Green Ports and Sustainable Shipping in the European Context

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Munim, Z. H. & Saha, R. (2021). Green Ports and Sustainable Shipping in the European Context. I A. Carpenter, T. M. Johansson & J. A. Skinner (Eds.), *Sustainability in the Maritime Domain: Towards Ocean Governance and Beyond* (s. 81-99). Springer International Publishing. https://doi.org/10.1007/978-3-030-69325-1_4

Green Ports and Sustainable Shipping in the European context

Ziaul Haque Munim[1] and Rana Saha[2]

Abstract

Ship emissions and emissions from the maritime industry, in general, are of great concern to various stakeholders due to their adverse impacts on climate change and the local community. Countries within the Europe (and also around the world) are developing strategies, technologies, and drafting laws and regulations for mitigating environmental impacts of the maritime industry. Air pollution from ship exhausts has a negative impact on the surrounding area of the ports and coastal zones. This chapter provides an overview of the green port and sustainable shipping practices within the European maritime transport network, which can be divided into three maritime regions - the North and Baltic Seas, Mediterranean Sea, and the Black Sea. For these regions, we present the green port and shipping practices, and relevant regulations for environmentally sustainable shipping. Furthermore, we propose a high-level conceptual framework for the implementation of the green port and shipping practices. Finally, we discuss some future research directions.

Keywords: Maritime transport; Green shipping; Green port; Shipping emission; European ports; Environmental sustainability.

Cite as: Munim, Z.H., Saha, R. (2021). Green Ports and Sustainable Shipping in the European Context. In: Carpenter, A., Johansson, T.M., Skinner, J.A. (eds) Sustainability in the Maritime Domain. Strategies for Sustainability. Springer, Cham. https://doi.org/10.1007/978-3-030-69325-1_4

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1. Introduction

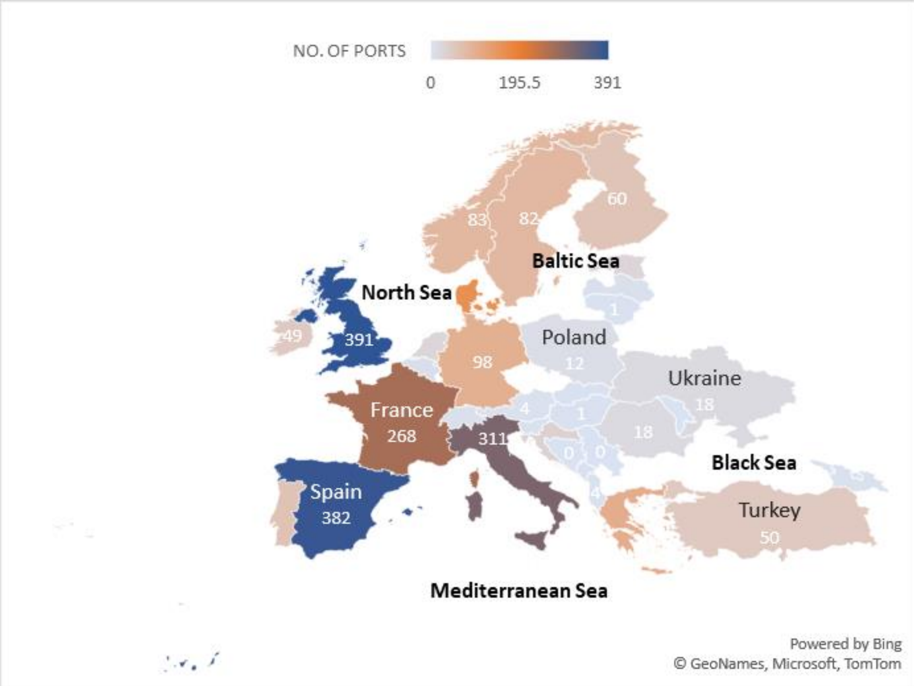
Historically the European nations are shipping nations. European cities in the Mediterranean Sea region were already popular seaborne trade destinations by the 375 BC. Due to its geographical position and industrial activities, maritime transport plays a vital role in the European economy. All European nations are connected via maritime transport, even those nations without a sea (e.g. Austria, Switzerland) are connected via inland waterways. Such a mature maritime transportation network within the Europe facilitates Short-Sea Shipping (SSS), which has emerged as a means of diverting the road congestion (Douet & Cappuccilli, 2011) during the last two decades within Europe. Furthermore, maritime transport is the driving force of Europe's imports and exports to the international markets. The European Union (EU) which, as of 2017 included the United Kingdom, had 329 key seaports, and 75% of its external and 36% of internal trades are carried out by the sea, while 32% of the world's fleet is controlled by companies within the EU (European Commission, 2020a). Overall, almost 90% of Europe's international and 40% of intra-EU trade is seaborne, including 3.5 billion tonnes of goods and 350 million passengers being transported (European Commission, 2020a). Despite the economic significance to the European continent, the maritime industry has adverse impacts on the natural environment that also affects human life.

During 2007-2012, maritime transport accounted for 2.8% of annual GHG emissions (IMO, 2015), which may seem negligible, but projected future growth is upward sloping. Green House Gas (GHG) emissions, that primarily include Sulphur Oxides (SO_x), Particulate Matter (PM) and Nitrogen Oxides (NO_x), from maritime transport accounts for 13% of total emissions from the transport industry within EU (European Commission, 2020b). According to the 3rd International Maritime Organization (IMO) GHG study, CO_2e emissions, including GHGs from total maritime transport was approximately 961 million tonnes in 2012 (IMO, 2015). For the year 2011 in Europe, total ship induced emissions of CO_2, NO_x, SO_x and $PM_{2.5}$ accounted for an estimated 121, 3.0, 1.2 and 0.2 million tons (Jalkanen, Johansson, & Kukkonen, 2016). While measuring the impact of ports on surrounding city's air quality, Viana et al. (2014) found that the port activities contribute to 33% of NO_2, 43% of PM_{10}, and 60% of SO_2 emissions at the city-port boundary. Hence, the negative impact of emissions from shipping on environmental cannot be ignored.

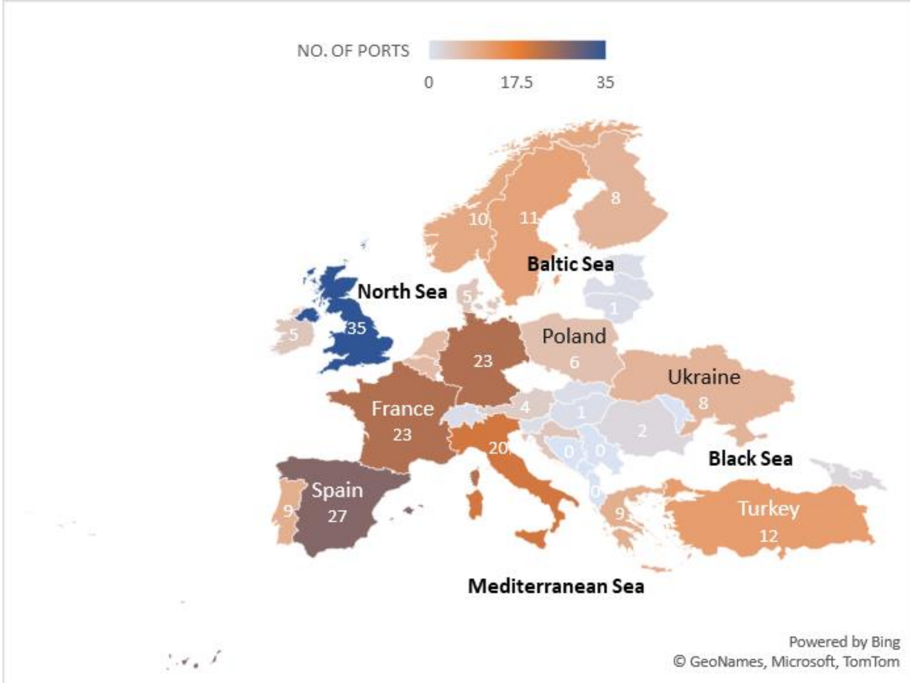
GHG emission affects the environment and causes air pollution leading to negative impacts on human health. Within Europe, an estimated 301,000 deaths per year due to $PPM_{2.5}$ (primary PM exposure) and 245,000 deaths due to SIA (secondary inorganic PM exposure) can be attributed to shipping emissions (Andersson, Bergström, & Johansson, 2009). The overall health cost in Europe from shipping emissions is expected to increase from €58.4 billion (7%) in 2000 to €64.1 billion (12%) in 2020 (Brandt et al., 2013). Similarly, Maffii, Molocchi, and Chiffi (2007) estimated an €57 billion in total external costs from maritime transport (considering marine discharges into sea, GHG emissions and atmospheric emissions) for the EU fleet in 2006. More recently, Chatzinikolaou, Oikonomou, and Ventikos (2015) estimated that the external health cost from ship air pollution calling at the Piraeus Port of Greece is about €26 million. Meanwhile, according to Brandt et al. (2013), the implementation of sulphur emission control areas was expected to reduce health cost in the North and Baltic sea region by 36%, from €22 billion in 2000 to €14.1 billion in 2020. Apart from GHG emissions, oil spills, accidents, and ballast water treatments remain a challenging environmental issue. Therefore, green port management and shipping practices are essential to reduce emission from shipping.

In an effort to reduce GHG emissions from ships, IMO aims to reduce total annual GHG emissions by at least 50% by 2050 in comparison to 2008 levels (IMO, 2020h). In recent years, sustainable shipping concerns enhanced practices both on ships and at ports. Although the environmental impacts from shipping have been well-known for decades (e.g. pollution from oil spills and discharge), more of the adverse effects (e.g. toxicity of antifouling paints, movement of alien species through ballast water) have been revealed during recent years, and some of the negative impacts such as stress to underwater marine ecosystem due to propeller noise needs further research. With growing concerns from both the political leaders and general public, European maritime bodies (regulators, ports, shipping companies) have increased their attention to maritime sustainability in recent decades.

In this chapter, first, we discuss the major local, national and international regulations governing maritime transportation in the European region. Based on satellite images, Figure 1(a) presents the total numbers of ports including very small ports, while Figure 1(b) presents only medium and larger ports within the European region. European countries with a higher total number of ports hosted comparatively larger ports than those with lower (correlation between number of ports in Figure 1(a) and 1(b) = 0.901). Then, we present some of the key green port management and shipping practices implemented by European ports and shipping companies. For easiness, based on geographic locations, shipping pattern, and regulatory practices, the European maritime territory can be categorized into three regions.



(a) All ports



(b) Only medium and larger ports

Figure 1: Ports in European maritime regions *(number of ports including inland waterway ports based on satellite image, Source: www.worldportsource.com)*

1.1. The North Sea and Baltic Sea region

The busiest European ports, namely Rotterdam, Antwerp and Hamburg, are located in this region. This region is governed under an Emission Control Area (ECA), more precisely Sulphur Emission Control Area (SECA). ECAs were introduced across North America, Caribbean Sea, North Sea and Baltic Sea by the IMO to reduce emissions of SO_x, NO_x and PM in deisgnated areas (IMO, 2020c). At the time of writing, the North Sea and Baltic Sea regions acconted for the reduction of only SO_x emissions to the air from shipping under the regulation 14 of MARPOL Annex VI, but soon to be accounted for NO_x emission control (IMO, 2020k, see Table 1). According to the revised MARPOL Annex VI, effective from January 1, 2020, sulphur limit in marine engine fuel has been reduced from 3.5% m/m to 0.50% m/m for areas outside ECAs, and from 1.00% m/m to 0.10% m/m for ECAs (IMO, 2020l). In addition, the Baltic Sea is defined as a special area under three other MARPOL Annexes — Annexes I, IV, and V — which introduce further restrictive requirements to prevent pollution from oil, sewage and garbage, respectively (IMO, 2020k). For further details of MARPOL, see Section 2.1.

Table 1: European ECAs and their effective dates (IMO, 2020k)

ECA	Emissions	Adopted	Entry into force	Effective
Baltic Sea	SO_x	Sep 16, 1997	May 19, 2005	May 19, 2006
Baltic Sea	NO_x	July 7, 2017	January 1, 2019	January 1, 2021
North Sea	SO_x	July 22, 2005	November 22, 2006	November 22, 2007
North Sea	NO_x	July 7, 2017	January 1, 2019	January 1, 2021

1.2. The Mediterranean Sea region

Historic shipping nations, namely, Greece, France, Italy and Spain, are located in this region. Being a bounded sea, this region is vulnerable to pollution, particularly due to high traffic volume, sensitive shallow and deep-sea habitats (Abdulla, 2008). There are more than 600 cities with a population of more than 10,000 along the Mediterranean coast, with about 175 millions annual tourist (Abdulla, 2008). For the year 2011, shipping activities in this region accounted for 40% and 49% of total CO2 and SOx emissions from the European shipping industry (Jalkanen et al., 2016). The same study reported that the combined shipping realted CO_2 emission from North Sea and Baltic Sea regions were almost same (88%) as the total emissions from the Mediterranean Sea region. Moreover, shipping related SO_x emission in the Mediterranean Sea region was significantly higher than SECAs (Jalkanen et al., 2016). Hence, there is an ongoing debate among the stakeholder nations to introduce an ECA (Brewer, 2020). Currently, this region is designated as speical area under MARPOL Annex I (effective from October 2, 1983) and Annex V (effective from May 1, 2009) for pollution prevention from oil and garbage, respectively.

1.3. The Black Sea region

This is a land locked sea surrounded by mostly non-EU member states, namely Russia, Turkey and Ukraine. The Black Sea is regarded as one of the most polluted seas in Europe (Altaş & Büyükgüngör, 2007). Europe's second-largest river, the Danube, transports a significant volume of land-based pollutants that enter the Black Sea every year (Galatchi & Tudor, 2006). This region is also designated as speical area for pollution prevention from oil and garbage under the MARPOL Annex I (effective from October 2, 1983) and Annex V (entry into force on December 31, 1988 but not in effect yet), respectively.

2. Maritime regulation in the European regions

At sea, international regulations by the IMO, European Commission (EC), vessels' flag state (port of registry), and classification society govern the environmental protection measures for the shipping industry. For coastal and port areas, local and/or national regulations apply in addition to the international rules. Here, we will first look into the international regulation for pollution prevention at sea, and then the regulations by the EU and its stakeholders on environmental protection.

2.1. MARPOL in European regions

The international regulation that has been continuously developed and widely used to control pollution at sea is MARPOL 73/78 — the International Convention for the Prevention of Pollution from Ships, originally proposed in 1973, later modified by the protocol of 1978 (IMO, 2020e). The Maritime Environment Protection Committee (MEPC) of IMO has been reviewing the MARPOL requirements to address any undercover challenges and to provide clarification. As a result, several amendments to the convention have been made over time.

MARPOL has six annexes, each of which specifies the pollution prevention measures at sea by ships. Further, they also have 'specified special areas' under each annex considering sea traffic, oceanographically and ecological condition. Regulatory measures are stricter on these special areas with specific requirements under each Annex. *Table 2* summarizes the list of special areas within the European territory.

Table 2: Special areas within Europe under MARPOL 73/78 (IMO, 2020k)

MARPOL Annex	***Special areas within Europe***	***Key point***
Annex I: Regulations for the Prevention of Pollution by Oil	Mediterranean Sea, Baltic Sea, Black Sea, Northwest European waters	Preventive measures such as 15 PPM on oily water separator, mandatory record keeping on oil record book, etc. to prevent oil pollution from operational processes and accidental discharge.
Annex IV: Regulations for the Prevention of Pollution by Sewage from Ships	Baltic Sea	Prohibits discharge of sewage unless the ship is 'en route' and has an operational Sewage Treatment Plant (STP).
Annex V: Regulations for the Prevention of Pollution by Garbage from Ships	Mediterranean Sea, Baltic Sea, Black Sea, North Sea	Prohibits discharge of garbage including food waste more than 25 mm so that it does not comminute or ground.
Annex VI: Regulations for the Prevention of Air Pollution from Ships	Baltic Sea, North Sea	Striker regulations on fuel oil quality (SO_x, NO_x, and PM); Mandatory technical and operational energy efficiency measures (e.g. EEDI) to reduce greenhouse gas emissions from the ships.

2.2. European pollution prevention regulations

The European Commission imposes stricter regulations within its maritime territory which comes through various directives such as Directive 2009/15/EC for inspection of vessels (see 2.2.1), Directive 2009/16/EC for Port State Control (see 2.2.2), Directive 2002/59/EC for monitoring vessels in the EU waters (see 2.2.3), and Directive 2000/59/EC on port reception facilities for ship generated waste (see 2.2.4). The objective is protecting Europe with stricter safety rules preventing sub-standard shipping, minimising the risk of accidents and environmental impact from maritime transport. The EU's pollution prevention actions can be summarised from the following perspectives:

2.2.1. Classification society

According to Lloyd's List, for the year of 2019, Europe hosts five out of the top ten classification societies of the world — DNV GL, Lloyd's Register, Bureau Veritas, RINA, and the Russian Maritime Register of Shipping (RMRS). Excluding the RMRS, classification societies within the EU are governed by the Directive 2009/15/EC on "common rules and standards for ship inspection and survey organisations and for relevant activities of maritime administration" (European Commission, 2009a). The purpose is to allow only reliable and skilled bodies as "recognised organisations", to carry out the statutory surveys and certification for the EU Member States. These societies ensure technical standards of a ship for both the construction and maintenance operations. Periodical assessment of these societies by the EC ensures indirect monitoring of the safety condition of the ships operating in EU waters. Moreover, under the Directive 2009/15/EC, the classification societies can be authorised to conduct inspection and surveys related to compliance with the International Conventions (European Commission, 2009a). Under the same directive, the classification societies are also authorised to issue ship certificates on behalf of a 'flag state', which is a member state of the EU.

2.2.2. Port State Control

Any ship calling to a foreign port other than their port of registry is subject to inspection by that port authority, commonly known as Port State Control (PSC). The purpose of these inspections is to ensure that the ship, its equipment, documentation, and operation are complying with the applicable local, regional, and international laws. The EU has its specific legislation on PSC, the PSC Directive 2009/16/EC (European Commission, 2009b). This directive is an extension of the Paris Memorandum of Understanding (MoU) on PSC, an agreement among EU maritime member states, together with Norway, Iceland, Russia and Canada (EMSA, 2020; Paris MoU, 2020). Furthermore, Directive EU 2017/2110 amends Directive 2009/16/EC introducing mandatory inspections for the high-speed passenger and ro-ro vessels by EU flag States and PSC (EMSA, 2020). The European Maritime Safety Agency (EMSA) has the technical responsivity to supervise the PSC activities within the EU. EMSA also operates its own database covering all the PSC inspection results to identify potential sub-classified vessels.

2.2.3. Maritime Surveillance

Due to its geographical position and strong consumers demand, European maritime territory has high vessel traffic, which possesses potential hazards for higher pollution from the ships. To address this issue, under Directive 2002/59/EC, the EU established a community vessel traffic monitoring and information system (European Commission, 2002). The purpose of establishing the directive includes improving efficiency of maritime traffic, increase maritime safety by enhancing the responsible authority's response on any incident or accident or potential hazards, and prevention of pollution by ships. Under Directive 2002/59/EC, all the ships calling at an EU port are responsible for notifying upon entering or leaving EU waters. Automatic Identification Systems (AIS) has played a significant role in the implementation of maritime surveillance within EU, and 'black boxes' or Voyage Data Recording (VDR) systems facilitated accident analysis and prevention (European Commission, 2002).

2.2.4. Ship-shore pollution prevention

To further support the pollution prevention measures under MARPOL and its Annexes, Directive 2000/59/EC on "port reception facilities for ship-generated waste and cargo residues" provided a framework for EU ports to ensure adequate reception facilities to collect all kinds of ship-generated waste including oil, sewage, plastic etc. (European Commission, 2000). The Directive 2000/59/EC has been amended as Directive 2010/65/EU, which was later amended as Directive (EU) 2019/883 (European Commission, 2019). Throughout those amendments, the aim was to constantly reduce marine pollution from ships by providing them with adequate reception facilities at the shore. For instance, the latest amendment, Directive EU 2019/883, included requirement of reception facilities at port for the newly introduced waste categories such as residues from exhaust gas cleaning systems that emerged due to the Annex VI of MARPOL.

3. Green port management practices

In comparison to ships, emissions from ports are relatively low. Even emissions from ships in port is a major concern for local authorities. Being hubs in the global transportation networks, ports are the centre of high-energy concentration activities such as the loading-unloading of cargo from ships, moving them within port areas, management of the administrative building, locks and bridges etc. Thus, a reduction in emissions from port operations can contribute to IMO's goal of reducing emissions from maritime transport and develop a sustainable global community. According to Acciaro, Ghiara, and Cusano (2014), port energy use can be categorized into three groups: (i) energy for direct port activities, (ii) energy for powering ships at port, and (iii) other port induced activities such as ship maintenance and repair works. While ports can adopt practices to reduce energy use, they can also take the initiative for greening their energy generation, particularly, renewable energy based solutions. European ports have been in the frontline for investing in sustainable energy generation based on solar technology (e.g. Amsterdam, Genoa, Antwerp), geothermal plants (e.g. Hamburg, Antwerp), wind (e.g. Hamburg, Rotterdam, Amsterdam), ocean energy (e.g. Leixoes, Naples) and hydrogen fuel (e.g. Valencia, Hamburg).

For the European port sector, there are mainly two institutional bodies driving green port practices. The first is the European Sea Ports Organization (ESPO)[3], and the second is the International Association of Ports and Harbors (IAPH)[4]. While the first is dedicated to European ports, the latter plays a significant role, too. ESPO promotes environmental sustainability of European ports through its set of rules and code of conduct. Essentially, in 1997 a group of European ports initiated the EcoPorts[5] environmental initiative — the first for the European post sector, and since 2011 fully integrated within the ESPO framework. As of May 2020, EcoPorts has 113 member ports in 22 countries, 52 of which are ISO certified (EcoPorts, n.d.). Santos, Rodrigues, and Branco (2016) found that the members of EcoPorts discloses their green practices in their official websites to a greater extent in comparison to non-members. Meanwhile, under the oversight of IAPH, the World Port Climate Initiative (WPCI) was initiated in 2008 by fifty-five of the world's major ports in an effort to reduce GHG emissions within the port and surrounding areas. In 2010, WPCI initiated the Environmental Ship Index (ESI) that evaluates NO_x, SO_x and PM emissions from a ship with a score ranging from 0 to 100. Different ports around the world reward ships when they score above a specified threshold on the ESI. For example, the Port of Oslo in Norway offers a 10% discount on normal rates to ships with an ESI score between 30 to 40, and a 40% discount to ships with an ESI score higher than 40 (Port of Oslo, 2020).

Despite the EcoPorts and WPCI initiatives, more needs to be done. According to ESPO (2019), the most important environmental priorities of its member ports are improving air quality, reducing energy consumption, contribute to climate change adaptation, reduce noise and work together with local communities. To better address these priorities, various Green Port Management (GPM) practices should be adopted by ports across the European region. Based on Munim, Sornn-Friese, and Dushenko (2020), we categorise and present some key GPM practices in Table 3. The adaptation of the presented GPM practices varies among ports in

[3] See website at https://www.espo.be
[4] See website at https://www.iaphworldports.org
[5] See website at https://www.ecoports.com/

different European countries. Major ports in Belgium, Germany, Italy, Netherlands, Spain, the United Kingdom and Nordic countries are the frontrunner in adapting the majority of the GPM practices listed in Table 3.

Table 3: *Key green port management practices*

Green port practices	Measurement indicators
1. Internal environmental management (IEM)	• Continuous environmental monitoring and reporting • Implementation of Energy Management Plan (EMP) • Achieving ESPO Code • Communication with local government to improve sustainability • Training employees on sustainable practices • Allocation of dedicated budgets for sustainable port performance
2. Sustainable port operations (SPO)	• Implementation of lean operations • Adapting sustainable port operating system • Reconfigure existing terminals
3. Environmental pricing (EP)	• Implementation of dynamic pricing • Offering incentives to port users • Implementation of penalty pricing
4. Adapting green technology (GT)	• Establishing cold ironing or onshore power supply (OPS) • Use energy efficient hardware and data centres • Continuously switching to cleaner port operation technologies • Use renewable or alternative energy generation
5. Supply chain collaboration (SCC)	• Collaboration with port operators to achieve environmental goals • Collaboration with other ports for GPM • Collaboration with shippers for GPM • Collaboration with shipping lines for GPM • Collaboration with other (hinterland) transport providers for GPM

Modified and adapted from Munim et al. (2020).

4. Green Shipping practices

Green Shipping Practices (GSPs) refer to environmental management practices by shipping companies to reduce waste, save resources, and protect the marine environment. Almost all shipping companies use strategic planning to reduce their environmental footprint. European, particularly Northern European shipping companies, are often considered as pioneers in sustainable shipping practices.

There are specific regulations that define mandatory green shipping practices for shipping companies. Driven by internal factors, pioneer companies often commit beyond mandatory conditions laid down by regulations. According to the IMO (2020g), the key regulations governing the green shipping practices are:

- *MARPOL 73/78:* This convention regulates pollution preventions measures from a ship. Although proposed in 1973, it was not effective until 1983 due to approval issues. As mentioned earlier, it has six annexes that have become effective during the period 1983-2005. The first five annexes have established mandatory record-keeping procedures, such as oil record book, garbage management plan etc. The sixth annex focuses more on the air quality. Under the 2010 amendment into MARPOL Annex VI, ECAs were established that have a limit of 0.10% m/m sulphur limit since January 1, 2015. Furthermore, effective from January 1, 2020, ships outside the ECAs also have a reduced sulphur limit of 0.50% m/m. In 2011, MARPOL amendments to Annex VI introduced the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). For further information on EEDI and SEEMP, see IMO (2020d).
- *The Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC), 1990:* This convention was adopted on November 30, 1990 (entered into force on May 13, 1995) to establish national and international co-ordination to prevent and act on oil pollution incidents. Under this convention, ships under the jurisdiction of participating parties must have an oil pollution emergency plan that includes reporting oil pollution related incidents to costal authorities, maintaining inventory of oil spill combating equipment as well as helping others in the event of oil pollution emergency. Later in 2000, a similar protocol to the OPRC to deal with pollution from incidents involving hazardous and noxious substances (OPRC-HNS) was adopted. For further information OPRC and OPRC-HNS, see IMO (2020f) and IMO (2020i), respectively.
- *International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), 2001:* Anti-fouling paints are used to coat the underwater hull of ships to prevent attachment or growth of sealife such as microorganisms, algae or molluscs on the hull. Such sealife growth on the hull reduces operational performance of ships. As early as in 1970s, anti-fouling paints, particularly tributyltin-based, has been recognized as harmful (Andersson, Brynolf, Lindgren, & Wilewska-Bien, 2016). The AFS convention prohibits harmful anti-fouling paint and systems to protect the marine environment from shipping operations. For more information on the AFS convention, see IMO (2020a).
- *International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM), 2004:* For steel-hulled vessels, ballast water plays an important role in stabilizing ships at sea, particularly when sailing unloaded. Meanwhile, ships loading

ballast water in one part of the world and discharging it in another can transport alien spices across geographical locations — a threat to marine the ecosystem. To address this issue, the BWM convention (entered into force on September 8, 2017) introduced the ballast water management plan with mandatory record-keeping by means of ballast water record book to restrict harmful aquatic organisms from travelling through ship ballast. For detail on the BWM convention, see IMO (2020b).

- *The Hong Kong International Convention (HKC) for the Safe and Environmentally Sound Recycling of Ships, 2009:* Currently, no international regulation exists governing ship scrapping — a process that has severe environmental and health impacts. The HKC was developed in May 2009 and aimed to reduce any potential hazard to the environment and human health from ship recycling activities as well as improving safety. This convention implies that ships to be sent for recycling must carry a ship-specific inventory of hazardous materials that must be verified during initial, renewal and final surveys. Besides, use or installation of some listed hazardous materials in the appendix of the convention is restricted or prohibited at premises of participating parties. The HKC convention has not yet entered into force awaiting approval by at least 15 member states. For more information on the HKC convention, see IMO (2020j).
- *EU MRV Regulation 2015/757:* On April 29, 2015, to reduce CO_2 emission from ships' energy consumption, the EU proposed the Monitoring, Reporting and Verification (MRV) system to stimulate more energy-efficient shipping practices. According to this regulation, ships over 5000 gross tonnage calling at a port within the EU must have a detailed analysis of CO_2 emissions. For detail, see European Commission (2015).

Several guidelines have been developed to simplify the execution of these conventions. The principal objective of these conventions is monitoring and managing the harmful substances (i.e. marine and air pollutants) emitted from the ships. To get an overview of the green shipping practices by European shipping companies, in Table 4, we compare 'sustainability report' or GSPs reported in the Corporate Social Responsibility (CSR) report of the three major shipping companies of Europe - A. P. Moller-Maersk, MSC and CMA CGM - possessing the world's 1st, 2nd and 4th largest fleet, respectively.

Overall, the three largest shipping company has been taking strategic, technical and operational level sustainably initiatives. Among them, A. P. Moller-Maersk has been disclosing more information on their sustainability practices which is rather rare but exemplary in the context of the shipping industry. We find A. P. Moller-Maersk as a pioneer in adopting sustainable shipping initiatives.

Table 4: Green shipping practices by three major European carriers (*based on data available on the company's website)*

Aspect	**A.P. Moller – Maersk**	**MSC**	**CMA CGM**
Annual sustainability reporting	Yes	Yes	No
CO2 emission	Aiming net zero CO2 emission by 2050, reduced CO_2 emissions by 41.8% between 2008 and 2019.	Reduced 13% in CO2 emissions per transport work in 2015-18.	Targeted a reduction of 30% CO2 per TEU transported by 2025, already reduced by 50% between 2005 and 2015.
Sustainable Development Goals (SDGs)	Five SDGs are highlighted: decent work and economic growth (SDG 8), Industry, innovation and infrastructure (9), responsible consumption and production (12), Climate action (13), and partnership for the goal (17).	Focused on life below water (SDG-14) and focused on life on Land (15) are key concerns for MSC's sustainability actions	In December 2019, CMA CGM joins the United Nations global corporate sustainability initiative, a technical network having nine Sustainable principles in an aim of preserving the ocean.
Technical solutions to improve vessels efficiency	→ Emission conversations and calculation, → High-capacity vessels (Triple-E vessels could improve CO2 efficiency by 50%), → Waste heat recovery system with an electronically controlled engine.	→ Air lubricating system, → Antifouling paint, → Bow modification, → Cold ironing (shore-based power), → Capacity boost, → Hull cleaning, → Propeller and rudder retrofit.	→ Retrofitting bulbous bow, → Twisted leading edge rudder, → LNG fuelled new vessels, → Ballast water treatment system, → Antifouling paint.
Participation in global environmental initiatives and platforms	→ The Ocean clean-up Project, → The Getting to Zero Coalition (which aims to decarbonising global shipping by 2050, deployment of zero-emissions vessels by 2030,	→ Cargo Incident Notification System (CINS), → Business for Social Responsibility (BSR), → North American Maritime Environment	→ Business Action Platform for the Ocean, → Charte Bleue -Armateurs de France for Safety at Sea (French charter promoting prevention and management of pollution risks, reduction

	→ Ocean-Going Vessel (OGV) Energy Efficiency Measurement Demonstration Project ("TAP Project").	Protection Association (NAMEPA), → United for Wildlife (addressing the unyielding conservation contests, prevention of extinction of endangered species).	of GHG, and effective waste management), → World Port Climate Initiative (WPCI), → Clean Cargo Working Group (CCWG).
Ship recycling following HKC 2009	Yes	Yes	Yes
Energy efficiency evaluation	Voyage Efficiency System (VES)	Energy Efficiency Operational Indicator (EEOI)	Energy Efficiency Design Index (EEDI)

While Table 4 reported GSPs adapted by the three major European liner shipping companies, we present a generic form of key GSPs in Table 5 to guide other shipping companies that are lagging behind in taking sustainable shipping initiatives. The similar to GPM practices in Table 3, the GSPs in Table 5 are categorised into five main factors, IEM, Sustainable Shipping Operations (SSO), compliance for green shipping (COM), adapting GT and SCC. Table 5 reports the measurement indicators for each of these five GSPs. Majority of the measurement indicators are modified and adapted from Lai, Lun, Wong, and Cheng (2013) and Munim et al. (2020).

5. A conceptual framework for maritime sustainability

In the previous two sections, we have presented some major green port management and green shipping practices. The implementation of those practices varies significantly across shipping companies, ports, counties and regions (Munim et al., 2020; Santos et al., 2016). While there are some frontrunners, to achieve maximum environmental sustainability in the maritime transportation sector, greater adaptation and implementation of the green port concept and shipping adjustments are required. Hence, we propose a conceptual framework for better implementation of green port and shipping practices across all European ports. Figure 2 presents the conceptual framework.

Table 5: *Key green shipping practices*

Green shipping practices	**Measurement indicators**
1. Internal environmental management (IEM)**	• Senior management support for GSP • Mid-level management support for GSP • Cross-departmental support for GSP • Company policies in support of environmental protection • Existence of environmental management systems (e.g. ISI 14001) • Corporate environmental sustainability report
2. Sustainable shipping operations (SSO)*	• Implementation of Voyage Efficiency System (VES) • Implementation of Energy Efficiency Operational Indicator (EEOI) • Implementation of Energy Efficiency Design Index (EEDI) • Handling shipping documents electronically**
3. Compliance for green shipping (COM)**	• Compliance with conventions to reduce environmental degradation* • Compliance for energy saving shipping equipment design • Compliance for shipping equipment reuse
4. Adapting green technology (GT)*	• Continuously replacing vessel fleet with new low-emitting vessels • Continuously switching to low-GHG-emitting fuel alternatives • Retrofitting vessel equipment for reduced environmental impacts
5. Supply chain collaboration (SCC)***	• Collaboration with shippers to achieve environmental goals • Collaboration with other shipping lines for GSP • Collaboration with ports for GSP • Collaboration with other (hinterland) transport providers for GSP • Collaboration with ship equipment suppliers for GSP**

**Proposed by authors. **Modified and adapted from Lai et al. (2013). ***Modified and adapted from Munim et al. (2020).*

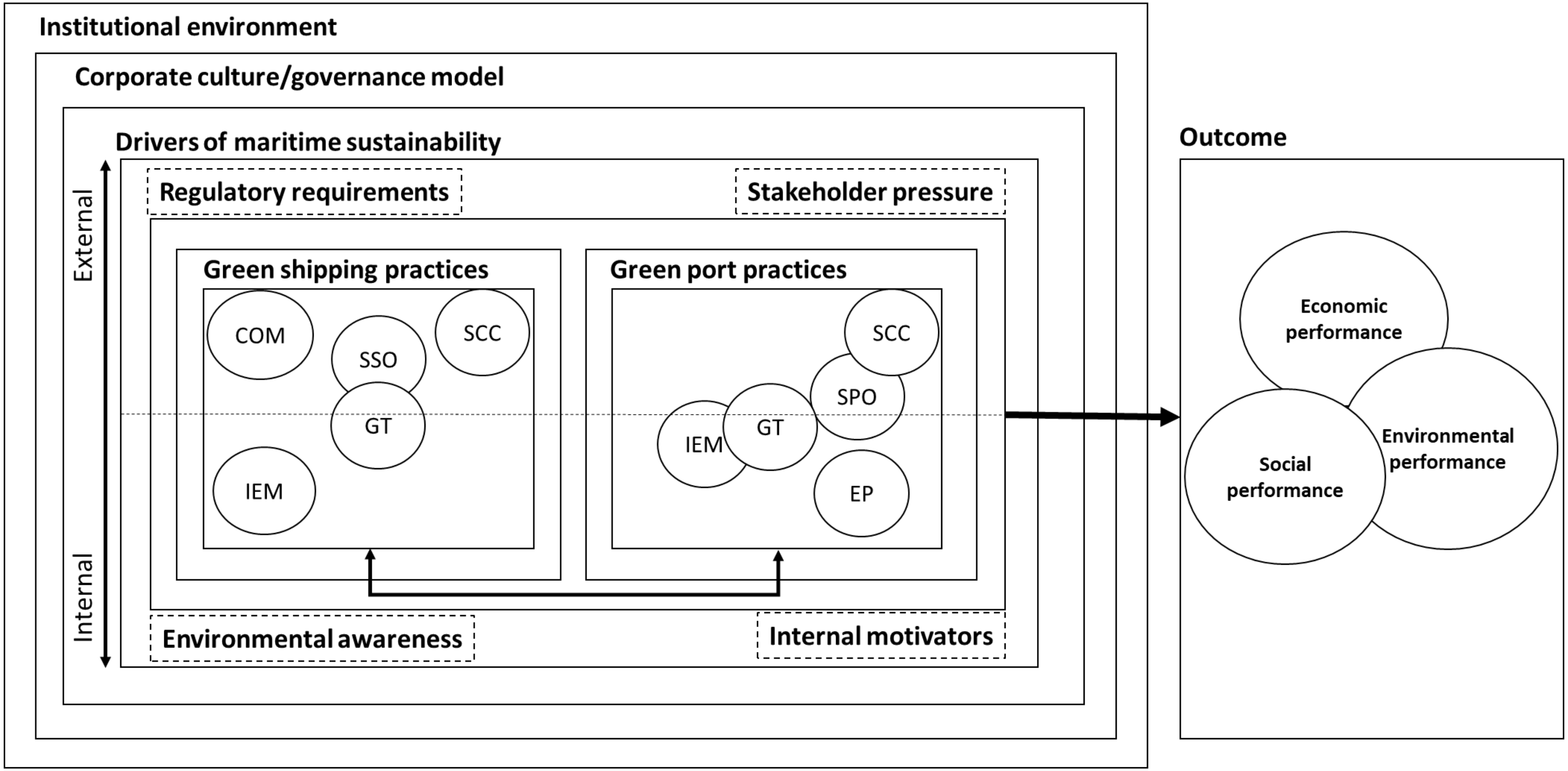


Figure 2: Conceptual framework for maritime sustainability

(COM: Compliance for green shipping, SSO: Sustainable shipping practices, IEM: Internal environmental management, GT: Adapting green technology, SPO: Sustainable port operations, EP: Environmental Pricing, SCC: Supply chain collaboration)

In Figure 2, the two inner-most rectangles represent the green port (see section 3) and green shipping (see section 4) practices broadly. All the sustainable maritime practices can be driven by four factors — regulatory requirements, stakeholder pressure, internal motivators and environmental awareness. While the first two are external drivers, the latter are internal. A dotted line in the middle separates the sustainable maritime practices driven by external and internal drivers, although some practices are driven by both. For instance, the existence of an IEM system in the port is a requirement of the EcoPorts initiative, which can also be driven by a port authority's environmental awareness. For shipping companies, IEM is most likely to be internally driven than externally. COM refers to compliance with international conventions including MARPOL, OPRC-HNS, AFS, BWM and HKC for green shipping — mainly driven by regulatory requirements. SSO in shipping companies include maintaining an energy efficiency evaluation management practice, be it a Voyage Efficiency System (VES), Energy Efficiency Operational Indicator (EEOI) or Energy Efficiency Design Index (EEDI), and can be driven by both regulatory requirements and stakeholder pressure. SPO in ports that include optimizing equipment use, adapting higher degree of autonomy in terminal operations and reconfiguring terminals for better efficiency, are more likely to be driven by stakeholder pressure and internal motivators. Environmental pricing practices in ports are mostly driven by the port's internal motivation. Internal motivators are those that contribute to the ports economic performance while improving environmental and social performance. Adapting to green technology both in ports and shipping companies is most likely be driven by the four drivers with more influence from the internal drivers. Finally, supply chain collaborations for both ports and shipping companies are likely to be driven mainly by stakeholder pressures.

The implementation of sustainable practices can vary depending on a shipping company's corporate structure or a ports governance model. For ports, some port managers believe that public ports implement a higher degree of green practices, while some port managers believe that private involvement in a landlord port model induces higher implementation (Munim et al., 2020). Interestingly both propositions seem to be true within the European context. For example, Norwegian ports are mainly governed by Public authorities and implemented many of the green practices listed in Table 3. Landlord ports such as Antwerp, Hamburg and Rotterdam are the leaders in implementing and innovating green practices. Besides, private ports from the UK, e.g. Port of Felixstowe, are also early adopters of green practices. As of shipping companies, it is likely that the largest ones are the large-scale adopters of green practices driven by the four drivers in the conceptual framework, while the smaller companies are most likely only complying with the regulatory requirements. On a higher level, the institutional framework of the host country of a shipping company or port has an impact on the sustainable practice implementation (Lai, Lun, Wong, & Cheng, 2011). In some countries, the institutional frameworks facilitate the process (e.g. Germany), while in some, it hinders (e.g. Italy) (Acciaro et al., 2014).

Overall, higher implementation of the green port and shipping practices leads to better performance of shipping companies or ports in terms of economic, environmental and social performances (Lun, Lai, Wong, & Cheng, 2016). The improved economic performance includes cost savings from sustainable port operations and growth opportunities due to greener image. Environmental benefits include a reduction in GHG emissions, fuel consumption and waste discharge. Social improvements include higher satisfaction levels for employees, customers, an improved image and greater support from the local community. Therefore, a higher degree of implementation of green measures potentially allows for easier compliance with regulatory authorities.

6. Conclusions and future research directions

This chapter presents an overview of the green port and sustainable shipping practices within the European maritime regions. While green shipping practices are highly driven by regulatory frameworks such as the IMO and EU, green port practices are mostly driven by CSR frameworks under sustainability initiatives such as EcoPorts and WPCI. Considering the European ports, we present a list of green port practices in Table 3, a list of sustainable shipping practices based on the websites of three of Europe's largest shipping companies in Table 4, and a generic list of green shipping practices in Table 5. The proposed conceptual framework in Figure 2 critically reflects on institutional frameworks of host countries of ports and shipping companies, as well as firm-level corporate or governance structure.

The 17 United Nations SDGs call for actions globally to protect the planet and improve quality of life on earth (United Nations, 2015). While several SDGs are indirectly related to maritime, the SDG 14 — life below water — dedicated to the need for conservation and sustainable use of maritime resources. While the IMO attempts to account for the SDGs by means of imposing stricter regulations, e.g. Directive (EU) 2019/883, to achieve greater maritime sustainability beyond the SDGs, much more needs to be done. The interrelationship of the institutional environment, corporate structure or governance model, drivers and practices of maritime sustainability needs further investigation. To achieve the most from the green port and sustainable shipping practices, large-scale implementation is required across ports and shipping companies of all sizes and types. Shipping companies willing to adopt sustainability practices beyond regulatory requirements should consider adapting GSPs reported in Table 4 and 5. Similarly, port authorities that are eager to adopt green practices should considers GPM practices in Table 3.

Finally, the three main pillars of a greener maritime industry are technological advancement, regulations, and increasing awareness (Andersson et al., 2016). Recently, major European ports and shipping companies have been scrutinizing digital technologies and circular economy potentials for achieving environmental sustainability to a greater extent. Electric autonomous ships are being developed with the potential for zero CO_2 emissions — and are expecting to launch commercially within a decade or so (Munim, 2019). Moreover, in the short-run, shipping companies should aim for making a transition from heavy fuel oil to comparatively less harmful alternatives such as liquid natural gas (Wang & Notteboom, 2014), and in the long-run, adaptation of low-emission fuel alternatives such as biofuels or hydrogen fuel are likely to happen. In addition, there exists enormous possibilities of big data and AI applications in reducing emissions from the maritime industry (Munim, Dushenko, Jimenez, Shakil, & Imset, 2020), for example, optimizing fuel or energy consumption from ships using machine learning algorithms. As of regulations, the implementation of NO_x ECAs in the Baltic Sea and North Sea region (effective for ships constructed on or after January 1, 2021) is likely to reduce air pollution and related external health costs significantly (Åström, Yaramenka, Winnes, Fridell, & Holland, 2018). And as can be seen in Figure 2 already, environmental awareness of ports and shipping companies as well as their stakeholder is a major driver of GPM practices and GSPs.

Acknowledgement

The authors thank the Editors of the book for constructive feedback that improved the quality of the chapter. Ziaul Haque Munim acknowledges support from the MARKOM 2020 project of the Norwegian government.

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