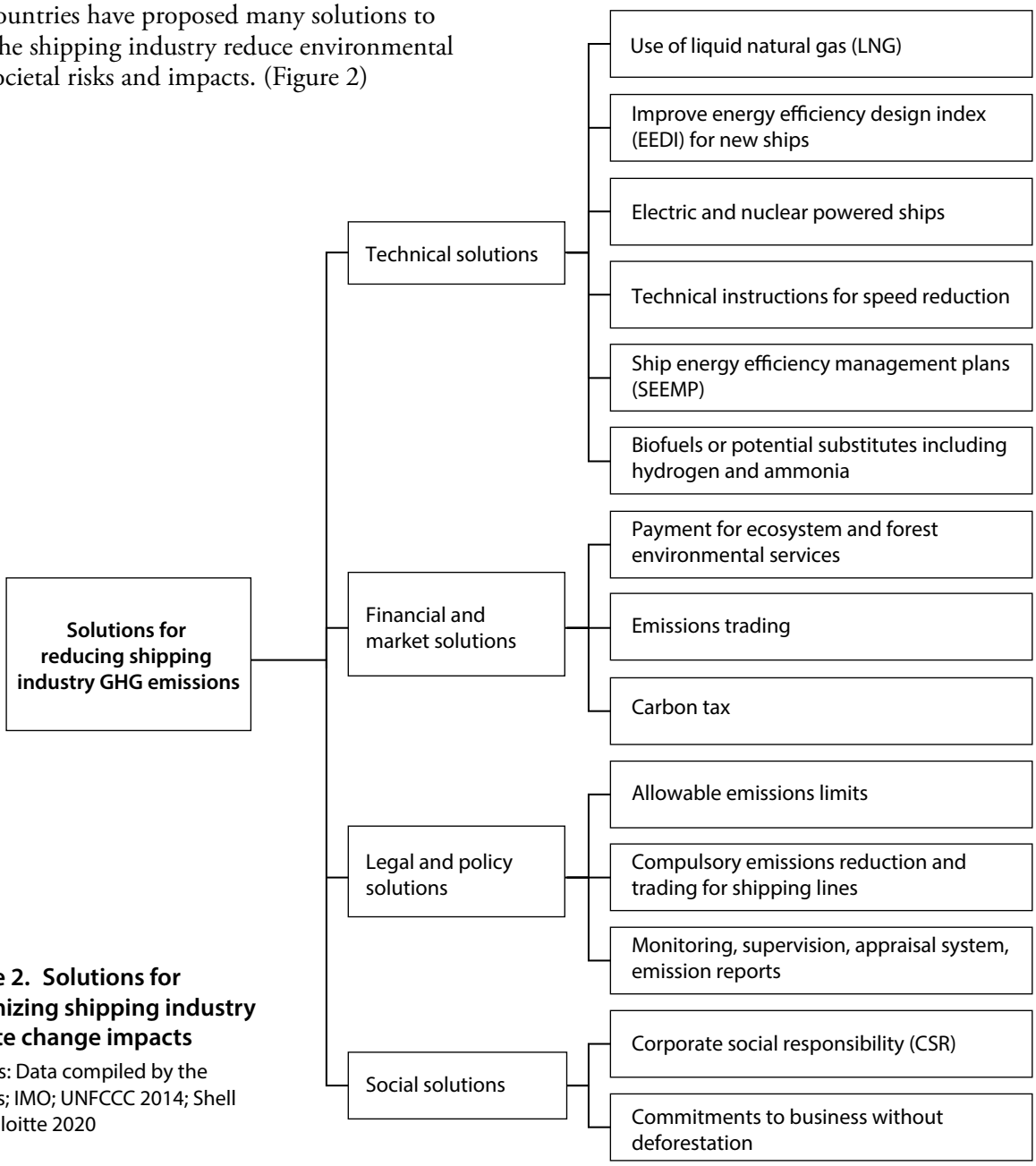

Figure 2. Solutions for minimizing shipping industry climate change impacts

Sources: Data compiled by the authors; IMO; UNFCCC 2014; Shell and Deloitte 2020

The research team will discuss each solution and approach shown in Figure 2 in more detail in the following sections.

5.1 Policy solutions

Since 1997, many policies, legal frameworks and commitments have been made at the global and national levels in the face of pressure surrounding the negative impacts the shipping industry has on the environment and society.

5.1.1 International regulations

Since 1997, international regulations on reducing shipping industry environmental impacts and emissions have made great strides. Initially just encouraging commitments and technological innovations, they have now established comprehensive legal systems addressing various economic, social, environmental and technical issues (Table 2).

Table 2. International regulations on reducing emissions from the shipping industry

Year	Name, legal framework, commitment	Details
1997	The 1997 Kyoto Protocol	The International Maritime Organization (IMO) is responsible for developing roadmaps and policies for reducing emissions from international shipping.
2009	MEPC agenda	The agenda discussed noise impacts from commercial shipping and their adverse effects on marine life.
2011 - 2013	New IMO energy efficiency requirements as amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) came into force on 1 January 2013	The requirements aimed at improving energy efficiency in international shipping.
2014	Guidelines for minimizing underwater noise from commercial shipping to address adverse impacts on marine life (MEPC.1/Circ.833)	The guide is not mandatory but provides general advice to ship designers, shipbuilders and commercial ship operators on improving noise generating factors, such as propellers, hull form and machinery in ships, as well as operations and maintenance measures.
2015	The Paris Agreement - United Nations Framework Convention on Climate Change (UNFCCC)	This international agreement on climate change affects the economies and operations of industries globally from now until 2030. Countries have committed to reducing GHG emissions to limit the increase in average global temperature to less than 2°C above pre-industrial levels, and pursue efforts to limit the rise to 1.5°C, in order to reduce climate change risks and impacts. Although the agreement does not mention shipping industry commitments specifically, countries have committed to reducing emissions from all sectors and industries, including shipping. The European Union (EU), for example, considers emissions reductions in the shipping industry important for meeting its Paris Agreement commitments.
2015	Regulation (EU) 2015/757 of the European Parliament and the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/ EC	Directive 2009/29/EC of the European Parliament and of the Council (3) and Decision No. 406/2009/EC of the European Parliament and of the Council (4) call for contributions from all sectors of the economy, including the international shipping sector, to achieve emissions reductions.

Continued on next page

Table 2. Continued

Year	Name, legal framework, commitment	Details
		The IMO proposal to include international shipping emissions in its commitment to mitigate climate change came into force in 2013. Regulations on transparent and publicly available monitoring, reporting and verification (MRV) of CO_2 emissions based on ships' fuel consumption together with emissions from other sectors have been and are contributing to that commitment, whilst reducing market barriers by providing reliable information and data on fuel consumption and energy efficiency to relevant markets. This data provides a reliable way to set precise emissions reduction targets and to assess shipping's progress towards a low-carbon economy. Given the international nature of shipping, the preferred and most effective method for reducing GHG emissions in international shipping would be by global agreement.
2016	Modification of MARPOL	This requires ships with 5,000 gross tonnage or more (which account for around 85% of GHG emissions from ships) to collect and submit fuel oil consumption data to IMO from 1 January 2019.
2016	International Organization for Standardization (ISO) 17208-1:2016 for underwater acoustics	Procedures describe the measurement of sound and underwater noise from ships.
2016	Ship Energy Efficiency Management Plan (SEEMP)	An SEEMP applies to ships with 400 gross tonnage or more; requires all ships, both new and existing, to develop and maintain a ship-specific SEEMP, to improve energy efficiency at sea and in port; The 2016 Guidelines for the Development of Ship Energy Efficiency Management Plans (Resolution MEPC.282 (70)) provide guidance on best practices for ship fuel efficiency but do not include requirements.
2016	The International Monetary Fund (IMF) and the Organization for Economic Co-operation and Development (OECD) proposed levying a carbon tax on shipping in order to implement the Paris Agreement	A tax rate of USD 25 per metric ton of CO_2 has been proposed. Such a tax would stimulate investment in energy efficiency, but the proposal has yet to be placed on the IMO agenda.
2016	Commission Implementing Regulation (EU) 2016/1928 dated 4 November 2016 on determination of cargo carried for categories of ships other than passenger, ro-ro and container ships pursuant to Regulation (EU) 2015/757 of the European Parliament and of the Council on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport	This regulation lays down rules for defining parameters applicable to the identification of goods carried for ships other than passenger ships, ro-ro ships and container ships for the purpose of monitoring information relating to other authorities on a per-trip basis under Article 9 (1) Regulation (EU) 2015/757. In the case of oil tankers, chemical tankers, gas carriers, bulk carriers, refrigerated cargo ships and mixed carriers, average operational energy efficiency should be determined using IMO guidelines on voluntary use of the ship Energy Efficiency Design Index (EEDI) (2) as those guidelines reflect industry practices.

Continued on next page

Table 2. Continued

Year	Name, legal framework, commitment	Details
		Parameters for determining "cargo carried" by each type of vessel for the purpose of tracking other relevant information on a per voyage basis pursuant to Article 9 (1) of Regulation (EU) 2015/757, are determined as follows: • For oil tankers - the mass of the cargo on board; • For chemical tankers - the mass of the cargo on board; • For LNG carriers - the volume of the cargo on discharge, or if the cargo is discharged at several occasions during a voyage, the sum of the cargo discharged during a voyage and the cargo discharged at all subsequent ports of call until new cargo is loaded; • For gas carriers - the mass of the cargo on board; • For bulk carriers - the mass of the cargo on board; • For general cargo ships - deadweight carried for laden voyages and as zero for ballast voyages; • For refrigerated cargo ships - the mass of the cargo on board; • For vehicle carriers - the mass of the cargo on board, determined as the actual mass or as the number of cargo units or occupied lane meters multiplied by default values for their weight; • For combination carriers - the mass of the cargo on board; • For ro-pax ships - the number of passengers and as the mass of the cargo on board, determined as the actual mass or the number of cargo units (trucks, cars, etc.) or occupied lane meters multiplied by default values for their weight; • For container/ro-ro cargo ships - the volume of the cargo on board, determined as the sum of the number of cargo units (cars, trailers, trucks and other standard units) multiplied by a default area and by the height of the deck (the distance between the floor and the structural beam), of the number of occupied lane-metres multiplied by the height of the deck (for other ro-ro cargo) and of the number of TEUs multiplied by 38.3m^3.
2018	Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814	Directive 2003/87/EC of the European Parliament and of the Council (4) established a system for greenhouse gas emission allowance trading within the Union, in order to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner. The EU Emissions Trading Mechanism is in place towards achieving the targets set out in the Paris Agreement by 2030. Measures to support certain energy-intensive industries that may experience carbon leaks as mentioned in Articles 10a and 10b of Directive 2003/87/EC should also be considered based on the climate policy measures in other major economies.

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Table 2. Continued

Year	Name, legal framework, commitment	Details
2018-2019	Monitoring, reporting and verification (MRV) of information carried out in accordance with Regulation 2015/757 (as amended by Regulation 2016/2071)	From 1 January 2018, large vessels over 5,000 deadweight tonnage (DWT) handling cargo or passengers at ports in the European Economic Area (EEA) are required to monitor and report their CO_2 emissions relating to fuel consumption and other parameters (distance travelled, time at sea and cargo carried per voyage), collect data and submit annual emissions reports to an accredited shipping MRV verifier. From 2019, before 30 April each year, companies submit verified emissions reports through the THETIS-MRV database to the Commission and the States where ships are registered (flag states). From 2019, companies must ensure all their ships calling at ports in the European Economic Area have fulfilled the requirements for the previous reporting period by 30 June each year and are carrying compliance documentation issued by THETIS-MRV. This obligation may be subject to examination by competent authorities in EU Member States. Each year, the Commission publishes a report to inform the public about the industry's CO_2 emissions.
2018	The Marine Environment Protection Committee (MPEC) of the International Shipping Organization (IMO) adopted the 'Initial IMO Strategy on [reducing] GHG emissions from ships'	Under the original strategy, GHG emissions from international shipping would be reduced by at least 50% by 2050 compared to 2008 levels. CO_2 emissions calculated for each transport activity in the entire international transport system have to be reduced by at least 40% by 2030 and 70% by 2050 compared to 2008 levels; Speed optimization and speed reduction are used as yardsticks, taking into account safety issues, distance travelled, market or trade distortions, and ensuring measures do not affect shipping's capacity to serve remote geographic areas; While this is non-binding, IMO expects to implement more specific measures by 2023. IMO is the first regulatory body to adopt global ambitions for the entire industry (Shell and Deloitte 2020).
2019	Energy Efficiency Design Index (EEDI)	Applies to all ships of 400 gross tonnage and above; Amendments to MARPOL Annex VI to strengthen energy efficiency design requirements for certain new ship classes were subsequently approved in May 2019 for adoption at the MEPC. 75 in April 2020;

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Table 2. Continued

Year	Name, legal framework, commitment	Details
		The index requires new ships to become more energy efficient, with standards that will become more and more stringent with different phases over time. Different ship classes and sizes have different standards to meet. The standards are compared with a baseline, which is set as the average performance of ships built between 1999-2009. Phase I: a target of 10% overall improvement in on-board energy efficiency applied to new-built ships between 2015 and 2019; Phase II: ships built between 2020 and 2024 have to improve their energy efficiency by 15% to 20%, depending on the type of ship; Phase III: ships delivered after 2025 will have to be 30% more efficient. Smaller vessels have different efficiency requirements for each phase.
2019	The European Green Deal (Bowers 2020a)	The European Green Deal is a set of policy initiatives by the European Commission with the overarching goal of making Europe climate neutral by 2050. It is committed to including transport sector emissions in the emissions trading system (ETS). The agreement includes an ambitious package of measures to transform the EU into a sustainable economy by turning climate and environmental challenges into opportunities across all policy areas and making the process more sustainable and inclusive for all. The European Green Deal requires all sectors, including shipping, to play their part in reducing emissions.
2019	EU emissions trading system (ETS)	Polluters, including those in the shipping industry, have to pay a penalty fee for each metric ton of CO_2 they emit, based on fuel consumption reported under MRV regulations. EU regulations require all ships over 5,000 deadweight tonnage (DWT) to report annual fuel consumption and associated CO_2 emissions from voyages: between ports in the European Economic Area (EEA); between the last non-EEA port and the next EEA port; between the last EEA port and the next non-EEA port and while the vessel is at berth; CO_2 emissions are determined based on the amount of fuel consumed combined with the specific CO_2 emission factor of the fuel. This policy scope allows the MRV to cover approximately 90% of EU shipping's total CO_2 emissions, while covering around 55% of all ships calling at EEA ports. Transport companies operating in EU shipping lanes and calling at EEA ports must compile data annually and have it verified by independent verifiers before submitting it to the European Commission. The Commission then publishes most of this verified data and prepares an annual report to inform the public and other European institutions.

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Table 2. Continued

Year	Name, legal framework, commitment	Details
2021-2022		The European Parliament has passed a draft law to include ship emissions in the ETS from 1 January 2022, while the Commission has launched an initiative to renew the ETS and expand its scope to the shipping industry. The public consultation phase for the initiative ended on 5 February 2021 (Hargreaves 2021).

Sources: EU 2016; Fenhane 2017; Reynolds 2019; Defour and Afonso 2020; EU 2020

The International Maritime Organization (IMO) now requires ships to reduce their emissions by 10% every five years until 2030, and ships built after 2025 to be 30% more energy efficient than ships built in 2014. The European Commission is also demanding changes through the 2013 Transport White Paper, which sets a target of reducing emissions by 40%–50% compared to 2005 levels, and requires reductions in nitrogen oxide (NOx) and sulphur oxide (SOx) particles from ship exhaust.

Along with the above-mentioned international regulations, major powers and continents around the world have also enhanced the strictness in the legal framework on environmental protection in the shipping industry. For example, both Europe and the United States have developed policies to establish low-emission zones around their coasts, in order to ensure human health and the environment in their countries (Vidal 2009). Pressure is also growing on the IMO and the EU to tighten ship emissions management laws following the US government's decision to impose a strict 230-mile buffer zone along the entire coast of the United States following the Canadian model (Vidal 2009). The UK is a pioneer in Europe when it comes to bringing international aviation and transport emissions into its national carbon budget, with its announcement to cut emissions by 78% by 2035 (Bowers 2021c).

Industry associations, along with the private sector, have also actively implemented many emissions reduction measures over the years. The World Shipping Council and its member companies are also engaged in a variety of efforts to reduce CO_2 emissions and further improve fleet-wide efficiency through fuel-saving measures, the introduction of new, larger and more efficient ships, reduced speeds, and technical modifications to existing ships. Under pressure from customers, many of the world's large shipping corporations have had to make climate change commitments. Danish shipping giant Maersk Line, for example, announced it would operate the world's first carbon-neutral cargo ship by 2030, but under pressure from customers it had to commit to shortening the deadline to seven years to get the product up and running by 2023 (Bowers 2021b). Shipping lines also aim to use bio-based "carbon neutral methanol" (Bowers 2021b).

5.1.2 Policy in Vietnam

In the past five years, the international community has recognized the Government of Vietnam's interest in environmental protection through environmental policies applicable to transport business activities (Table 3).

Table 3 shows the Government of Vietnam is aiming for a combination of technical, social and economic solutions. Many new policies have been introduced, and although it may take time to confirm their practicality and effectiveness, this legal foundation and corridor has changed stakeholder perceptions and encouraged shipping industry companies to have clearer orientation in environmentally friendly production and business.

5.2 Economic and market solutions

5.2.1 Economic solutions

For shipping businesses, the challenge posed when implementing environmental solutions is that costs incurred may affect their revenues. The International Maritime Organization (IMO) has set an ambition to reduce shipping industry GHG emissions by at least 50% by 2050 compared to 2008 levels, and reduce the intensity of carbon emissions by 40% by 2030 and 70% by 2050

Table 3. Regulations and policies related relating to Vietnam's shipping industry.

Year	Name, legal framework, commitment	Details
2017	Circular No: 15/2017/TT-BGTVT	National Technical Regulation on classification and construction of steel-shell inland watercraft carrying dangerous chemicals in bulk First Amendment 1:2016 QCVN 01:2008/BGTVT, and National Technical Regulation on prevention of pollution caused by inland waterway vessels Second Amendment 2:2016 QCVN 17:2011/BGTVT
2017	Circular No. 41/2017/TT-BGTVT	Regulation on the management of collection and treatment of waste from ships in seaport waters
2017	Circular No. 46/2017/TT-BGTVT	Regulation on safety and prevention of environmental pollution when transporting dangerous goods by sea
2017	Forestry Law	Users of forest environmental services must pay forest environmental service fees to forest environmental service providers.
2017	National program on reducing GHG emissions from deforestation and degradation; conservation, enhancement of carbon stock and sustainable management of forest resources until 2030	The REDD+ program aims to address the causes of deforestation and forest degradation (including mangroves) and shift priorities to improving the quality of natural and planted forests; limiting deforestation to maximize social, economic and environmental benefits; exploit the value of forest environmental services; and create sustainable sources for financing forest protection and development.
2018	Circular No. 40/2018/TT-BGTVT	Regulation on Vietnamese ship fuel consumption data collection and reporting
2018	Circular No. 09/2019/TT-BGTVT	QCVN 26:2018/BGTVT National Technical Regulation on ship marine pollution prevention systems
2020	Decision No. 2027/QD-BGTVT approving the Green Port Development Project in Vietnam	The State's guiding point of view: Respecting the laws of nature, being consistent with actual conditions, avoiding violent interference in nature; choosing a model that adapts according to nature, is environmentally friendly and develops sustainably with the motto of proactively living with floods, inundation, brackish water and salt water; research, develop scenarios and have effective solutions to natural disasters such as storms, floods, droughts and saltwater intrusion, with the most unfavourable situations due to climate change and development of the upstream Mekong River. Economic development is associated with social development, poverty reduction, job creation, social security settlement, environmental protection and new rural construction. Encourage the participation of all stakeholders, ensure organic cohesion within the region as well as close links with the Southern key economic region and the Mekong Sub-region. One of the solutions offered for the implementation of the Green Port project is coastal protection, mangrove protection and development.
2020	Environmental Protection Law	National policies give priority to environmental pollution treatment, restoration of degraded natural ecosystems, and focus on environmental protection of residential areas. The State emphasizes the need to diversify sources of investment capital for environmental protection.
2020	National Voluntary Commitment	Vietnam committed to reducing emissions by 9% unilaterally and by 27% with international support

Sources: Authors' own complied data

compared to 2008 levels. The urgency is clear, but the total cost of decarbonization is estimated to be USD 1.65 trillion by 2050 (Healy and Graichen 2019).

Figure 3 shows the three types of costs associated with shipping business activities.

According to Stopford (2009), capital and trip costs account for 42% and 40% of total transportation costs, respectively, for a 10-year-old bulk carrier (in 2005 prices) with operating costs accounting for an additional 14%. These operating costs comprise insurance at 32%, followed by crew costs (31%), maintenance and repairs (15%), procurement of supplies and consumables (11%) and general expenses (11%).

Several reports show that over the past decade, the transport industry has experienced periods of financial crisis leading to difficulties in ensuring profitability (European Government 2020). Consequently, developing countries such as India and Brazil have expressed concerns over having to cut CO_2 emissions, especially when their economies and technologies are still weak, as their emission reduction targets will incur huge costs to their businesses (Fenhan 2017). While developing countries mainly use old ships that require major investments in technological improvements, finding other economic solutions such as purchasing new ships is not easy (European Government 2020). Recent studies also show that the investment in building eco-friendly ships like Maersk Line's new Triple E, which cost USD 185 million each (Fenhan 2017) is very difficult for developing countries. In addition, when the EU brought shipping operations into the carbon market, many global corporations protested because they feared the inclusion of long-distance voyages in the EU's emissions trading system would lead to shipping lines looking to circumvent the law. To avoid paying for pollution permits on transcontinental voyages, for example, shippers warn that to reduce shipping costs they can simply evade EU carbon pricing rules by stopping in countries neighbouring the EU, such as Morocco, before arriving in Spain, and then only purchase a permit for the short, final leg of the trip (Defour and Afonso 2020).

However, choosing this solution will only save businesses around 7% of costs (Hargreaves 2021), due to extra costs including fuel, port fees, crew costs, insurance, and the opportunity cost, while the maximum cost of obtaining a pollution permit is only around 1%–2% of total shipping costs (Hargreaves 2020; Hargreaves 2021; James 2021). In addition, although the EU will add the shipping industry to the carbon market, it remains unclear which voyages will be entitled to purchase and insure, so it is necessary to build global insurance systems for financial security for both arrivals and departures (Hargreaves 2021).

As the shipping industry involves many stakeholders: (i) shipowners, owners and investors in ships; (ii) charterers including shipping companies that charter and operate vessels for the carriage of goods; and (iii) engineering managers,

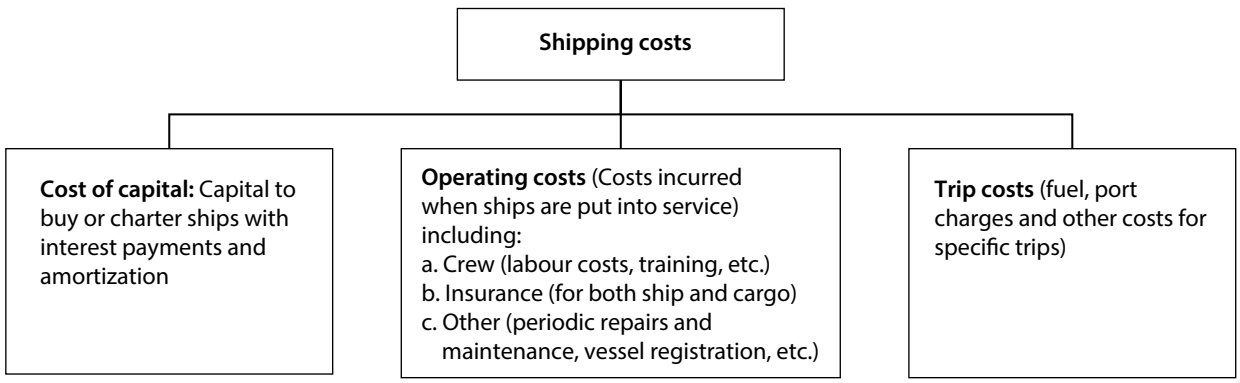

Figure 3. Costs associated with shipping activities

Sources: Stopford 2009; Healy and Graichen 2019

and because shipping lines carry cargo originating in many places, stop in many countries, and connect with company networks of different sizes (Selin and Cowling 2018), the question is who will bear the costs incurred when implementing environmental solutions as everyone in service supply chains wants to save money (Fenhan 2017).

While many businesses are concerned about costs, many financial groups, mainly commercial banks and asset managers with more than USD 50 billion, are prioritizing investment in logistics, marine and coastal tourism, and renewable energy because they believe these are sustainable investment models, especially in the context of GHG emissions reduction (World Ocean 2021). In 2019, international shipping organizations, including the International Chamber of Shipping, proposed creating a USD 5 billion fund to support the research and technology needed to cut GHG emissions (Saul 2019).

5.2.2 Market solutions

European regulations and the IMO plan both emphasize the importance of market-based policy measures and instruments (Curtis 2012; EC 2016). As mentioned above, the world, the EU and the US are building a carbon market and a market for emissions reductions. The tightening of environmental protection regulations along with the introduction of international and domestic carbon markets will encourage businesses, industries and countries to implement measure and communicate their emissions reductions. The carbon market and emissions trading policies also clearly address the mandatory participation of economic sectors, including shipping (EC 2016).

5.3 Technical solutions

In the face of environmental pollution caused by the shipping industry, many domestic and foreign technical regulations and guidelines have been introduced to limit and minimize environmental impacts (Table 2 and Table 3). These solutions focus on technological innovations and clean fuel replacement. Thanks to these regulations, while shipping volumes have increased by 101%, emissions have increased by only 40% over the same time frame, and by 2008 the carbon performance per weight gap of some ships had improved by 75% (Shell and Deloitte 2020). Many large corporations have invested in technological transformation and replacing polluting fuels with environmentally friendly alternatives. However, the number of companies and shipping lines using clean alternative fuels remains very limited (CC 2020; Ovcina 2020). In addition, although shipowners were initially concerned about energy efficiency as fuel accounted for around 25% of shipping costs, the sharp drop in oil prices in 2014 has dampened investment interest in energy efficiency due to falling profits (Fenhan 2017).

Moreover, despite the many proposed technical solutions, these are unlikely to help the shipping industry achieve its target of reducing emissions by 40% by 2030. This also creates many concerns and pressure in the international community about the shipping industry's failure to achieve the goals of the Paris Agreement.

Technical solutions to reduce fuel use are not really effective. Although the shipping industry claims to always strive to improve its environmental performance, Bannon (2016) demonstrates that ships manufactured in recent years actually use around 10% more fuel than ships produced earlier (Abbasov 2020). This also explains the pressure and lobbying for tightening management policies in the shipping industry.

The EEDI index is not really effective in achieving emissions reduction targets. IMO has acknowledged that the EEDI index is not a performance indicator because it does not really motivate businesses to improve technology or use fuel more efficiently (Bannon 2016). Around 70% of newly built container ships, which generate about a quarter of CO_2 emissions of ships globally, have so far met requirements set for 2025 (Bannon 2016). In any case, the IMO focuses on CO_2 emissions and has agreed to the new EEDI regulation, which will take some time to implement, but at least the process has begun. IMO has also agreed to an EEDI for ships over 400 gross tonnage (GT) in international traffic, or approximately 95% of all ships. Inland shipping is excluded from the EEDI and will instead be included in the CO_2 emissions account for each country.

EEDI has the following requirements and stages: EEDI Phase 0 came into effect in 2013 and provided an efficiency formula for all new diesel and dual fuel ships built after 1 January 2013. The

industry completed this stage with relative ease. From 2015, Phase 1 required CO_2 emissions be reduced by 10% compared to 2013. The industry also implemented this easily. Phase 2, requiring reductions of 15%–20%, came into effect after 1 January 2020 but is facing obstacles in the shipping industry. The more stringent Phase 3, requiring a 30% reduction in CO_2 emissions, will come into effect in 2025 (Fenhann 2017).

The solution of slow burning and reducing ship transit speeds has also failed to achieve optimum emissions reduction targets. With slow burning, vessels' operating machinery does not run at maximum capacity, thus saving fuel and reducing pollutant emissions. Reducing a ship's speed by 10% can reduce its emissions by up to 27%. A 25% reduction in engine speed can lead to a reduction in fuel consumption of around 58% a year. Lower ship speeds also reduce negative impacts on marine animals (Curtis 2012). However, this also means that market supply capacity decreases as more ships are needed to move goods volumes at the same rate as before. Therefore, in practice this solution only reduces emissions by 19% (Curtis 2012). Most vessel speeds remained unchanged between 2013 and 2015. However, the largest tankers (> 200,000 DWT) and the largest container ships (> 14,500 TEU) seem to have increased their speeds by around 4% and 11%, respectively between 2013 and 2015 (Reynolds 2019). Further, shipping lines are in fact reducing ships' moving speeds to cut fuel costs in the context of the current economic crisis, not because environmental goals are their top priority. However, although optimum targets are not expected to be achieved, reducing ship speed by low vapor combustion can still contribute to shipping industry emissions reduction targets, and is therefore still considered an important policy for climate change mitigation and adaptation. This policy solution can be easily implemented both legally and technically when applying the Automatic Identification System (AIS) (Shipmap 2012), a mandatory system that has already been applied to very large ships. As the system provides information about a ship's position, speed and direction, ships cannot evade requirements or give false information about their activities (Faber et al. 2020). In addition, under the system, EEDI is calculated for each new ship built using a complex formula that includes several factors and coefficients to represent the climate benefits to society, ship deadweight, emissions and speeds as well as other specifications (Fenhan 2017).

Liquefied natural gas (LNG) - new solution or problem to solve? LNG is currently a consideration for many parties as it can reduce SOx and NOx emissions by 100% and 90%, respectively. However, LNG use accounts for only 3% of total fuel consumption (European Commission Europe 2020). Many studies have shown that in fact, in the best-case scenario, using LNG may only reduce emissions by 10% compared to using petroleum. Some studies show that if methane leakages occur, using LNG can even increase GHG emissions compared to using conventional fuel (Bannon 2016). Though using LNG instead of heavy fuel oil (HFO) and marine oil (MGO) is believed to bring human health benefits, it is not the only technical solution for doing so while reducing emissions (Abbasov 2019). Cleaner marine oil with sulphur content of 10 ppm combined with selective catalytic reduction (SCR) and diesel particulate filter (DPF) systems can provide the same benefits as LNG. At the same time, unlike using LNG, these technologies will not require vessel conversions or expensive investments in building LNG refuelling infrastructure (Fenhann 2017). Therefore, in terms of costs and benefits, using cleaner marine oil will be the more affordable option (Abbasov 2019). Theoretically, the lower carbon content of LNG reduces CO_2 emissions, but this does not take risks relating to methane leaks into account during mining, transportation, and onboard LNG use. The GHG concentration of fossil methane (CH_4) is 30 times higher than CO_2 when averaged over 100 years, meaning LNG use risks increasing rather than reducing the climate impacts of transportation (Abbasov 2019).

Renewable energy, bioenergy. The development of alternative fuels and propulsion systems will have to be accelerated if the global fleet is to reduce CO_2 emissions significantly. Although the first steps to do so have been taken, introducing new alternative fuels in this area is complicated and time consuming, and the trend for ocean freight is huge container ships up to 400 meters in length, which consume 80,000 litres of fuel daily (Fenhanne 2017). Fuels derived from biomass can be used for maritime transportation, but vast areas of land will be needed to grow enough crops to produce sufficient volumes of biofuel, while the area for other crops is shrinking globally.

5.4 Social solutions

Consumers are increasingly interested in corporate social responsibility (CSR), and the shipping industry is no exception. Shipping businesses are paying more and more attention to the impacts shipping has on the environment, and investing in fuel-efficient fleets. They operate within the framework of international conventions and laws under the supervision of the International Maritime Organization (IMO) on protecting the environment, ensuring the safety of crew members, and the interests of experts in the shipping industry (Hiteshk 2019).

Although CSR is a relatively new concept in the industry, its role is increasingly important. CSR can help the shipping industry build environmentally friendly ships; ensure the welfare of seafarers and their families in terms of safety, security, health and communications; build unity in diversity; foster ethical communication of company policies to stakeholders; create good relations between a company and its employees; and build a reputable shipping brand (Maritime Transport 2016).

Increasingly strict sustainability demands from customers are another force driving the shipping industry towards environmental protection to maintain market share (Shell and Deloitte 2020). Maersk Line, for example, has signed agreements to reduce CO_2 emissions with companies such as BMW, AkzoNobel and Huawei as a demonstration to customers of its commitment to go green (Fenhann 2017). Similarly, Unilever has announced that it will put labels on all of its products to tell customers how much CO_2 was released during the product's production and transportation (Unilever 2021). Many ports around the world, such as Port Everglades in Florida, are investing in mangroves as part of their commitment to environmental sustainability (Kennedy 2016). Transportation businesses such as Tokio Marine Holdings, Inc. and its subsidiary Tokio Marine and Nichido Fire Insurance Co., Ltd. are also enlarging mangrove areas as a measure of low-carbon economic development (Tokio Marine Holdings 2020).

6 The role of mangroves in supporting shipping industry emissions reductions, environmental protection and sustainable development

Mangrove ecosystems play an important role in protecting the environment of Ho Chi Minh City and surrounding areas. Mangrove forests in Can Gio district, for example, not only provide large volumes of oxygen, and absorb and store CO_2 (~80 tons/ha/year), but also contribute to reducing GHG emissions. Can Gio mangrove forest is also a habitat for marine life and valuable aquatic species, and home for local residents and fishermen. Mangrove ecosystems provide protection from storms and coastal erosion, and are of particular interest for ecotourism development, environmental education and extra-curricular courses for students in the city and surrounding areas (Shingeyuki et al. 2014).

Mangroves also contribute significantly to socioeconomic development in Vietnam, and especially for coastal communities. Contributions include the provision of firewood, charcoal, electric poles, building materials, pulp, etc. Besides the direct economic value of wood and fuel, mangroves also play an important role in the sustainable production of fish, shrimp, shellfish, crabs, etc. and are important for the long-term stability of coastal fisheries.

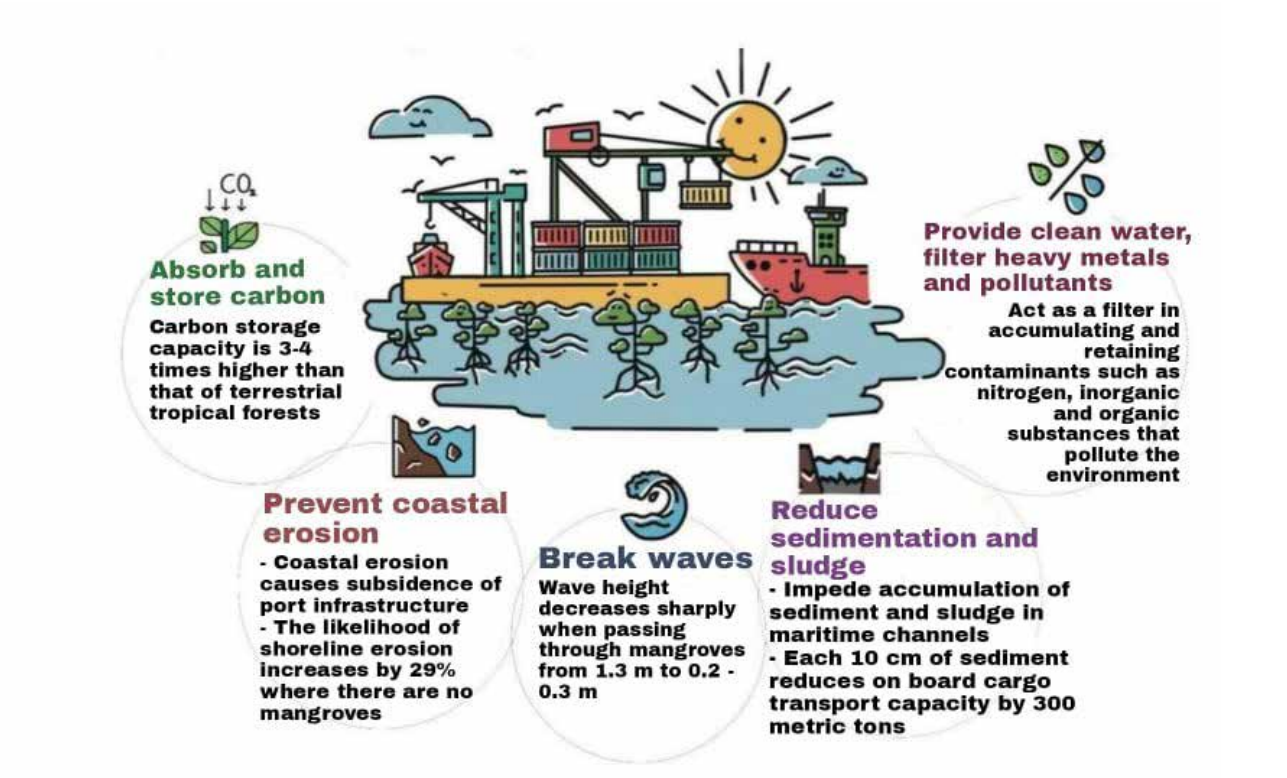

Figure 4. The roles of mangroves inplay for the shipping industry
Source: Hoai Dan 2021

Table 4. The Roles and potential of mangroves in for addressing negative environmental impacts from the negative impacts of the sector maritime transport sector

Problem	The role of mangroves
Air pollution/ GHG emissions	Mangroves are one of the most important carbon sinks on the planet. They are ten times more efficient at sequestering carbon than tropical rainforests and have 3–5 times higher carbon sequestration capacity than terrestrial forests.
Water pollution	Mangroves have the ability to accumulate heavy metals and thus have the ability to purify wastewater.
Noise pollution	Mangroves have the ability to reduce noise caused by shipping activities. The ability to reduce noise depends on the thickness of the mangrove forest and the density of the trees.
Coastal erosion and subsidence	Conservation and new planting of mangroves has always been considered a priority solution by the State and has been proposed by project designers to address and prevent coastal erosion and subsidence.
Effects on human health	The ability of mangroves to absorb CO_2 will help create fresh air, thereby reducing the risk of respiratory and cardiovascular diseases. In addition, bathing in mangroves is also considered an important medical therapy and is applied in many countries, including Japan.

Sources: Tam and Wong 1994; Kaye 2019; Adame et al. 2020; Alongi 2020; Pham et al. 2019; Pham et al. 2020)

Due to the strong circulation of nutrients in mangroves, they provide a rich source of food for many marine animals, and provide ideal conditions for breeding and rearing aquatic species. Many studies also show a significant positive correlation between mangrove area and offshore fishing, especially for shrimp (Vien NN et al. 1993).

Numerous studies have demonstrated the role of mangroves in addressing the environmental and social problems created by the shipping industry, as shown in Figure 4.

To be able to maintain and expand the area of mangrove forests, thereby enhancing their ability to mitigate and adapt to climate change, and to help the shipping industry fulfil its environmental protection commitments, it is necessary to have policies for creating sustainable sources of finance, such as the payment for forest environmental services (PFES) mechanism. Developing a payment mechanism for mangrove forest environmental services is not only in line with global trends in the application of financial instruments (e.g., carbon market, emissions trading), but also encourages society to participate in forest protection. More research is needed to raise stakeholder awareness on the roles and potential of mangroves, and to develop an effective mechanism for mobilizing and managing financial resources for mangrove conservation and development.

7 Conclusion

As a key economic sector both globally and in Vietnam, the shipping industry is facing many economic development and environmental protection challenges. Many policies have proposed technical, financial and ecological measures to support the shipping industry in achieving inclusive development goals. The synchronous combination of these measures will not only help the shipping industry achieve its sustainable development goals in a timelier manner, but will also reduce costs for environmental protection.

Mangroves, with their important role in the fight against climate change, can assist the shipping industry in solving some environmental pollution problems, and in return the shipping industry can contribute by providing a sustainable source of finance for mangrove planting and conservation, thereby expanding Vietnam's mangrove ecosystems and increasing its green growth index. However, more research is needed on the scientific and legal bases for future implementation of a payment for mangrove environmental services mechanism.

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Due to the increasing speed and impacts of climate change, the United Nations Framework Convention on Climate Change (UNFCCC) and countries around the world are calling for active participation from all sectors in helping to resolve global environmental problems. The shipping industry, which plays a leading role in world commerce by transporting 90% of goods globally, has the potential to contribute significantly in the battle to adapt to and mitigate the impacts of climate change.

This report explores shipping industry contributions to Vietnamese and global economic development, analyses the environmental impacts shipping activities can cause, and reviews upcoming solutions for tackling environmental risks in Vietnam and globally. At the same time, the report reviews the role of mangroves in supporting shipping industry commitments to environmental protection and sustainable development.

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