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Ports in Energy transition
Case of Port of Rotterdam and Port of Singapore

by

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Abstract

Since it has been acknowledged by the humanity that the greenhouse effect and climate change are the consequences of industrial emissions mostly generated by fossil fuels, energy transition strategies and search for alternative energy resources to reduce greenhouse gas emissions are under deep discussion worldwide. The shipping industry together with port operations are the main contributors to the air emissions and experience serious transformation forced by the global emissions regulations. Ports have a unique centralized position in the global supply chains, and this gives the ports the opportunity and the power to influence the stakeholders and take measures to become CO2 neutral thus reducing the environmental impacts of port operations. This research aims at analysing how energy transition affects the business profiles of the two largest ports operating in different markets and geographical locations but having similar power and importance to local economies. The research is based on the cases of Port of Rotterdam and Port of Singapore. With help of the case study and elements of content analysis, this research assesses the port energy transition initiatives and actions undertaken to reduce CO2 and other emissions at ports. The investigation is made on the basis of academic research, analysis of scenarios by industry experts and official media reports by the ports' authorities. The results suggest that Port Authorities of both ports are highly engaged in energy transition activities. Use incentives to encourage shipping companies to switch to climate-friendly fuels. From this research it can be concluded that both of these ports have a powerful position to regulate emissions from shipping, cargo handling, logistics and industrial functions by influencing stakeholders. The Port of Rotterdam has greater potential in reducing CO2 emissions compared to Port of Singapore and is in a more advantageous position in terms of the growth of energy clusters and industry concentration. The largest emission reduction initiative of the Port of Singapore is its objective of becoming an LNG hub. Port of Rotterdam plays an active role in lowering port emissions in different industries and is ahead in implementing renewable energy initiatives.

Keywords: energy transition, port emissions, green port, alternative fuel, renewable energy, sustainability.

Table of Contents and Appendices

List of Abbreviations

BAU	Business-as-usual
CCUS	Carbon Capture Usage and Storage
CBS	Central Bureau Statistics (Netherlands)
CO2	Carbon Di-Oxide
CSR	Corporate Social Responsibility
ESI	Environmental Ship Index
GHG	Greenhouse Gas
GPP	Green Port Programme
GSP	Green Ship Programme
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied natural gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environmental Protection Committee
MPA	Maritime and Port Authority of Singapore
NEA	Dutch Emissions Authority
NOx	Oxides of Nitrogen
PAs	Port Authorities
PoR	Port of Singapore
PoS	Port of Rotterdam
SOx	Oxides of Sulphur
TEU	Twenty-Foot Equivalent Unit
UNCC	United Nations Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
WPCD	World Ports Climate Declaration
WPCI	World Ports Climate Initiative
UNCTAD	United Nations Conference on Trade And Development

List of Tables

List of Figures

1 Introduction

Ports since long have been the worldwide trade gateways and remain critical to world economies to date. They are integral to the shipping industry and are major hubs for transportation of goods onto and off the ships. Despite the economic advantages associated with ports operations, port activities generate an array of environmental problems, such as emission of polluting gas, water pollution, environmental and health risks related to the poor air quality. The chief pollutants contributing to the greenhouse effect are sulphur oxides (SOx), carbon monoxide (CO2), nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matters (PM).

Considering global shipping activity, there are now over 20,000 seaport facilities operating worldwide with over 1.1 million crafts and vessels of different types currently in operation (Marine traffic database). Ports activities have a significant environmental impact given the concentration of a large number of industrial and logistics facilities in port areas and the strong reliance of ports on freight mobility overland and via the sea (Lam and Notteboom, The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe 2014).

It has been acknowledged by the maritime community that air pollution from ships has a cumulative effect that contributes to the global greenhouse effect and air quality affecting people and nature. The MARPOL regulation which entered into force in 2005 and was revised in 2018 (Annex VI) sets forth significant tolerable emission limits and port authorities are increasingly adopting measures to reduce port pollution, particularly NOx and SOx. Furthermore, ports are often located near densely populated residential regions which further amplifies the problem. Facing the pressure of environmental regulations reduction of port emissions has become a top priority for many Port Authorities and Governments largely due to achieve global CO2 emission targets.

As the ports have become more interconnected throughout the global supply chain involving many stakeholders and interacting operations, they also gained a unique position from where they have the opportunity to influence the actors operating at different stages of port activities. In this regard, local communities, terminal operators, shipping companies, vessels calling to ports, hinterland vehicles, terminal cranes and equipment, industrial facilities in the harbour area may be considered. Port operators have a position from where they could create a strategy to reduce emissions throughout the whole maritime supply chain (Martínez-Moya, Vazquez-Paja and Maldonado 2019). On a large scale, the ports' role has the potential to shape the social and environmental performance of transport systems globally (Bergqvist and Monios, Green Ports: Inland and Seaside Sustainable Transportation Strategies 2018).

Port development has socio-economic and environmental impacts (Schipper, Vreugdenhil and Jong 2017) and often has negative effects on the local ecosystem. Ports Authorities worldwide have initiated many projects aiming at reducing emissions and greenhouse gases generated by the port operations and parties involved in the port operations.

This research identifies the measures undertaken by the Port Authorities of the two largest ports located in Europe and Asia, namely Port of Rotterdam (PoR) and Port of Singapore (PoS) to follow global energy transition trends and challenges they face in implementing the strategies and policies. The two ports were chosen for the analysis due to 1) comparatively strong market position in the location areas; 2) significant cargo throughput values and high environmental impact; 3) high importance for the regional economies; 4) the ports have expansion and modernisation projects; 5) they are active members of international climate change initiatives and have enough power to force the actors involved in the port activities to facilitate the industry changes. The ports are located in different geographical areas which makes use of comparative analysis.

The research design is organized as follows: after providing the background on climate change and growing concern on the environmental impact from shipping and port sector we will discuss the relevance of the energy transition and give a short overview of the traditional fossil-based energy resources and renewable alternatives. Then, we will summarize global regulations aiming to prevent environmental changes as well as mention specific regulations that are in force in the maritime industry. Next, we will review sources of emissions at ports to define the role and effect the ports have in the climate change. After discussion of the theoretical background, we will apply content analysis methodology to investigate the research question in regards to the selected ports and their strategies on the way to decarbonization as well as evaluate to which extent the Port Authorities are open to the new regulations and business challenges. Investigate tools and directions in which Port Authorities influence the stakeholders.

In conclusion, we will summarize thesis outcomes and suggest further research area.

1.1 Structure outline

The Thesis is organized in 9; chapters. Chapter 1 introduces the problem and its background, defines the research question and lays a basis for the research.
Chapter 2 contains a theoretical background on the main research components. First, types of ports and their main functions are described in terms of the port operational activities, further, we define major emission sources at ports and provide information on the actual global environmental regulations that forced ports to develop new business models and strategies and may affect port operation structure. We will examine existing papers in the fields relevant to the research objectives.
Chapter 3 provides literature review related to the ports functions and studies conducted to investigate ways to decrease negative effect of the port operations.
Chapter 4 describes the research methodology.
Chapter 5 introduces emissions in ports and port initiatives towards the sustainable development.
Chapter 6 and Chapter 7 represent a case study related to the Port of Rotterdam and Port of Singapore. We will discuss competitive strategies of the ports, define differences and similarities and give information on current business activities and analyse strategies of Port of Rotterdam and Port of Singapore in the field of the energy transition.
Chapter 8 provides a discussion of the cases and the main findings.
Chapter 9 will provide conclusions of the research, answers to the research questions and outline the research limitations. The key findings will be summarized and suggestions for further research will be provided. Finally, we will outline limitations of the research and suggest areas for further research which may add value to the research.

1.2 Research question and objectives

Based on the historical background of the steps undertaken by the international community on the way to mitigate carbon emissions and short overview of the shipping industry as one of the contributors to global GHG, discussed in the previous sections, we will further focus attention on the seaport sector which is recognized as the international seaborne trade hub and alongside with cargo transshipment functions often creates an energy cluster in the surrounding areas and together generate significant amount of emissions in port areas.

The Thesis objective is to analyse how Port Authorities adapt to energy transition global demands and re-shape port business structure. The result will show whether the different geographic locations and business profile of the Port of Rotterdam and Port of Singapore have an influence on the emission reduction strategies.

Therefore, the research question is identified as follows:

How do Port Authorities adapt to the global energy transition challenges and implement emission reduction measures in ports?

The following sub-questions supporting the research objective will be evaluated in the Thesis:

- What are modern trends in port development models?
- What are the sources of emissions in ports and what areas are under pressure of modernisation?
- What are the current Port of Rotterdam and Port of Singapore operational activities and how are they affected by the energy transition initiatives?

The questions stated above will be answered with the help of qualitative methodology in particular through the elements of content analysis and case study.

The research will be based on the data available at the open sources such as recent sustainability reports issued by the Port Authorities, industry conference and presentations, specific field studies of DNV-GL, UNCSTAD, IPCC, statistical reports, International Energy Agency and other databases.

Due to the time limitation of this thesis, it was not possible to organize the interviews with respondents from the Port Authorities. The Green Award 25 years anniversary conference was attended in June 2019 in Rotterdam to get insight information on the current trends and innovative projects in the field.

It is necessary to mention thoroughly updated corporate web-site of Port of Rotterdam which is a very valuable source of actual information and data as well as a comprehensive annual report of MPA Singapore and Singapore Government agencies that have become primary resources of data related to Port of Singapore.

2 Role of ports in greenhouse gas emission

In this section the evolution of various sources of fuel through history has been outlined and the relation of the these greenhouse gasses to port functions has been laid out.

2.1 Port functions

Ports serve as an interface between land and sea and play a key role in the international seaborne trade (Roe 1998). Ports are very divergent in their assets, activities, functions and institutional organization. A single port can range from a small quay for berthing a ship to a very large-scale centre with many terminals and a cluster of industries and services. (Bichou and Gray 2005)

For the purposes of this research, we will examine the seaports as the most relevant to the case.

(Stopford 2009) categorizes ports according to the facilities available and services provided in the port areas and defines four levels of port activity:

- small local ports with basic infrastructure for servicing local trade:

- large local ports with more advanced terminals for handling different cargo and bigger vessels;

- large regional ports handling high volumes of cargo brought by the deep-sea vessels and requiring complex terminal equipment and specialized cargo terminals, and finally

- regional distribution centres with extensive infrastructure for servicing all types of cargo in specialized terminals and intermodal transport system from the port area to local ports. One can notice that M. Stopford concentrates only on cargo handling ports and does not mention cruise or fishery ports

World Bank Group seaports classification is based on the type of cargo handled activities that take place in the ports (Kruk and Donner 2010). According to the classification seaports are divided into the following groups:

- Multi cargo ports (handling more than one type of cargo);
- Container ports (handling foremost containerized cargo);
- Bulk ports - handling mainly dry (iron ore, coal, grain) or liquid (oil) bulk cargo;
- Industrial ports, serving the requirements of large industrial areas;
- Specialized ports (such as ferry ports, cruise ports, fishery ports)

Together with globalisation of the world economy and liberalization of trans-continent trade ports have become an important mode of global cargo transportation, they diversified their primary cargo loading-unloading function and serve not only as cargo transfer node in a transport chain but also function as a location area for petrochemical industry, logistic hub integrating hinterland transport systems and performs trade activities. we may highlight the following port functions common in the modern system: transport node, cargo distribution and logistics and hub for the industry. The detailed overview is given in Chapter 3.

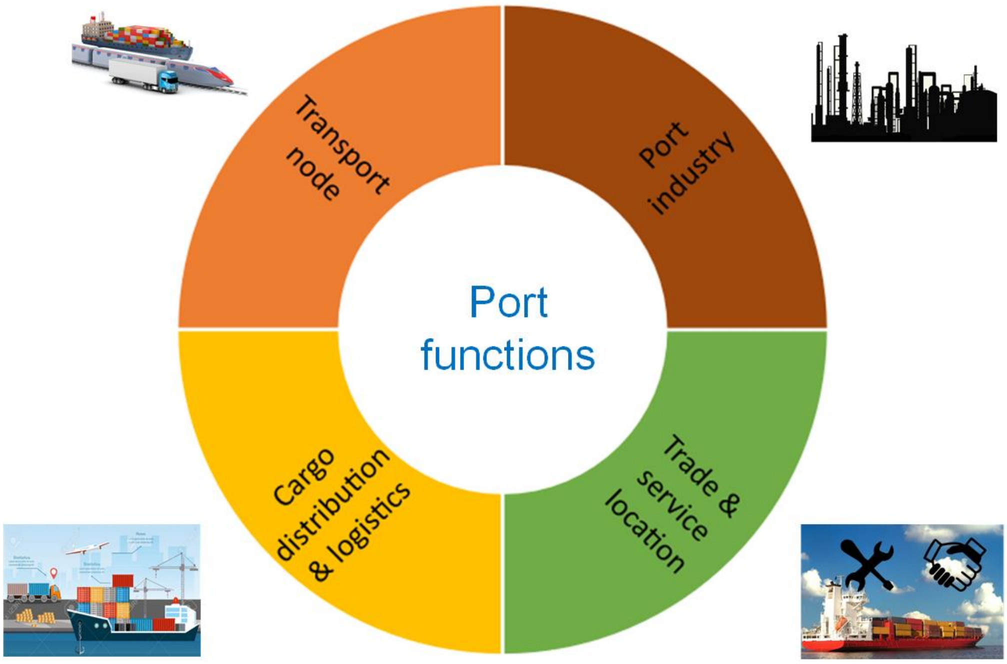

Figure 1 Port Functions.

2.2 Global climate change concern

For millions of years greenhouse gases, mainly carbon dioxide (CO2) and methane have kept Earth's climate habitable by trapping heat from the Sun but nowadays the same greenhouse gases are causing a rise in temperature of the Earth's atmosphere. The gases absorb solar energy and keep heat close to the planet surface, rather than letting it escape into space. That trapping of heat is known as the greenhouse effect. The greenhouse effect causes climate change and unpredictable weather conditions which have a catastrophic impact on the world population.

The process of heating is cyclic (over 10000 years) and has happened before humans but this time the warming is taking place at an unprecedented rate, mainly due to the release of large amounts of greenhouse gasses into the atmosphere in the postmodern industrial era by burning the fossil fuels. Climate change resulting from anthropogenic carbon emissions is already interfering with the climate system in a visible way, and any further small temperature increase will worsen the effects (DNV 2018). Climate change and its implications have become a key driver of the energy transition.

The process of reducing emissions by transiting from traditional fossil fuels such as oil, natural gas, lignite and coal to more sustainable renewable forms of energy like hydropower, solar power, geothermal energy, is known as the energy transition or green transition and it is taking place at an exponential pace across the world today and couldn't be ignored by the maritime industry.

However, anthropogenic climate change is happening and will continue to happen in the coming decades, despite an ongoing, rapid and comprehensive energy transition. International Energy Agency estimates that global energy demand will double from 2015 to 2070 which consequently will increase CO2 emissions, thus finding the way to switch from fossil fuels becomes a priority. Table 1 below demonstrates that modern energy system is still highly dependent on fossil fuels. Though coal and oil growth rates are comparatively low they are still an important part of the global energy demand.

Table 1 Global energy demand by source

Energy Demand (Mt)		**Growth rate 2018 vs 2017 (%)**
Oil	4 488	1.3
Coal	3 778	0.7
Gas	3 253	4.6
Biomass/Waste	1 418	2.5
Nuclear	710	3.3
Hydro	364	3.1
Other renewables	289	14.0
Total	**14 301**	**2.3**

Source: Adapted from IEA.org.

Furthermore, some studies estimated emission pathways until 2300 and suggested that 1.5°C target is unrealistic while below 2°C target is achievable only in case of implementation of innovative technologies that are expected to mitigate the climate change effects (Akimoto, Sano and Tomoda 2018). Despite all the efforts, CO2 emissions are still increasing and fossil fuels are keeping the position as the major energy resource. The Table below represents consequent CO2 emissions from fossil fuel combustions in 2018.

Table 2 CO2 emissions from fuel combustion by regions

Total CO_2 emissions (Mt)		**Growth rate 2017- 2018**
World	**33 143**	**1.7%**
Rest of world	11 249	1.1%
China	9 481	2.5%
United States	4 888	3.1%
Europe	3 956	-1.3%
India	2 299	4.8%

Source: Adapted from IEA.org.

2.2.1 Fossil fuels

Fossil fuels have been used as the main energy resource for centuries but in the last decades, these traditional resources are blamed for the negative environmental impact such as global warming and air pollution as a result of the combustion. Being the main contributors to the emission of greenhouse gases fossil fuels have become a driver for the energy transition. In the section below we will give a brief overview of the three types of fossil fuels making the basis of the modern energy system.

Coal: Coal is one of the earliest fossil fuels that was used by humans but it was during the Industrial Revolution that coal started to become popular. Growing demand for products and industrialization led to the inclusion of coal for powering numerous steam engines. Coal-based electricity still accounts for 40% of the world's energy production (Sustainable Development Goal 2019).

Oil and oil products: Oil is another type of the oldest fossil energy resource. The importance of oil was realized and started to be used as a reliable fuel source not until the latter half of the 19^{th} century. During the industrial age, oil was chosen as the fuel for ships instead of coal. This was because oil offered improved velocity and range for the ships. After the invention of the oil-powered car, oil consumption skyrocketed. Petrol is well-known and the most commonly used oil product by most cars and trucks on today's roads. Diesel, originally intended for heavy engines and industrial equipment, is widely used in transportation vehicles. It is one of the major contributors to greenhouse gases.

Liquid petroleum gas (LPG) : LPG is a gaseous by-product of oil-refining. It is made of propane and butane gasses and in the compressed form is used as fuel in internal combustion engines and household cooking and heating.
Natural gas is a fossil fuel that is formed deep in the earth as extremely high temperatures are needed for the creation of gas. Early natural gas utilization was primarily for cooking and lighting purposes only. It was only after world war 2 that natural gas started to be widely used. The use of natural gas as a fuel for transportation is slowly gaining popularity in developing countries due to its low price.

2.2.2 Major fuel consumers and GHG emissions

Industry sector: The industry sector produces greenhouse gasses as a side product of production and processing processes. The renewable imitates being taken up the industry sector are the energy and material efficiency, adoption of waste heat/gas recovery and cogeneration, reducing waste during manufacturing and construction and developing sharing and circular economy-based business models.

Transport: Transport accounts for 24% of the immediate production of CO2 pollution (Sustainable Development Goal 2019). Energy demand is increasing every year for every mode of transportation such as road transport (cars, trucks, buses and two- and three-wheelers) as well as aviation and shipping. The technologies that assist in sustainable transportation are electric vehicles. Rail transport is one of the most energy-efficient modes of transport, the unparallel expansion of high-speed railways in countries like China is helping offset the GHG emissions from the aviation industry. Transport biofuels that are sustainably produced are growing steadily over the years.

2.2.3 Alternative fuels and Renewable energy

In 2018, the electricity industry generated 42 per cent of all energy-related CO2 emissions (Sustainable Development Goal 2019), which remained the biggest cause of energy-related CO2 pollution. The energy industry is, therefore, a critical stakeholder for the energy transition. In this respect, the development of new technologies aiming at clean power generation is in high demand. Major technologies that can assist in the energy transition and can be implemented in the port area are:

- Solar panels
- Onshore & Offshore wind
- Hydropower
- Biomass energy

- Geothermal
- Ocean/wave
- Containerized energy storage

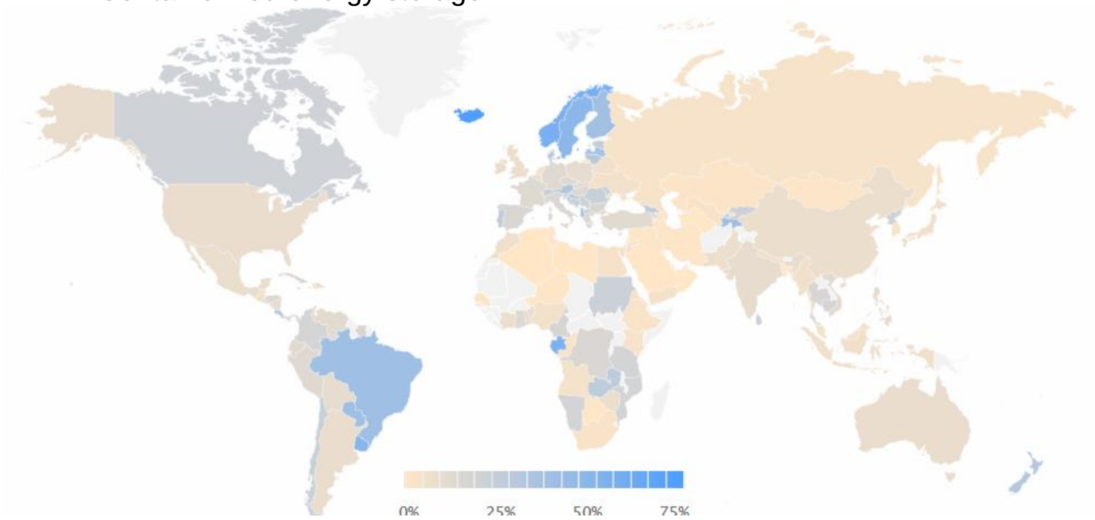

Figure 2 Current renewable share in total energy consumption, 2017
(Sustainable Development Goal 2019)

All the renewable energy sources mentioned above need to be integrated into the existing energy system to re-shape it and facilitate the energy transition. One of the biggest hurdles in this process is the storage of renewable energy. The most efficient and well-known form of energy storage is in batteries. Recent developments are the use of large self-contained battery storage units in containers.
Another form of energy storage is hydrogen. Although industrially the Hydrogen sector is big, there is a little share of hydrogen as renewable energy and an even lower share of fuel cell vehicles.

2.3 Timeline GHG regulation / stance of shipping industry

The following section discusses the various events that led to the formation of vision to reduce GHG, globally as well as by the shipping industry.

2.3.1 International treaty and regulations to prevent the GHG effect

In 1992 United Nations Climate Change Conference declared its objective to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system", the document entered into force on 21 March 1994 and following this, in 1997, the Kyoto Protocol established legally binding obligations for developed countries to reduce their greenhouse gas emissions in the period from 2008 to 2012. Furthermore, in 2010 United Nations Framework Convention on Climate Change (UNFCCC) issued an agreement stating that future global warming should be limited to below +2C relative to the preindustrial level and take efforts to limit the temperature increase to +1.5C.

At the 21st Conference of the Parties to UNFCCC held in Paris in December 2015, 196 countries agreed on the Paris Agreement to combine efforts to mitigate greenhouse gas emissions. The EU, in particular, established its decarbonization goals suggesting a target of GHG emissions 80% below 1990 levels by 2050 with the milestones of 40 per cent reduction by 2030 and 60 per cent 2040 (DNV 2018).

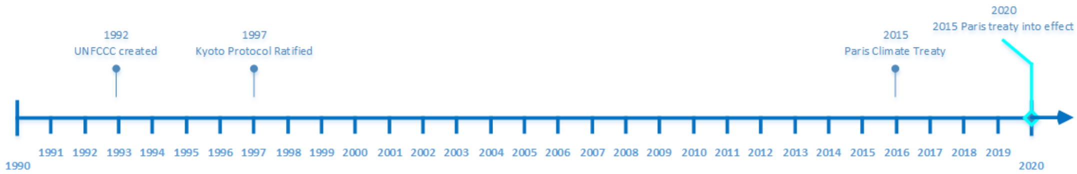

Figure 3 Climate change regulation timeline
Source: Author's compilation

2.3.2 Response from the shipping Industry

Though the shipping industry acknowledged the global climate change problems it was not a part of the Paris Agreement on climate change (DNV 2018) .
As a response to a global climate change concern, the International Maritime Organisation (IMO), specific body of the United Nations, responsible for the development of rules covering issues related to the safety at sea and prevention of marine and atmospheric pollution from shipping, complemented international efforts to decrease air pollution by formulation of its vision of the ways to reduce air emissions from the sea vessels. IMO adopted a strategy aiming to contribute to the global reduction of GHG emissions (DNV 2018) . The revised MARPOL, Annex VI set the progressive reduction in emissions of Sox and NOx in the bunker oil.
The sulphur content in the marine fuel was limited by 3.5 per cent starting from 2012 and will be reduced to 0.5% effective from 2020.

Table 3 IMO sulphur content limits in marine fuel

IMO global sulphur limits in marine fuel	
Before 01. 2012	4.5%
01. 2012 – 01. 2020	3.5%
After 01. 2020	0.5%

Source: Author's compilation

Taking 2008 as a base year, IMO regulators expect to reduce total GHG emissions from shipping to at least 50 per cent by the year 2050 and to reduce the average carbon intensity to at least 40% by 2030 and aiming for 70% in 2050. All in all IMO sets the target to completely eliminate shipping emissions in the 21st Century.

2.3.3 Seaborne Trade contribution to the Greenhouse effect

International Maritime Organisation reports that more than 80% of the world trade is carried by sea. Moreover, in recent years international seaborne trade has been growing steadily. According to ''UNCSTAD Review of maritime transport 2018" seaborne trade showed the fastest annual growth of +4% for the last five years and reached 10 702 mln of tons. Furthermore, the forecast for the period from 2018 to 2023 is positive with another 3.8% annual growth rate (Lim, et al. 2019).

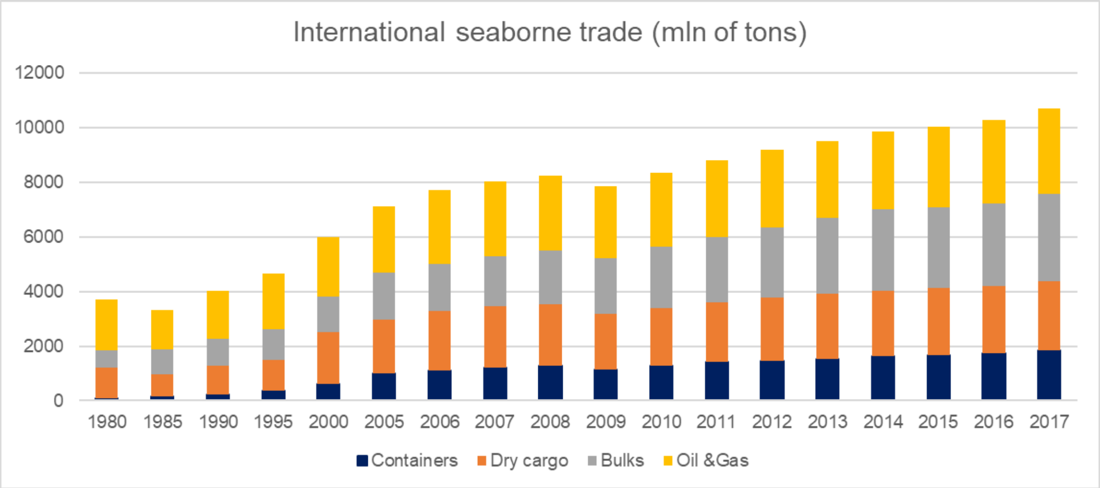

Figure 4 Seaborne Trade by type of Cargo
Source: Adapted from *(DNV 2018)*

In the meantime, according to the Third IMO Greenhouse Gas Study of 2014 greenhouse gas emissions from international shipping reached 796 million tonnes of CO2 which equals 2.2% of anthropogenic carbon dioxide emissions. Furthermore, growing maritime trade volumes could increase these emissions up to 250 % by the year 2050 (Leong, et al. 2015).

IMO actively facilitates efforts to develop measures to reduce emissions from ships. Ports have faced increased stakeholders demand for sustainability and have to adapt by the development of the innovative technologies to transform from carbon-intensive and dependent on fossil fuels port industry to a low-carbon port model implementing renewable energy and clean fuels (Iris and Lam 2019).

Liquid biofuels market is expected to grow and experience the highest sector growth. It is set to increase by 280% and will grow to be one of the major energy sources used for transport, especially in aviation and shipping. The major driver for this growth will be decarbonization policies. DNV forecasts that shipping activity driven by the international trade will continue to grow till 2050, thus the IMO target on 50% reduction looks ambitious. To reach the target it will be necessary to develop the advanced energy-efficiency technologies and solutions and deploy large volumes of carbon-neutral sustainable fuels. Such fuels are presently not unavailable to cover the shipping industry demand. A lot of efforts from the shipping industry players are needed to make alternative fuels available in sufficient volumes and acceptable prices (DNV 2018).

Table 4 Energy Demand and Transition Forecast

Energy Transition Forecast (EJ/year)		
	2016	**2050**
Fossil energy demand	403	451
Electricity	75	205
Sources of Energy		
coal	163	160
crude oil	168	86
natural gas	140	149
biomass	56	67
hydropower	14	24
solar energy	1	96
wind-power	3	68
CO2 emissions	36	20
CO2 capture and storage	21	300

Source: Adapted from (DNV 2018)

3 Literature Review and theoretical background

3.1 Available literature and studies towards ports' sustainability

The thesis is related to several interrelated streams of literature, in particular seaports, port emissions, green ports, energy transition, sustainability, renewable energy and supply chain.

The transition from non-renewable energy resources to alternative fuels is a widely discussed topic nowadays. Fossil energy on the basis of coal, crude oil and natural gas was a driver to the Industrial Revolution in the XVIII-XIX Centuries and still dominate in the global energy systems. Despite the undisputed economic advantages, the combustion of fossil fuels is the main reason for the CO2 emissions and GHG effect (Barreto 2018). Since MARPOL Annex VI and its amendments limiting air pollution from shipping came into force there have been increasing concerns on the environmental impact of port operations and development.

Together with the increase of international trade volumes and seaborne connections ports have diversified their functions from ships receipt and cargo handling to becoming a global transport hub handling different transportation modes, keeping substantial inventories of cargo and raw materials like crude oil, coal and natural gas and locating industrial facilities related to the energy production. This multifunctional role has socio-economic benefits creating added value and employment in the location areas. Despite the interrelated nature of the above functions every single role involves its own group of port actors. Each functional activity contributes to the port emissions and requires separate measures due to different emission sources associated with it. There is an extensive literature on the global greenhouse gas emissions but not many studies relating to emissions from shipping and port operations. The majority of the studies are focused on air pollution however there are issues with noise, dust, waste and water pollution.

Port authorities and terminal operators have started to become aware of the challenge of energy efficiency, as many of them are increasingly concerned with their emission profiles, and regulation in port areas have become more stringent, mostly in relation to sulphur and nitrogen oxides (Acciaro, 2014). Terminals around the world are working to change their dependence on fossil fuel to electricity. These efforts are accompanied by the development of renewable energy sources within the port perimeter (Acciaro, Ghiara and Cusano, 2014).

Considering the diverse functions of the seaports and their central role in the global supply chain it is necessary to address the port emission issues in connection with the exact port functions. Global nature of the seaborne trade resulted in the extension of the port functions from servicing the ships and loading/unloading of cargo to becoming a multifunctional logistics hub. According to (Geerlings, H., Kuipers, B., & Zuidwijk, R., 2018) there are three major functions of the modern seaports:

- port as a transport node;
- location area for petrochemical industry;
- centre for the logistics activities and trade.

Each function role attracts different groups of stakeholders, business operations, and generate consequent emissions.

In the following sections we shall discuss the research conducted by various groups of authors and correlate them to the above port functions.

3.1.1 Ports as transport node

Seaports' function as a transport node is mainly focused on handling of different types of cargo: containerised, liquid and dry bulk, general cargo, oversized project cargo, roll-off/roll-on. Cargo distribution is performed by the diverse transport modes having different capacity and environmental impact. Intensity of the international trade and trade flows influence port operational structure and the ways the cargo is handled. Ports may be a transhipment hub with large amount of terminal equipment for consolidation / reconsolidation activities or interconnecting link between producers and customers with inventory hub for commodities.

The cargo handling, its exchange and storage are the major port services. These activities depend on the ships arrival and further passed to harbour crafts and terminal operators. Given that ships arrival is the core action which determines the primary port function and entails the largest number of transport modes visiting the port and using fossil fuels as well as harbour crafts servicing the vessels, this functional activity generates the heaviest burden on the port's air quality and pollution.

(Gibbs, et al. 2014) analysed emissions generated by four ports in the UK as well as by ships calling at ports and concluded that emissions from ships are the major pollutants and need special attention from the port authorities.

There are certain tools and measures available to the Port Authorities to minimize emissions from vessels. These are:

- switch to alternative clean fuels (LNG, hydrogen, biofuels);
- deployment of infrastructure for onshore power supply through green electricity generated by the renewable energy resources like solar panels, wind energy, tidal energy;
- new technologies (containerised batteries);
- slow steaming;
- reduction of vessel time in port through efficient cargo handling;
- port incentives and dues stimulating shipping companies to join the ports' green efforts through use of advanced ship design.
-

(Styhre, Winnes and Black, et al. 2017) gave an overview of the ship emissions in ports and discussed options on how to abate emissions. The conclusion suggests the ports can facilitate a reduction of vessels emissions through the incentives, differentiated port dues applied to ships and other measures that imply a shift to alternative fuels and innovative technologies.

Facing global sustainability demands some ports started development of infrastructure for sustainable sources such as green electricity from wind energy or onshore power supply to fulfil the electricity requirements during operation. Many port authorities are responding to the new technological demands of the shipping sector, and studies are being carried out in major ports to test the feasibility of LNG terminals, biofuels or Onshore Power Supply (OPS), among other solutions. (Acciaro, Ghiara and Cusano 2014).

3.1.2 Ports as hub for the industry

Ports grow together with the development of large-scale industries based on the availability of fossil fuels and sea transport linking the international trade flows. Ports often become an industrial cluster where we can observe concentration of energy intense industries which perform power generation and energy consumption activities (Acciaro, Ghiara and Cusano 2014).

Extensive port areas and sea transport accessibility make ports not only the trade hubs for the fossil fuels but also a location for refineries and energy production with various storage and processing plants for coal, oil and gas as well as petrochemical products. It is convenient to have these operations at port in order to save time and costs for the stakeholders. The processing of oil and gas as well as petrochemical products is an energy intensive process that requires heat and steam. The production of heat and steam is presently done using conventional fuels that leads to CO2 emissions.

On the other hand fast growing port infrastructures dependent on fossil commodities face challenges due to the global trends of sustainability and energy transition. The following graph predicting the use of fossil fuels shows that after a peak in 2020 supply of oil and coal will decline whereas natural gas will rise. The decreased volumes of oil transported and oil products processed at the refineries will affect the refinery industry.

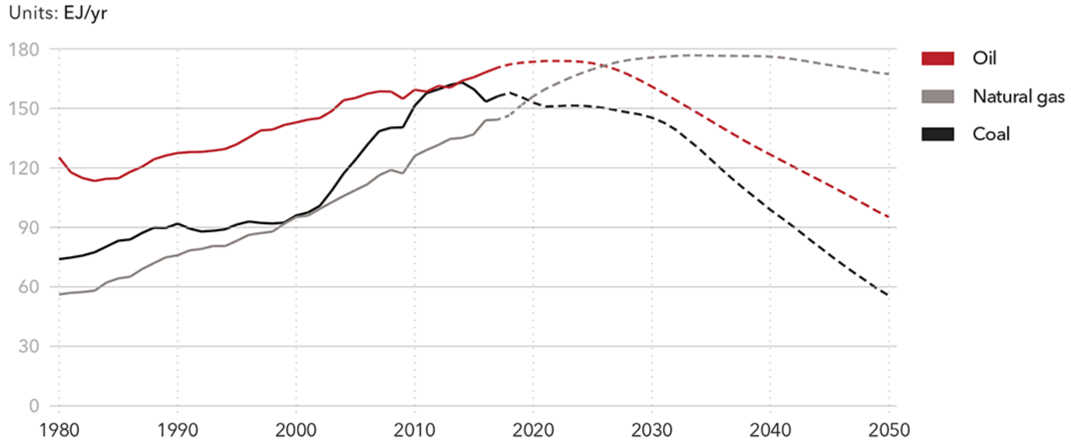

Figure 5 World primary fossil fuel supply by source
Source: DNV-GL, 2019

In this environment ports as location areas of energy clusters have to adapt to the global energy transition trends through developing of new technologies and tools. The refinery cluster most probably will experience overcapacity and have to find the alternative ways to use the facilities. There are specific studies that investigated obstacles on the way to implement energy-efficient technologies in shipping (DNV 2018); (Acciaro, Ghiara and Cusano 2014); (Rehmatulla, Calleya and Smith 2017). The result showed the inevitability of financial and technical barriers, the importance of management practices and legal constraints. Every new energy-efficient technology brings specific challenges and barriers.

The role of Port Authorities in implementing energy transition strategies (Rietkerk et al, 2002) suggested that ecologies of scale have potential in the large petrochemical clusters like ports of Singapore and Rotterdam where waste and residual heat generated and can be utilised by the industries. One of the sustainable initiative is the adoption of residual heat supply to households and capture and storage of CO2.

Moreover, (Lam and Notteboom, The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe 2014) suggested that the actual feasibility of port sustainability level depend very much on the green port policies and tools implemented by port authorities. (Schipper, Vreugdenhil and Jong 2017) assuming that green ports by definition shall be liable for ecosystem protection and support its development with sustainable plans and regulations created a comparative methodology with KPIs to assess port management sustainable plans and verify socio-economic and environmental aspects.

3.1.3 Logistics and trade

Ports as a logistic hub have tight connections with hinterland via different transport modes mostly represented by the heavy trucks. Emissions generated by the hinterland transport are not under direct port control but definitely is a result of the port activities. Ports may influence the inland actors through promoting the modal shift, effective logistics schemes reducing number of hinterland transport and applying the port dues.

Terminal activities related to cargo handling result in emissions from terminal vehicles and rail locomotives. The most appropriate measures to decrease the emissions are:

- terminal automatization and intelligence;
- use of advanced automated guided vehicles (AGVs);
- use of electro-driven RTG cranes;
- efficient cargo handling.

Energy management as a new role of the Port Authorities in light of the strict IMO regulations was discussed (Acciaro, Ghiara and Cusano 2014) investigated innovations improving the environmental sustainability of seaports.

Since the start of the port decarbonization discussions, a number of studies and reports have been issued to investigate the ways the ports may achieve CO2-neutral objectives. Port of Rotterdam, as a significantly energy-intensive industrial cluster and source of emissions in the EU attracted some academic attention that resulted in quite a number of studies suggesting decarbonization paths and policies to the Port Authorities.

In this respect, it is necessary to mention Wuppertal Institute for Climate, Environment and Energy (Samadi, Schneider and Lechtenböhmer 2018) which proposed three possible decarbonization pathways for the industrial cluster of Port of Rotterdam until 2050. The scenarios are based on the renewable energy sources to reduce CO2 emissions values of 2015 by 75-98 per cent in 2050. According to study the major strategies were defined: electrification, closed carbon cycles and carbon capture and storage (CCS). They made an attempt to predict future in the following directions: closed carbon cycle, use of biomass and CCS (drastic shift towards 100% renewable energy production and large-scale CCS to eliminate CO2 emissions), implementation of the best technologies.

Following the report of 2016 Wuppertal institute issued an additional report in 2017 investigating deep decarbonization pathways on "how "fossil port of Rotterdam" can hold its leadership in the EU and keep the strategy to become a CO2 neutral port. Two scenarios were discussed 1) use of Biomass and CCS for power generation at refineries and chemical facilities, 2) Closed Carbon Cycle (CYC) scenario assuming power electricity generation from the renewables to supply heat for the chemical industry. The above reports were complemented by the Rotterdam-Moerdijk Industry Cluster Report (2018) presenting a package of measures to achieve significant CO2 reduction.

Independent studies of DNV-GL (DNV 2018) (https://afi.dnvgl.com/ 2019) attributable to Maritime energy transition, 2014; Det Norske Veritas AS, 2012 contribute to the overall knowledge of the industry.

Bosman et al. 2018 made a research on the transition management process undertaken by the Port Authorities and characterized its actions as proactive but still not sufficient enough to be in line with Paris Agreement.

(Schneider, Lechtenböhmer and Samadi 2019) evaluated key risks associated with decarbonization pathways and concluded that global ambitious CO_2 reduction plans may fail due to slow implementation of the industrial policy measures and lack of governmental support.

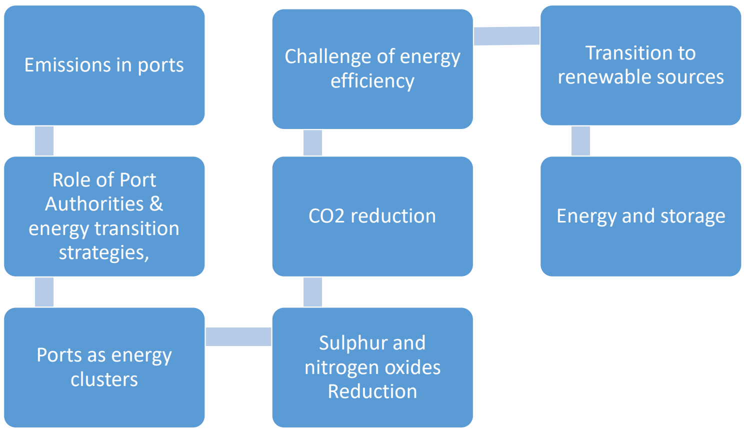

Figure 6 Summary of efforts from various authors

The complex structure of port management and diverse externalities of port activities involves a significant number of stakeholders who can influence or may be influenced by the activities of the port. In this respect, stakeholder management becomes an important issue in the port governance. Due to different levels of the port environment complexity and stakeholder structure there are several views on the port stakeholder classification. They may be categorized as internal (port management, shareholders, employees) and external (contractual port companies, government, local community); according to the level of involvement and influence in the management and planning process (Dooms, van der Lugt, et al. 2019) which may create stakeholder conflicts related to environmental issues. Dooms, 2019 identified the following groups of stakeholders:

- Port authority
- Port users (terminal operators, shipping lines, hinterland actors)
- Governmental agencies on different geographic and competency levels;
- Local communities (residents and tourists)

Dooms paper gives a comprehensive analysis of the existing literature on stakeholder categorisation and presents mapping of stakeholders.

4 Research methodology

Based on the research question formulated above we are going to explain the research methodology applied to the thesis development and steps taken to link the data and available literature with the research objectives.

The research objective is focused on the implementation of the energy transition strategies of the Port of Rotterdam and Port of Singapore by the Port Authorities. Considering the two ports as single entities the research design will be based on the case study as a specific method of the qualitative research methodology.

The selection of the case study as an intense research strategy is primarily guided by the character of the research question (G 2010) which in our case may be characterised as broad and descriptive.

The port core green strategies were divided into groups according to the port functions: control of the emissions from ships, emissions generated by landside port activities, and inland transportation network.

As it was already mentioned in section 1.7 the data collection is based on textual data sources such as:

- Review of existing academic literature including published research articles, books and industry reports related to ports operation and green strategies;
- Annual reports, official press releases issued by the Authorities of selected ports;
- Maritime industry review reports and presentations from specific conferences.

Availability of the diverse data sources of this kind implies that case study and content analysis methodology are the most appropriate for the thesis elaboration.

A case study is aimed at in-depth description and analysis of a single object. The purpose of content analysis is to organize and extort the core meaning from the data collected and to draw realistic conclusions from it.

After comparative study of the Port Energy Transition strategies was defined as a research subject the following steps were followed to support the methodology. The steps are defined according to (Galvao, Wang and Mileski 2016).

4.1 Content analysis

4.1.1 Data sources and data collection

Ports have complex organizational structures with plenty of stakeholders. Annual reports issued by the Port Authorities for public disclosure are the first data sources to get overview of the strategic goals, financial performance, stakeholder's relationships and ongoing projects. Thus, Port of Rotterdam Authority annual report of 2018 and Integrated sustainability report of MPA Singapore became the basis for further research.

The port industry as a facilitator of international trade and enormous economic activities associated with cargo handling and logistics makes a wide area for academic research. Academic studies, books and articles are used to obtain current trends, models and research outcomes.

Another batch of the descriptive documents are the industry reviews, statistical databases and reviews, and forecast reports presented by third parties and industry experts. For the purpose of this research, we will address to comprehensive studies of (DNV 2018) "Energy transition outlook. A global and regional forecast to 2050'' and '" Maritime forecast'' as well as to governmental agencies on emissions and statistics.

4.1.2 Research Design

The research design will be based on the methodology defined by (Galvao, Wang and Mileski 2016). The research process is split into phases and described below.

4.1.3 Hypothesis statement

The theoretical foundation is based on the fact that ports are exposed to the energy emission control regulations and have to adapt to the energy transition regulations through re-shaping of the business models and at the same time they have a unique position from where they have the power to influence the industry actors.

The content analysis implies collection of words and phrases relevant to the subject and classification to categories. Assuming extensive field of studies related to ports operations it is necessary to define appropriate terminology (keywords, definitions, phrases) associated with energy transition steps at sea ports and highlight the subject throughout the literature. Identifying the appropriate search terminology will be completed through several trials to narrow the scope of literature. For the purposes of content analysis, the following content units were determined:

1. Ports and seaports (main field of interest)
2. Keywords related to specific interests to narrow the scope

- Energy transition
- Emissions
- Green port
- Alternative fuel
- Sustainable

The time period was limited by 2010-2019 as the most relevant period of the energy transition discussions.

4.1.4 Selection of academic literature sources

For the purposes of the research ScienceDirect database and online database of the Erasmus University Library were primarily used to get the academic research papers relevant to the field of study. The articles selected according to the keywords were checked for their relevance, those which do not fit were removed from the list.

The search generated about 3 600 papers on the main field of interest. The most used keywords among the predefined keywords were "sustainable" – 300 outcomes and "emissions'' – 200 outcomes. After a detailed review of the selected literature, 50 articles were considered as relevant to the scope of the study and mentioned throughout the paper.

5 Port emissions and Energy transition vision

5.1 Emissions in ports

Although most of the shipping-related emissions happen at sea, a significant amount of the emissions is registered in the port areas which drastically affects air quality in the port cities and has consequent health issues for the population. Waste disposal from port operations, hinterland transportation, industrial activities, construction and expansion projects cause a major category of environmental externality (Lam and Notteboom, The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe 2014). In addition, diesel engines of terminal equipment and vehicles have a negative impact on the emissions.

One of the major environmental impacts generated by ports is air pollution, particularly greenhouse gases (GHG) emission which leads to global warming. Ships calling to ports are the main sources of pollutants which generally are CO2, SO_2, NO_x and VOC. These compounds have a prolonged effect which causes respiratory diseases, cancer and premature death of those living in communities around the port area.

There is a wide range of air pollution emitters in ports, they may vary from port to port depending on the port business profile and its functions. In general, sources of air pollutants can be categorized into the following groups:
1. Transport modes;
2. Industrial cluster operations.

Table 5 Sources of air pollution in Ports

Transport Modes at Port	Industrial cluster
Sea-going vessels	Oil refineries
Harbour vessels	Power stations
Terminal cargo handling equipment (cranes, forklifts, vehicles)	Bulk storage facilities (coal, iron ore, chemical, fertilizers)
Hinterland transport (trucks, cars)	Tank Terminals
Trains (diesel carriages)	Bunkering facilities

Source: Author's compilation

Figure 4 below illustrates the contribution of different modes of transportation to the SOx emissions at ports.

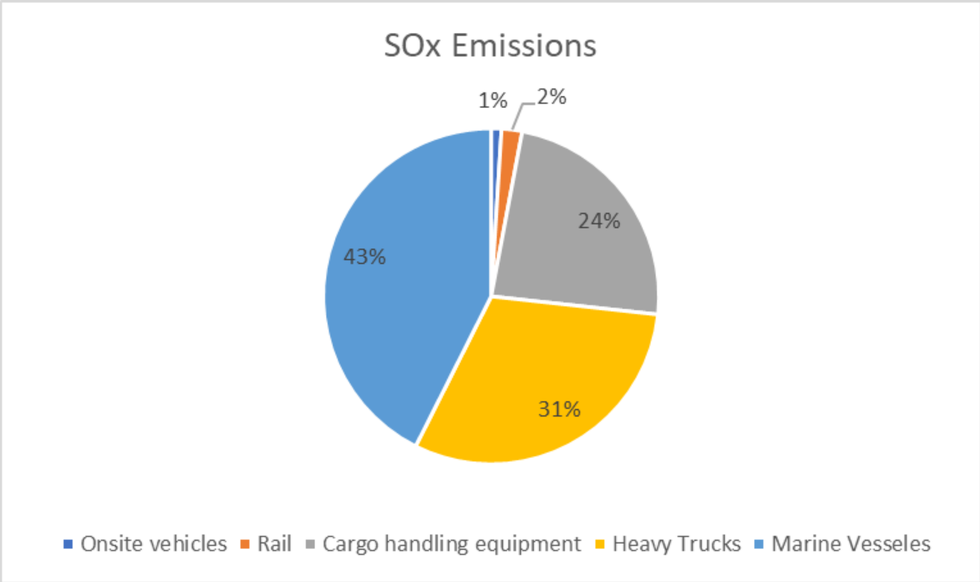

Figure 7 Transport modes contributors of SOx at ports
Source: adapted from http://www.nrdc.org

Vessel emissions in ports are of increasing concern, especially for SOx, NOx, and PM that affect the health of local populations.

Decarbonization and electrification are the most discussable trends of the energy transition. Decarbonization in the maritime industry implies the use of alternative fuels with low carbon emissions. A wide range of energy efficiency measures, alternative fuels and other emission reduction technologies and finally for full-scale implementation, changing the shipping fleet as we know it today. (DNV, 2018)

The most appropriate way to decrease vessel emissions in ports waters is switch to LNG which is considered to be the most sustainable fossil fuel. However, the LNG fleet capacity is not sufficient yet, currently there are around 170 LNG-powered sea-going vessels.

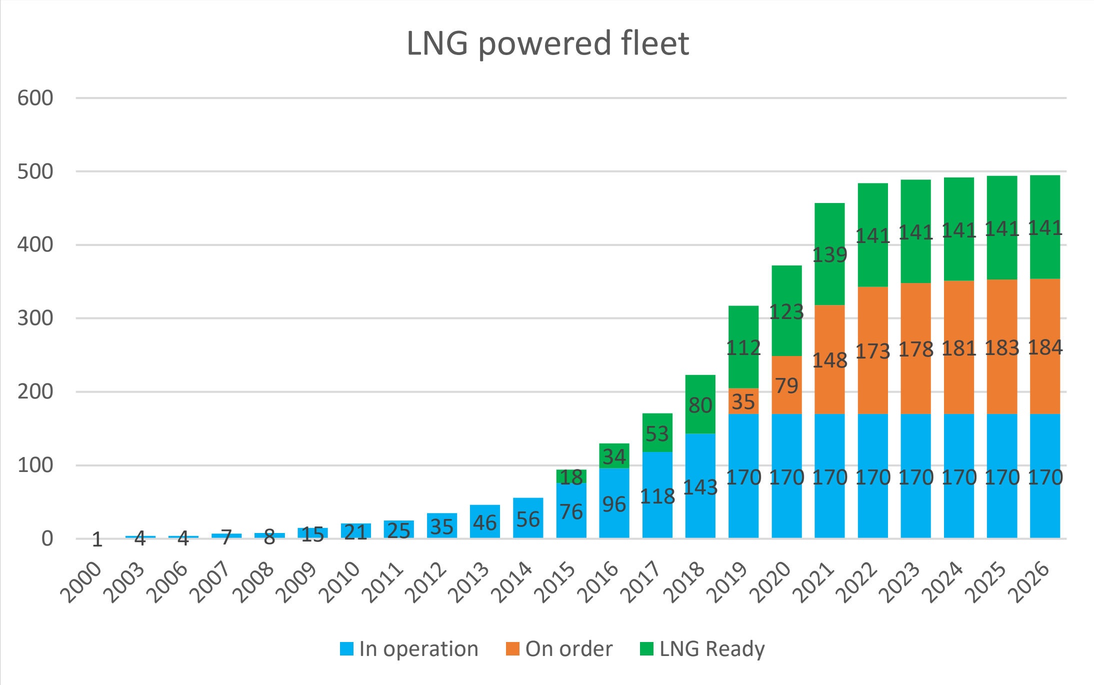

Figure 8 Yearly development of LNG-powered fleet
Source: (https://afi.dnvgl.com/ 2019)

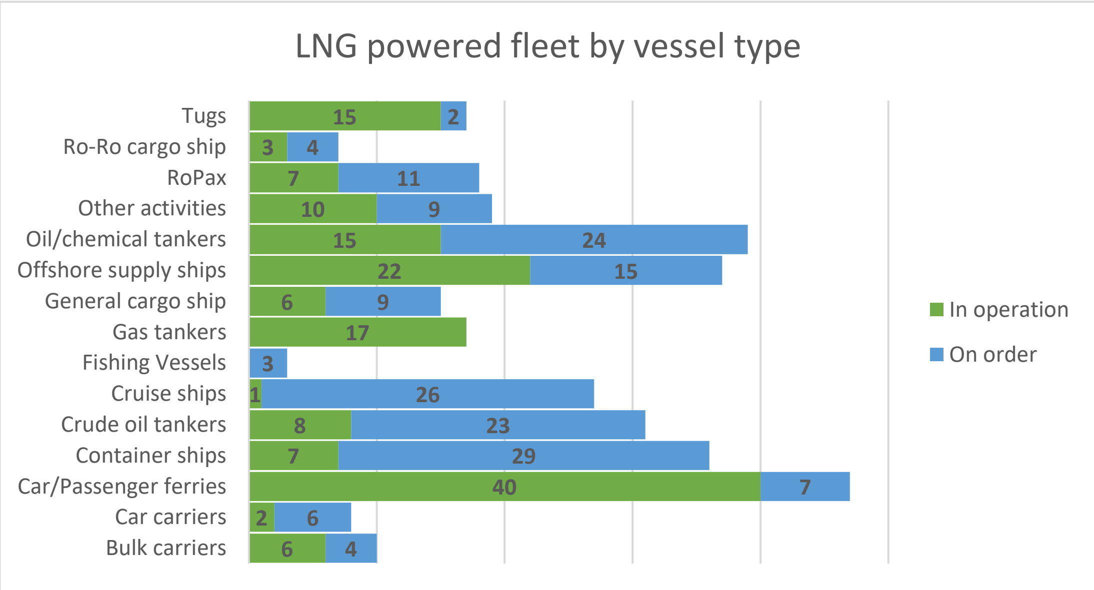

Figure 9 LNG powered fleet by vessel type
Source: (https://afi.dnvgl.com/ 2019)

Another option is a shore-side power supply. This measure implies the development of specific infrastructure by the port authorities and availability of green electricity generated by the renewable resources like wind-power, solar panels or residual heat from industries at port.

5.2 Green port initiatives

Green port initiatives is one of the instrument available to port authorities and aiming to reduce air emissions from ships and at port facilities. They are in place in particular in the USA, Europe and to some extent in Asia. The World Port Climate Declaration of 2008 having 55 members pursued various green measures and proclaimed that ports have to adopt mechanisms to drive emission reductions and push innovations. World ports expressed their mutual agreement to explore the ways to reduce emissions from the sea-going vessels calling to ports, terminal operations and hinterland transport, the ports are also expected to promote and use renewable energy and biomass for port operations.

The World Port Climate Declaration fixed foundation for future transformations of the port sector. The initiatives relevant to the reduction of emissions extend their force to several directions of improvement and control:

- Reduce emissions from sea-going vessels calling at ports,
- Reduce emissions from port operations and development,
- Reduce emissions from hinterland transport,
- Adapt technology and promote the use of renewable energy sources,
- Promote the development of CO2 inventories.

The port authorities are expected to support the development of advanced ship design, technologies on CO2 capture and storage facilities in the port industrial areas and use of alternative fuel.

Overview of the basic tools proposed by WPCD is presented below.

5.2.1 CO2 reduction from port operations and industries

Promote CO2 reduction measures for terminal operations and cargo handling.
Promote shared utilities to capture residual heat and energy.
Develop sustainable nautical services provided by LNG-fuelled tugs and other harbour craft. Encourage sustainable shore-side electricity supply for inland navigation on the basis of renewable energy resources. Improve energy efficiency of buildings, cargo handling, transportation another elements of public and private port operations.

5.2.2 Reduction of hinterland transport emissions

Ports can influence the amount of the emissions produced by the hinterland transport through development and adaptation of efficient and innovative logistics chains which will reduce number of hinterland transport in port.
Promote modal shift towards clean and energy efficient modes of transport and stimulate the environmental performance of all transport modes having access to ports.

5.2.3 Energy management

Promote switch to renewable energy by coordinating power generation and energy use.

5.2.4 CO2 footprint reporting and monitor

CO2 footprint report and monitor system. Manage CO2 footprint by creating carbon inventories for the industry activities at ports and relevant parts of the supply chain.

5.2.5 Port incentives to encourage green shipping

Following the objectives of WPCD many ports started voluntary incentive programmes to encourage ships calling at their ports to use cleaner marine fuel. The programmes are losing its importance in the ECA areas due to upcoming strict IMO regulations in regards to SOx and NOx limits but still popular worldwide.

There are programs initiated by the industry and programmes active at the country level. In this paper we will give an overview of the following major incentive programmes: Environmental Ship Index (ESI), Green Award and Maritime Singapore Green Initiative.

The Environmental Ship Index is an industry-based programme, it was introduced in 2010 by the ports in Hamburg – Le Havre range and addressed to the sea-going vessels and qualify ships according to the scored SOx and NOx emissions and gives numerical representation of the ship performance. The ESI provides a reduction in port dues and tonnage charges for registered sea-going vessels with below-average emissions of SOx, NOx and CO2. As of 2019 there are 56 ports providing ESI incentives and 8 549 vessels qualified. The index expresses the environmental performance of vessels in terms of the emission of air pollutants (NOx and SOx) and CO2. The performance is measured on a scale of 0 to 100, whereby a score of 1 already indicates an improvement in relation to the current environmental regulations for shipping, while 100 is exceptional.

The Singapore Green Initiative was introduced by MPA in 2011 to reduce emissions from ships and promote green shipping in Singapore. The initiative is addressed to ships calling to port both Singapore-flagged and other ocean-going vessels and local marine companies creating technologies. The detailed description is given in the Port of Singapore case study.

The Green Award is a voluntary quality assessment certification scheme established in 1994. In 2019 there are 120 ports participating and about 264 sea-going vessels certified, primarily oil tankers (178 vessel) and LNG carriers (72).

6 Port of Rotterdam in Energy transition

The Port of Rotterdam (further - PoR) is the largest port in Europe and major international transport hub and the gateway to Europe (PoR, The and Report 2018) with primary business in containers and bulk (dry and liquid) handling.

Port of Rotterdam has an advantageous location in Northern Europe on the North Sea and at the mouth of the river Rhine. The port has an extensive modal network of rail, inland shipping, road, short sea and pipelines which provides a perfect connection and network to all parts of Europe. The Deepwater terminals are easily accessible from the open sea for the vessels with the highest draught without need for the sea locks. Port Authorities report the shipping of about 30 000 sea-going vessels and 111 000 inland vessels per year.

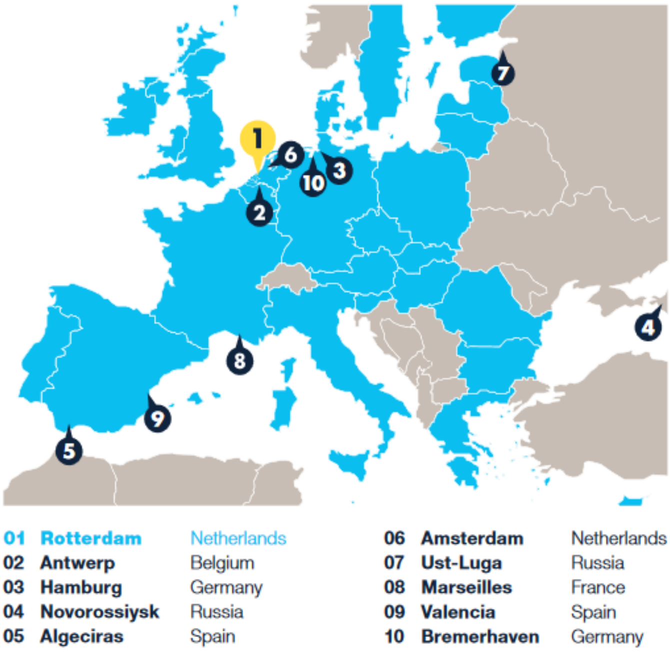

Figure 10 Port of Rotterdam and European Ports
Source: Port of Rotterdam authority

6.1 *Cargo throughput*

In 2018 total cargo handling throughput reached 468,9 million tonnes where containers throughput, strategic business priority, take 31% out of total cargo values and equals to 149 mln tonnes (14,5 million TEU) which are an increase of 5.7% compared to 13,7 million TEU in 2017 (Lloyds, 2018). Throughput values of another important sector - crude oil and other liquid bulk amounted to 45,8% out of total.

Table 6 Cargo Throughput Rotterdam

Type of Cargo	2018	2017
Dry bulk	77,6	80,2
Liquid Bulk	211,8	214,3
Containers	149,1	142,6
Break-Bulk	30,4	30,3
Total	**468,9**	**467,4**

** unit - million tonnes*
Source: Adapted from Port of Rotterdam

According to Lloyd's List ranking of the world's largest container ports as of 2018 Port of Rotterdam takes the 1st rank among the European ports and 11th worldwide.
The closest competitor is Antwerp followed by Hamburg which experiences decline presently.

6.2 Port Area and Infrastructure

Port area stretches to more than 40 km and takes around 12 713 ha, 80% of which is occupied by land and 20% is water area. Port infrastructure comprises of the diverse facilities from deep-sea terminals to, Port infrastructure is presented in the table below:

Table 7 Port of Rotterdam infrastructure

Major Terminals and Facilities		
Container terminals	- deep sea - short sea - empty depots	6.0 3.0 24.0
Bulk terminals (41 total)	- dry bulk - general cargo	15.0 26.0
Tank storage (mln m3)	- crude oil - mineral oil products - chemicals - edible oil	14.5 14.8 2.4 1.4

Source: adapted from Port of Rotterdam

6.3 Energy Hub

Apart from cargo handling, Port of Rotterdam is an important energy and petrochemical industrial cluster based on oil refineries, chemical production and power generation. Through development of the accompanying infrastructure, the port has been able to become a transhipment hub for high volumes of crude petroleum and derivative products (Bosman, Loorbach, et al., Carbon Lock-Out: Leading the Fossil Port of Rotterdam into Transition 2018). The port area is home to about 80 % of the total Netherlands' petrochemical industry and power plant capacities (PoR, The and Report 2018). Its beneficial maritime access and extensive connections by all possible transport modes such as barge transportation, waterways, pipelines, rail and roads make it very attractive base for the chemical and energy companies.

Energy and petrochemical operations give 55% of total port revenue and play an important role in Port of Rotterdam development strategy. There are over 120 industrial companies operating in the production of oil and oil products including chemicals, biofuels and edible oils, gas and power, coal and biomass, industrial gases and water. Refinery industry facilities together with chemical production take more than 75% of the PoR industrial area with Shell, BP, Exxon Mobil and VOPAK being the key actors in the sector.

Brief information on the energy cluster facilities is presented in Table 8 below.

Table 8 Energy Cluster infrastructure at PoR

Refineries	- refineries - refinery terminals - tank terminals	5 6 11
Power plants	- gas - coal and biomass - natural gas - wind turbine	3 3 1 86
Chemical facilities		45

Source: adapted from Port of Rotterdam

Port of Rotterdam energy cluster is based on all major energy sources from fossil (coal and natural gas) to renewables - biomass and steam, wind and solar energy. The combination of coal-fired power stations, biomass power station and gas-fired power stations located in the port give power capacity of about 7,000 megawatts that may supply electricity to the quarter of industries and homes in the Netherlands. A complex of energy sources creates enormous capacity in the areas of supply, production and distribution of energy but in the meantime, it generates a significant amount of CO2 emissions. The recent report of CBS shows that average GHG footprint in the Netherlands has been rising in for the second year in a row, from 15.1 tonnes of CO2 equivalents in 2017 to 15.8 tonnes in 2018. (Cbs.nl).

6.4 A frontrunner in Energy transition

Major activities of the Port of Rotterdam industrial cluster like fuel and power production are major contributors to CO2 port emissions and require critical review and redesign. Considering global decarbonisation trends industrial cluster is under pressure of modernisation where new business opportunities shall be investigated. A significant part of business activities associated with fossil fuels trading, refinery and utilization need modernization.

Port Authorities see the energy transition as a supercharger for the economic upgrade of the Port itself and industrial complex in total. Port of Rotterdam focused on the objective of becoming a sustainable port by developing energy efficiency schemes, using renewable energies and capturing and storing CO2 (Lam and Notteboom, The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe 2014). Energy transition program of Port of Rotterdam is aiming to be in line with Paris Climate Agreement objectives and to become a CO2-neutral port. The ultimate goal is a 49% reduction of CO2 emissions by 2030 and to become a CO2 neutral in 2050.

The energy transition programme takes a number of directions:

Table 9 Energy Transition Programme of the Port of Rotterdam

Energy Transition Options	Expectations
Alternative Fuels	Decarbonisation of the transport market
Biobased Economy	Development of the biobased chemical industry
Circular Economy	Circular Port
Electrification	Electrification of the industrial complex based on green hydrogen
Energy infrastructure	New infrastructure in the Port area as CO2 capture and storage, heat & steam capture and transfer
Renewable Energy	Green electricity based on solar and wind energy, batteries
Sustainable supply chain	Development of sustainable supply chains

Source: Author's compilation from "Green Award, 2019" presentations

Port of Rotterdam has a strong ambition to reduce 49% of CO2 emissions by the year 2030 and become CO2 neutral port in 2050 through the implementation of innovative technologies and becoming a hub for alternative fuels with zero emissions from production to utilization.

Port of Rotterdam has three main scenarios for CO2 reduction. The baseline scenario is business as usual which predicts at 30% reduction in CO2 levels by 2050, the factors driving this 30% reduction are the slow adoption of best available technologies, water electrolysis for hydrogen, the use of electric power for heat generation and the reinvestment in petrochemical and oil refineries without much changes in CO2 production technologies.

The other scenario where a 75% reduction in CO2 emissions by 2050 is predicted is by using carbon capture and storage and the rapid adoption of the best available technologies today. This scenario also needs to large-scale use of carbon capture and storage especially for the power plants and refineries. Along with this technology is like power to heat and water electrolytes should also be adopted.

For the scenario which calls for a 98% reduction in CO2 levels in 2050 compared to the 2015 levels, also needs to represent equation of the best available technologies today into the port industries as well as Port operations. To implement this the large scale ability of sustainable biomass and production methods of synthetic fuels need to be optimized. The power plants need to operate at 100% biomass or using waste feed.

Another way to achieve this 98% reduction is by using closed carbon cycle methods, in which heat is produced from geothermal sources unconventional chemicals how to place by synthetic chemicals produced from carbon-based waste. the scenarios for calls for the 100% reduction of renewable sources enjoy the production and Port operation processes.

Companies invest in energy efficiency measures, use of renewable energy and capture of CO2 for storage or reuse. The port has the ambition to become a Carbon Capture and Storage (CCUS) hub of Europe, Port Authorities are working on the development of the infrastructure for collection of CO2 via pipelines and transportation to the offshore reservoirs. Despite a total increase of GHG footprint in the Netherland mentioned in section 6.3 above It has already been reported that over the recent 2 years the shipping sector managed to cut emissions by 4.2 mln tonnes (13,6 per cent), (NEA).

6.5 Energy transition as a supercharger for economic renewal

Port of Rotterdam is following its vision on the way towards the CO2 neutral port in close cooperation with leading energy and industrial companies. Based on the Port Authorities strategy there are several directions according to which the projects are primarily defined.

6.5.1 Efficient use of the existing industry

There is a number of projects on capture and supply of the residual heat and CO2 generated by the industrial facilities in the port area and transfer it to the greenhouses and homes. This technology is a good example of a circular economy and efforts to replace natural gas.

6.5.2 Industrial steam and residual heat capture

Botlek steam pipeline started its operation in 2013 to capture steam from the industries and transfer to the nearby companies. The technology already resulted in the reduction of CO2 emission up to 400,000 tonnes.

The Pernis project is an example of cooperation between the Port of Rotterdam authorities and Industry represented by Royal Dutch Shell and the Rotterdam Heat Company. The Project was launched in 2018 and supply about 15,000 households in Rotterdam with heating and hot water from Pernis refinery residual heat, moreover, it is expected to reduce carbon emissions in Rotterdam by 35,000 tonnes annually (Shell, 2018). Shell installed unique technology to capture and store heat while Port of Rotterdam contributed by the construction of the underground pipeline system to transport heat to the operator and end-users. The Pernis Project contributes to the Dutch ambition of a 50% reduction of CO2 emissions by 2030

6.5.3 Carbon Capture Usage and Storage

Another innovative project is Porthos (Port of Rotterdam CO_2 Transport Hub & Offshore Storage) is under development to capture the greenhouse gas - CO2 for reuse and storage underground as a measure to reduce CO2 emissions in the short term. Port of Rotterdam, Gasunie and EBN are working on the project in which CO2 generated by the industry in Rotterdam's port area will be captured and then fed into public collection pipeline and stored in empty gas fields 25 km off the coast deep in the North Sea seabed at a depth of 3 km. The Porthos Project is an example of the open dialogue with industry and promotes Joint Development Agreements with interested industrial companies. Up to now, they consider interest in supplying or storing CO2 in the system sufficient to continue the project. The final contracts are expected already in mid-2020 and project investment decision in 2021. The CCUS Project is considered as the short-term measure in the reduction of the CO2. It has advantages as it can be implemented within a short period compared to electrification or other technologies. CCUS presents an opportunity to reduce CO_2 emissions during these sectors' transition towards biobased, renewable or circular processes.

6.5.4 Shore power supply

Shore power supply at the berthing places of the sea-going vessels arriving in Rotterdam is a good option to decrease the use of diesel generators. Heerema, Eneco and the Port Authority are working on the Calandkanaal Project which implies the use of grid shore power connection of approximately 20MVA to power the vessel. The feasibility study had been completed in April 2019 and showed that shore power connection is technically viable and will enable Heerema's fleet to berth in the port using 100% clean power.

6.5.5 Renewable Energy

Switch from oil and gas to electricity and green hydrogen for heating.
For temperatures up to around 300 degrees, the industry can switch to electricity. For higher temperatures, hydrogen is a good alternative (Port of Rotterdam, 2018). If this is produced using green power, it is CO_2 neutral. In the long term, electricity and hydrogen can play a huge role in making the industry more sustainable through solar, wind and water power.

6.5.6 Sustainable logistics sector

Replacement of fossil fuels with biomass, recycling 'waste' and green hydrogen. As well as industry, the transport of freight also needs to become more sustainable. a range of solutions to improve the supply chain and port operation, such as Pronto.

6.5.7 Port Incentives

Port of Rotterdam is a member of industry-initiated green shipping incentive programmes, in particular, Green Award and Environmental Ship Index. These programmes allow the qualified vessels to get incentives from participating ports for adopting green shipping technologies.

Port of Rotterdam grants 15% discount on the port dues related to the size to all liquid bulk carriers (LNG tankers, Chemicals/Gas tankers and Oil/Product tankers) provided with a Green Award Certificate.

6.6 Current Status

Despite the efforts of the Port of Rotterdam to curb CO_2 emissions, the CO_2 volume still has been increasing. In the period from 2007 to 2016 the CO_2 emissions have risen from 28,104 kiloton to 34,189 kiloton and the largest part of this emissions, almost 90%, is from the port industries. The other contributors are the transport sector and buildings in the port region. The share of renewable energy in the port region which primarily are wind, solar and biomass has been increasing and was 6% of the total energy use in 2016. Although wind energy is the dominant renewable energy source in the Port of Rotterdam, the capacity of installed wind energy is expected to be in operation in 2020 is 297.6 MW. This is very close to the planned capacity for wind energy of 300MW by the Port of Rotterdam (Port Compass, 2017).

7 Port of Singapore and Energy transition

The port of Singapore (further - PoS) is the second-largest container port in the world after Shanghai and major transhipment hub in Asia. The primary business is container transhipment and bunkering. Port of Singapore is a top bunkering port in the world with the annual bunker sales volume of 50 million tonnes.

Port of Singapore is located in Southeast Asia on the way from Pacific to the Indian ocean. Port of Singapore serves 130 000 sea-going vessels annually (MPA) and connected to 600 ports over 120 countries which makes it major regional transconnecting hub.

7.1 Cargo throughput

Cargo throughput in 2018 reached 36,5 mln TEU which is 8.7% increase vs 2017.

Table 10 Cargo throughput Singapore

Type of Cargo	2018	2017
Containers (TEU)	367,42	349,10
Liquid Bulk	221,53	233,04
Break-Bulk	24,32	26,94
Dry bulk	16,85	18,60
Total	**630,13**	**627,69**

** unit – ‘000 tonnes*

Source: Adapted from MPA Singapore

7.1 Port Area and Infrastructure

Port of Singapore is a complex of 6 terminals able to accommodate all types of vessels and handle all types of cargo from containers to break bulk and automobiles. PoS is operated by two commercial terminal operators: PSA Corporation Ltd. and Jurong Port. PSA manages container handling and Jurong is dedicated to bulk and conventional cargo.

7.1.1 PSA Singapore

PSA operates a total of 67 berths at four integrated container terminals. The terminals use fully-automated electric yard crane system which ensures zero-emissions on the land side.

Table 11 PSA Infrastructure

Terminals	Type	Berths	Quay (m)	Area (ha)	Quay Cranes
Pasir Panjang	cont.	38	13,447	551	147
Tanjong Pagar		7	2,097	80	0
Keppel		14	3,164	102	27
Brani		8	2,325	84	26
Sembawang	bulk	4	660	28	0
Auto	auto	3	1,010	25	0
	Total:	**74**	**22,703**	**870**	**200**

Source: Author’s compilation from (Maritime and Port Authority of Singapore (MPA) n.d.)

PSA is not the sole operator of the container terminals, they have established joint ventures with shipping lines namely CMA CGM, COSCO, MSC, ONE and some others to operate mega-container berths to secure best services for the shipping-lines.

7.1.2 Jurong Port

Jurong Port is a multi-purpose port mainly for dry and liquid bulk, conventional cargo operations and break bulk. Jurong port consists of 32 berths with a total area of about 155 ha.

7.2 Port of Singapore as a petrochemical cluster

More than just a container transhipment hub, Singapore is also the world's third-largest petrochemical refiner and top bunkering port in the world.

The PoS strategic position along the trade routes has made Singapore a natural location for oil storage and refining facilities. The refining and petrochemical facilities create synergies for the port development but generate the largest amount of carbon emissions. In the business-as-usual profile industry based emissions are expected to reach 77,7 MT in 2020.

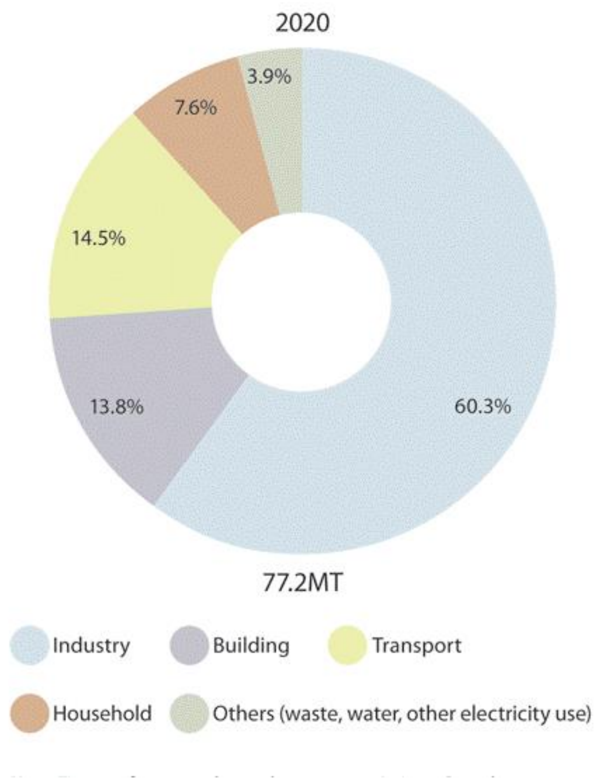

Figure 11 Singapore emissions profile
Source: https://www.nccs.gov.sg/

7.3 Green Initiative

Singapore has been an active council member of the International Maritime Organisation (IMO) conventions on ship safety and marine pollution prevention as well as a party to WPCD. Port Authorities support IMO efforts to balance environmental protection and maritime safety. (Lam and Notteboom, The Greening of

Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe 2014)

Singapore Port Authorities implemented a Green Initiative with the main objective to reduce the environmental impact of shipping and port activities to promote clean and green shipping around Singapore. This initiative supports Singapore's commitment as a responsible flag and port state to clean and green shipping. The program comprises of five voluntary sub-programmes and each of them is different in its priorities and objectives.

7.3.1 Green Port Programme

The Green Port Programme objective is to reduce emissions of pollutants from the sea-going vessels calling to port. The port provides a progressive reduction of port dues to the vessels that use clean fuel or approved scrubber technology during the port stay, vessels can benefit port dues concession of 15% reduction to those that comply while staying at berth and 25% reduction to the ships doing so during the entire stay at port.

7.3.2 Green Ship Programme

The Green Ship Programme stimulates the Singapore-flagged ships to reduce carbon dioxide and sulphur oxides emissions through the use of energy-efficient ship design, scrubbers, LNG and advanced technologies which reduce fuel consumptions and associated emissions. The ships that qualify to the programme get 75% of registration fees and up to 50% rebate on Annual Tonnage Tax. As of mid-2016, there were 302 vessels registered in the database as complying ships which is not a big value considering 4 400 vessels in Singapore Registry of Ships.

7.3.3 Green Technology Programme

The Green Technology Programme is addressed to Singapore-registered maritime companies and promotes developing and adopting of green technologies leading to reduction of SOx, NOx and CO2. The Programme provides grants up to S$3 million per project to the companies dealing with terminal operations, harbour operations and ship owning and requires installation in Singapore. Moreover, MPA provides up to 50 % co-funding for the development and adoption of technologies related to a reduction of SOx, NOx and CO2 emissions. Twenty-two projects were approved among which Diesel-electric engine, Electric rubber tyre gantry crane, Emulsified fuel system and others.

7.3.4 Green Awareness and Green Energy Programmes

The Green Awareness Programme encourages the entire maritime community in Singapore to promote sustainable shipping. MPA organizes events to let the participants share the latest ideas and best practices in sustainable shipping. As of 2016, the program has more than 100 signatories that expressed a commitment to environmentally friendly shipping. Green Energy programme aims to promote the adoption of alternative fuels.

7.4 LNG Hub ambitions

Singapore is a relatively small country with limited access to the renewable energy resources. Since the wind speed in Singapore is not sufficient for operation of the large commercial wind turbines this kind of alternative energy source is not viable.

Much of the sea space is used by the ports which limits the application of ocean energy technologies. There are also no rivers and geothermal energy sources.

In the situation with limited access to renewable energy the port does can not follow the path of renewable energy sources. Instead they invest in LNG development.

As the world's largest bunkering hub, Singapore is working on providing a wide range of bunkering options. Facing the IMO regulations on sulphur content in the marine fuel and considering that LNG is currently the only available green fuel for long-distance transport at sea, Port of Singapore has taken steps to become an LNG bunkering hub in Southeast Asia. The first terminal with total LNG storage capacity of 540,000 m3 was launched in 2017. There is an ongoing pilot LNG bunkering program. Furthermore, they invested in building of the first two LNG bunker supply vessels for the Port of Singapore to promote ship-to-ship bunkering in Singapore.

Aiming to encourage the uptake of LNG use by the harbour craft and reduce emissions in the port area the Port Authorities applied waiver of craft dues for LNG-fuelled harbour craft and grant additional 10 per cent port dues concession for the vessels that engage LNG crafts (MPA).

Port Authorities actively cooperates with leading LNG bunkering ports like Antwerp, Rotterdam, Zeebrugge and port authorities in Norway to establish a network of LNG bunker-ready ports across the world to encourage adoption of LNG as a marine fuel by the ship owners.

8 Comparison and analysis of POR an POS strategies

This Chapter will discuss current status of port actions in the field of the energy transition. Both ports have expressed ambitions in the reduction of emissions and working towards the implementation of projects to comply with IMO environmental regulations.

8.1 *Energy transition vision*

IMO aims to reduce CO2 emissions for international shipping, by at least 40% by 2030, and 70% by 2050, compared to the levels in 2008, IMO aims to be CO2 neutral by the end of this century. Port of Singapore has no such vision defined, it can be assumed that port of Singapore will adopt the energy transition vision of the IMO.

Port of Rotterdam aims to reduce its CO2 emissions by at least 49% by 2030 and to become a CO2 neutral in 2050.

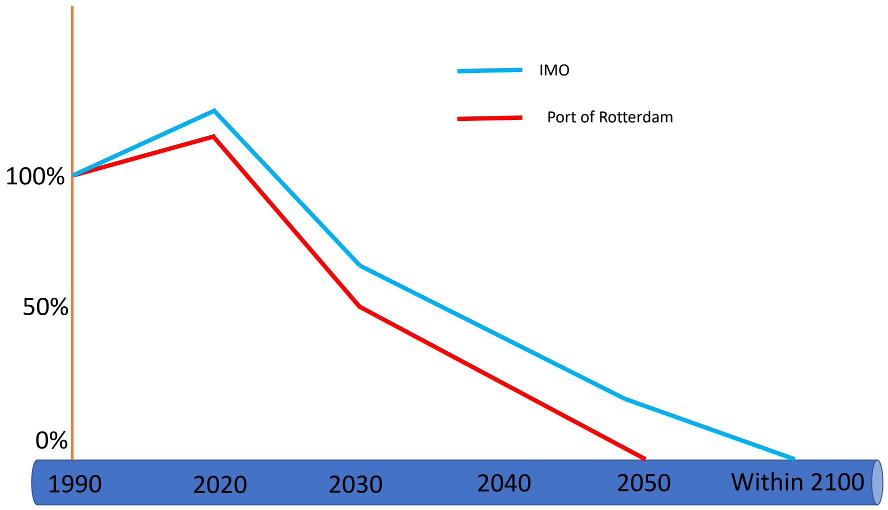

Figure 12 Energy transition vision
Source: Author's compilation

Being a country with limited access to natural resources, Singapore key strategy is energy efficiency and regulations.

8.2 *Port throughput*

The key data on the ports profile is listed in the table below.

Table 12 Key data for Port of Rotterdam and Port of Singapore

	Rotterdam	**Singapore**
Geographical location	Europe	Asia
Cargo throughput (mln tonnes), incl	469	630
- Dry bulk	77.6	16.85
- Liquid Bulk	211.8	221.53
- Break-Bulk	30.4	24.32

	Rotterdam	Singapore
- Containers (mln TEU)	14.5	36.5
Number of deep-sea container terminals	6	4
Quay length	74.5	106

The findings of the port initiatives implemented in practice by two ports are listed in the table below.

Table 13 Energy Transition actions

	Port of Rotterdam energy transition and environmental measures			Port of Singapore energy transition and environmental measures		
Sources of Emissions	**Transport node**	**Logistic Hub**	**Industrial cluster**	**Transport node**	**Logistic Hub**	**Industrial cluster**
Shipping	Renewable energy/ Biomass, OPS, containerised batteries, speed reduction		LNG infrastructure	Local Green Initiatives	N.A	LNG infrastructure
Cargo handling and transportation	Hydrogen	Efficient cargo handling, AGV's, electric cranes and digitalization			Digitalization	
Industry emissions	ESI, Green Award	Green Award	Residual heat/CO2 capture and storage			

8.3 Comparative analysis

Both ports have active policies that push towards energy transition and emission reduction of port activities but despite all the efforts the majority of cargo handled is still with traditional oil.

As it can be seen in the comparative Table 13, Port of Rotterdam takes an active role in reducing port emissions in various sectors and is ahead in the implementation of the projects related to the use of renewable energy for port operations. The Port of Singapore's biggest initiative for emissions reduction is its goal towards becoming an LNG-hub.

Port of Singapore focuses its strategy on the development of stronger ties with the local stakeholders providing price incentives for the local companies and ships that are registered in Singapore. Another factor is that Port of Singapore does not have ready access to renewable sources such as PV, due to the lack of space and underdeveloped offshore wind farms. Due to this lack of renewable energy resources Singapore is more focused on becoming an LNG-hub. To achieve this goal, Port of Singapore is developing LNG infrastructure, installing advanced terminal equipment and has put into action the incentive programmes. A direct comparison of Port of Singapore as a Logistic Hub cannot be made as it does not have hinterland transport.

Port of Rotterdam has a more advantageous position in terms of energy cluster development and concentration of industries which may utilize each other's residual products, such as heat and steam. Port of Rotterdam has easy access to offshore as well as onshore wind power, and some of the industries, such as for hydrogen production, apply carbon capture and storage that can help compensate the CO_2 emission from the entire port. In future the refinery cluster may compensate undercapacity resulted from the decrease of the crude oil flows by modernisation of the facilities for production of the low-sulphur oil. CO_2 neutral target is possible to achieve by putting in operation a CO_2 capture and storage project and implementing incentives to attract the industries to contribute to CO_2 capture volumes.

9 Conclusions

Together with the globalisation of the world economy and liberalization of transcontinent trade, ports have become a vital link in global cargo transportation. They diversified their primary cargo loading-unloading function and serve not only as cargo transfer node in a transport chain but also function as a location area for the petrochemical industry, logistic hub integrating hinterland transport systems and performs trade activities.

This research has investigated measures undertaken by the Port Authorities to comply with global energy transition demands. The study is executed in the form of a comparative case study from the perspective of port functions, the port functions being: transport node, cargo handling, industrial operations and logistics.

For this investigation, the two largest ports in Europe and Asia, Port of Rotterdam and Port of Singapore were analysed by the means of case studies. The research has compared ports' efforts and summarized direct actions and incentives applied by the ports to the port stakeholders. We also defined the differences in port strategies, which were mostly resulting from a specific geographical location.

Both ports have a strong position in order to influence the stakeholders to control the emissions resulting from shipping, cargo handling, logistics and industrial functions. In anticipation of the IMO low sulphur oil regulation Port of Rotterdam and Port of Singapore have leveraged their positions in adapting alternative fuels and developing LNG infrastructure. To meet the IMO targets both the ports have taken the efforts to diversify fuel choice through investments in alternative and carbon-neutral fuels like LNG.

The Port of Rotterdam has an advantageous spot on the North Sea and at the mouth of the Rhine River in Northern Europe. The port has a comprehensive modal rail, inland shipping, highway, short sea and pipelines network that offers an ideal link and network across all areas of Europe. Compared to Port of Singapore, the Port of Rotterdam has bigger potential in the reduction of CO2 emissions. This is mainly due to the extensive industrial network located at the vicinity Port of Rotterdam and potential to total capture of CO2 through the Project. The CO2 capture may solve the major emission problem. In addition to this, Port of Rotterdam is taking the initiative to make port transportation and logistics more sustainable and switching port operations to be run by electricity.

Decrease of oil throughput may be compensated by modernisation of the refineries for producing of the alternative fuels.

There is a number of projects currently being run by the Port of Rotterdam towards achieving the emission reduction and energy transition goals, some of the projects are Botlek steam pipeline, The Pernis project, Shore power supply electricity and green hydrogen for heating, Replacement of fossil fuels with biomass for logistics sector, Industry-initiated green shipping incentive programs such as Green Award and Environmental Ship Index.

Port of Singapore does not have ready access to renewable sources such as solar panels, due to the lack of space and underdeveloped offshore wind farms, neither does it have hinterland transport network. Singapore is more focused on becoming an LNG hub because of the absence of renewable energy resources. Port of

Singapore is developing LNG infrastructure to accomplish this objective, installing clean terminal equipment and implementing incentive programs.

As a final note, this research tries to answer the question of how the two port authorities are planning to adapt to the global energy transition challenges and implement emission reduction measures. For the future research more port case studies could be looked into and elaborated in regards to hinterland transport.

10 Bibliography

Acciaro, Michele, Hilda Ghiara, and Maria Inés Cusano. 2014. "Energy management in seaports: A new role for port authorities." *Energy Policy.* doi:10.1016/j.enpol.2014.04.013.

Akimoto, Keigo, Fuminori Sano, and Toshimasa Tomoda. 2018. "GHG emission pathways until 2300 for the 1.5 °C temperature rise target and the mitigation costs achieving the pathways." *Mitigation and Adaptation Strategies for Global Change* (Springer Netherlands) 23 (6): 839-852.

n.d. "All about energy transition | Port of Rotterdam." https://www.portofrotterdam.com/en/doing-business/port-of-the-future/energy-transition/all-about-energy-transition-0.

n.d. *Alternative Fuels Insight.* https://afi.dnvgl.com/.

Barreto, Raul A. 2018. "Fossil fuels, alternative energy and economic growth." *Economic Modelling* (North-Holland) 75: 196-220.

Bengtsson, Mariette. 2016. "How to plan and perform a qualitative study using content analysis." *NursingPlus Open* (Elsevier) 2: 8-14.

Bergqvist, Rickard, and Jason Monios. 2018. *Green Ports: Inland and Seaside Sustainable Transportation Strategies.* Elsevier.

Bergqvist, Rickard, and Niklas Egels-Zandén. 2012. "Green port dues - The case of hinterland transport." *Research in Transportation Business and Management.*

Bichou, K., and R. Gray. 2005. "A critical review of conventional terminology for classifying seaports." *Transportation Research Part A: Policy and Practice* (Pergamon) 39: 75-92. doi:10.1016/j.tra.2004.11.003.

Bosman, Rick, Derk Loorbach, Jan Rotmans, and Roel Raak. 2018. "Carbon Lock-Out: Leading the Fossil Port of Rotterdam into Transition." *Sustainability* (Multidisciplinary Digital Publishing Institute) 10 (7): 2558.

Bosman, Rick, Derk Loorbach, Jan Rotmans, Roel Van Raak, Rick Bosman, Derk Loorbach, Jan Rotmans, and Roel Van Raak. 2018. "Carbon Lock-Out: Leading the Fossil Port of Rotterdam into Transition." *Sustainability 2018, Vol. 10, Page 2558* (Multidisciplinary Digital Publishing Institute) 10: 2558. doi:10.3390/SU10072558.

Chen, Bin, Rui Xiong, Hailong Li, Qie Sun, and Jin Yang. 2019. "Pathways for sustainable energy transition." *Journal of Cleaner Production* 228: 1564-1571. doi:10.1016/j.jclepro.2019.04.372.

de Langen, Peter, and Henrik Sornn-Friese. 2019. "Ports and the Circular Economy." *Green Ports* (Elsevier) 85-108.

DNV, G. L. 2018. "Energy Transition outlook 2018 - Maritime Forecast to 2050." 148. https://eto.dnvgl.com/2018/maritime.

DNV-GL. 2019. *Peak hydrocarbons.* https://eto.dnvgl.com/2019/peak-hydrocarbons.

Dooms, Michaël. 2019. "Stakeholder Management for Port Sustainability: Moving From Ad-Hoc to Structural Approaches." *Green Ports* (Elsevier) 63-84.

Dooms, Michaël, Larissa van der Lugt, Steven De Schepper, and Onno de Jong. 2019. "Socioeconomic Performance Assessment of Port Clusters: More Challenges, Fewer Solutions?" *Green Ports* (Elsevier) 231-253.

Duriau, Vincent J., Rhonda K. Reger, and Michael D. Pfarrer. 2007. "A content analysis of the content analysis literature in organization studies: Research themes, data sources, and methodological refinements." *Organizational Research Methods* 10: 5-34. doi:10.1177/1094428106289252.

G, Peter. 2010. *What is a Case Study?" In Swanborn, Peter G. Case Study Research: What, Why and How? London: SAGE.* http://methods.sagepub.com.eur.idm.oclc.org/methods-map/research-design.

Galvao, Cassia Bömer, Grace W. Y. Wang, and Joan Mileski. 2016. "Public-Private Interests and Conflicts in Ports: A Content Analysis Approach." *Asian Journal of Shipping and Logistics.*

Gibbs, David, Patrick Rigot-Muller, John Mangan, and Chandra Lalwani. 2014. "The role of sea ports in end-to-end maritime transport chain emissions." *Energy Policy* 64: 337-348.

2019. *Greenaward.org.* Accessed 09 15, 2019.

Ha, Min-Ho, Zaili Yang, and Jasmine Siu Lee Lam. 2019. "Port performance in container transport logistics: A multi-stakeholder perspective." *Transport Policy* (Pergamon) 73: 25-40.

Halff, Antoine, Lara Younes, and Tim Boersma. 2019. "The likely implications of the new IMO standards on the shipping industry." *Energy Policy* 126: 277-286. doi:10.1016/j.enpol.2018.11.033.

Hiranandani, Vijay. 2014. "Sustainable development in seaports: a multi-case study." *WMU Journal of Maritime Affairs* 13 (1): 127-172.

https://afi.dnvgl.com/. 2019. Accessed 09 10, 2019.

Iris, Çağatay, and Jasmine Siu Lee Lam. 2019. "A review of energy efficiency in ports: Operational strategies, technologies and energy management systems." *Renewable and Sustainable Energy Reviews* (Pergamon) 112: 170-182. doi:10.1016/J.RSER.2019.04.069.

Kotowska, Izabela, and Daria Kubowicz. 2019. "The role of ports in reduction of road transport pollution in port cities." *Transportation Research Procedia* (Elsevier) 39: 212-220. doi:10.1016/J.TRPRO.2019.06.023.

Kruk, C. Bert, and Michel Donner. 2010. "Freight transport for development toolkit : ports and waterborne freight." 1. 1-79. http://documents.worldbank.org/curated/en/874431468331826338/Freight-transport-for-development-toolkit-ports-and-waterborne-freight.

Lai, Kee Hung, Y. H. Venus Lun, Christina W. Y. Wong, and T. C. E. Cheng. 2013. "Measures for evaluating green shipping practices implementation." *International Journal of Shipping and Transport Logistics* 5 (2): 217.

Lam, Jasmine Siu Lee, and Kevin X. Li. 2019. "Green port marketing for sustainable growth and development." *Transport Policy* (Pergamon).

Lam, Jasmine Siu Lee, and Theo Notteboom. 2014. "The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe." doi:10.1080/01441647.2014.891162.

Leong, See Chuan, Carol Anne Hargreaves, Prateek Singhal, and Jun Yuan. 2015. "Estimation of CO2emission from marine traffic in Singapore Straits using Automatic Identification Systems data." *Environmental Science and Information Application Technology - Proceedings of the 2014 5th International Conference on Environmental Science and Information Application Technology, ESIAT 2014.*

Lim, Sehwa, Stephen Pettit, Wessam Abouarghoub, and Anthony Beresford. 2019. "Port sustainability and performance: A systematic literature review." *Transportation Research Part D: Transport and Environment* (Pergamon) 72: 47-64. doi:10.1016/j.trd.2019.04.009.

Lindstad, H. Elizabeth, Carl Fredrik Rehn, and Gunnar S. Eskeland. 2017. "Sulphur abatement globally in maritime shipping." *Transportation Research Part D: Transport and Environment* (Pergamon) 57: 303-313. doi:10.1016/J.TRD.2017.09.028.

n.d. "Maritime and Port Authority of Singapore (MPA)." https://www.mpa.gov.sg/assets/integrated-reports/2018/index.html.

Martínez-Moya, Julián, Barbara Vazquez-Paja, and Jose Andrés Gimenez Maldonado. 2019. "Energy efficiency and CO2 emissions of port container terminal equipment: Evidence from the Port of Valencia." *Energy Policy* (Elsevier) 131: 312-319.

Martins, Florinda, Carlos Felgueiras, and Miroslava Smitková. 2018. "Fossil fuel energy consumption in European countries." *Energy Procedia* 153: 107-111.

Merriam, S.B. 2010. "Qualitative Case Studies." *International Encyclopedia of Education* (Elsevier) 456-462.

Montwiłł, Andrzej. 2014. "The Role of Seaports as Logistics Centers in the Modelling of the Sustainable System for Distribution of Goods in Urban Areas." *Procedia - Social and Behavioral Sciences* (Elsevier) 151: 257-265.

Ng, Adolf K.Y., and Su Song. 2010. "The environmental impacts of pollutants generated by routine shipping operations on ports." *Ocean & Coastal Management* (Elsevier) 53 (5-6): 301-311.

Othman, Mohammad Khairuddin, Noorul Shaiful Fitri Abdul Rahman, Alisha Ismail, and A. H. Saharuddin. 2019. "The Sustainable Port Classification Framework for Enhancing the Port Coordination System." *The Asian Journal of Shipping and Logistics* (Elsevier) 35: 13-23. doi:10.1016/J.AJSL.2019.03.003.

PoR, Highlights O. F. The, and Annual Report. 2018. "Room for Today and Tomorrow . Make It Happen ."

Port, Waste-to-value. n.d. "International position as Waste-to-Value Port Rotterdam circular hub for raw materials transition." 1-6.

Rehmatulla, Nishatabbas, John Calleya, and Tristan Smith. 2017. "The implementation of technical energy efficiency and CO2 emission reduction measures in shipping." *Ocean Engineering* (Pergamon) 139: 184-197.

n.d. "Residual heat from Shell's Pernis refinery helps heat Dutch homes | Shell United Kingdom." https://www.shell.co.uk/media/2018-media-releases/residual-heat-from-shells-pernis-refinery-helps-heat-dutch-homes.html.

Roe, Michael. 1998. "Maritime economics." *Journal of Transport Geography* (Routledge) 6: 311. doi:10.1016/s0966-6923(98)00021-0.

Samadi, Sascha, Clemens Schneider, and Stefan Lechtenböhmer. 2018. "Deep decarbonisation pathways for the industrial cluster of the Port of Rotterdam."

Schipper, C. A., H. Vreugdenhil, and M. P. C. Jong. 2017. "A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements." *Transportation Research Part D: Transport and Environment* 57: 84-111. doi:10.1016/j.trd.2017.08.017.

Schneider, Clemens, Stefan Lechtenböhmer, and Sascha Samadi. 2019. "Risks and opportunities associated with decarbonising Rotterdam's industrial cluster." *Environmental Innovation and Societal Transitions* (Elsevier) 1-15. doi:10.1016/j.eist.2019.05.004.

Stopford, Martin. 2009. *Maritime economics.* Routledge. https://www.academia.edu/37713869/CompetitiveStrategyforthePortofRotterdamPortCompetitionAnalysiswithaQuantitativeApproach.

Styhre, Linda, and Hulda Winnes. 2019. "Emissions From Ships in Ports." *Green Ports* (Elsevier) 109-124.

Styhre, Linda, Hulda Winnes, John Black, Jimyoung Lee, and Hanh Le-Griffin. 2017. "Greenhouse gas emissions from ships in ports – Case studies in four continents." *Transportation Research Part D: Transport and Environment* (Pergamon) 54: 212-224.

2019. *Sustainable Development Goal.* Accessed September 2019. https://www.iea.org/sdg/renewables/.

Tichavska, Miluše, Beatriz Tovar, Daria Gritsenko, Lasse Johansson, and Jukka Pekka Jalkanen. 2019. "Air emissions from ships in port: Does regulation make a difference?" *Transport Policy* (Pergamon) 75: 128-140.