



Current Status and Environmental Incentive Policies of Seaports and Inland Ports in Europe

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Table of Contents

| | |
|--|----|
| Abbreviations | 5 |
| Summary | 7 |
| 1. Introduction | 8 |
| 2. International and German policies towards green shipping | 9 |
| 2.1. Air pollution and the development of Emission Control Areas | 9 |
| 2.2. Governmental approach: Germany's National Port Strategy | 14 |
| 3. Environmental operations of selected ports in Europe | 18 |
| 3.1. Port of Hamburg (Germany) | 19 |
| 3.2. Port of Duisburg (Germany) | 24 |
| 3.3. Port of Antwerp (Belgium) | 27 |
| 3.4. Port of Gothenburg (Sweden) | 31 |
| 3.5. Port of Rotterdam (Netherlands) | 34 |
| 4. Concluding remarks | 40 |
| Sources | 42 |

Abbreviations

| | |
|--------|---|
| CER | Container Exchange Route |
| CLINSH | Clean Inland Shipping |
| CNG | Compressed Natural Gas |
| CNNR | Central Commission for the Navigation of the Rhine |
| CSI | Clean Shipping Index |
| ECA | Emission Control Area |
| EEDI | Energy Efficiency Design Index |
| ESI | Environment Ship Index |
| EU | European Union |
| GHG | Greenhouse Gas |
| GNP | Gross National Product |
| GTL | Gas-to-Liquids |
| HHLA | Hamburger Hafen und Logistik AG |
| IMO | International Maritime Organization |
| LNG | Liquefied Natural Gas |
| LED | Light Emitting Diode |
| MARPOL | Maritime Agreement Regarding Oil Pollution |
| NECA | Nitrogen Emission Control Area |
| OCS | Operation Clean Sweep |
| PM | Particulate Matter |
| PV | Photovoltaic |
| SAP | System Applications and Products |
| SDG | Sustainable Development Goal |
| SECA | Sulphur Emission Control Area |
| SEEMP | Ship Energy Efficiency Management Plan |
| TEU | Twenty-foot Equivalent Unit |
| UNCLOS | United Nations Convention on Law of the Sea |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WPCI | World Port Climate Initiative |



Summary

How do international organisations and national governments minimise shipping emissions? How can ports contribute to the reduction of greenhouse gas (GHG) emissions, energy demand, and air pollution in port cities, thus making the shipping sector cleaner? Which incentives, policies, and regulations do European ports already use to solve urgent and long-term environmental problems?

There is a wide range of policies and measures port authorities in Europe can use to reduce air pollution, energy demand, and emissions. Most of the ports' strategies involve a mixture of inter-related instruments to combat emissions at ports [1]. However, cost and future uncertainties often generate the old chicken and egg story – shipping companies wait for adequate port infrastructure and legal certainty before investing in new and cleaner technologies, and ports wait for shipping demand and political backing.

Within the last two years, the selected ports collaborated closely with public authorities and energy suppliers to build up the first LNG (liquefied natural gas) infrastructures, extend shore connections, and adjust existing laws and port regulations. By subsidising pilot projects and providing additional port infrastructure for ships, these ports set an example in the reduction of GHG emissions and air pollution in the shipping sector. This is the first step in addressing future uncertainties regarding the efficiency of ship propulsion and onshore-based power supply.

Environmentally driven financial port incentives have been well received in the selected European ports and the number of ships that qualify for reduced port dues is steadily rising. In order to reduce emissions and encourage the adoption of more environmentally friendly methods, the selected European ports provide incentives for the production of energy-efficient ships and other green technologies. Voluntary financial incentives are flexible in weighing scores and ports can set their own standards. The more ports that join voluntary incentive projects, the more shipping companies are attracted, and thus the bigger the impact on environmental performance in the shipping sector.

Moreover, the selected European ports illustrate the transition from ports functioning as mere providers of infrastructure to becoming global competence centres for sustainable and innovative concepts and technologies. As a result of heightened economic competition and societal pressure on ports, the selected European ports have increasingly focused on smart and sustainable logistical concepts; this focus, along with the building of innovative research centres for advanced maritime gadgets and renewable resources, will create their own ecosystems while being part of advanced international initiatives.



1. Introduction

Both air pollution and the growing concentration of GHG in the atmosphere pose a serious threat to the earth's ecological equilibrium. The increased concentration of air pollution and ongoing climate change have, for the most part, been a result of economic activities including energy, transport, and industrial production. The importance of the shipping sector for the transportation of goods and development cannot be underestimated: in 2017, over 80 % of global trade by volume and more than 70 % of its value was carried on ships and handled by seaports worldwide [2]. Between 1990 and 2016, seaborne trade volumes increased by around 250 %, and it is forecasted that seaborne trade will further expand across all segments within the next decade [2].

But environmental concerns have cast a large shadow on this development. Even though shipping can be considered a relatively clean mode of transportation, overall shipping emissions have a major effect on both global warming and local air quality in and around port areas [1, 3].

After ratification of the Paris Climate Agreement in 2015, public focus shifted towards the maritime and aviation sectors since they were not specifically covered in the agreement [4]. In its latest report in 2015, the International Maritime Organisation¹ (IMO) concluded that the global shipping sector contributed approximately 1 billion metric tons of CO₂ emissions per year, of which about 900 million tonnes arose from international shipping [5]. Although such emissions currently account for less than 3 % of overall GHG emissions, it is forecasted that shipping emissions will revert to prior trends and continue to increase. Depending on future economic and energy developments, these emissions could rise substantially, by up to 250 % by 2050 relative to 2012 levels, and thus reach 17 % of global CO₂ emissions [5-7].

Although most of these emissions are emitted at sea, the most concentrated and immediately noticeable portion of shipping emissions takes place in port areas, which carry far-reaching health impacts for local residents. In order to reduce future projected emissions, global organisations as well as national governments and ports themselves are in charge of mitigating shipping emissions at sea and especially in port areas. The following analysis of the German Port Strategy², which concerns both selected international shipping regulations and European sea and inland port concepts, presents a general overview of the current status and incentive policies in terms of sustainable shipping in and around European ports.

¹ More information on the International Maritime Organization (IMO): <http://www.imo.org>

² More information on the German Port Strategy: <https://www.bmvi.de/SharedDocs/DE/Artikel/WS/nationales-hafenkonzept.html>



2. International and German policies towards green shipping

2.1. Air pollution and the development of Emission Control Areas

Air pollution has an indirect, mainly regional, and cumulative effect that leads to grave degradation of ambient air quality in ports and surrounding areas. For example, around 70 % of the particulate emissions from shipping occur within 400 km of the coast. Ship emissions are often one of the major sources of urban pollution in and around port cities, whereas the port operations' share of emissions do not exceed 15 % [1, 8]. The share of total emissions in a port city depends on the size of the port and size of the city, respectively, and the character of the city, such as its industrialisation level [1].

Sulphur and nitrogen oxide emissions can harm vegetation and people long-term by contributing to acid deposition, which can in turn lead to adverse changes in aquatic ecosystems and soil quality or to the formation of smog and a tropospheric ozone. As a secondary particulate pollutant, sulphur oxide emissions adversely affect human health by reducing lung functions and causing asthma [9]. With regard to air pollution, nitrogen and sulphur oxide emissions from all shipping activities represent about 15 % and 13 % of global emissions from anthropogenic sources, respectively [10]. In European coastal areas, shipping emissions contribute 1-7 % of particulate matter PM₁₀, at least 11 % of particulate matter PM₁, and between 7-24 % of nitrogen oxide to mean annual levels [11]. With the aim to reduce the emission of harmful pollutants such as sulphur and nitrogen, a combination of measures in different sectors has led to decreases in sulphur and nitrogen oxide emissions in Europe. The shipping sector can reduce emissions via similar measures such as low-sulphur fuels – LNG, or Liquefied Natural Gas, is currently the most promising alternative fuel in maritime transport – or scrubbers and soot particle filters which filter emissions before they are released into the atmosphere [12, 13]. Several studies have examined the effectiveness and cost/benefit of shipping sector emissions control measures [14, 15].

To combat climate change and reduce air pollution in the shipping sector globally, three international regimes – the United Nations Framework Convention on Climate Change³ (UNFCCC), the United Nations Convention on the Law of the Sea⁴ (UNCLOS), and the IMO – are crucial to the regulation of emissions from ships [16]. As a United Nations agency, the IMO is responsible for regulating international maritime shipping. Its main role is to create a regulatory framework for the shipping industry which covers safety and security standards as well as prevention of marine pollution by ships [17]. In 1997, the IMO defined and introduced special Emission Control Areas (ECAs) to minimise pollution in designated sea

³ More information on the United Nations Framework Convention on Climate Change (UNFCCC): <https://unfccc.int>

⁴ More information on the United Nations Convention on Law of the Sea (UNCLOS): http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm



areas [17]. There are two facets of ECAs which set limits on sulphur oxide and nitrogen oxide emissions: Sulphur Emission Control Areas (SECAs) and Nitrogen Emission Control Areas (NECAs). Figures 1 and 2 below display existing SECAs and NECAs, followed by what are likely to become future-designated areas.



Figure 1: Existing Emission Control Areas all around the world (Source: [18])



Figure 2: Existing and possible future Emission Control Areas all around the world (Source: [18])

The requirements in SECAs – which currently include the Baltic Sea, in effect from 2006; the North Sea, in effect from 2007; the North American coasts, in effect from 2012; and the United States Caribbean Sea, in effect from 2014 – are stricter than the general requirements and laws. Additionally, all ships spending energy by using fuel at berth in EU ports are required to use low-sulphur fuel (0.1 %) from 1 January 2010. Thanks to this law and further regulations, European ports have far fewer emissions of sulphur oxide (5 %) and particulate matter (7 %) than their share of port calls (70 %) [1]. Moreover, all ships driving in the North Sea,



Baltic Sea, North America, and the United States Caribbean Sea were required to use fuel with sulphur content not exceeding 1.0 %, thereby implementing the revised Annex VI of the International Convention for the Prevention of Pollution from Ships⁵ (MARPOL), which entered into force on 1 June 2010 [19]. As shown in Table 1, as of 1 January 2012, the current global limit of ships' fuel using sulphur content is 3.5 % mass by mass. Within SECAs, the maximum permissible sulphur content in marine fuels was lowered to 0.1 % in January 2015. The same year, the sulphur content of fuels used in SECAs decreased substantially. SECA requirements were implemented into European law on 21 November 2012 by the Sulphur Directive [20]. Most importantly, from 2015, ships operating in SECAs have to adopt clean technologies such as scrubber systems or LNG for their primary propulsion. However, in their current state, ships will unlikely achieve such ambitious sustainability goals. In Europe, the introduction of SECAs has already proved effective, resulting in a 50–66 % decrease in sulphur oxide emissions [11].

Table 1: Fuel quality requirements to limit sulphur oxide emissions (Source: own representation based on [21])

| Fuel Sulphur Content | 2008 | 2010 | 2012 | 2015 | 2020/2025 |
|----------------------------|-------|-------|-------|-------|-----------|
| SECAs: | | | | | |
| Baltic Sea (2006) | | | 1.0 % | 0.1 % | |
| North Sea (2007) | 1.5 % | 1.0 % | 0.1 % | | |
| North America (2012) | | | | 0.1 % | |
| U. S. Caribbean Sea (2014) | | | | | 0.1 % |
| Worldwide | 4.5 % | 3.5 % | 3.5 % | 0.5 % | |

Nitrogen oxide emissions from shipping are regulated by mandatory limits on the emissions of newly-built engines. These regulations entered into force in 2005. MARPOL established the first nitrogen oxide regulations with three tiers [17]. Firstly, marine diesel engines installed on ships constructed between 1 January 2000 and 1 January 2011 are required to comply with Tier I emission limits. Secondly, Tier II emission limits for engines installed on ships apply to ships built after 1 January 2011; this corresponds to approximately a 15–25 % reduction compared to Tier I. Thirdly, Tier III requirements comprise installed marine diesel engines on ships constructed on or after 1 January 2016 and which are intended for operation in NECAs; the relative reductions are 80 % below Tier I emission standards. Today, there are two NECAs, both in North America. One NECA is along the coasts of Canada and the U. S. and a second NECA is along the Caribbean portion of the U. S. coastline. There are several ways for new and existing ships to meet the increasingly stringent nitrogen oxide emission standards [22]. The regulations, which apply to diesel engines with an output of over 130 kW and to ships with a length over 24 meters, are shown in Table 2.

⁵ More information on the International Convention for the Prevention of Pollution from Ships (MARPOL): [http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-\(MARPOL\).aspx](http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx)



Table 2: Mandatory limits for nitrogen oxide emissions of new-built engines (Source: own representation based on [21])

| | Entry into Force | Diesel Engines installed on Ships | Nitrogen Oxide Limit in g/kWh | Regions |
|---------|------------------|---|-------------------------------|---|
| Tier I | 2005 | 1 January 2000 - 1 January 2011 | 9.8-17.0 | Worldwide |
| Tier II | 2011 | After 1 January 2011 | 7.7-14.4 | Worldwide |
| Tier II | 2016 | After 1 January 2016 only operating in NECA's | 2.0-3.4 | NECA's: North American Coasts U. S. Caribbean Coastline |

Taking environmental concerns and the manipulation of competition within European ports into account, the IMO designated the North Sea and Baltic Sea as NECA's starting from 1 January 2021 [17]. Based on available emission scenarios, the European Monitoring and Evaluation Programme estimates that the annual reduction in total nitrogen deposits into the Baltic and North Sea will be around 22,000 tonnes compared to a non-NECA scenario [23-25].

Additionally, in January 2011, the IMO introduced two efficiency measures to address GHG emissions in the shipping sector, namely, the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan⁶ (SEEMP). The EEDI enables estimation and comparison of the energy efficiency of newly-built ships on a tonne-kilometer basis. This ensures data comparability and has boosted efforts to promote energy-efficient shipbuilding. The SEEMP requires ships to develop a strategy to monitor and improve their energy efficiency [26]. It is estimated that the energy consumption and CO₂ emissions of newly-built ships may be reduced by up to 60 % by 2050 through waste heat recovery, innovations in engine and transmission technologies, aerodynamics, electronically controlled engine systems designed for fuel efficiency and speed, and auxiliary power systems [10]. But the volume of GHG emissions emitted per unit of transport supply will equalise or even rise if the biggest ships – and others which follow their lead – continue to speed up [6].

In addition to international regulations and rules, there are voluntary initiatives by international organisations such as the World Port Climate Initiative⁷ (WPCI). Launched in 2010, the Environmental Ship Index⁸ (ESI) from the WPCI aims to achieve a substantial reduction in the emission of nitrogen and sulphur oxide, as well as CO₂ in the longer-term, by encouraging ports to grant shipping companies discounts on port dues or a reduction in tonnage charges for using ESI-certified seagoing ships. Therefore, shipping companies must self-register their ship's emissions performance through the ESI website. The ESI score ranges from 0 to 100. A ship that is just in compliance with the mandatory IMO regulations for nitrogen and sulphur oxide emissions respectively, is set at 0, whereas on the other extreme a ship with a score of 100 emits no nitrogen or sulphur oxide emissions at all. In 2017, there was a total

⁶ More information on the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP): <http://www.imo.org/en/ourwork/environment/pollutionprevention/airpollution/pages/technical-and-operational-measures.aspx>

⁷ More information on the World Port Climate Initiative (WPCI): <http://wpci.iaphworldports.org>

⁸ More information on the Environmental Ship Index (ESI): <http://www.environmentalshipindex.org>



of 6,857 ships with a valid ESI score, representing more than 7 % of the world's commercial fleet of seagoing ships; 52 ports globally – 38 of which are located in Europe – were also members of the alliance (Figure 3) [2, 27].



Figure 3: Countries with participating ports at the ESI project (Source: own representation based on [27])



2.2. Governmental approach: Germany's National Port Strategy

Efficient transport infrastructure and economically competitive ports are essential to Germany's export-oriented economy. Nearly a quarter of Germany's total external trade is managed by German seaports and inland ports, which ensure the transportation of raw materials to downstream processing companies throughout the country [28]. Therefore, the Federal Government's policy aims to cope with future challenges, such as increasing international competition, and seeks opportunities to expand its leading role in the development of sustainable technologies [29]. Within its long-term strategy to improve the competitiveness of the whole logistics sector, the German Federal Government, in cooperation with the federal states, ports, the logistics sector, and trade unions, introduced the second National Port Concept in 2015. This program was designed to accelerate the economic strength of ports, improve the competitiveness of sea and inland ports, and reduce emissions incurred by international and domestic shipping. The first National Port Concept introduced in 2009 proved to be successful [28]. The current National Port Concept contains seven general measures to be implemented by the Federal Government, the federal states, unions, and the port sector; they range from the building of infrastructure to guaranteeing safety standards and employment. As shown in Figure 4, this environmental framework includes eight bullet points, intended to ensure and promote the shift towards sustainable shipping and port development. One focuses on measures for climate change mitigation, the use of alternative fuels, and the deployment of shore connections.

| | | | |
|--|---|--|---|
| Create EU-wide and International Environmental Standards | Introduce a Worldwide CO ₂ Monitoring System | Promote Research in the Field of Alternative Fuels | Ensure Onshore-Based Power Supply |
| Introduce Emission-Based Port Dues Nationwide | Mitigate Noise Impact | Protect German Coasts against the Consequences of Climate Change | Guarantee Port Development in Flood Zones |

Figure 4: Measures within the Germany's National Port Strategy in terms of environmental aspects (Source: [28])

Firstly, the planned introduction of limits for emissions from shipping and the discharge of sewage seeks to create no further harm to the environment or to public health. Therefore, the Federal Government will continue to lobby for uniform European and international limits for emissions that pollute the air and sewage discharge from ships by campaigning for the designation of SECAs and NECAs. Additionally, with support from the federal states and local authorities in its search for adequate solutions, the port sector will deploy port waste reception facilities for sewage from cruise ships in the Baltic Sea area by 1 June 2019.



By campaigning and lobbying for the introduction of an internationally accepted CO₂ monitoring system, the Federal Government is also playing an active part by contributing its own ideas to negotiations being led by the IMO. Furthermore, the European Council has submitted regulations for an EU monitoring and reporting system of CO₂ emissions in the shipping sector. It was adopted in May 2015 and will enact emissions monitoring from 2018 and reporting from 2019. Nevertheless, and although it is currently not possible to estimate how much the negotiations concerning the internationally applicable CO₂ monitoring system will require, the Federal Government and European Commission prefer international rules and regulations that prevent the manipulation of competition and the emergence of two different monitoring systems [28].

Nurturing LNG as the most promising way to reduce GHG emissions and fulfil SECA requirements in the shipping sector, the European Commission set out a proposal for the development of alternative fuels which focuses on achieving a minimum of infrastructural deployment that would cover LNG refuelling points within all sea and inland ports. The proposal was adopted by the European Parliament and Council on 29 September 2014. Hereby, all major ports in Europe are required to provide LNG by 2025 [30]. In 2016, the Federal Government has, in cooperation with relevant industries – especially the Maritime LNG platform – and federal states, developed a national policy regarding the deployment of alternative fuels infrastructure. The policy implemented the EU Clean Power for Transport Directive⁹ and was driven by the Federal Government's Mobility and Fuels Strategy, which embraces and subsidises market entry strategies for LNG in the shipping sector [31–33]. The ports sector is responsible for investments establishing an LNG bunkering infrastructure. The investments are supported by

⁹ More information on the Clean Power for Transport Directive: https://ec.europa.eu/transport/themes/urban/cpt_en



federal states and local authorities, which will help to implement the deployment by providing land for LNG infrastructure and by subsidising selected LNG projects. In addition, the Federal Government will lobby for a harmonisation of internationally recognised approval standards and procedures for LNG infrastructure [28]. Table 3 summarises the measures and responsible parties within the German Port Strategy 2015.

Table 3: Measures and responsible bodies within the German Port Strategy 2015 (Source: [28])

| Measures \ Responsibility | Ports Sector | Federal States | Federal German Government |
|--|--------------|----------------|---------------------------|
| Creation of EU-wide and International Environmental Standards | x | x | x |
| Introduction of a Worldwide CO ₂ Monitoring System | | | x |
| Advance Market Development in the Field of Alternative Fuels | x | x | x |
| Ensure Onshore-Based Power Supply | x | x | x |
| Introduction of Emission-Based Port Dues Nationwide | | x | |
| Mitigation of Noise Impact | x | x | x |
| Protection of German Coasts against the Consequences of Climate Change | | x | x |
| Ensure Port Development in Flood Zones | | | x |

Another section deals with onshore-based power supply. The energy requirements of ships at berth can be met either by internal auxiliary engines or an external power supply. Given today's electricity prices in Germany, onshore-based power supply is not an attractive economical option for ships. Therefore, the Federal Government will campaign for a mandatory tax exemption for onshore-based power supply going to commercial shipping. This tax exemption will, at best, encourage ships to use onshore-based power supplies and thus contribute to a better air quality within and around port cities. The federal states, the energy supply sector, and the ports sector oversee the provision and operation of shore-side electricity systems [28].

With regards to nationwide emissions-based port dues, several German ports currently grant an ESI-based discount on port dues on a voluntary basis. Ships with a high number of ESI points benefit from lower port dues, whereas non ESI-registered ships pay full port dues. In the future, federal states will be commissioned to think about the introduction of emissions-based port dues valid for all German ports [28].

With regard to noise pollution, the Federal Government, federal states, port authorities, and the logistics sector are responsible for implementing mitigation



measures, chiefly concentrating on the sources themselves. In cooperation with Deutsche Bahn Netz AG, the Federal Government is in charge of reducing noise on existing railway lines and roads which pass through or near residential areas. Noise sources in ports are the responsibility of the ports sector itself. This counts especially for ports which are in proximity to residential areas or port cities [28].

On climate change, the Federal Government, in cooperation with the federal states and society stakeholders, has developed the Strategy for Adaptation to Climate Change¹⁰. The objective of this strategy is to reduce vulnerability to climate change and maintain the adaptability of the ecosystem [34]. The Federal Government and federal states will jointly ensure port development in endangered coastal areas by implementing measures such as the heightening of flood defences, breakwaters, and other in-sea installations. The Federal Government is responsible for clarifying competences and responsibilities to ensure future construction work in German ports in or near flood zones [28].

Responsibilities concerning port development are flexible and likely to change over time. Incentives for clean shipping in Europe are to be prepared at European national governmental and federal state levels in cooperation with the European port authorities. However, thanks to the global market, the EU and national governments are increasingly shaping port policy with regard to international and European regulations. Hence, the federal states and port authorities are encouraged by the EU and national governments to involve them more closely in their port policy planning. To prevent conflicts regarding future port policies, the Federal Government has commissioned a study to identify the existing institutional structures, legal bases and reciprocal exchanges of information between the Federal Government and the federal states and port authorities in port policy at the national and European levels [28].

¹⁰ More information on the German Strategy for Adaptation to Climate Change: <https://www.umweltbundesamt.de/en/topics/climate-energy/climate-change-adaptation/adaptation-at-the-federal-level/german-adaptation-strategy>



3. Environmental operations of selected ports in Europe

In the last couple of years, European ports have started to undergo important changes concerning air pollution and ship emissions. That is because ports are now confronted with many performance criteria, such as ensuring high quality, deployment, safety, resource conservation, and environmental protection standards, many of which are part of the Sustainable Development Goals (SDGs) [17, 35]. Due to increasingly critical customers, ports have to undergo new measures and break new ground in order to meet increasing societal and legal requirements. Thus, the ports themselves are responsible for implementing clean port plans to enhance their environmental credentials. Furthermore, they offer a wide spectrum of environmentally-driven incentives for shipping companies (Table 4).

Table 4: Financial incentives on port dues (Source: collected data from port websites)

| Incentive \ Port | Hamburg | Antwerp | Gothenburg | Rotterdam |
|-----------------------------------|---|--|-----------------------------|-------------------------|
| ESI Score | $20 \leq x \leq 24$ = 0.5 % (max. 250 €) $25 \leq x \leq 34$ = 1.0 % (max. 500 €) $35 \leq x \leq 49$ = 5.0 % (max. 1,000 €) $50 \leq x$ = 10.0 % (max. 1,500 €) | $31 \leq x \leq 50$ = 5.0 % $50 < x < 70$ = 10.0 % $70 \leq x$ = 15.0 % | $30 \leq x$ = 10.0 % | $31 \leq x$ = 10.0 % |
| ESI-NO _x | - | - | - | $31 \leq x$ = 10.0 % |
| CSI | - | - | 4 Stars or more = 10.0 % | - |
| Green Award | = 3.0 % | - | - | = 6.0 % |
| Blue Angel Award | = 2.0 % | - | - | - |
| LNG Propulsion | = 15.0 % (incl. ESI) | - | = 30.0 % (incl. ESI) | - |
| Use of Onshore-Based Power Supply | = 15.0 % (if ESI-registered or/and Green Award Certificate) | - | - | - |

*In order to increase the comparability among the ports, only sea ports are selected.

As the following analysis will demonstrate, there are many options for reducing emissions in ports, involving changes in infrastructure deployment and operational practices.

3.1. Port of Hamburg (Germany)

Almost as old as the city itself, the Port of Hamburg was founded on 7 May 1189. The port enabled Hamburg to strengthen its position in Central Europe and to develop a prosperous economy based on international trade. Today, Hamburg is one of the world's largest and busiest ports which hosts a wide range of shipping activities. The Port of Hamburg handles around 9,000 seagoing-ship calls per year (Table 5) and is served by more than 2,300 freight trains per week, of which 1,300 are destined for the hinterland. The Port of Hamburg has 280 berths for seagoing ships, three cruise terminals, four state-of-the-art container terminals, and about 7,300 logistics companies within the city limits [36, 37]. Its three main trading partners in terms of seaborne cargo throughput are China, Russia, and Brazil. Regarding only container throughput, the port's main trading partners are China, Singapore, and Russia. Accordingly, the Port of Hamburg is the largest seaport in Germany and known as the nation's gateway to the world. It is the third largest container port in Europe and 17th in the world [38]. It is also Germany's second largest inland port. The port covers an area of 7,105 hectares, of which 4,258 are on land. Around 166,000 jobs are directly and indirectly dependent on Hamburg's port activities [37]. Ensuring maximum efficiency and economy in all areas of the port infrastructure, the Port of Hamburg is also highly aware of the need for new technology and innovative approaches to achieve a sustainable symbiosis of port activity and environmental concerns [36].

Table 5: Facts about the Port of Hamburg in 2016 (Source: [36])

| Container (TEU) | Cargo Tonnage | Seagoing Ships | Inland Ships |
|-----------------|---------------|----------------|--------------|
| 8,900,000 | 138,200,000 | 8,719 | 10,000 |





Port incentives

The Port of Hamburg has taken a variety of actions to push shipping companies towards more environmentally friendly technologies and propulsion. In accordance with the Air Pollution Control Plan passed by the Hamburg Senate, a new fee rating system featuring an environmental component is being introduced in 2018 [39]. Seagoing ships will be granted a discount on port dues up to 10 %. Ships with an ESI score between 20 and 24 will be given a discount of 0.5 %, up to a maximum of 250 EUR; those with a score between 25 and 34 will qualify for a discount of 1 %, up to a maximum of 500 EUR; those with a score between 35 and 49, a discount of 5 % up to a maximum of 1,000 EUR; and those with a score of 50 or more, a discount of 10 % up to a maximum of 1,500 EUR. In 2016, more than 15 % of ship calls were made by ships registered with an ESI score and 18 % of all calls were far cleaner than the required law. In 2016, nearly one of every three ESI-registered ships had more than 35 ESI points, an increase by 41 % compared to 2015 [36].

In terms of environmental financial incentives, the discount increases even more. Ships that have the Green Award certificate are granted an additional discount of 3 % and ships with a Blue Angel Award¹¹ can receive a discount of 2 % on port dues. A special discount of 15 % is provided for ships with an exclusively LNG propulsion system until 31 December 2018. Ships that do not have exclu-

¹¹ More information on the German ecolabel Blue Angel: <https://www.blauer-engel.de/en>

sively LNG propulsion but do hold an ESI score above 0 or a Green Award can receive a discount of 15 % on port dues, up to a maximum of 2,000 EUR if they predominantly use an onshore-based power supply. The introduction of a nitrogen oxide-based tariff system is in progress [36, 39].

Infrastructure deployment

Since 2015, fuelling via truck-to-ship is complemented by the LNG Hybrid Barge Hummel, the world's first environmentally friendly hybrid LNG barge. Hummel silently supplies low-emission electric power to ships at berth. It was shown that the LNG Hybrid Barge reduced CO₂ emissions by 20 % and nitrogen emissions by 80 %, with no particulates or sulphur oxide emissions. The 76 meter LNG Hybrid Barge is classified as a seagoing ship and can also operate as a heat plant and floating power plant during the winter season [36, 40].

Alternatively, mobile LNG PowerPacs, which consist of containers equipped with gas engines and are placed onboard ships, minimise air emissions within the port of Hamburg. A PowerPac is the size of two 40-foot containers and combines a gas-fired generator with an LNG tank. PowerPacs can be implemented quickly and provide a high degree of operational flexibility [37, 40].

Promoting the use of environmentally friendly fuels, the Port of Hamburg also seeks to provide proper infrastructure for onshore-based power supply for inland and seagoing ships, especially cruise ships. Today, shore power is produced entirely from solar panels and wind parks, and thus is 100 % renewable. However, it is also roughly four times more expensive than auxiliary engines. In 2017, shore connection was used by just one cruise ship [39, 41].

Port-owned efforts

To reduce its carbon footprint, the Port of Hamburg promotes the use of low-emissions, energy-efficient machinery, and equipment. With the help of T-Systems and SAP, it created a smartPORT philosophy which promises digital intelligence and guarantees sustainable economic growth. As a result, the port's smartPORT Logistics covers about 20 projects and focus on optimising three sub-sectors, namely, traffic flows, infrastructure, and the flow of goods. In addition, smartPORT Energy boosts environmentally friendly mobility and accounts for reduced energy consumption. It has three focuses: renewable energy, energy efficiency, and clean mobility [36].

Sustainable mobility/Traffic relocation

Within its smartPort Energy strategy, the Port of Hamburg has a carpool of 248 vehicles, 13 of which have CNG (Compressed Natural Gas) propulsion and 18



which drive electrically. Additionally, Hamburger Hafen und Logistik AG (HHLA), recently awarded as the best green container terminal operator, has ordered a fleet of 64 all-electric cars, the largest fleet of electric cars owned by a European port operator. They cover about 475,000 km each year, reducing CO₂ emissions by 148 tonnes. Additionally, HHLA purchased two new straddle carriers [37, 42]. The development of greener transport is further encouraged by a discount, in effect since 2011, for shunting engines equipped with soot particle filters to prevent particulate emissions. Over 50 % of railways are electrified [36, 42]. Metrans, a port subsidiary rail company with 272 km of tracks, has acquired two new hybrid locomotives for heavy-duty shunting. Thanks to this new technology, harmful substances such as particulate emissions have been reduced by up to 70 %. In 2015, 38 out of 231 shunting locomotives in the port were equipped with particle filters [39]. Most of the port-owned ship fleet has switched to fuel gas liquid (Gas-to-Liquids: GTL), which emits less nitrogen oxide and particulates compared to diesel [36].



Logistics systems

With regard to cloud-based digital control systems, the smartPORT Logistics strategy facilitates interactions between sensor technology and analysis, information, and forecasting systems to ensure effective and traceable improvements. For example, digital solutions like real-time navigation, mobile GPS all-purpose sensors, and smart maintenance supplementing the flow of goods help ensure an efficient, intermodal, and sustainable transport system within the port. Computer-aided optimisation of container storage positions mitigates the distance travelled by transport equipment, reducing both energy consumption and noise pollution [36].

Energy saving

In accordance with the smartPORT Energy project, both the Pintsch-Aben and the Port of Hamburg installed a geothermic switch-point heating for 880 switch points along the dock railway, thus reducing external power supplies and saving energy. Additionally, the port has a real-time information system to monitor the condition of rails and switches via sensors. Early warnings on traffic conditions and malfunctions allow it to plan efficient maintenance and improve the utilisation of port rail infrastructure [36, 43]. Furthermore, several projects were also continued in the field of energy-efficient lighting. For example, the HHLA terminal is one of the first northern range ports that completely adopted LED lamps for lighting terminal areas and outfitted all container cranes with LED lighting. The LED lights automatically turn off when unneeded. HHLA estimates electricity savings of more than 95 % for the lighting of its block storage facilities. Additionally, approximately 50 container gantry cranes have been fitted with energy recovery systems, which have saved around 20 to 25 % of the energy used [42].

Renewable sources

By 2015, so that the HHLA terminal could receive environmentally-produced electricity, it installed a widespread photovoltaic system and seven wind turbines [42]. Above all, Eurogate strives to be the first port terminal in Hamburg which covers its own electricity demand by self-owned renewable sources. Therefore, the company installed a wind turbine on one of its container terminals at the beginning of 2015, thereby generating its needed electricity. The terminal and wind turbines save 9,000 tonnes of CO₂ emissions per year. Nearly two-thirds of power consumption at the Eurogate Terminal is provided by solar energy combined with heat, power plant, and wind power [44].



3.2. Port of Duisburg (Germany)

First mentioned in the late middle ages, for centuries the Port of Duisburg was a central hub for the coal, mining, and steel-producing industries. Today, together with its subsidiaries, it comprises an area of 1,550 hectares, of which 300 are covered by the logistics centres Logport I and II, with eight container terminals fitted with 21 gantry cranes and 130 cranes with a lifting capacity of up to 500 tonnes. It is the world's largest container inland port [45]. Expanding its role as a competence centre for automotive logistics, the Port of Duisburg is home to premium German manufacturers including Audi and Volkswagen. In 2017, Daimler started construction of a new logistics centre at the Port of Duisburg [45].

Located in the heart of Europe's largest consumer market with over 30 million customers within a radius of 150 km, the Port of Duisburg offers a wide range of services including package logistics, rail freight, and consulting management. The port is served by 400 weekly train connections to over 80 direct destinations in Europe; 1,100 employees handle 20,000 trains and 25,000 ships annually (Table 6). In 2011, Duisburg inaugurated a direct rail connection to Chongqing in China, and since 2014 has been served by about 25 freight trains weekly. The one-way journey takes 13-15 days compared to 30-40 days by sea, and at a fifth of the cost of air freight. In order not to operate at the expense of the environment or nearby residential areas, the Port of Duisburg has made efforts to reduce the emission of air pollutants. The port plans to achieve this by linking sustainability with technical innovation, and by promoting an efficient use of its area and ecological transport chains [45].

Table 6: Facts about the Port of Duisburg in 2016 (Source: [45])

| Container (TEU) | Cargo Tonnage (including Private Ports) | Seagoing Ships and Inland Ships |
|-----------------|--|------------------------------------|
| 3,700,000 | 133,000,000 | 25,000 |

Infrastructure deployment

In cooperation with partners and customers, the Port of Duisburg is undertaking several projects involving alternative fuels for logistics. One of them concerns a cooperation with RWE Supply & Trading GmbH. They are jointly developing LNG infrastructure for the port area and, once implemented, the system will constitute a sustainable and integrated logistics concept for the procurement, storage, use, and distribution of LNG within the port [46]. Before choosing a location for the LNG service station, the partners evaluated various applications for replacing diesel fuel and recently installed a mobile fuel pump for supplying LNG to port vehicles and lorries, along with a mobile LNG gas station for port-internal vehicles and trucks [45].

Port-owned efforts

Sustainable mobility/Traffic relocation

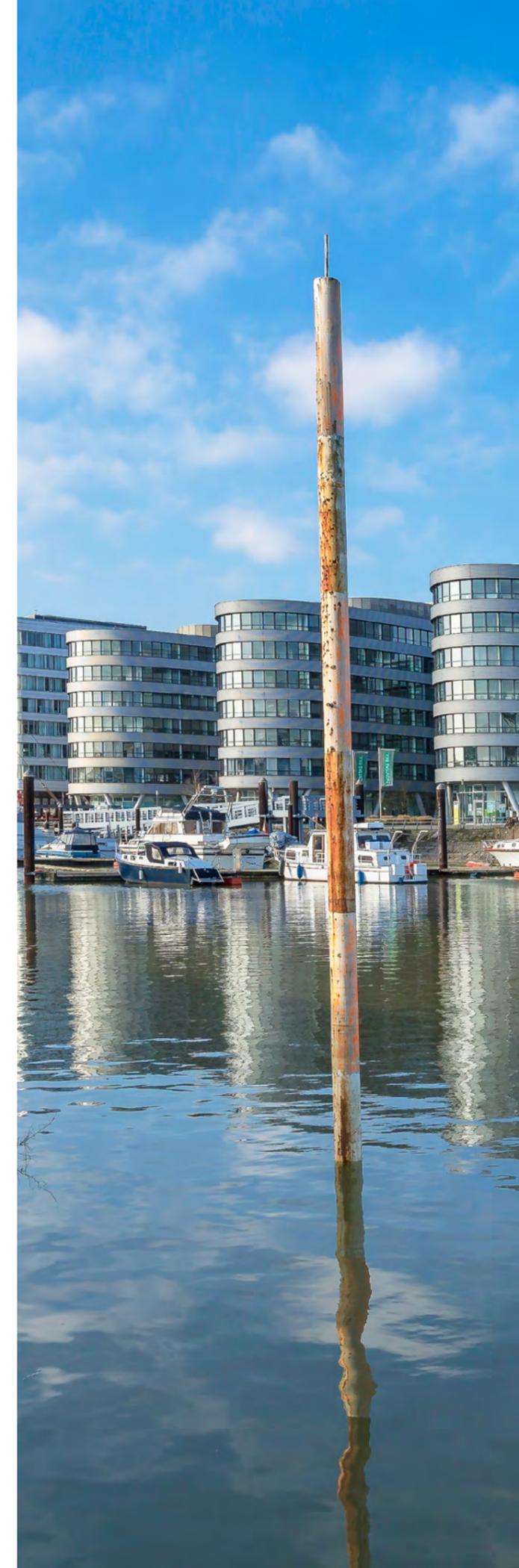
The Port of Duisburg promotes the shift of goods from the highways to alternative modes of transport, especially rail and inland waterways, thus replacing an estimated 100,000 truck trips per year through its strategy of traffic relocation. For example, the Audi AG logistics centre within the Port of Duisburg transports automobile components by inland waterways or rail to Antwerp, saving around 13,000 truck trips per year. New rail connections such as the Chemsite-Express, the Ost-westfalen-Express, and the Glückauf-Express are making the shift to rail more efficient and attractive to customers [45].

Logistics systems

Road traffic is also the focus of efficiency measures. Therefore, the Port of Duisburg and Siemens AG signed a strategic agreement to develop an integrated truck guidance system, aiming to raise the efficiency of logistics hubs by faster truck handling. An intelligent flow control system facilitates the integration of IT systems, minimises congestion and waiting times, reduces fuel consumption and emissions, increases throughput, and boosts overall performance [45, 47].

Renewable sources

In partnership with innogy SE, the Port of Duisburg wants to develop a so-called hub for energy market transformation, becoming a test centre for new methods of saving energy and using renewable sources in logistics and industry. The first tests with ultra-light, organic, and flexible solar films installed in the Port of Duisburg have been undertaken, which were





found to be suitable for locations where conventional PV modules proved too heavy; consequently, these films have the potential to be installed on facades, thin rooftops, and logistics containers [45].

Recycling

Lastly, by using reusable wood packages in industrial packing, the Port of Duisburg reduced wood consumption by 200 tonnes [45].

3.3. Port of Antwerp (Belgium)

The Port of Antwerp was first mentioned in the 12th century and developed into an export point for wine from Germany to England, as well as a port for passengers travelling to the Netherlands or to England. The 16th century was Antwerp's golden age, when exports of wool, textiles, and paintings produced in the provinces of South Netherlands boomed. Today, the Port of Antwerp is not only the largest port in Belgium, with a size of 12,068 hectares (or about 20,000 football fields), but also the largest port area in the world, ranking 14th worldwide in container traffic volume [38, 48]. 40 docks, 86 terminals, and seven locks produce a smooth transfer of traffic within the port area. On the so-called superstructure, about 900 private companies are active, employing no less than 150,000 people. In addition, the Port of Antwerp has 85 European and more than 500 direct destinations all over the world [48].

Since 2012 there has been an upward trend in the volume of shipping freight handled in the Port of Antwerp. In 2015, the port's freight volume passed 200 million tonnes and the port handled 14,500 seagoing ship calls (Table 7). This naturally has both positive and negative impacts on economic and environmental issues in and around the port's surroundings [48].

Table 7: Facts about the Port of Antwerp in 2016 (Source: [48])

| Container (TEU) | Cargo Tonnage | Seagoing Ships | Inland Ships |
|-----------------|---------------|----------------|--------------|
| 9,654,000 | 208,420,000 | 14,417 | 58,006 |

Incentives

The Port of Antwerp grants a discount on port dues for ships with a good ESI score. In 2017, a new graduated system was introduced, in which ships with a score between 31 and 50 were given a discount of 5 %, those with a score between 50 and 70 a discount of 10 %, and those with a score of 70 or more a discount of 15 % on port dues. As a result, the number of calls by ships with such characteristics has considerably increased over the years, from 462 calls in 2012 to 1,137 calls in 2016. At the same time, the total number of calls at the Port of Antwerp slightly decreased. In 2016, the Port of Antwerp granted ESI discounts for about one in 13 calls, whereas roughly one in every 40 ships calling at the Port of Antwerp had emission-reducing technology such as scrubber systems [48].

Infrastructure deployment

From 2011 to 2016, the Port of Antwerp worked to make LNG available as an alternative fuel for inland and seagoing ships. Even though the bunkering volumes still remain small, they have been increasing from year to year, ranging from 68 tonnes in 2013 to 468 tonnes in 2016. In 2016, the port signed a 30-



year concession with the energy company ENGIE to develop and operate an alternative energy hub to supplement truck-to-ship and ship-to-ship LNG fuelling [48, 49]. This first shore-to-ship multifunctional LNG bunkering and LNG fuelling facility in Europe consists primarily of an LNG bunkering station for inland barges and short sea ships. It will also feature an LNG and CNG filling station for trucks, buses, and cars. The CNG will be produced from the LNG storage tank with inputs from LNG boil-off. In addition, the multifunctional alternative energy hub will have fast charging facilities for electric vehicles. Thanks to the boil-off process, it is supposed to become a local zero-emission facility [49].

In an effort to combat air pollution on a local scale by avoiding active auxiliary engines producing electricity at berth, the Port of Antwerp installed seven new shore connections in 2017; these connections avoid noise nuisance for people living nearby the port area, and also drastically reduce CO₂ emissions and other harmful pollutants such as nitrogen oxide and particulates. The electricity for onshore power is mainly produced by port-owned wind parks within the port area [48].

In addition, the Port of Antwerp and various partners jointly support the Clean Inland Shipping¹² (CLINSH) project, which is a two-year demonstration project that assesses the effectiveness of alternative fuels, emissions control technology, and onshore-based power supply by collecting data during regular operations. Valuable information about the ecological performance and operating costs of the monitored ships will help to develop a smart and sustainable inland shipping sector [48].

Port-owned efforts

Sustainable transport/Traffic relocation

To foster good and sustainable accessibility to the port area, the Port of Antwerp looked at both alternative and sustainable transport possibilities and implemented them accordingly. For a workforce of nearly 60,000 employees commuting to and from the port every day, the port installed park and ride car parks, the Port of Antwerp shuttle bus, and a special water bus for bicyclists. Moreover, with special reference to trucks and private cars, the port and its partners introduced a campaign to encourage private companies to increase investments in sustainable transport. By replacing diesel-engine straddle carriers with hybrid versions, the Port of Antwerp set a good example for others to invest in environmentally friendly traffic. Furthermore, the Port of Antwerp has successfully encouraged several companies in the port area to both reconsider their carbon footprints and transportation methods. Honouring their intentions and already implemented measures, the Port of Antwerp has nominated and listed selected companies as

¹² More information on the project Clean Inland Shipping (CLINSH): <https://www.clinsh.eu>



Greening Ambassadors. Moreover, in 2017 the Port of Antwerp issued a call for proposals to make transport in and around the port of Antwerp more efficient and sustainable. Seven projects, ranging from innovations in barge transport to shifts in rails, were selected and each received financial support up to a maximum of 200,000 EUR spread over a period of three years. The projects are supposed to relieve the streets by up to 250,000 truck trips annually [48].

Renewable sources

In 2016, roughly one-fifth of the installed capacity was produced by renewable sources such as wind power, solar panels, and biogas. The Port of Antwerp expects to double its production of sustainable energy in the coming years [48].

Gas venting

Highly aware of its environmental impact, the Port of Antwerp is preparing to implement a ban on the free venting of gases. Therefore, electronic detectors, including so-called iNoses (devices for monitoring the air quality) and infrared cameras, will be installed around the port to identify and prevent the release of hazardous and noxious substances [48].



3.4. Port of Gothenburg (Sweden)

First mentioned in the 1620s, the Port of Gothenburg started to grow rapidly in the middle of the 19th century as the Swedish export industry gathered momentum. Ships began to grow in size and technical progress enhanced transportation of a large amount of export goods and materials. It is the largest port in the Nordic countries. Nowadays, approximately 30 % of foreign trade in Sweden passes through the Port of Gothenburg. Main exported goods comprise forest product and vehicles, as well as paper and steel products, whereas goods such as food, electronics, and clothing are largely imported. Moreover, with a consumption of around 20 kg per person per year, the Swedes are the largest banana consumers in the world and the Port of Gothenburg has been famous for more than 100 years for welcoming banana boats. Located on the west coast of Sweden, around 70 % of the population and industry of Scandinavia stand within a radius of 500 km. With over 11,000 ship calls per year from over 130 direct destinations in Europe, Asia, the Middle East, Africa, and North America, the Gothenburg region has been awarded as the best logistics location in Sweden for 15 successive years (Table 8). The self-financed port, owned by the City of Gothenburg, employs directly and indirectly around 22,000 people. The Port of Gothenburg sets itself ambitious aims. It targets to reduce CO₂ emissions from shipping within Gothenburg's geographical area by at least 20 % during the period 2010-2030 [50]. Its major challenge in the future is to achieve its growth and environmental ambitions simultaneously.

Pilot projects/International initiatives

As the main polymer hub in Europe for the production, handling, and distribution of plastic pallets, the Port of Antwerp recently became the first port to officially join Operation Clean Sweep¹³ (OCS), aimed at keeping plastic out of the sea [48].

Table 8: Facts about the Port of Gothenburg in 2016 (Source: [50])

| Container (TEU) | Cargo Tonnage | Seagoing Ships |
|-----------------|---------------|----------------|
| 798,000 | 40,900,000 | 11,000 |

Port incentives

Following an agreement between the Swedish Maritime Administration, the Swedish Shipowners' Association, and the ports of Sweden to reduce nitrogen and sulphur oxide emissions, Sweden has since 1996 applied a differentiated port dues system that rewards clean ships and penalises dirty ones. To honour the efforts of ships toward sustainable transport, the Port of Gothenburg offers a discount for ships that report good environmental performance. Ships that have a score of at least 30 points according to ESI, or at least four stars according to the Clean Shipping Index¹⁴ (CSI), receive a 10 % discount on port dues. Above all, the Port of Gothenburg grants an extra discount for ships that run on LNG, resulting in a total discount of 30 % for every call. In 2016, 29 % of all ship calls received an environmental discount [50].

¹³ More information on the program Operation Clean Sweep (OCS): <https://opcleansweep.org>

¹⁴ More information on the Clean Shipping Index (CSI): <https://cleanshippingindex.com>



Infrastructure deployment

Existing LNG fill-ups, like truck-to-ship and ship-to-ship supplied by Skangas, facilitate the refuelling of ships with LNG at the Port of Gothenburg. In 2015, the first ship at the Port of Gothenburg was fuelled with LNG, and in 2017 it saw the first bunkering of a ship with LNG while the ship was being loaded. There will also be an LNG import terminal for ships, factories, and land transport in the port area run by Swedegas, and it is scheduled to be fully operational in 2018. For this, LNG will arrive at the terminal in containers or trailers and then be transported to the quayside via a 450-meter pipeline. The pipeline infrastructure will supply LNG both from land and the sea for ships at three berths. The new facility also has the capacity to store and transport renewable gas such as biogas [51].

In addition, since 1989 the Port of Gothenburg has been a world pioneer in terms of using low-voltage to supply ships with electricity from shore. If a shipping company signs an onshore power agreement, the Port of Gothenburg is obliged to provide onshore equipment. Moreover, the Port of Gothenburg also subsidises on-shore-based power by waiving charging fees for the power provided – conversely, ships connected to an onshore-based power supply benefit from a higher ESI/CSI index. Moreover, taxes on onshore power have been reduced substantially in Sweden over the years. In 2016, 35 % of all ship calls at the Port of Gothenburg had the capacity to connect to onshore power supply [50].



Port-owned efforts

Sustainable mobility/Traffic relocation

The Port of Gothenburg provides green mobility and flexibility. Its long-running investment in rail shuttles that link the port to inland terminals and towns throughout Sweden and Norway made an impact. The intermodal system of rail shuttles for inland transport managed by Railport Scandinavia handles 25 rail shuttles daily, carrying containers and several normal trains loaded with export goods. The shift to rail reduced CO₂ emissions by over 60,000 tonnes and decreased energy consumption by up to 70 %. Furthermore, it was more cost-effective and helped to prevent congestion on the roads, as it avoided around 360 truck transits per day through the city. Setting an example, all of the port's ships use marine gas oil in the immediate area in order to save on emissions [50].

Renewable sources

In accordance with its efforts to mitigate the environmental impact of port-owned activities, the Port of Gothenburg invested in solar panels, biogas, and district heating while offsetting its remainders – all of this resulting in the port having become a climate-neutral company [50].





3.5. Port of Rotterdam (Netherlands)

For decades, the Port of Rotterdam has been both the world's and Europe's largest port for containers and both liquid and dry bulk. With over 100,000 calls in 2015, it was the 5th biggest port by cargo volume and 11th biggest port by container traffic in the world (Table 9) [38]. The total port area comprises 12,643 hectares, of which 7,843 are on land. The total length of Rotterdam's port area stretches over a distance of 42 km. The Port of Rotterdam directly and indirectly employs more than 175,000 people. Moreover, it is responsible for more than 3.5 % of the gross national product (GNP) of the Netherlands [52]. Essential to the Port of Rotterdam is the large petrochemical industry and general cargo transshipment handlings. Five oil refineries, six refinery terminals, 45 chemical locations, and 25 multi-user berths for ship-to-ship transfers ensure that the port can handle the largest ships and has the capacity to handle and store enormous quantities of diverse cargo and liquid bulk. For example, the terminal of Maasvlakte II opened on 24 April 2015 and was supposed to be one of the most technologically advanced container terminals in the world, with a throughput capacity of 2.7 million TEU per year. It can handle the world's largest containerships with its 1,000 meters of quay and 20-meter depth [53].

Connected to the Rhine and Maas rivers, the Port of Rotterdam also provides good access to the hinterland. In the future, the Port of Rotterdam wants to become a global hub for LNG and biomass to strengthen its position as one of the most innovative, competitive, and dynamic ports around the world. This includes the reduction of CO₂ emissions and efficient use of raw and residual materials through a combination of technology, capacity, knowledge, and incentives [52].

Table 9: Facts about the Port of Rotterdam in 2016 (Source: [52])

| Container (TEU) | Cargo Tonnage | Seagoing Ships | Inland Ships |
|-----------------|---------------|----------------|--------------|
| 11,577,000 | 461,200,000 | 29,022 | 105,000 |

Port incentives

Seagoing ships travelling in a more sustainable way than conventional ships are rewarded with discounts. In the case of receiving an ESI score that is more than 31 points, the ship will be rewarded a 10 % discount on the gross tonnage part of port dues. This can be doubled when ships also have an individual ESI-NO_x score of 31 or more, which is typically achieved by using LNG as fuel and/or large catalysts. In 2016, the Port of Rotterdam granted arriving ships ESI-based discounts of almost three million EUR. However, discounts further increase if oil, LNG, or freight tankers with a load capacity of more than 20,000 tonnes hold the Green Award certificate; in such a case, they are granted an additional 6 % discount on seaport dues. But it is not only the seagoing ships which have the opportunity to



get a discount for environmentally friendly shipping. The inland shipping sector can also receive a discount by having the Green Award certificate and/or a propulsion engine performance in compliance with the Central Commission for the Navigation of the Rhine 2's¹⁵ (CCNR 2) emission requirements. The discounts for inland ships on port dues can increase to as much as 30 % if engines are more than 60 % cleaner than the CCNR 2 emission requirements and/or have a valid Green Award certificate with a score of 400 points or more for the main engine. In 2016, almost 600 inland shipping companies received a discount. Inversely, inland ships which do not satisfy CCNR 2 emission standards receive a 10 % surcharge on harbour fees, which is then used for research and development activities by which the Inland Shipping Expertise and Innovation Centre in the Netherlands works toward further greening inland shipping [52].

Infrastructure deployment

The Port of Rotterdam is the number one European hub for LNG, with its terminals holding a capacity of twelve billion m³ for the import and re-export of LNG. With large investments in LNG infrastructure, it is a strong supporter of LNG and it is

¹⁵ More information on the Central Commission for the Navigation of the Rhine (CCNR): <http://www.ccr-zkr.org>



playing a pioneering role in its introduction. Since 2014, the Port of Rotterdam has been the first port in which ship-to-ship LNG bunkering for seagoing ships was officially allowed, whereas only truck-to-ship fill-ups were possible before. The Gate Terminal, a new LNG import terminal provided by a joint venture between Gasunie and Vopak, has also been built up at the Port of Rotterdam. Located near the port entrance, the LNG import terminal is easily accessible to LNG tankers, and each of the three storage tanks has a capacity of 180,000 m³. In addition to its Gate Terminal, in 2016 a break bulk facility allowing smaller quantities of LNG to be pumped into bunker ships and smaller sea-going tankers was put into operation. LNG is also used to fuel trucks and inland ships heading for the hinterland. Plans to gradually expand the LNG infrastructure are in progress [52].

To reduce sulphur, nitrogen, CO₂ emissions, and noise nuisance, shore connections for both seagoing and inland shipping are widely available in the port. With over 500 quayside electricity connections, inland skippers can conveniently find their power supply via the mobile phone application "Shore" [54]. The use of auxiliary engines on inland vessels is not permitted at locations where onshore-based power supply is available [52].

Port-owned efforts

Sustainable mobility/Traffic relocation

In order to prevent road congestion and highway truck traffic, a dedicated double-track, electric-powered freight line which links the Port of Rotterdam with the German border has already been planned and implemented. Furthermore, in 2018, the port will deploy a newly built LNG-powered dredging ship which will be used for dredging maintenance work [52].

Logistics systems

Moreover, in 2019, the port will be introducing a completely new and elaborate system that covers infrastructure, logistics agreements, and IT systems by linking the port's terminals, empty depots, and storage facilities. This so-called Container Exchange Route (CER) is supposed to minimise the cost of container exchanges by bundling them such that trains, barges, and ships no longer have to call on terminals individually. It is estimated that over one million containers per year will be handled in this CER area [52].

Energy saving

The Port of Rotterdam embarked on replacing all public lighting in its port area with LED lights, which consume 50 % less energy than conventional lights. Making use of the residual heat generated by the port's industrial sector is yet an-

other strategy to lower emissions and potentially supply reliable heat to 13,000 households and 200 companies. The port has already undertaken a number of steps to construct an underground network of pipelines [52].

Renewable sources

In 2017, wind turbine capacity in Rotterdam's port was 200 MW. This currently represents about 10 % of the total wind energy capacity in the Netherlands. Aiming at a total installed capacity of 300 MW by 2020, the Port of Rotterdam joined the North Sea Wind Power Hub Consortium to speed up efforts by developing large-scale offshore wind energy capacity to reach its ambitious climate targets. In addition, there is a pilot study in progress with floating solar panels at the Sluter, which is a 250-hectare depot for contaminated dredged material [52].

Gas venting

The Port of Rotterdam not only encourages companies to minimise their emissions, but also takes action itself by commissioning hybrid patrol ships equipped with iNoses to identify noxious and hazardous substances leaking from ships. Within the port area, there are more than 250 iNoses installed [52].

Pilot projects/International initiatives

The most effective and obvious way to reduce carbon emissions quickly is to capture and store CO₂. Therefore, the Port of Rotterdam plans to lay a pipeline straight across the port area connected to enterprises. The idea behind this initiative is that this pipeline would go to empty gas fields under the North Sea and store CO₂ there, thus impeding its seeping into the atmosphere. From 2018 to 2020, this pipeline is slated to store two million tonnes of CO₂, with an even





larger potential for subsequent years. CO₂ is also being transferred to greenhouse growers as a residual product, creating a small-scale recycling economy [52].

Start-Up/Innovation

The Port of Rotterdam wants to be a catalyst for innovation. By working closely with students, research institutes, and universities, the port aims to become a hub of innovation. In this innovation ecosystem, researchers are encouraged to produce prototypes and space for testing, and start-ups and entrepreneurs are accompanied in all phases of the innovation process, from ideation to scaling and economic independence. The Port of Rotterdam supports not only local start-ups but has also initiated a partnership with an open innovation program titled World Port Accelerator PortXL¹⁶ in 2015, focusing on port-related tech start-ups all over the world. With its network of potential clients and partners in the energy, maritime, transport, and logistics sectors, the PortXL program located in Rotterdam leverages the entrepreneurial activity and tries to bring providers and consumers together through its platform and innovative ecosystem. Consequently, in the last couple of years, the Port of Rotterdam backed various developments and start-ups willing to reduce waste within port areas and set an innovative example of smart and sustainable port solutions [52, 55].

For example, the Port of Rotterdam's latest subsidised innovation is a water drone from the start-up AquaSmartXL¹⁷, a small, unmanned boat equipped with



a camera to provide flexible solutions for surveillance and inspection from the water surface. The Waste Shark from RanMarine Technology¹⁸, another drone, is an unmanned electric catamaran whose primary task is to independently clean docks and canals of floating plastic and other small trash under-water. Also on the digital solutions front, the digital marketplace 4Shipping is intended to promote the position of inland shipping by making supply and demand of such shipping containers more transparent and thus more effective [52, 56].



¹⁶ More information on the World Port Accelerator PortXL: <https://portxl.org>

¹⁷ More information on AquaSmartXL: <http://aquasmartxl.com>

¹⁸ More information on RanMarine Technology's Waste Shark: <https://www.ranmarine.io/aquadrone-wasteshark>



4. Concluding remarks

Ports can lower the costs of trade, attract maritime and port-related sectors, and generate employment. Well-functioning ports are generally associated with many economic benefits [57]. However, negative environmental impacts from ports significantly decrease the quality of life in and around port areas. The overview of environmental impacts and incentive policies undergone by the aforementioned European ports shows that there is a wide variety of technologies and operational measures which can effectively mitigate emissions in said port areas. It is worth noting, however, that while most of these ports are still in the beginning stages of their transition to an environmentally friendly and holistic port strategy, their first efforts have already proven to be successful.

The ports presented in this report made progress in addressing air emissions by giving shipping companies monetary incentives to invest in, for example, more sustainable propulsion. In particular, schemes like ESI that provide access to a large number of financial incentive providers through a flexible framework for ports, and which have low entry barriers for shipping companies to become participants, are increasingly accepted [58]. It is thus not surprising that in 2016, nearly 29 % of all ship calls received an environmental discount from the Port of Gothenburg. At the Port of Antwerp, ESI discounts were granted for about one in 13 calls, while the Port of Rotterdam spent almost three million EUR in ESI based discounts, with 600 inland ships having received an incentive [48, 50, 52]. Even though the discounts burden the budgets of the ports, they are still reluctant to penalise seagoing ships with high emissions, likely due to risk of manipulating competition. This is true across the board with the exception of the Port of Rotterdam, where inland ships have to pay an extra fee in the event that they do not meet minimum environmental standards [52].

Downsizing their own carbon footprint is challenging but necessary for both cutting the environmental impact of ports and setting an example of sustainable action themselves, especially for ports in close proximity to residential areas. For this reason, ports are investing substantially and with varied focuses and



results in cost-effective digital transport systems, renewable sources, and innovative tech solutions. They are also using alternative propulsions for their own ship and car fleets (Table 10). Those efforts led to noticeable results. At the Port of Antwerp, from 2000 to 2012, the total emission of particulates by all sources decreased by over 63 %, while total goods handling rose 10 %. Over the period of the last five years, the port's CO₂ emissions fell by 10 % [48]. Since 2011, the Port of Rotterdam has been a CO₂-neutral company, offsetting its remainders through the purchase of Gold Standard emission allowances [52]. Since 2015, the Port of Gothenburg has been a climate-neutral company as well. It offsets its remainders by contributing to the expansion of a wind park in Jilin province in North-East China, which was built exclusively by companies seeking to offset their emissions [50].

Table 10: Evaluation of ports in Europe in terms of environmental aspects

| Criteria \ Port | Antwerp | Gothenburg | Rotterdam | Hamburg |
|---------------------------|---------|------------|-----------|---------|
| Infrastructure Deployment | ++ | +++ | +++ | ++ |
| Incentive Policies | ++ | ++ | ++ | ++ |
| Port-owned Efforts | ++ | ++ | ++ | ++ |
| Digital Intelligence | ++ | + | ++ | +++ |

*Explanations: +++ immense high, ++ very high, + high

**In order to increase the comparability among the ports, only seaports were selected.





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