# Benchmark for seaport sustainability

## The environmental performance of Dutch and international seaports

CE Delft
Committed to the Environment

natuur en milieu federatie zuid-holland

# Benchmark for seaport sustainability

## The environmental performance of Dutch and international seaports

This report was prepared by: Peter Scholten, CE Delft in collaboration with Michael Verhoeckx, Natuur en Milieufederatie Zuid-Holland (NMZH).
Projectmanagement: Michael Verhoeckx, NMZH
Supervision by Jasper Faber, CE Delft & Alex Ouwehand, NMZH

Delft, CE Delft, March 2020

Publication code: 20.7T36.036

Seaports/ Sustainability / Climate / Environment / Air quality / Water quality / Transport / Waste / Renewable energy / Benchmark

Client: Natuur en Milieufederatie Zuid-Holland (NMZH)
Your reference: Benchmark sustainability seaports 2020

Publications of CE Delft are available from www.cedelft.eu

Further information on this study can be obtained from the contact person Peter Scholten (CE Delft)



**CE Delft**
Committed to the Environment

Through its independent research and consultancy work CE Delft is helping build a sustainable world. In the fields of energy, transport and resources our expertise is leading-edge. With our wealth of know-how on technologies, policies and economic issues we support government agencies, NGOs and industries in pursuit of structural change. For 40 years now, the skills and enthusiasm of CE Delft's staff have been devoted to achieving this mission.

# Content

# Glossary

| Term | Explanation |
|---|---|
| $CH_4$ | Methane |
| CO | Carbon-oxide |
| $CO_2$ | Carbon-dioxide |
| $C_{20}H_{12}$ | Benzo(a)pyrene |
| DALY | Disability-Adjusted Life Year |
| ESI | Environmental shipping index |
| GHG | Greenhouse gas |
| GWP | Global Warming Potential |
| HGV | Heavy goods vehicles |
| IWT | Inland waterway transport |
| kV | Kilovolt |
| $N_2O$ | Nitrous-oxide |
| $NH_3$ | Ammonia |
| $NO_x$ | Nitrogen-oxides |
| $NO_2$ | Nitrogen-dioxide |
| OPS | Onshore power supply |
| PB | Lead |
| PM | Particulate Matter |
| $PM_{2,5}$ | Particulate Matter smaller than 2.5 micro-metre |
| $PM_{10}$ | Particulate Matter smaller than 10 micro-metre |
| $SF_6$ | Sulphur hexafluoride |
| $SO_2$ | Sulphur-dioxide |
| Tkm | Ton kilometre |

# Summary

Seaports are nexuses for multiple modes of transport, making them attractive sites for trade and manufacturing. Consequently, seaports facilitate employment and broad economic development. At the same time, seaports have impacts on climate, their environment and the wellbeing of local communities. A sustainable port minimizes these externalities. Monitoring port sustainability is of major importance in light of international climate transition goals and environmental and social responsibility.

This report presents a benchmark for measuring the sustainability performance of seaports. This benchmark was applied to fourteen ports in the Netherlands, other European countries and North America. The data used for the benchmark mainly cover recent years (2015-2018) and include an earlier reference point where possible, usually 2010, to gain insights into longer-term trends. Sustainability performance is assessed in the following areas: climate, renewable energy, air quality, water quality, maritime waste, modal split, community relations and sustainability strategy (vision). Other sustainability topics, for example use of space, safety and nature development have not been included in this benchmark because of the difficulty of developing accurate indicators and datasets.

The benchmark serves two purposes. First, to identify the sustainability progress of individual ports. Second, to identify frontrunners and best practices which can stimulate the sustainable development of seaports in general. The benchmark is not suitable for scoring or ranking ports, because of their heterogeneous nature.

The primary data sources are publicly available datasets and reports published by port authorities. Other sources used include reports by companies or local environmental NGOs. Port authorities were also contacted to review the collected data, with most responding, resulting in a comprehensive dataset and insightful benchmark results.

**Greenhouse gas emissions** differ widely across seaports. The Dutch ports and the ports of Antwerp and Le Havre host large industrial complexes and power stations. As a result, $CO_2$ emissions in these ports are high. Transport is generally responsible for less significant emissions, and as a result ports hosting less industrial activity have significantly lower emissions. At most Dutch and international ports there was no significant decline in $CO_2$ emissions between 2010 and 2017. Many international ports do not monitor all the of greenhouse gas emissions in the port area. Monitoring these emissions with an identical scope at all ports would greatly improve the quality and value of future analysis.

The amount of **renewable energy capacity** differs widely among ports. The Dutch ports, Antwerp and Hamburg have installed significant renewable energy capacity. Renewable energy in other European ports and the North American ports is still in its infancy. The amount of renewable energy installed increased between 2010 and 2018, especially for wind and solar PV.

Seaport **air quality** has long been a topic of concern. As a result, most ports measure the emissions and concentrations of most key air pollutants, such as particulate matter and nitrogen oxides. However, the scope of measurements differs across ports, with some including all sources and others including only mobile sources or shipping emissions. At most ports, emissions of the majority of air pollutant have been slowly declining. Where they have increased, this often appears to be due to port expansion or increased productivity levels. A variety of measures are applied to improve air quality in port areas. These include

environmental zones for heavy goods vehicles, reduced fees for environment-friendly vessels and onshore power supply. Onshore power supply is not widely available, even though it is an effective way of improving air quality. Ports have also taken other air quality improvement measures, revealing several best practices. There are still major differences between ports, however.

Ports only have limited influence on **water quality**, as the water and its pollutant load generally originate upstream. Still, port activities are themselves associated with discharges of pollutants, wastewater and cooling water to surface water. At Dutch ports there has been a steady reduction in pollutant emissions, including those of Substances of Very High Concern, while several other ports are taking steps to improve water quality. At international ports the availability of water quality data is limited.

The **modal split of hinterland transport** depends largely on the infrastructure available at the port. Differences among ports are consequently explained by locations and port characteristics and are not necessarily due to sustainability efforts. To measure any shift to more sustainable forms of transport, modal split results need to be updated regularly, which only a few ports currently do.

The attention given to **community relations** varies significantly among the ports in our sample. In general, larger ports situated in densely populated areas perform better in this respect. Effective instruments to this end include dedicated websites or platforms for local communities, port-financed projects and nuisance hotlines.

**Waste** produced by maritime vessels is collected by ports. All Dutch seaports are required to facilitate the collection of waste in line with European regulations. The volume of waste deposited in the Netherlands has increased significantly since 2005. This increase is due to a higher share of vessels depositing waste; the average amount of waste deposited per vessel remained more or less constant between 2005 and 2018. The benchmark indicator for waste is still under development and the results were therefore collected for Dutch ports only. It is recommended to develop an indicator for how waste is processed after collection.

This benchmark analysed the **sustainability strategy** of the Dutch ports based on strategy documents (vision). The sustainability strategy documents of international ports were not included in this benchmark. While the strategy documents of the Dutch ports do include all the key topics, they often lack detail, leaving it unclear what steps are needed to achieve the stated ambitions and how progress is to be monitored. It may be the case, though, that such steps have been defined by the port authority, yet not shared publicly in the interest of competition.

When it comes to sustainability and its management, there are major differences among ports, which can be explained partly by differences in their basic characteristics. Many best practises can be identified from the various ports, making it possible for ports to learn from each other. The benchmark presented in this report provides a valuable resource for this purpose. In order to support the sustainable development of seaports worldwide it is recommended to monitor and report on a range of key sustainability indicators in a uniform manner. Benchmarking the sustainability performance of seaports every two years would support the transition towards climate-neutral, healthy and sustainable seaports.

# 1 Introduction

## 1.1 Introduction

Seaports are important nodes of transport and can also host industrial clusters. As centres of economic activity, they also have environmental impacts. These range from negative, for example emissions, noise and land-use for transport and industry, to positive, such as offering opportunities for renewable fuels, sustainable production and economic growth. As the Paris Agreement compels economies to change profoundly from carbon-intensive to carbon-neutral production and consumption, many ports face uncertain and unpredictable developments. Nevertheless, ports can adopt forward looking strategies which align with the ongoing sustainable transitions and that foster economic growth.

This report aims to develop a benchmark to assess the sustainability of seaports. The benchmark is applied to key European seaports as well as three North American seaports. The benchmark presents data on the sustainability performance of the most recent years (2010-2018) and reports the port sustainability strategy. Even though a comparison of seaports is difficult due to the inherent differences of the ports as well as the variation in the available datasets, valuable insights can still be gained from this benchmark. These insights can be used by port authorities, policy makers and other stakeholders to adjust and improve the plans and actions towards more sustainable and climate neutral ports. Additionally, the various best practices of each port can be shared so as to speed up the actions and improve the results towards more sustainably operating ports. This benchmark provides a valuable tool for NGO's and other organisations in the discussions and lobby concerning the sustainable development of the seaports.

The Nature and Environment Federation South Holland (NZMH), a provincially oriented NGO in the Netherlands, has commissioned CE Delft to research and report the sustainability of seaports. NMZH has actively participated in the sustainable development of the port of Rotterdam since 1972. The NMZH is partner in many sustainable development projects and initiatives. They are also partners in the execution of the Port Vision 2030 which describes the future prospects for the port and industrial complex, also in regards to sustainable development. The Port of Rotterdam[1] aims to be the most sustainable port in Western Europe in 2030. This benchmark aims to support the Port of Rotterdam in this goal by presenting the sustainability performance of the port of Rotterdam. In order to strengthen the quality of the sustainability performance review the NMZH has decided to benchmark the performance of several other major sea ports in the Netherlands, Europe and North America. This will provide insight on possible measures that the port of Rotterdam, and other seaports, can take to improve their sustainable performance.

The information presented in this report could not have been available without the cooperation of the port authorities of the selected ports. The authors of this report would like to express gratitude to the port authorities which have cooperated with the data request. Special thanks also goes out to 'Bond Beter Leefmilieu', a nature and environmental NGO in Belgium, for assisting in collecting the data for the port of Antwerp.

[1] This report uses the terms Port of Rotterdam and port of Rotterdam. Port of Rotterdam refers to the port authority while port of Rotterdam refers to the port as a whole. The same methodology applies for other ports.

## 1.2 Topics

The report is divided in to two parts, the first parts analyses the sustainability of Dutch ports. The second part of the report adds perspective by focussing on European and North American ports. The results for the second part are subject to more limited data availability. The topics covered in this report are based on the sustainability areas identified by the European Sea Ports Association (ESPO, 2019) and the Dutch government (Ministry of Infrastructure and Water Management, 2008). The topics are the following:

- **Climate** - greenhouse gas emissions, emission reduction as well as indirect contribution to climate change by supporting fossil based industry versus alternative industry.
- **Renewable energy** - Investments in energy transition to renewable energy sources.
- **Air quality** – emission and concentration of air pollutants as well as incentives for stimulating better air quality.
- **Water quality** – chemical and ecological water quality, harmful industrial water emissions, industrial water cooling emissions.
- **Waste** - concerning waste generated at sea.
- **Modal split inland transport** – modal share of land transport (trucks, pipeline, river barges, and trains) from the port.
- **Public relations** – availability of discussion platforms neighbouring communities, hotline for complaints and other services aimed at better communication and collaboration between neighbouring communities and the port.
- **Sustainability strategy** –vision of port towards a sustainable future.

## 1.3 Selected ports

Among the selected seaports are the largest seaports in the Netherlands as well as several important European seaports, most of which are located in Western Europe. The selected seaports are shown in Table 1, Figure 1, and Figure 2.

**Table 1 – Selected European seaports**

| Port number | Port name | Port number | Port name |
|---|---|---|---|
| 1 | Port of Amsterdam | 9 | Port of Felixstowe |
| 2 | Port of Groningen | 10 | Port of Hamburg |
| 3 | Port of Moerdijk | 11 | Port of Le Havre |
| 4 | Port of Rotterdam | 12 | Port of London |
| 5 | Port of Zeeland/North Sea Ports* | 13 | Port of Long Beach |
| 6 | Port of Antwerp | 14 | Port of Los Angeles |
| 7 | Port of Barcelona | 15 | Port of Vancouver |
| 8 | Port of Bremen | | |

* In 2018 the Port of Zeeland (located in Terneuzen & Vlissingen) merged with the Belgium Port of Gent to form the cross-border North Sea Ports. Due to among others historical data availability this report focuses on the Dutch ports of the North Sea Ports hereafter called Port of Zeeland.

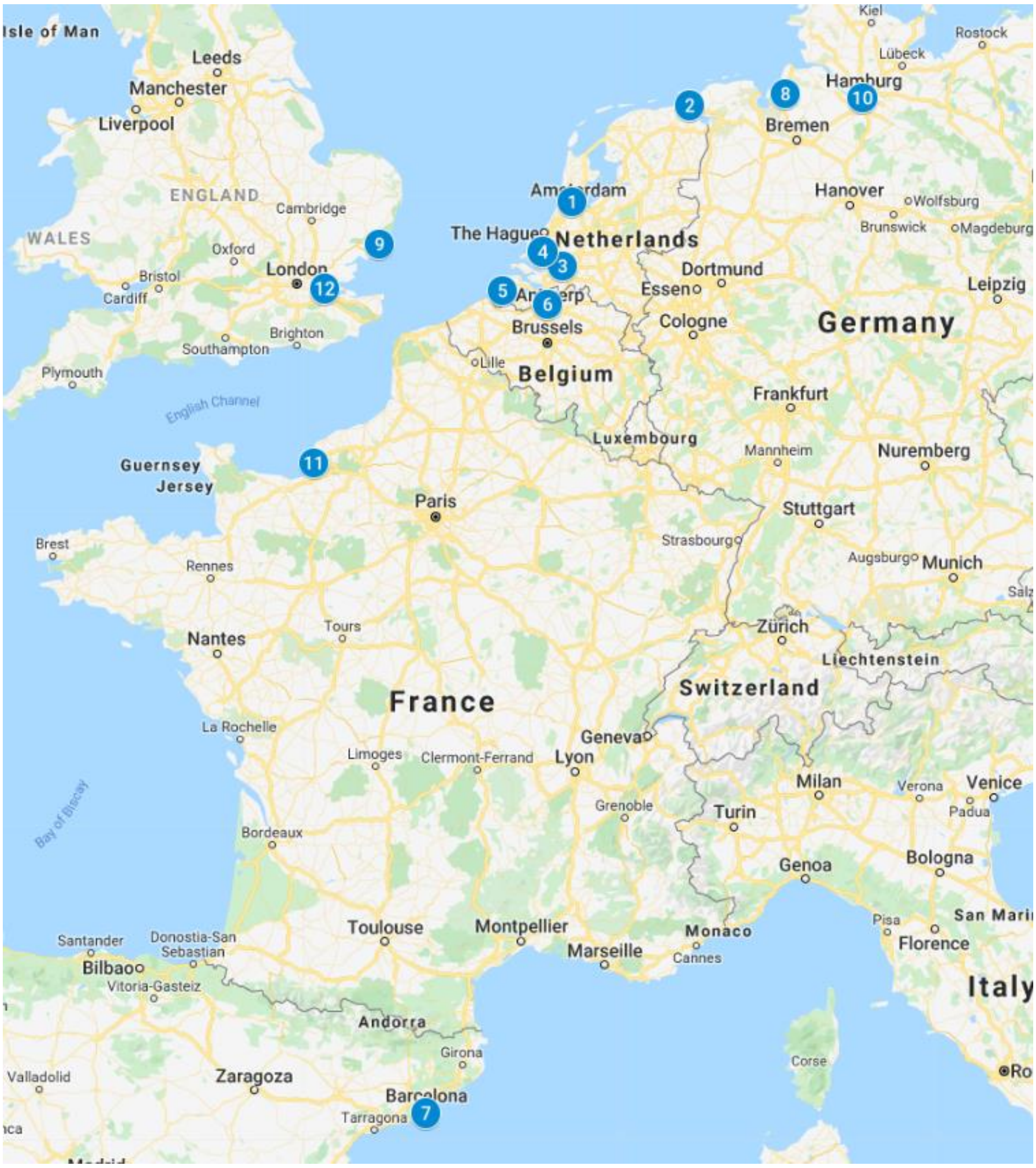
### North American ports

Recently the ambitious World Ports Climate Action Program[2] was signed by the European ports of Rotterdam, Antwerp, Barcelona, and Hamburg as well as the North American ports of Long Beach, Los Angeles, and Vancouver Fraser. Together with stakeholders these leading ports are committed to develop short-, medium- and long-term actions to advance decarbonisation of maritime transport and improve air quality. Although this benchmark

[2] World Ports Sustainability Program

primarily focusses on European ports, the inclusion of the above mentioned North American ports will provide deeper insights in the sustainability actions of several leading ports outside Europe. These North American ports will be included in the benchmark albeit on a more limited level of detail due to time, data and financial project constraints. There included North American ports are shown in Table 1, and Figure 2.

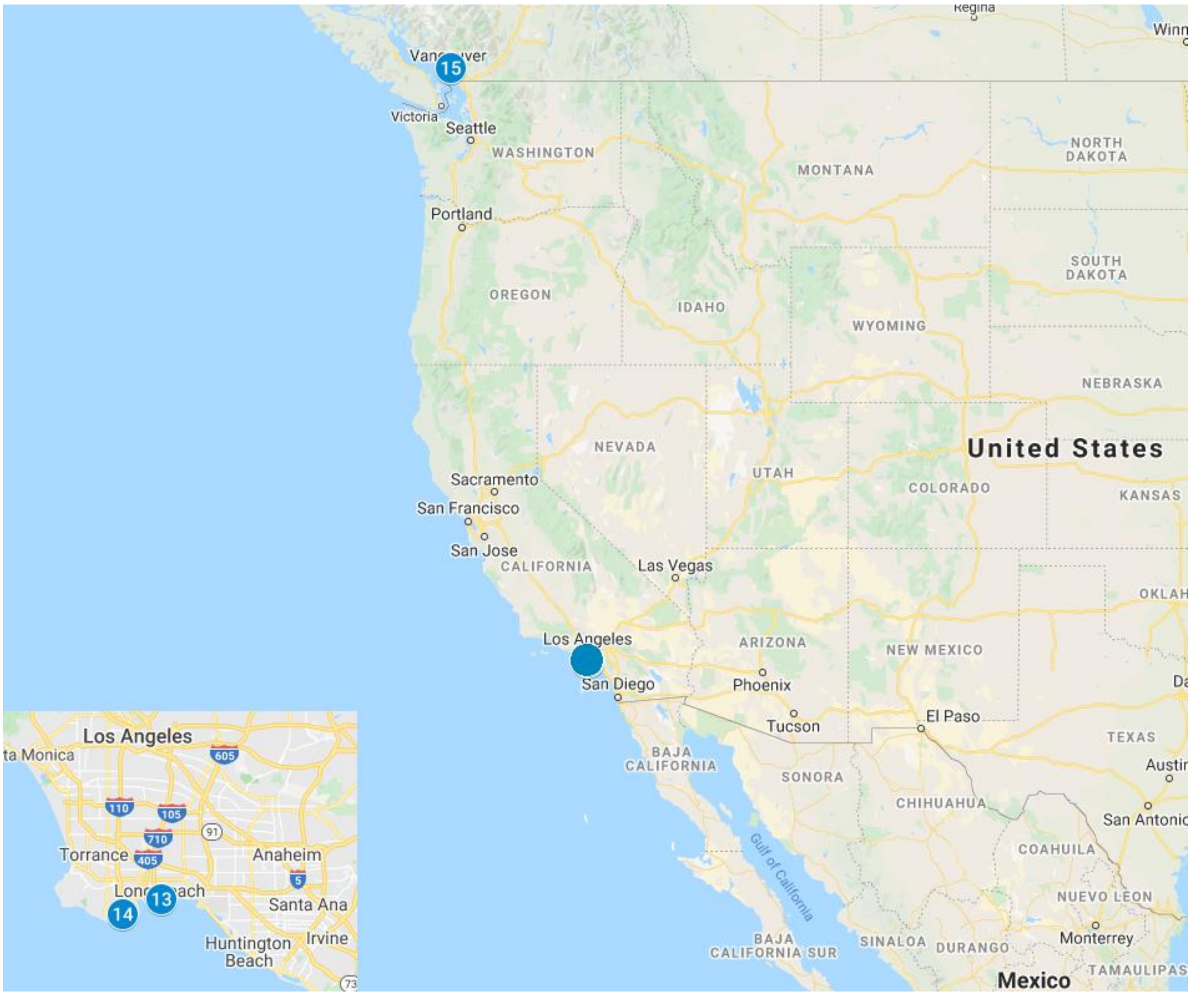
**Figure 1 - Locations of selected European ports**






natuur en milieu federatie zuid-holland

**Figure 2 – Location of selected ports in North America**



# 2 Methodology

This benchmark is based on various sources of data and information. This chapter explains the reasons and relevance of the selected topics, the data sources used as well as key assumptions made during the data gathering for the Dutch, European and North American ports.

## 2.1 Relevance of selected topics

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It encompasses more than care for the environment. Development is sustainable if it also takes into account economic, human and social aspects: scarcity not only applies to natural resources; a highly educated and healthy population, well-functioning social networks, social trust, machines and infrastructure are also not in unlimited supply. Several topics regarding sustainability have been selected. This paragraph explains the relevance of the selected topics and possible criteria that measure the performance of ports.

### Climate

According to the UN: "*climate change is probably the defining issue of our time".*
Reducing climate change is a key example of sustainability and therefore climate is the first selected topic. The emission of greenhouse gases into the atmosphere leads to global warming and climate change. The IPCC (2013) has estimated that without concrete climate policies temperatures may be expected to rise significantly by the end of the century. Such radical change will have an important and largely irreversible impact on ecosystems, human health and societies. Climate change costs are defined as the costs associated with all of the effects of global warming, such as sea level rise, biodiversity loss, water management issues, more and more frequent weather extremes and crop failures. Port operations results in emissions of carbon dioxide ($CO_2$), nitrous oxides ($N_2O$), sulphur hexafluoride ($SF_6$) and methane ($CH_4$), all of which are greenhouse gases contributing to climate change.

Several criteria have been included in the benchmark to measure the impact of ports on climate change. These include:
- the emissions of greenhouse gasses ($CO_2$, $CH_4$, $N_20$, $SF_6$) in port areas;
- the application of mitigation measures to reduce emissions.

These measures include the use biomass, residual heat, carbon capture and usage or storage, and residual steam.

### Renewables

The second topic, renewable energy production, is to a large extent related to (mitigating) climate change. Production of renewable energy is one of the most important measures to reduce greenhouse gas emissions. Energy produced by fossil fuels, for example coal and gas, is replaced by more sustainable alternatives methods of energy production, for example wind or solar powered installations. This so called energy transition will be critical in the development towards a carbon neutral future. Power plants can be situated in port areas as the accessibility of seaports allows for easy transportation of (fossil) fuels. Another benefit is that large energy consumers, in the form of heavy industry, are often located in or nearby ports. As a result, energy production is currently often situated in port areas.

Renewable energy production also has great potential in port areas. Wind power densities are higher in coastal areas making most seaports a suitable location for wind turbines. The vicinity of industries could also lead to projects in port areas that focus on innovative forms of energy production, for example hydrogen production based on renewable energy sources (green hydrogen). Renewable energy, especially wind and solar, result in better air quality.

The following types of renewable energy production sources have been considered:
- wind;
- solar;
- hydro;
- geothermal heat;
- certified biomass.

As well as the following carrier:
- green hydrogen.

The amount of renewable production (and energy production in general) depends on internal and external conditions like weather and operation hours. As a result, the production of energy is not constant at the same level. Energy production is therefore defined by the capacity of the generator rather than the total energy produced. For example, a wind turbine with a capacity of 3 Megawatt (3 MW) will produce 3 MW electricity per hour (3 MWh) of operation at full capacity. In order to measure the progress of ports towards the energy transition the following criteria is selected:
- capacity (MW) renewable energy production per type of renewable energy.

## Air Quality

The emission of air pollutants can have several negative effects. Most relevant and probably best analysed are the health effects due to air pollutants. However, other effects are also relevant, such as building and material damages, crop losses and biodiversity loss. Air quality emissions are not only a local issue, for example about 30% of the air quality pollutions in the Netherlands have originated from neighbouring countries. (Milieu Centraal, -)

Health effects:
- The inhalation of air pollutants such as particulate matter ($PM_{10}$, $PM_{2,5}$ and the even smaller $PM_{0.5)}$ and nitrogen oxides ($NO_x$) leads to a higher risk of respiratory and cardiovascular diseases (e.g. bronchitis, asthma, lung cancer). These negative health effects lead to medical treatment costs, production loss at work (due to illness) and, in some cases, even to death.
- Crop losses: Ozone as a secondary air pollutant (resulting from the emission of $NO_x$ and VOC) and other acidic air pollutants (e.g. $SO_2$, $NO_x$) can damage agricultural crops. As a result, an increased concentration of ozone and other substances can lead to lower crop yields (e.g. for wheat).
- Material and building damage: Air pollutants can mainly lead to two types of damage to buildings and other materials: a) pollution of building surfaces through particles and dust; b) damage of building facades and materials due to corrosion processes, caused by acidic substances (e.g. nitrogen oxides $NO_x$ or sulphur oxide $SO_2$).

Biodiversity loss: Air pollutants can lead to damage to ecosystems. The most important damages are a) the acidification of soil, precipitation and water (e.g. by $NO_x$, $SO_2$) and b) the eutrophication of ecosystems (e.g. by $NO_x$, $NH_3$). Damages to ecosystems can lead to a decrease in biodiversity (flora & fauna).

In order to measure the effect seaports have on air quality the following criteria are used:
- The amount of emissions of the following air quality pollutants: Particulate matter ($PM_{10}$ and $PM_{2,5)}$, Nitrous oxides ($NO_{x)}$, Ammonia ($NH_3$), Benzopyrene ($C_{20}H_{12}$), Sulphur oxides ($SO_2$), Carbon Oxide (CO) and Lead (PB).
- The concentrations of the following air quality pollutants: Particulate matter ($PM_{10}$ and $PM_{2,5}$), Nitrous oxides ($NO_x$), Ammonia ($NH_3$), Benzopyrene ($C_{20}H_{12}$), Sulphur oxides ($SO_2$), Carbon Oxide (CO) and lead (PB).
- Measures taken to reduce air quality emissions, including onshore power supply, discounts for environmental friendly vessels and environmental zones.

## Water quality

Seaports operate on water connected directly to sea or inland waterways. The water will continue to flow after it has circulated inside a port. Any pollutants emitted in ports will thus affect humans, fish and other ecosystems in the region. The water quality in port areas has a direct influence on biodiversity in the port vicinity. The water quality in port areas is influenced by the quality of water supplied by rivers and discharges of waste water in the port areas. Discharges of pollutants to surface water in port areas have a direct impact on the water quality. Pollutants can be emitted to the water by industries or vessels alike. Another influence on biodiversity is the discharge of water used for cooling, the heat contained in this water is a disturbance in the ecosystems. The following criteria measure the water quality:
- water quality scores according to the European water Framework;
- emissions of pollutants to surface water and sewers;
- emissions of cooling water in MW heat.

## Waste management

Vessels produce waste during their operations. In general, two main types of waste are produced, oily waste (e.g. from engines) and garbage. Vessels have to deposit this waste at the ports they visit. Ports should provide adequate waste collection services to avoid discharges at sea. A portion of vessels still (illegally) dump waste at open sea. In order to avoid dumping ports can take measures to increase the collection of waste. For example, in the Netherlands vessels have to pay a fee regardless the amount of garbage that is collected. In order to assess management of waste by seaports we use the following criteria:
- number of vessels depositing waste;
- volume ($m^3$) of waste collected per type.

## Modal split

Seaports often have an important logistical function. Goods are transhipped from large sea going vessels towards smaller vessels, trains, trucks or pipelines. These modes of transport have different levels of emissions. An inland vessel can transport up to 500 containers at once making it more efficient than a truck. Electric trains on the other hand do not have any local greenhouse gas (GHG) emissions. The shares of goods transported per mode is

called the modal split. High shares for (electric) rail and inland waterway transport (IWT) are preferred over truck transport. As shown in the report by CE Delft, et al. (2019) the total costs per tonne-kilometre[3] of trucks exceed trains and IWT, with IWT being the least costly option per tonne-kilometre. Pipeline transport has not been considered in the study by CE Delft, et al. (2019). Pipeline is a safe and very efficient method of transport of bulk liquid goods. The ability to transport goods via pipelines is however limited, only certain types of high volume liquid bulk can be transported on specific routes as pipelines are designed for specific substances. The modal split measures the sustainability of hinterland transport, higher shares of sustainable forms of transport reduce the impact of hinterland transport and thus increase the environmental performance of a port. A caveat is that not all transport modes are substitutes in all cases. For example, absence of a navigable inland river reduces the opportunities to ship goods via inland vessels. However, the port authority can create the right conditions to increase the use of sustainable forms of transports over time (modal shift). This influence is limited as the companies in the port are free to choose transport modalities. The following criteria is selected for hinterland transport:
— Shares of hinterland transport per mode.

### Community relations

Developments of ports has historically been related with the development of surrounding cities. As a result, ports are often closely situated to densely populated urban areas.
A sustainable port is characterized by its good relations with its local communities. Firstly, by improving the local environmental quality which will benefit ecosystems and health of local communities. The environmental quality can be improved by complain systems for noise or scent nuisances, active reduction of the number of nuisances or the management of local nature. A sustainable port is transparent about its port operations and will ensure a reliable communication in the case of incidents. Secondly by active community engagement. This can be in the form of local committees, organised activities for locals or a fund for local projects.

### Sustainability strategy

Global dynamics are constantly changing and trade patterns shift over time. It is important for ports to anticipate future developments to avoid path dependencies. A sustainable port operates from a vision and facilitates innovations. Is the port working towards a carbon neutral future and is the energy transition considered in their sustainability strategy? Is the transition towards a digital and service focused economy taken into account? Is the transition towards a circular economy facilitated? These questions are central when we consider sustainability strategy and investments.

## 2.2 Data gathering, sources and availability

The benchmark is to a large extent based on quantitative information. Several assumptions have been made for the gathering of data. In first instance only publicly available datasets have been considered. A second step was to collect data from publications from port authorities. The third step included the consultation of publications from companies or NGO's associated with the port authority. The fourth step included news reports and other miscellaneous sources. This resulted in a preliminary set of data for each port. The

[3] A tonne-kilometre is the transPort of one tonne of goods over one kilometre. The total costs exist of infrastructure and external costs. External costs includes climate, air quality, noise, accidents, and congestion.

respective port authorities have been contacted with a request to verify the data and to provide additions if available. The sources of the data for each port can be found in Appendix A. Not all ports have been able to meet our request. The Ports of Bremen has not replied to multiple telephone call and emails, the Port of Groningen and the Port of Le Havre have decided not to respond to our request while the Port of Felixstowe could not reply due to restrictions to share data under very strict corporate rules. Data has been collected for the years 2010–2018 in case data was readily available, otherwise data has been collected for the most recent years.

### 2.2.1 Dutch seaports

Table 2 shows the public sources used for the data gathering in the Netherlands. The data sources often report the data for various years. The emissions reported by Emissieregistratie are available for 2010 and the years 2015 until 2017, no data is collected for the years 2012 until 2014. The air quality concentrations are available for each year between 2011 and 2018. The water quality scores are available for 2015, while the waste collection data are available for 2005, 2015-2018. Unfortunately for many topics no sources report similar data on a European level.

**Table 2 - Public sources for Dutch data gathering**

| Data subject | Source | Years available |
|---|---|---|
| Greenhouse gas emissions | Emissieregistratie | 2010, 2015, 2016, 2017 |
| Air quality emissions | Emissieregistratie | 2010, 2015, 2016, 2017 |
| Air quality concentrations | RIVM | 2011-2018 |
| Water quality scores | Waterkwaliteitsportaal | 2015 |
| Pollutant emissions to water quality | Emissieregistratie | 2010, 2015, 2016, 2017 |
| Collected maritime waste | I&W | 2005, 2015-2018 |

#### Assumptions

Some data was easily available at port level, while for other data sources certain assumptions had to be made in order to retrieve the relevant information. In order to gather certain data, it was necessary to define the borders of the Dutch port areas in order to gather certain data. The port borders are based on the port areas reported on maps of the port authority websites. The resulting port areas are used to gather emission figures from Emissieregistratie. Also, average concentration figures from RIVM are based the on the port borders. Furthermore, renewable energy production located outside port areas (e.g. off shore wind) has not been taken into account.

#### Climate and air quality

An assumption had to be made about assigning emission grids to the port areas. Climate and air quality emissions have been derived from emission maps reported on the website of Emissieregistratie. This website provides emissions towards air for 1x1 km and 5x5 km grids in the Netherlands. 1x1 km squares have been allocated to ports when the port is located for at least 50% in the square. 5x5 km squares are allocated to ports when at least one 1x1 km square is located in the 5x5 km square. This leads to an overestimation of port emissions based on the 5x5 km squares. However, analysis showed that port emissions greatly exceed emissions of surrounding areas. A partial allocation would lead to an underestimation of emissions. For consistency reasons 5x5 km squares have been fully allocated to port areas when at least 1 of the 25 grids of 1x1 km falls within port territory.

Data on the following substances is collected via 1x1 km grid squares:
- carbon dioxide ($CO_2$);
- ammonia ($NH_3$);
- nitrogen dioxide ($NO_2$);
- particulate matter smaller than 10mm ($PM_{10}$);
- sulphur dioxide ($SO_2$).

Data on the following substances is collected via 5x5 km grid squares:
- methane ($CH_4$);
- sulphur Hexafluoride ($SF_6$);
- nitrogen oxide ($N_20$);
- benzo(a)pyrene ($C_{20}H_{12}$);
- particulate matter smaller than 2,5 mm ($PM_{2,5}$);
- carbon monoxide (CO);
- lead (PB).

### *Water emissions*

For the emissions to water an assumption had to be made about which companies are situated in port areas. The Dutch Emissieregistratie collects emissions (in kg) from companies to surface water as well as sewage water of Substances of Very High Concern (SVHC). In the Netherlands over 1,500 substances are recognised as a SVHC (more precisely ZZS) and therefore are dangerous for humans and the environment[4]. About 100 of these substances are emitted by companies situated inside the five selected port areas. Companies are assigned to the five Dutch ports based on postal code or town. As a result, the emissions (in kg) of various toxic substances in port areas are known.

The toxicity of the various pollutants varies. To compare the toxicity of the pollutants, a life cycle analysis database is used to determine the damage factors. Life cycle impact assessment (LCIA) translates emissions and resource extractions into a limited number of environmental impact scores by means of so-called characterisation factors. These characterisation factors are collected in the Ecoinvent database. The characterisation factor provides an indication of the toxicity of emissions of pollutants to water. Two types of damage are considered: damage to human health and damage to ecosystems.

### 2.2.2 European and North American ports

The data gathering for international ports was based on several sources. Unfortunately, no datasets exist that cover multiple ports. Therefore, the data used is port specific. In order to collect data local NGO's and port authorities have been contacted. In some cases this helped to locate documents that would have otherwise been difficult to find.

## 2.3 Scale differences between ports

The selected ports have various functions and different focus areas. As a result, the impact of these port differs in absolute terms and in relative terms. For example, a port with a large industrial complex will have higher emissions compared to a port which mainly focusses on logistics. The heterogeneity of port characteristics makes it difficult to draw conclusions based on the comparison of ports. A port which contains high emitting industry might be run very efficiently.

[4] RIVM Zoeksysteem Risico's van stoffen

In order to control for the scales of the various ports several characteristics have been determined (see Table 5 to Table 7) such as size of the port, throughput and added value. Specific characteristics are used to for specific topics, as shown in Table 3 for the Dutch ports. For example, the capacity for renewable energy capacity is related to the size of a port, in a larger port there is more space for wind turbines and solar panels. The emission of pollutants however, is more related to the amount of economic activity compared to the size of a port. By considering the scale of the port and its activities, through different parameters, it is possible to better visualize the efforts of ports.

**Table 3 - Relative comparison of topics for Dutch ports**

| Sustainability topic | Dependency | Related to |
|---|---|---|
| Climate emissions | Business activity | Added value |
| Renewable capacity | Available space | Size of port (square km) |
| Air quality emissions | Business activity & space | Added value & size of port |
| Onshore power supply | Number and size of vessels | Throughput |
| Pollutants to water | Business activity | Added value |
| Maritime waste management | Maritime activity | Throughput |

Due to limited data availability for international ports not all topics are corrected for scale differences of ports. Only renewable energy capacity and air quality emissions are shown in relative terms, as can be seen in Table 4.

**Table 4 - Relative comparison of topics for international ports**

| Topic | Dependency | Related to |
|---|---|---|
| Renewable capacity | Available space | Size of port (square km) |
| Air quality emissions | Business activity & space | Size of port (square km) |

# 3 Ports in the Netherlands

In this chapter the benchmark process and results are presented for the Dutch seaports.

## 3.1 Characteristics of Dutch seaports

Below the characteristics of the five selected Dutch seaports are described.

### Amsterdam

The Amsterdam port region is one of the world's largest logistics hubs. Handling 80 million tonnes in cargo traffic annually (Dutch statistics office: CBS), Amsterdam is one of Western Europe's Top 5 largest sea ports. The port's strategic and central location within Europe makes it easily accessible and ensures excellent connections to all major European markets. The main products transhipped in Amsterdam are petrol, coal and other bulk products like agribulk and cacao. These products are first shipped to Amsterdam in bulk, then these products are processed in Amsterdam and subsequently transported onwards. Focus areas for the port of Amsterdam are; energy transition, circular economy, logistics and accessibility as well as digitalisation. Amsterdam is the largest port in the area called Noordzeekanaalgebied. Other ports in this area are located in Zaanstad, Beverwijk, Velsen and IJmuiden which are considerably smaller. A special focus area in Amsterdam are cruise vessels, of which more than 1,500 cruise vessels visited Amsterdam in 2013 (Port of Amsterdam, 2015).

### Groningen

Groningen Seaports is the company which controls the ports in Delfzijl and Eemshaven which are situated in the Dutch province of Groningen. The ports have a direct connection to the North Sea and can be reached via road, rail and inland waterways. The focus areas in the Eemshaven are energy, offshore wind and datacentres. Eemshaven has an energy production capacity of 8,000 MW and produces about 30% of all energy in the Netherlands. Delfzijl contains a large chemical and circular industry as well as a logistical centre. The two ports are about 28 square km in size.

### Moerdijk

The port of Moerdijk is the 4$^{th}$ largest sea port in the Netherlands based on throughput figures (Dutch statistics office: CBS). It is a sustainable hub for chemicals and a logistics hotspot. The pipeline system is directly connected with the chemicals clusters in Antwerp, Rotterdam, Zeeland, North Limburg and the Ruhr area. In Moerdijk, chemical and petrochemical companies have plenty of space for growth and the ability to pursue greening initiatives. Furthermore, chemical and chemical-related companies make use of each other's raw materials and residual streams and thus close the chains. Moerdijk is connected by inland waterways, rail, road and pipelines and offers good connectivity to the Flemish-Dutch Delta.

## Rotterdam

The Port of Rotterdam is Europe's largest sea port. The port owes its leading position to its outstanding accessibility by (large) sea-going vessels and to its intermodal connections and the 385,000 people working in and for Rotterdam's port and industrial area. The Port of Rotterdam is a main logistical hub with access by inland waterways, rail, road and pipelines. With a transhipment of 1.6 million containers Rotterdam is also the largest container port in Europe. The Port of Rotterdam focusses on the most important trade routes between East and West. To facilitate this the infrastructure supports the largest vessels in the world. Transhipment and refinement of crude oil are important operations as well. Besides a large logistical function the Port of Rotterdam also contains a large complex of industrial and chemical industry. To power this industry Rotterdam has an electricity production capacity over 6,000 MW (Port of Rotterdam, 2017).

## Zeeland

Zeeland seaports have merged in 2018 with the Belgium Port of Gent to become North Sea Port. This report will focus solely on the Dutch ports of Vlissingen and Terneuzen, known by their company name of Zeeland seaports. Zeeland seaports is the third largest port area in the Netherlands and consists of the ports in Vlissingen and Terneuzen. The Port of Vlissingen is located at banks of the Western Scheldt and is accessible by very large vessels. The Port of Terneuzen is situated alongside the Ghent-Terneuzen Canal. The Port of Terneuzen contains a logistical and chemical complex. Zeeland seaports is the largest European port for transhipment of wood products, fertilizers and construction foundations. For the transhipment of non-ferrous metals Zeeland seaports is the largest port worldwide.

## Scale

The various functions and characteristics of the ports are also shown in the scale of the ports. Table 5 shows the size, excluding water surface, in square km of the various ports.

**Table 5 - Size (square km) of ports 2017**

| Square km | 2017 |
|---|---|
| Amsterdam | 16 |
| Groningen | 28 |
| Moerdijk | 26 |
| Rotterdam | 79 |
| Zeeland | 44 |

Rotterdam is the largest port while Zeeland is the second largest port in the Netherlands. Groningen and Moerdijk are comparable in size. Amsterdam is the smallest port and it mainly has a logistical function as is exemplified by Table 6. The throughput in Amsterdam is the second highest in the Netherlands, followed by Zeeland which has remarkably stable throughput figures. Throughput in the Port of Groningen has increased significantly since 2010.

Table 6 – Total marine related throughput (million ton) of ports between 2010 and 2017

| Mil Ton | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 73 | 79 | 79 | 81 |
| Groningen | 3 | 6 | 6 | 7 |
| Moerdijk | 6 | 6 | 7 | 7 |
| Rotterdam | 405 | 461 | 467 | 469 |
| Zeeland | 34 | 34 | 34 | 34 |

A third way to compare the port is through the added value they produce. Added value is the difference between buying price of inputs and the price for which the processed products are sold. Added value is thus the additional value that is created by the processes performed by a company. It is possible to calculate the added value of a port area by summing up the added values of the companies inside a port area. Added value is a proxy for the economic scale of a port. The Erasmus University annually reports (Erasmus UPT, 2018) the added values of the various port areas in the Netherlands. The results are shown in Table 7.

The Port of Rotterdam has the largest added value in the Netherlands, unsurprisingly since Rotterdam is the largest port in Europe. Groningen and Moerdijk are the ports with the lowest added value. The added value in the ports depends on more than the throughput or square kilometres of a port. For example, the Port of Zeeland only has about half the tonnes in throughput compared to the Port of Amsterdam. However, the added value in Zeeland is significantly higher which is most likely due to the large chemical complex situated in Zeeland. This creates more added value from transhipped goods than the goods that are transhipped in the Port of Amsterdam.

Table 7 – Direct added value in million € for ports between 2010 and 2017

| Mil Euro | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 1,645 | 2,069 | 2,125 | 2,159 |
| Groningen | 814 | 1,087 | 1,235 | 1,323 |
| Moerdijk | 1,276 | 1,376 | 1,398 | 1,471 |
| Rotterdam | 11,143 | 11,962 | 13,716 | 14,689 |
| Zeeland | 3,119 | 3,241 | 3,477 | 3,594 |

Source: EUR.

## 3.2 Climate

This paragraph discusses the emissions of greenhouse gasses in ports and the most important mitigation measures to reduce greenhouse gas emissions. First the results are discussed for the most prominent GHG, carbon dioxide ($CO_2$). Secondly the results are discussed for other GHG namely methane, nitrous oxide and sulphur hexafluoride.
This paragraph ends with an overall discussion of the most important mitigation measures that are applied in the Dutch ports.

### 3.2.1 Carbon dioxide

The best known GHG emission is carbon dioxide ($CO_2$) and this is reported on 1x1 km squares since 2015 by Emissieregistratie. The figures for 2010 are based on 5x5 km squares, which result in a slight overestimation as emissions from outside the port are included as well (see Paragraph 2.2.1). $CO_2$ is mainly emitted during the combustion of fuel, this can be fossil fuels like coal as well as certain renewable sources like biomass. $CO_2$ is the most important greenhouse gas with a share of 85% in 2017 in the Netherlands (CBS, 2018). The sectors with the most $CO_2$ emissions are the energy production sector, the large industrial sector as well as road traffic. Common sources are energy producers and industries that are located in the port, as well as transport that occurs in port areas. As a result $CO_2$ emissions in the five port areas are significant, as is shown in Table 8.

**Table 8 - $CO_2$ emissions in port areas of the selected Dutch ports**

| Kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 5,906 | 6,020 | 6,235 | 5,441 |
| Groningen | 7,429 | 10,573 | 13,911 | 13,359 |
| Moerdijk | 5,366 | 3,803 | 5,167 | 5,828 |
| Rotterdam | 29,722 | 31,195 | 32,803 | 30,702 |
| Zeeland | 14,538 | 10,246 | 10,993 | 10,908 |
| Total | **62,960** | **61,837** | **69,109** | **66,238** |

* Results for 2010 are based on 5x5 km grid squares. Which results in a slight overestimation as emissions from outside the port are included as well.

The total $CO_2$ emissions of the Dutch seaports equalled 66 Mton in 2017, which is about 40% of the total $CO_2$ emissions in the Netherlands. The port of Rotterdam has the largest emissions of all Dutch ports. Groningen and Zeeland have emissions over 10 Mton $CO_2$ as well. The ports of Amsterdam and Moerdijk have emissions just below 6 Mton $CO_2$ in 2017. $CO_2$ emissions have increased significantly in Groningen since 2010, while Zeeland has lower emissions. The $CO_2$ levels in the other ports have remained more or less stable since 2010. The emission increase in Groningen coincides with the opening of a new power plant in 2015.

*Large emitters*

Table 9 shows the most important sources of emissions in port areas in 2017. The sectors chemical industry (12 Mton), the energy sector (35 Mton) refineries (11 Mton) and waste disposal (5 Mton) contribute the most. These sectors represent 95% of the $CO_2$ emitted in port areas as can be seen in Annex C.1. In the port of Groningen over 90% (12M ton) of the emissions in 2017 are the result of companies in the energy sector. In the port of Amsterdam in 2017 3.4 Mton was emitted by energy sector and 1.6 Mton by waste disposal. Chemical industries emissions in Moerdijk and Rotterdam are about 3 Mton. In Zeeland emissions of the chemical industry are over 6 Mton. The energy sector (15 Mton) and refineries (9 Mton) are large $CO_2$ emitting sectors in the port of Rotterdam.

**Table 9 - Important sources of $CO_2$ emissions in port areas**

| Kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Chemical industry | 12,049 | 11,760 | 12,487 | 12,387 |
| Energy sector | 27,926 | 31,274 | 37,579 | 34,753 |
| Mobility and transport | 3,014 | 1,668 | 1,366 | 1,386 |
| Refineries | 10,722 | 11,213 | 11,186 | 10,578 |
| Waste disposal | 4,570 | 4,594 | 5,373 | 5,359 |
| Other sectors | 4,679 | 1,328.07 | 1,117.16 | 1,775.66 |
| **Total** | **62,960** | **61,837** | **69,109** | **66,238** |

* Results for 2010 are based on 5x5 km grid squares. Which results in a slight overestimation as emissions from outside the port are included as well.

The emission in these sectors are mostly dominated by large companies situated in the port area. In the port of Groningen over 90% of the emissions in 2017 are the result of companies in the energy sector. The port of Groningen contains an energy production complex which includes four power stations powered by gas, coal and biomass. According to the Dutch Emissions Authority the largest $CO_2$ emitting company of the Netherlands is situated in the port of Groningen (ING, 2018). Emissions of the Eemshaven Centrale equalled about 8.3 megaton $CO_2$ in 2016, about 60% of all emissions in the port of Groningen. This power station has been in operation since 2015 and is responsible for the increase of $CO_2$ emissions in the port of Groningen.

The port of Groningen is not the only port where large emitters are situated. Of the fifteen largest emitters in the Netherlands 11 are situated in the five selected seaports. Only one of the fifteen emitters is not situated in a seaport. Amsterdam contains two power plants, one powered by coal (4 Mton) and one powered by gas (2.1 Mton). While Moerdijk contains a chemical company with 2.6 Mton emissions. Rotterdam contains two power plants (4.7 Mton and 3.2 Mton) and three refineries (4.3, 2.3 and 2.1 Mton). The port of Zeeland contains chemical industry which emit large quantities of $CO_2$. It includes a company specialised in fertilizers (3.7 Mton) and plastics (2.7 Mton). The seaports contain other companies which emit large quantities of $CO_2$ as well.

**Text box 1 - Outlook on $CO_2$ emissions**

This report has included verified $CO_2$ emissions figures up to and including 2017. According to the provisional data from Emissieregistratie the emissions by energy producers have reduced in 2018 (Rijksoverheid, 2019a). This reduction is due to reduced use of coal powered energy production. In the port of Rotterdam in 2018 the emissions from refineries have reduced significantly as well according to the Dutch emissions authority[5]. Future reduction of emissions are foreseen from among others the energy producers. In 2019 a coal powered plant in Amsterdam closed[6] and before 2025 the remaining Dutch coal power plants have to close[7]. Furthermore, the large emitters have committed to the Dutch climate agreement which aims to reduce greenhouse gas emissions in 2030 with 49% compared to 1990. In order to comply with the climate agreement significant reductions should be visible in future years.

[5] Rotterdamse industrie stoot minder $CO_2$ uit

[6] Hemwegcentrale officieel gesloten, nog vier kolencentrales over

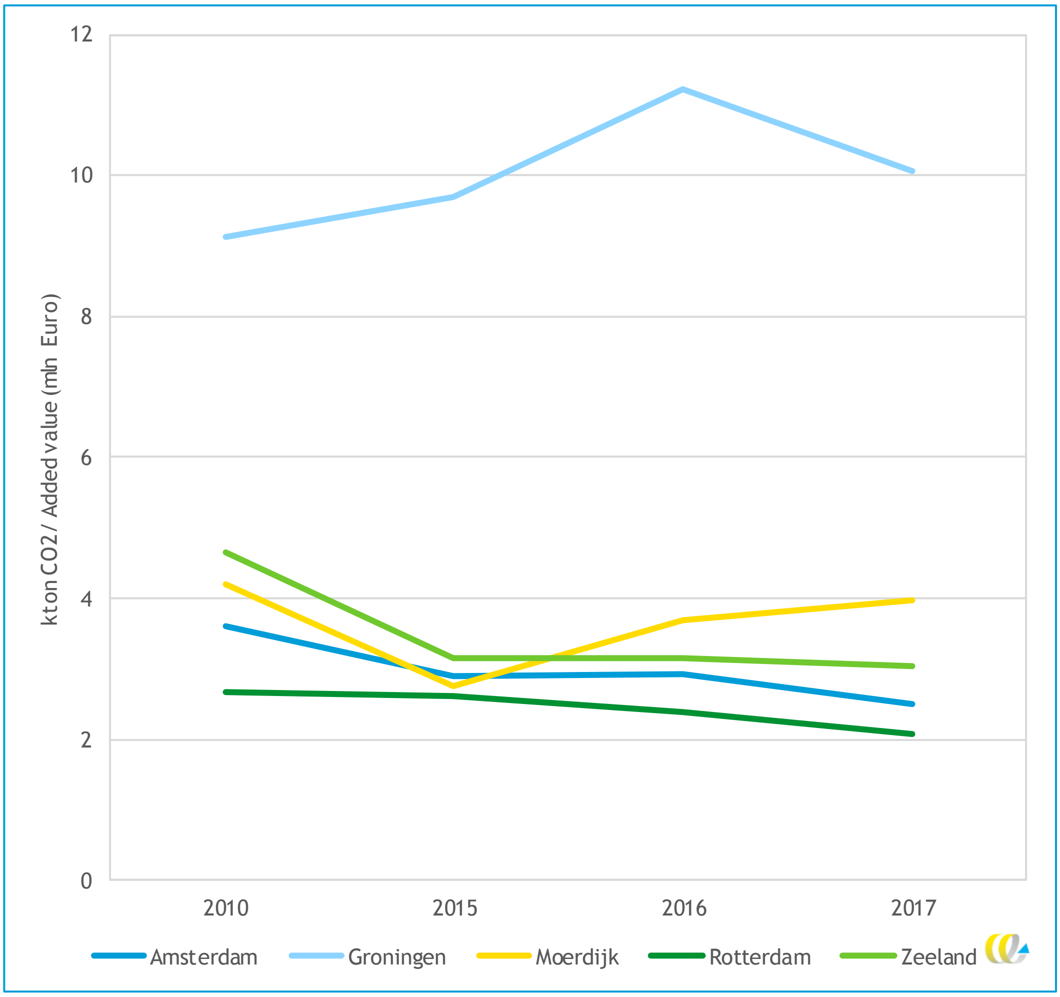
[7] Kabinet dwingt vervroegde sluiting oudste kolencentrales af

## *Relative emissions*

Looking at the absolute $CO_2$ emissions of ports shows some interesting results. These results do not consider any increases in port size or activity levels. It is possible that a port has grown more in size or activity levels compared to $CO_2$ emissions. This would result in a decrease of relative $CO_2$ emissions; more is produced with relative less $CO_2$ emissions.
The amount of production is difficult to determine but there are some options. First of all the amount of throughput provides information about the maritime activity. However ports have other functions besides logistical functions, such as industrial activity.

The $CO_2$ emissions relative to the added value are shown in Figure 3. The carbon intensity in the ports of Groningen and Moerdijk has increased since 2015. The other ports show a decrease in the carbon intensity. The increase in carbon intensity in Groningen and Moerdijk coincides with the increase of two forms of energy production. The opening of the Eemshaven Centrale in the port of Groningen during 2015. In Moerdijk the use of energy and gas has increased by changes in production processes by two large companies (Port of Moerdijk, 2017). This resulted in increasing $CO_2$ levels back to the business as usual levels of 2013. The higher production levels are also reflected in the increased production of residual heat as can be seen in Figure 9.

**Figure 3 - $CO_2$ emissions relative to added value in port areas the Netherlands**





natuur en milieu federatie zuid-holland

According to the CLO (Dutch Government, 2018) waste management is the industry with the highest $CO_2$ intensity, followed by energy production and petrochemical industry. Incineration of waste produces a lot $CO_2$ emissions while relatively little added value is created. Groningen is the port with the highest carbon intensity, which is unsurprising given the large energy production industry. The ports of Amsterdam, Rotterdam, and Zeeland have the lowest carbon intensities of all ports. On average these ports make more money for each kg of $CO_2$ emissions. The growth seen in Figure 3 in Groningen and Moerdijk is thus a consequence of increased production by carbon intensive industries in these ports.

**Figure 4 - $CO_2$ emissions in port areas the Netherlands relative to throughput (Mton)**

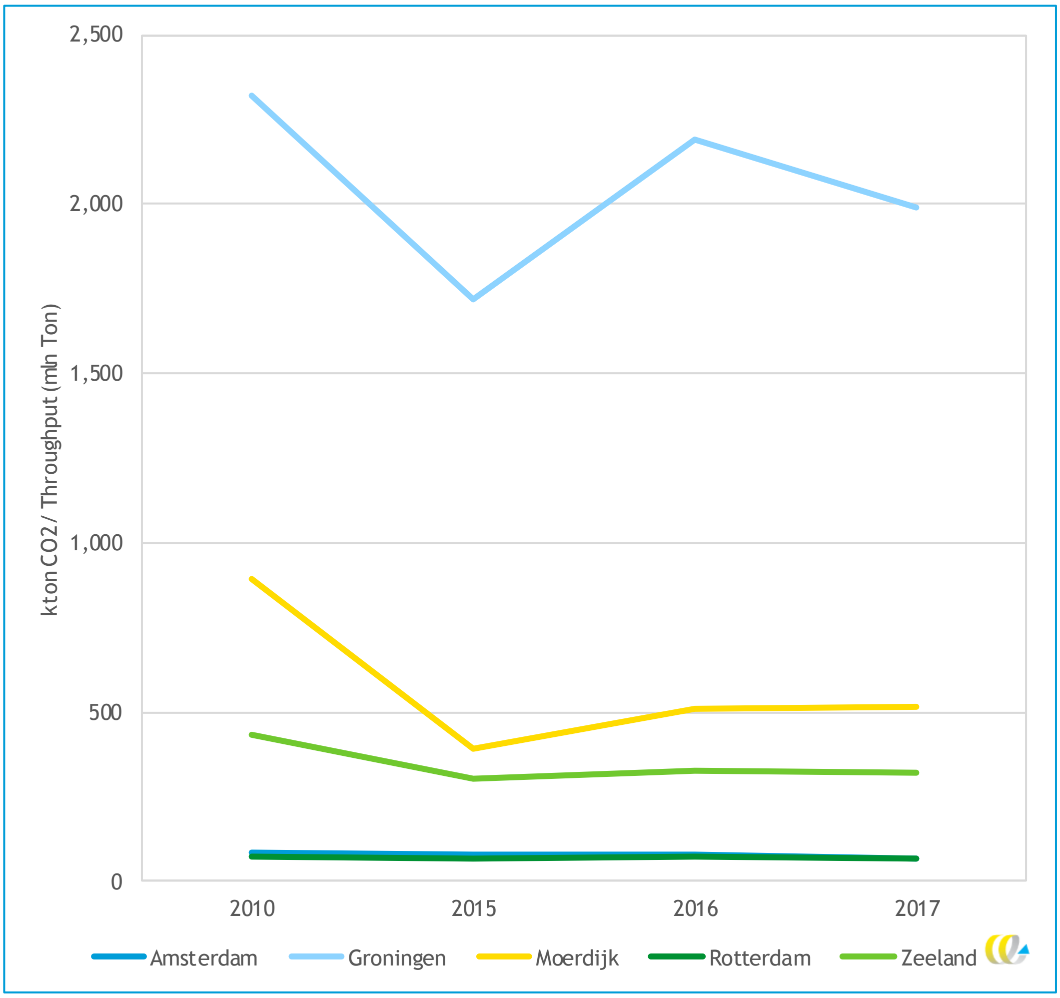



Figure 4 shows the emissions of $CO_2$ relative to the throughput of goods. Amsterdam and Rotterdam have the lowest emissions per ton of throughput. Both ports are specialised in transhipment of goods and have high throughput figures. Groningen has the relative highest emissions per ton of throughput. The $CO_2$ emissions in the port are high due to energy production industry.

**Text box 2 - Conclusion $CO_2$ emissions**

According to the Paris agreement the use of fossil fuels has to decline in order to shift to a carbon neutral future. The Dutch climate agreement 'Klimaatakkoord' aims to reduce greenhouse gas emissions with 49% in 2030 compared to the 1990 level. $CO_2$ emissions are the main source of global warming and the Dutch seaports contribute significantly. About 40% of all Dutch $CO_2$ emissions is emitted in the five seaports. In order to comply with the Klimaatakkoord and the Paris agreement significant reductions are expected from the seaports.
The total of all $CO_2$ emissions in port areas does not show a significant reduction yet. On the contrary, absolute $CO_2$ emissions have increased between 2010 and 2017. This increase is partly the consequence of higher production levels. Some seaports have become less $CO_2$ intensive relative to the added value, which means that they produce more with similar $CO_2$ emissions. These improvements have not resulted in $CO_2$ reductions in absolute terms and additional efforts are necessary to reduce $CO_2$ emissions.

### 3.2.2 Other greenhouse gasses

#### *Methane*

Methane has a global warming potential that is 34 times stronger than carbon dioxide. Methane is naturally emitted by wet areas like swamps. It is also emitted through human actions as well. The most important sources are production and use of fossil fuels, waste management and dairy farming of especially cows. Rotterdam and Zeeland have the highest methane emissions as can be seen in Table 10. Most ports show a decline in methane emissions, only the port of Rotterdam had an increase of methane emissions in 2016. Groningen has the lowest methane emissions. Total methane emissions in the Netherlands was 721 kton in 2017. Agriculture is the main contributor with 540 kton, while the total of industry in the Netherlands emits 40 kton. The five port areas are responsible for almost 22 kton in 2017. Ports are not the largest contributor to methane emissions, in contrast to $CO_2$ where ports contributed about 40%.

**Table 10 – $CH_4$ emissions in port areas the Netherlands**

| Kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 3.8 | 3.1 | 3.0 | 2.9 |
| Groningen | 1.1 | 1.8 | 1.8 | 1.7 |
| Moerdijk | 3.2 | 2.6 | 2.4 | 2.3 |
| Rotterdam | 8.1 | 8.9 | 9.6 | 8.3 |
| Zeeland | 9.2 | 7.1 | 6.8 | 6.4 |
| **Total** | 25.4 | 23.5 | 23.7 | 21.7 |

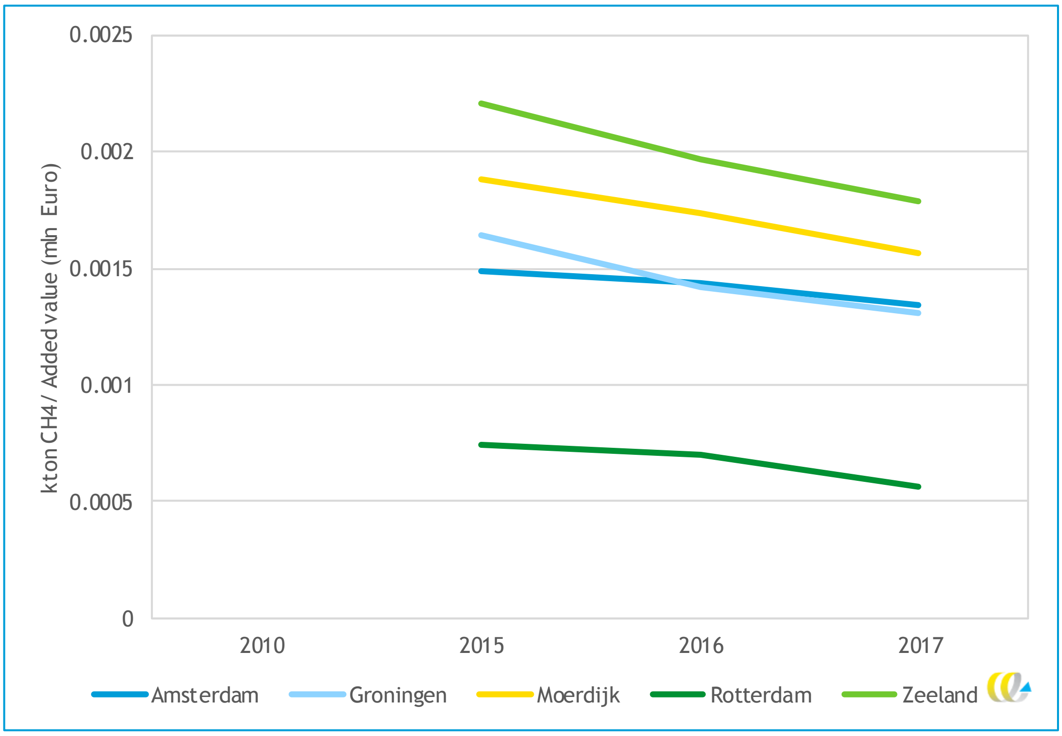
Methane is emitted in ports by most sectors distinguished by EmissieRegistratie. The most important sectors are agriculture, energy and waste disposal in ports as can been in Table 11. Interestingly agriculture is an important source in port areas. This can be the result of farms situated just outside the port area, which are included in the results. Emissions from waste disposal in 2017 occur mostly in Zeeland (5.1 Mton), Rotterdam (2.4 Mton), and Moerdijk (1.9 Mton) as can be seen in Annex C.1.

**Table 11 - $CH_4$ emissions in port areas the Netherlands by sector**

| Kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 4.6 | 4.4 | 4.7 |
| Energy sector | 1.7 | 2.1 | 3.0 | 1.7 |
| Waste disposal | 17.0 | 12.4 | 11.7 | 10.9 |
| Other sectors | 6.74 | 4.47 | 4.56 | 4.31 |
| **Total** | 25.4 | 23.5 | 23.7 | 21.7 |

Zeeland has the highest methane emissions relative to added value, followed by Moerdijk, Groningen and Amsterdam as can be seen in Figure 5. The relative methane emissions are the lowest in Rotterdam. It is somewhat surprising that methane emissions in Groningen are relatively low, considering the high $CO_2$ intensity of this port. Apparently the industries located in the port of Zeeland and Moerdijk are more methane intensive. The port of Rotterdam has the highest methane emissions in absolute terms, though it scores the lowest relative to added value.

**Figure 5 - Methane emissions in port areas the Netherlands relative to added value**




* 2010 methane emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to methane emissions is large. From 2015 onwards data is available on 1x1 km squares. The 2010 results are not comparable to 2015 onwards and are therefore not included.

### *Nitrous oxide*

Nitrous oxide ($N_2O$) is 298 times more effective than $CO_2$ at absorbing heat. The global warming potential of nitrous oxides is thus a lot higher than $CO_2$. Nitrous oxide is naturally emitted by oceans, rainforest and bacteria in the ground. Non-natural emission sources are fertilizers containing nitrogen, burning of fossil fuels and chemical processes based on nitrogen. Emissions in the Dutch ports have increased since 2010 as can be seen in Table 12. The port of Zeeland emits the most nitrous oxide, almost 1 kton in 2017.

**Table 12 – Nitrous oxide emissions in port areas in the Netherlands**

| Kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.12 | 0.18 | 0.19 | 0.18 |
| Groningen | 0.01 | 0.17 | 0.22 | 0.23 |
| Moerdijk | 0.17 | 0.17 | 0.20 | 0.24 |
| Rotterdam | 0.28 | 0.40 | 0.42 | 0.39 |
| Zeeland | 0.84 | 0.87 | 0.88 | 0.93 |
| **Total** | **1.42** | **1.79** | **1.90** | **1.97** |

The sectors emitting the most nitrous oxide in port areas are shown in Table 13. The chemical industry, mostly in Zeeland, has the largest contribution as can be seen in Annex C.1. Other sectors which emit higher quantities of nitrous oxide are energy, waste disposal and agriculture. The port of Zeeland hosts a large chemical complex which is responsible for the high nitrous oxide emissions. According to Emissieregistratie a company producing fertilizers emitted 0.82 kton nitrous oxide in 2017, which is almost 90% of total nitrous oxide emissions in the port of Zeeland. The least nitrous oxide is emitted in the ports of Amsterdam, Groningen and Moerdijk. Unlike $CO_2$ and methane and nitrous oxide emissions increased in multiple ports. Nitrous oxide emissions have increased in the ports of Groningen, Moerdijk and Zeeland between 2015 and 2017. The total nitrous oxide emissions in the Netherlands is almost 30 kton in 2017 (CBS), of which almost 6 kton by industries. This figure used to be a lot higher before 2005, the contribution of chemical industry alone was over 20 kton. However, since 2005 emissions from chemical industry have reduced and the level is now around 4 kton per year. This reduction is due to a change in production method of nitric acid (Rijksoverheid, 2019a), which has many technical applications. Agriculture is responsible for the most nitric oxide emissions, contributing more than 21 kton in 2017.

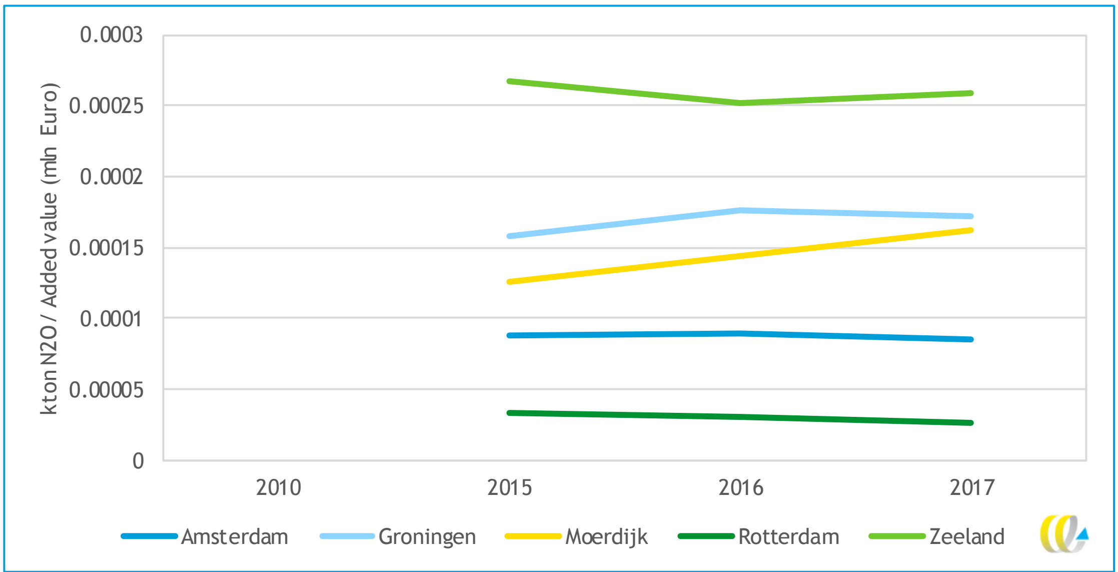
**Table 13 – Nitrous oxide emissions in port areas in the Netherlands**

| Kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Chemical industry | 0.81 | 0.76 | 0.81 | 0.86 |
| Energy sector | 0.18 | 0.35 | 0.40 | 0.37 |
| Waste disposal | 0.23 | 0.23 | 0.26 | 0.29 |
| Agriculture | - | 0.25 | 0.23 | 0.24 |
| Other sectors | 0.20 | 0.21 | 0.20 | 0.20 |
| **Total** | **1.42** | **1.79** | **1.90** | **1.97** |

The contribution of the five ports in 2017 was almost 2 kton, which is quite small compared to the contribution of ports towards total $CO_2$ emissions in the Netherlands. The emissions of nitrous oxide are however showing an increase due to higher emissions in Groningen, Moerdijk and Zeeland.

The relative nitrous oxide emissions are highest in Zeeland as is shown in Figure 6. Rotterdam has the lowest emissions relative to added value of the five ports. The nitrous oxide intensity has increased in Moerdijk and Groningen since 2015. Amsterdam and Zeeland are on similar levels as in 2015. Rotterdam is the only port where the nitrous oxide intensity has decreased over the years.

**Figure 6 - Relative $N_2O$ emissions in port areas the Netherlands relative to added value**




* 2010 nitrous oxide emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to methane emissions is large. From 2015 onwards data is available on 1x1 km squares. The 2010 results are not comparable to 2015 onwards and are therefore not included.

## *Sulphur hexafluoride ($SF_6$)*

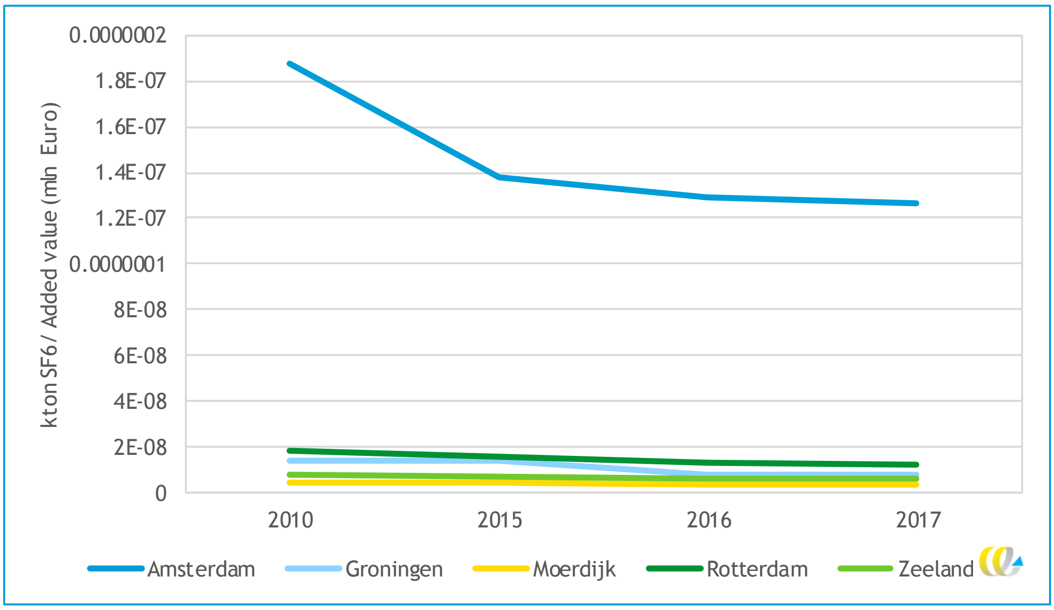
Sulphur hexafluoride ($SF_6$) is 23,000 times more effective compared to $CO_2$ in global warming potential. Sulphur hexafluoride is a gas that is used as isolator for high voltage switches where leakages could occur. Emissions also occur at the semiconductor industry and at processes where sulphur hexafluoride is used for cleaning. Annex C.1 shows that the emissions of sulphur hexafluoride only occur in the sector 'other industries'. Amsterdam and Rotterdam emit the most sulphur hexafluoride as can be seen in Table 14. Sulphur hexafluoride emissions are relatively low in Groningen, Moerdijk and Zeeland. Most ports show a decrease in sulphur hexafluoride emissions, only Groningen had an increase of sulphur hexafluoride emissions in 2015 compared to 2010. The total sulphur hexafluoride emissions in the Netherlands where almost 6 tons in 2017, of which only a small portion (0.5 ton) was emitted in the five ports.

**Table 14 - Sulphur hexafluoride emissions (ton) in port areas the Netherlands**

| Ton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.31 | 0.29 | 0.27 | 0.27 |
| Groningen | 0.01 | 0.02 | 0.01 | 0.01 |
| Moerdijk | 0.01 | 0.01 | 0.01 | 0.01 |
| Rotterdam | 0.20 | 0.18 | 0.18 | 0.18 |
| Zeeland | 0.02 | 0.02 | 0.02 | 0.02 |
| **Total** | **0.55** | **0.51** | **0.49** | **0.49** |

Figure 7 shows the sulphur hexafluoride emissions relative to the added value. The highest relative emissions are found in the port of Amsterdam. The ports of Moerdijk, Groningen and Zeeland have relatively low sulphur hexafluoride emissions. All ports show a decrease in the sulphur hexafluoride intensity, which is in line with the decrease in absolute sulphur hexafluoride emissions.

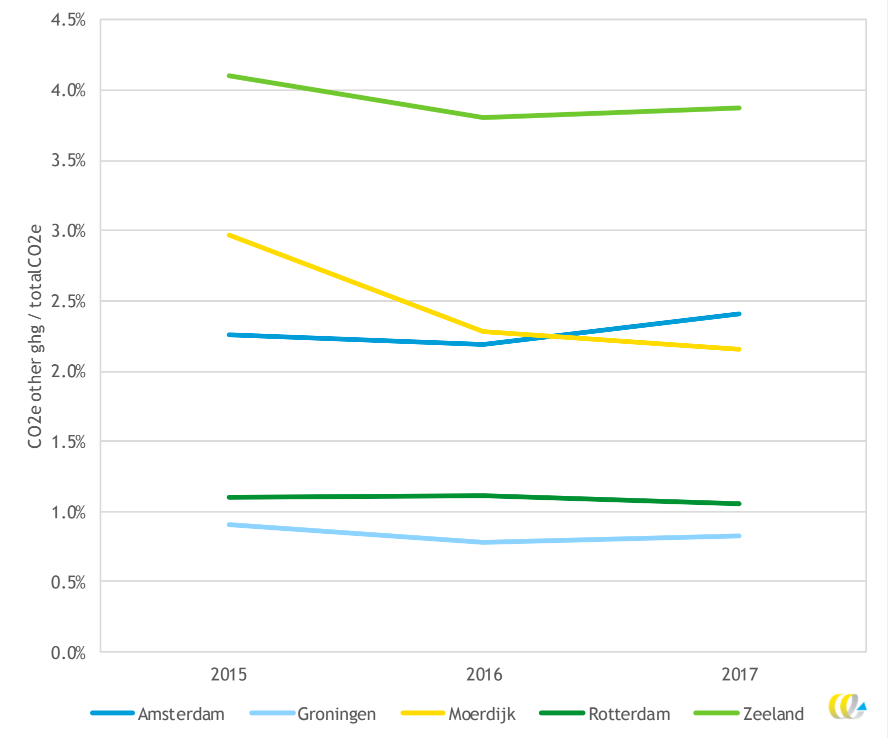
**Figure 7 - Sulphur hexafluoride emissions in port areas the Netherlands relative to added value**



**Text box 3 - Conclusions greenhouse gas emissions**

The contribution from Dutch seaports to $CO_2$ emissions is high, about 40% of total Dutch $CO_2$ emissions are emitted in the five ports. The $CO_2$ emissions in the ports are mostly from large emitters from industry located in the port area. The $CO_2$ emissions in the Dutch port areas have not been reduced between 2010 and 2017.
The increase in emissions can be ascribed to the opening of a coal fired power plant in Groningen. Reduction of $CO_2$ emissions results are foreseen for the years 2018 and beyond due to reduced use of coal for power production. The contribution from ports to the total emissions of methane, nitrous oxide, sulphur hexafluoride does not exceed 10%[8]. The absolute emissions of methane and sulphur hexafluoride show a decreasing trend between 2010 and 2017. The absolute emissions of nitrous oxides have increased in Groningen, Moerdijk and Zeeland. In Groningen and Zeeland the increase of nitrous oxide emissions is offset by higher economic output. Overall the amount of greenhouse gas emissions besides $CO_2$ from port areas is relatively small compared to other sectors like agriculture or transport. The emissions of other greenhouse gasses can be expressed in $CO_2$-equivalents as is shown in Annex B. As can be seen in Figure 8 the contribution of the other greenhouse gasses in terms of climate impact in port areas is small compared to $CO_2$. However, a large challenge remains for ports to conform $CO_2$ emissions to the Dutch and international targets.

**Figure 8 - Contribution of other greenhouse gasses to global warming in port areas**




## 3.2.3 Mitigation measures

Ports can implement various measures to reduce climate emissions. These measures include the use of heat, biomass and carbon capture and utilisation (CCU). The information is based on publicly available data and it is possible that some measures are overseen. The data sources are shown in Appendix A. The estimated annual reduction is shown in Table 15 and includes measures installed up to the year 2018.

8 Port methane emissions are about 3% of Dutch total, nitrous oxide about 7% and sulphur hexafluoride 9%.

### *Heat and steam*

The most common mitigation measure is the use of residual heat. Heat is produced as a by-product for certain production processes. This residual heat can be used by other processes as input, for example to feed a district heating network, as is the case in Rotterdam and Amsterdam. Therefore $CO_2$ emissions are prevented as less fossil fuels are used to maintain the district heating. The residual heat in Moerdijk is produced by a waste incineration plant in the form of steam, the steam is then used by two other companies in Moerdijk. The waste incineration plant can produce up to 6,820 TJ heat. This heat in Moerdijk could also be used to produce electricity making the term residual heat in this case somewhat misleading. In Groningen a waste incinerator produces steam and energy. The residual heat in Amsterdam is produced by a waste incinerators which also produces electricity and biogas. The presented $CO_2$ reduction incorporates benefits from heat, electricity and biogas (AEB, 2018). In Zeeland about 1,800 TJ heat is used to feed greenhouses. This is the equivalent of the $CO_2$ emissions of 7,500 households.

**Text box 4 - Waste incineration**

Incineration of residual waste can produce energy in the form of fuel, electricity or heat. This heat can be used to feed district heating or as energy for industry. Part of the residual waste processed in a waste incinerator is biomass, like paper and food. The carbon emitted when burning this biomass has been absorbed at an earlier stage, making it a renewable and carbon neutral form of production. The energy from this biogenic part of waste is considered renewable energy under Dutch law. About 50% of all incinerated waste in the Netherlands is of biogenic origin. Incineration of waste to produce electricity is thus partly a renewable energy source.
The capacity of waste incinerators has not been included in Chapter 2 as only part of the capacity is used to produce renewable energy. Incinerated residual waste can be used to produce heat or steam as well, as is the case in the port of Moerdijk. In the case of Moerdijk the term residual heat is somewhat misleading as the produced heat can be used to generate electricity with a back-pressure turbine.

### *Biomass*

Biomass is organic material used for energy or as feedstock during industrial processes (as raw material). Sources of biomass include tree clippings, wood shavings, certain crops, manure and certain types of waste residues. Biomass has various uses including incineration to generate heat or power, conversion to biofuels or the production of biogas. Biomass is a carbon neutral solution when used correctly. The carbon in this biomass originates from plants or trees turning atmospheric $CO_2$ into carbon rich biomass. The combustion of biomass therefore doesn’t lead to additional $CO_2$ emissions, since the $CO_2$ emitted during combustion was absorbed earlier. This exemplified by the use of production forest to produce biomass. Production forests are generally managed as a series of stands of different ages, harvested at different times, to produce a constant supply of wood products. If annual harvest in the forest landscape does not exceed the annual growth of the forest there is no net reduction in forest carbon.

**Text box 5 - Sustainability of Biomass**

If used correctly biomass is a sustainable source of energy. However renewable energy production using biomass, especially wood pellets, is in strong debate regarding its sustainability globally and in the Netherlands.
The discussion mainly concerns wood pellets used to replace coal in power plants. These wood pellets are often imported. The increased demand for biomass has made it unclear whether or not, in the future, sufficient amounts of biomass could be produced in a sustainable manner – i.e. without negative impacts on climate, biodiversity and food supply.

The sustainability depends on the origin of the biomass and the way it is harvested, transported and treated. Land use and soil exhaustion are two important factors. A key requirement is that land used for biomass production does not replace existing trees or fields used for food production. Another key requirement is that forests are regenerated and that carbon stock levels and carbon uptake capacity in the forest are at least maintained. In order to properly assess the sustainability of biomass the complete life cycle of the bioenergy system need to be compared with the situation in the absence of bioenergy. Certification of biomass ensures that biomass is produced, used and managed in a sustainable way. For example the Better Biomass certificate has been awarded to a biomass plant in Groningen. Sustainability can also be guaranteed by a study using life cycle analysis as for example a manure incinerator in Moerdijk has done (CE Delft, 2017).

Biomass is currently used in the ports of Moerdijk, Rotterdam, Groningen and Zeeland. In Moerdijk a company uses poultry manure to produce electricity. The $CO_2$ reduction is estimated based on a study of CE Delft (CE Delft, 2017) according to which the $CO_2$ reduction is 300 kg $CO_2$ per ton of manure processed. With an average annual production of 440,000 tons of manure about 127 kton $CO_2$ is reduced each year. The port of Delfzijl hosts a bio-energy plant that produces both electricity and steam. The $CO_2$ reduction of both types is fully included under biomass in Table 15. In Rotterdam two companies use biomass. A power plant is partly running on biomass, and a waste incinerator in Rotterdam uses paper pulp residue and waste wood to produce sustainable energy. Also part of the residual waste is of biogenic origin. The waste incinerator produces energy, steam and heat from biomass and residual waste which in 2014 resulted in 0.38 Mton of avoided $CO_2$ emissions. The results for later years are included in Table 15. In Zeeland biomass is used to produce biogas. The biomass plants in Groningen and Moerdijk have received the better biomass certificate. Also the waste incinerators in Amsterdam and Moerdijk have received a better biomass certificate.

## *CCU and other measures*

The $CO_2$ produced by waste incinerator in Rotterdam is captured, and transported (CCU) to greenhouses in the Westland area. Other companies contribute to the pipeline as well, resulting in a total $CO_2$ emissions reduction of 0.25 Mton[9]. Greenhouses use $CO_2$ to increase the growth of crops. A similar concept is applied in Zeeland. $CO_2$ and heat (1,800 TJ) are by-products of a company producing fertilizers. The $CO_2$ and heat produced are transported to nearby greenhouses which require $CO_2$ and heat for their crops. Due to expansions of contributing companies the $CO_2$ reduction in 2019 is estimated to be around the equivalent 23,500 households (WarmCO2, 2018). Another project in Zeeland is a 12 km long hydrogen pipeline connecting three chemical companies. The hydrogen is a by-product from the production of the first company, enabling the other two companies to use the hydrogen to produce ammonia. The $CO_2$ reduction currently is 0.01 Mton, but there is a potential reduction of 0.04 Mton[10].

[9] Homepage OCAP Nederland

[10] Omroep Zeeland : Dow en Yara zetten handtekening onder waterstofleiding (2018)

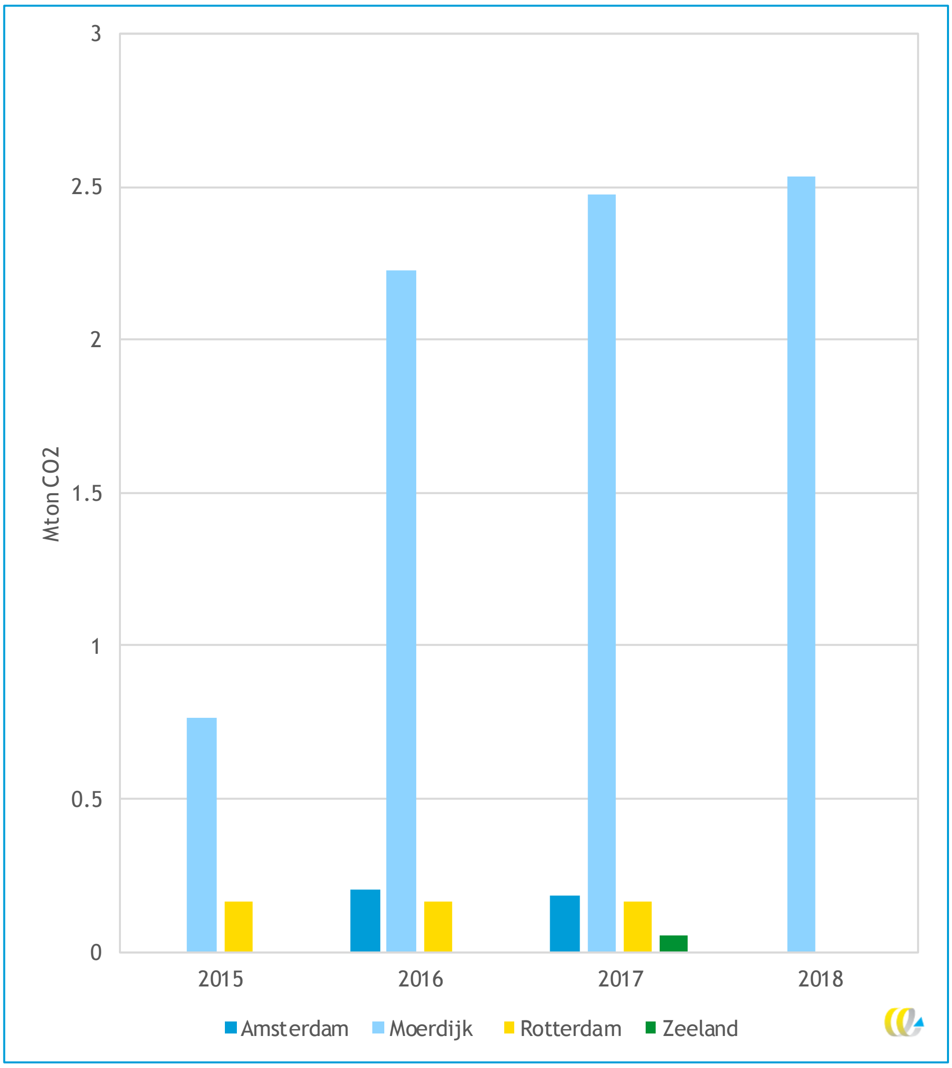
**Table 15 – Most important mitigation measures (cumulative) in Dutch ports**

| Annual Mton $CO_2$ reduction | Amsterdam | Groningen | Moerdijk | Rotterdam | Zeeland |
|---|---|---|---|---|---|
| Biomass | | 0.25** | 0.13** | 0.43* | 0.05* |
| Biomass (certified) | | 0.25** | 0.13** | Unclear | |
| Residual heat | 0.21** | | 2.53* | 0.16** | 0.25* |
| Carbon capture and usage | | | | 0.4*** | Included in the 0.25* |
| Carbon capture and storage | | | | | |
| Steam | | 0.80* | Included in the 2.53* | 0.25** | |
| Hydrogen pipeline | | | | | 0.01** |
| **Estimation 2018** | **0.21** | **1.05** | **2.66** | **1.3** | **0.31** |

$CO_2$ reduction in Moerdijk estimated based on production of heat (Mw) in Moerdijk relative to Mw and $CO_2$ reduction other ports. Data for year: * 2018 ** 2017, *** 2015.

The $CO_2$ reduction of the mitigation measures can differ between years depending on various factors. Figure 9 shows the evolution of $CO_2$ reductions due to the use of heat between 2015 and 2018. The port of Moerdijk is the only port that has consistently reported the amount of heat used between 2015 and 2018. The production of heat has increased significantly due to increased operation hours of the relevant company. Unfortunately other ports have not updated the use of waste heat annually. Amsterdam shows a small decrease between 2016 and 2017, as does Rotterdam between 2015 and 2016.

**Figure 9 – Mton $CO_2$ reduced by heat in Dutch ports between 2015 and 2018**




* Data is based on publicly reported results, results for Amsterdam, Rotterdam and Zeeland for 2018 are unknown.

** Reduction Moerdijk estimated based on MWh.

There is uncertainty about the actual $CO_2$ reduction of the measures. The company in charge of the CCU pipeline in Rotterdam does not report the amount of $CO_2$ transported. Therefore we have to rely on other sources to estimate the $CO_2$ reduction. According to Nieuwe Oogst (2017) and CE Delft (2016b) this can amount to more than 400 kton. However the actual $CO_2$ reductions are not reported on annual basis. The same applies for the steam pipe in Rotterdam[11] which, according to the Port of Rotterdam, saves about 200-400 kton annually (Gemeente Rotterdam, 2014). Annually updated results are however not released regularly. The hydrogen pipeline in Zeeland started in 2018, so results for earlier years are not available.

[11] Port of Rotterdam : Lopende projecten

Table 16 – $CO_2$ reduction (in Mton) due to CCU, steam and hydrogen pipeline in Dutch ports

| Port and measure | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Rotterdam CCU | 0.4 | 0.4 | 0.4 | 0.4 |
| Rotterdam steam | 0.4 | 0.4 | 0.4 | 0.4 |
| Zeeland hydrogen pipeline | | | | 0.01 |

**Text box 6 - Conclusions mitigation measures**

Measures to reduce $CO_2$ emissions have been taken in all five ports. Use of mitigation measures depends on the existing facilities and possibilities, therefore results of a single port can't necessarily be duplicated at other port. The most common measures are the use of residual heat or steam between companies. In all ports systems are in place where heat or steam generated by production processes or energy production is used by a different company. The ports of Rotterdam and Zeeland are involved in carbon capture and usage in collaboration with greenhouses. Carbon capture and storage (CCS) is currently not applied in any port, although is being researched in Rotterdam and Amsterdam (Porthos and Athos). Biomass is used for energy production in Rotterdam, Moerdijk and Groningen. The $CO_2$ reductions from the various measures are in general not reported annually. It often remains unclear what reductions are achieved in other years. Furthermore, due to limited data availability it remains unclear whether the amount of mitigation measures is increasing or not. The total amount of $CO_2$ reduced remains small in comparison with the total $CO_2$ emissions in the port areas. An exception is Moerdijk, where almost 10,000 TJ of heat was re-used in 2017. This results in significant less energy production and therefore reduced $CO_2$ emissions. The term residual heat is somewhat misleading in this case as the energy could have been used to produce electricity as well. Improved data collection and reporting is necessary to show to which extent mitigation measures reduce climate impact.

## 3.3 Renewables

This paragraph discusses the production of renewable energy in ports. First we discuss the results of renewable energy production in the five port areas in 2018. Secondly we have a look at the developments during the previous years. And lastly, we look at the relative comparison between ports.

### 3.3.1 Renewable energy production

Renewable energy is produced in every port area as can be seen in Table 17. All ports are producing solar energy and wind energy, although the quantities differ substantially. Groningen and Moerdijk produce renewable energy based on biomass as well. Other forms of renewable energy production, for example geothermal energy or tidal energy, are not yet applied in ports.

The biomass plant situated in Groningen has a capacity of 139 MW in thermal energy and about 50 MW in electricity. This power plant produces renewable energy via steam and energy. The biomass is waste wood from the so called B category, this includes waste wood from construction, household disposal and local waste dumps among other sources. Special companies process waste wood to wood chips, which is the fuel of the biomass plant. The wood chips arrive in Groningen via trucks and ships. The power plant has received a Better Biomass certificate which ensures that plant operates in a sustainable way[12].

[12] Eneco Bio Golden Raand

The biomass plant in Moerdijk operates on manure, originating from poultry farming all over the Netherlands. The plant can process up to 450,000 tons of manure each year (BMC, 2016), which is about one third of the total poultry manure produced in the Netherlands. This power plant has the largest manure capacity in the world. The ashes that remain after the combustion can be used as fertilizers. According to CE Delft (2017) the energy production of this power plant is the most sustainable use of poultry manure among other forms like fermentation and composting.

The port of Groningen is indeed an energy port, with the highest renewable energy capacity in the Netherlands. Over 426 MW of wind turbines are installed onshore, and over 600 MW was installed offshore in the end of 2018 according to Groningen Seaports (2019). The total energy capacity in the port of Groningen is over 8,000 MW, renewable energy thus has only a small portion of about 12% of total energy capacity. Amsterdam and Moerdijk are ports with the smallest capacity of renewable energy production. Groningen and Zeeland have the highest capacity in solar energy production.

**Table 17 – Renewable energy production capacity (MW) 2018**

| MW capacity 2018 | (Certified) biomass | Solar | Wind |
|---|---|---|---|
| Amsterdam | | 7 | 64 |
| Groningen | 50 | 42 | 426 |
| Moerdijk* | 36 | 9 | 2 |
| Rotterdam | 21 | 7 | 194 |
| Zeeland | | 65 | 163 |

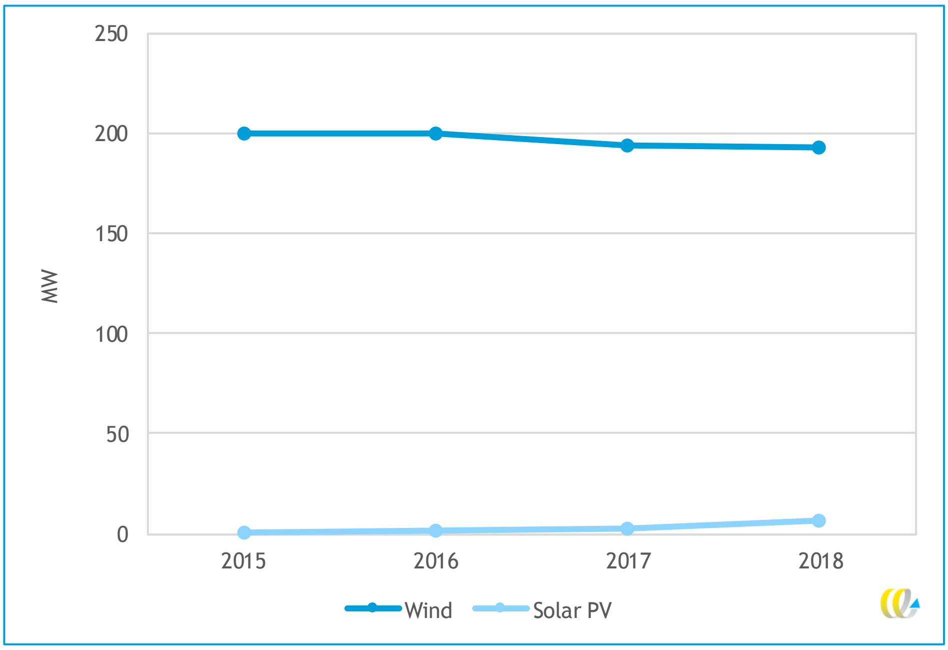
* Results Moerdijk are for 2017.

### 3.3.2 Development over time

Table 17 has shown interesting results about the current situation. It remains however unclear how the renewable energy production capacity in the ports has developed over time. Are the ports accelerating the installation of renewable energy production or has the renewable energy production remained stable over time?

Unfortunately, not many ports have documented the renewable energy capacity in earlier years. The port of Rotterdam is the only port where the development of renewable energy capacity has been documented for recent years. Figure 10 shows the renewable energy capacity in Rotterdam between 2015 and 2018. The wind capacity has remained stable, though there was a decline in 2015. The capacity of solar powered energy production has increased slightly since 2015. Other forms of renewable energy production have not been reported.

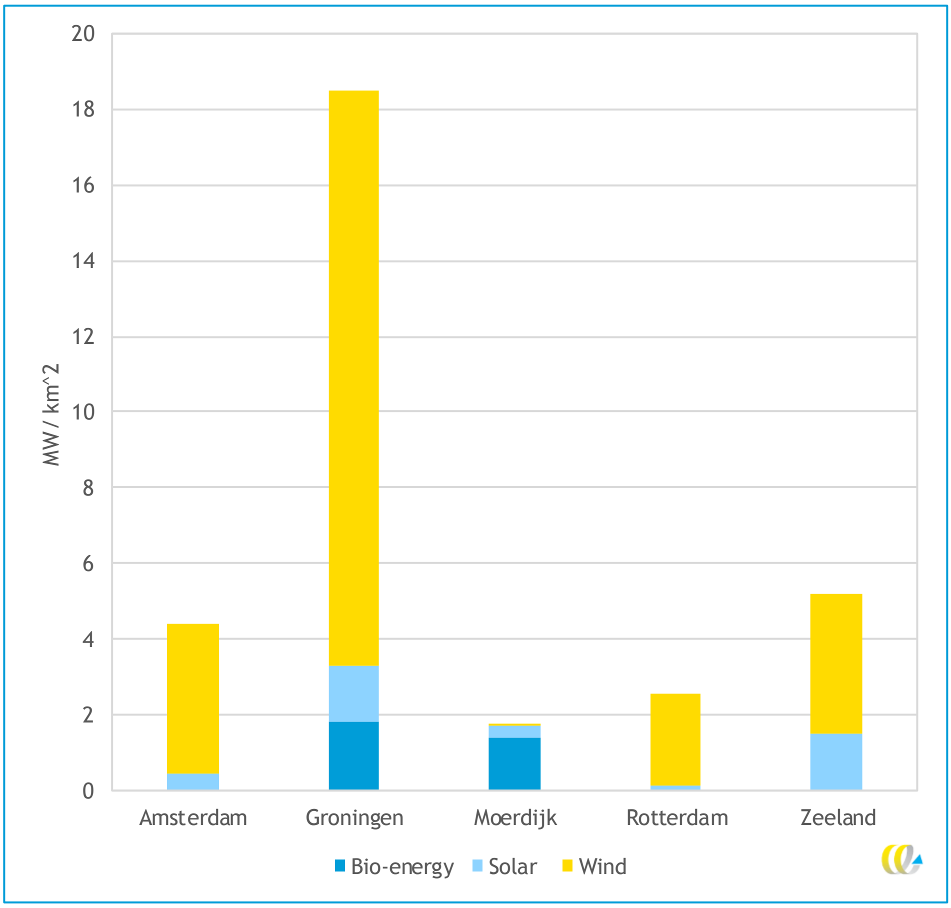
**Figure 10 - Renewable energy production capacity (MW) in port of Rotterdam over time**




### 3.3.3 Relative performance

Groningen is the port with the highest renewable energy production capacity in absolute terms. The port of Groningen is however relatively large and spaciously build. Both Amsterdam and Moerdijk are smaller in size. When we consider the size (in square km) of the ports similar results emerge, as can be seen in Figure 11. The port of Groningen has the highest renewable energy capacity production relative to the size of the port. Moerdijk has the relative lowest renewable energy production capacity, as was the case in absolute terms. Rotterdam has higher renewable energy capacity in absolute terms than Amsterdam and Zeeland. However, in relative terms the port of Rotterdam has less renewable energy capacity than Amsterdam and Zeeland.

**Figure 11 – Renewable energy capacity in latest year available relative to port size (square km)**




**Text box 7 - Conclusions renewables**

All ports are producing some form of renewable energy. Wind and solar energy production are the most popular forms used by all ports. The capacity of wind energy is the largest source of renewable energy capacity in most ports. Bio-energy production takes place in Groningen, Moerdijk and Rotterdam. The exact capacity is however unknown in Rotterdam. Historical information about the renewable energy capacity is not available for many ports. Only the Port of Rotterdam presents data for time period longer than two or three years. Renewable energy production capacity in Rotterdam has remained more or less stable between 2015 and 2018. It is unclear whether the renewable energy capacity in other ports is increasing. This could be important in order to prepare for a carbon neutral future. Groningen is the port with the highest capacity of renewable energy production, both in absolute and relative terms. This is in accordance to their focus area of energy production. A future benchmark could include the output of renewable electricity, in MWh, as well. This would show what amount of electricity is generated with the capacity installed.

## 3.4 Air quality

This paragraph discusses the emissions that influence the air quality in ports, the concentrations of air quality pollutants and the most important measures that improve the air quality. First the emissions and concentrations of particulate matter are discussed. The second substance is nitrogen oxides followed by a selection of other substances including ammonia, benzopyrene, sulphur dioxide and carbon monoxide. This paragraph ends with a discussion of the most important measures that are applied in the Dutch ports that improve the air quality.

### 3.4.1 Particulate matter

Particulate matter (PM) is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope. Primary particulate matter arises due to combustion, friction or evaporation. Secondary particulate matter arises as a result of complex reactions of chemicals such as sulphur dioxide and nitrogen oxides.

Particulate matter is emitted by natural and human sources. Natural sources include friction by the wind or evaporation of seawater. Human sources include transport emissions, transport wear and tear (such as rubber tyres), industry emissions, livestock farms and open fires like barbecues. Human sources are responsible for the largest share of particulate matter emissions, about 75% (Milieu Centraal, -). The most important sources of particulate matter in the Netherlands are road traffic, industry and agriculture according to Emissieregistratie. In the Rotterdam area the most important source is the industry contributing with almost 40% of $PM_{10}$ according to DMCR (DCMR, 2019). Road traffic and marine traffic each contribute 10%.

Two types of particulate matter that generally are measured are $PM_{10}$ and $PM_{2,5}$. $PM_{10}$ are inhalable particles, with diameters that are 10 micrometres and smaller. $PM_{2,5}$ are fine inhalable particles, with diameters that are 2.5 micrometres and smaller. Both types of particulate matter can't be seen with the naked eye. Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometres in diameter can get deep into your lungs and some may even get into the bloodstream. Of these, particles less than 2.5 micrometres in diameter pose greater risk to health. Particles less than 0.5 micrometres pose even greater health risks but these particles are difficult to measure. Particulate matter in the form of soot also affects visibility (smog), dirties buildings and pollutes nature.

Table 18 and Table 19 show the $PM_{2,5}$ and $PM_{10}$ emissions in the Dutch Ports. In general the emissions of particulate matter in port areas have decreased since 2010. The port of Groningen is the only port without a reduction in particulate matter emissions. Absolute $PM_{2,5}$ and $PM_{10}$ emission have increased in Zeeland since 2015. Rotterdam is still the port with the most particulate matter emissions, but the port of Zeeland is a close second. The port of Groningen and Moerdijk have the lowest emissions of particulate matter in absolute terms. The ports areas are responsible for about 10% of all Dutch $PM_{10}$ emissions, which were almost 30 Kton in 2017 (CBS).

**Table 18 – $PM_{2,5}$ emissions in port areas the Netherlands**

| Kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.39 | 0.39 | 0.35 | 0.30 |
| Groningen | 0.12 | 0.12 | 0.11 | 0.13 |
| Moerdijk | 0.21 | 0.08 | 0.10 | 0.10 |
| Rotterdam | 1.11 | 0.94 | 0.75 | 0.76 |
| Zeeland | 0.87 | 0.62 | 0.67 | 0.78 |
| **Total** | **2.69** | **2.16** | **1.98** | **2.07** |

**Table 19 – $PM_{10}$ emissions in port areas the Netherlands**

| Kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | n/a | 0.50 | 0.46 | 0.41 |
| Groningen | n/a | 0.15 | 0.14 | 0.17 |
| Moerdijk | n/a | 0.07 | 0.09 | 0.09 |
| Rotterdam | n/a | 1.35 | 1.25 | 1.24 |
| Zeeland | n/a | 0.76 | 0.88 | 1.00 |
| **Total** | **n/a** | **2.84** | **2.82** | **2.91** |

The most important sources of emissions in port areas are shown in Table 20 and Table 21. The largest source is the chemical sector, mostly in the port Zeeland. As can be seen in Annex C.2 0.6 kton of $PM_{2,5}$ is emitted by the chemical industry in Zeeland. Trade, services and government is a significant source of $PM_{10}$ emissions in Amsterdam (0.21 kton) and Rotterdam (0.49 kton)

**Table 20 – $PM_{2.5}$ emissions in port areas the Netherlands by sector**

| Kton $PM_{2.5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Chemical industry | 0.70 | 0.53 | 0.60 | 0.71 |
| Mobility and transport | 0.93 | 0.71 | 0.59 | 0.57 |
| Other industry | 0.44 | 0.25 | 0.19 | 0.25 |
| Other | 0.62 | 0.54 | 0.49 | 0.46 |
| **Total** | **2.69** | **2.16** | **1.98** | **2.07** |

**Table 21 – $PM_{10}$ emissions in port areas the Netherlands by sector**

| Kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Chemical industry | n/a | 0.72 | 0.84 | 0.93 |
| Mobility and transport | n/a | 0.44 | 0.35 | 0.35 |
| Other industry | n/a | 0.33 | 0.36 | 0.43 |
| Trade, services and government | n/a | 0.80 | 0.77 | 0.75 |
| Other | n/a | 0.54 | 0.49 | 0.46 |
| **Total** | **n/a** | **2.84** | **2.82** | **2.91** |

The results in relative terms show a different story as can be seen in Figure 12 and Figure 13. The highest PM emissions relative to added value can be found in Zeeland and Amsterdam. Two ports which facilitate production that emit relatively high amounts of particulate matter; Zeeland hosts a large industry complex while Amsterdam tranships large quantities of bulk goods. Especially coal transhipment can result in emissions of particulate matter[13]. The emissions in Zeeland are mostly the result of a single company producing fertilizers, according to Emissieregistratie about 50% of $PM_{2,5}$ and $PM_{10}$ emissions are the result of this company. The port of Zeeland has started to emit relatively more particulate matter since 2015, while the port of Amsterdam shows a reduction of relative emissions of particulate matter.

[13] Port of Amsterdam : 'Economische groei is fijn, maar niet voor de luchtkwaliteit' (2018)

**Figure 12 – $PM_{2,5}$ emissions in port areas the Netherlands relative to added value**

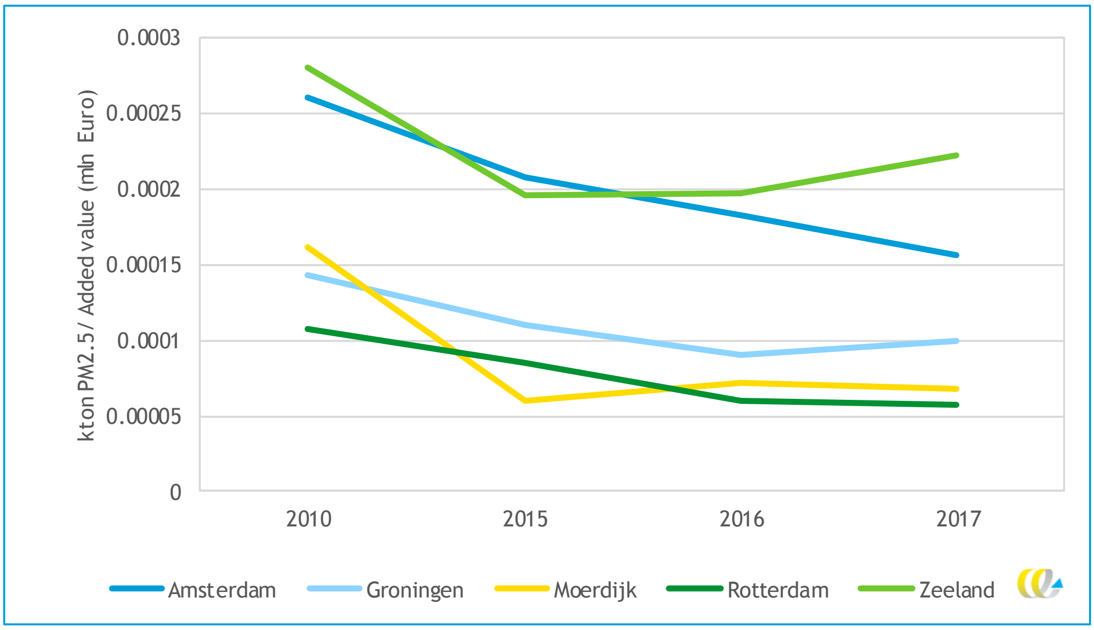
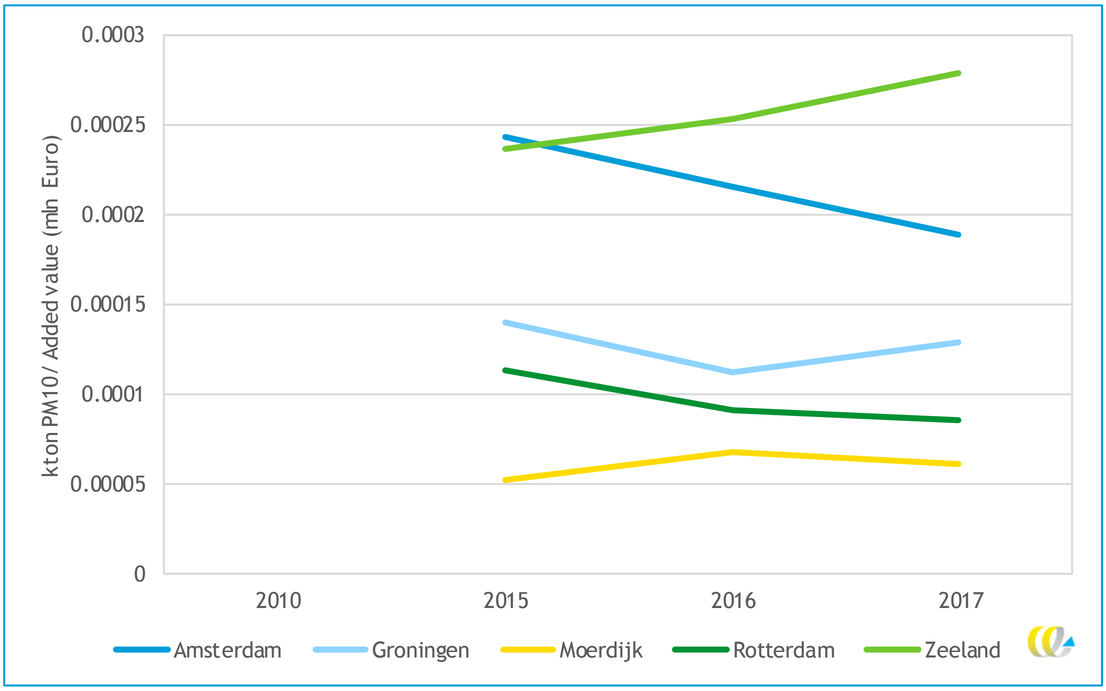



**Figure 13 – $PM_{10}$ emissions in port areas the Netherlands relative to added value**




The concentrations in the port areas show a reduction since 2010 as well, as can be seen in Figure 14 and Figure 15. The reduction in these ports follow a similar trend which seems to be related to economic growth. The concentration is the lowest in Groningen, which is a port in a sparsely populated area with relatively little particulate matter emissions itself. Concentrations are highest in Amsterdam, Moerdijk and Rotterdam. This could partly be due to higher emissions in the port area. However, particulate matter can also be blown over from other sources. This is not unlikely as the ports of Amsterdam, Moerdijk and Rotterdam are situated in densely populated areas. The concentration of particulate matter is relatively low in Zeeland although the emissions of particulate matter is high. This could be explained by less particulate matter blowing over from the surroundings of the port. The low concentration could also be due to the relatively large size of the port of Zeeland, resulting in lower average concentrations.

**Figure 14 - Average $PM_{2,5}$ concentration in port areas the Netherlands**

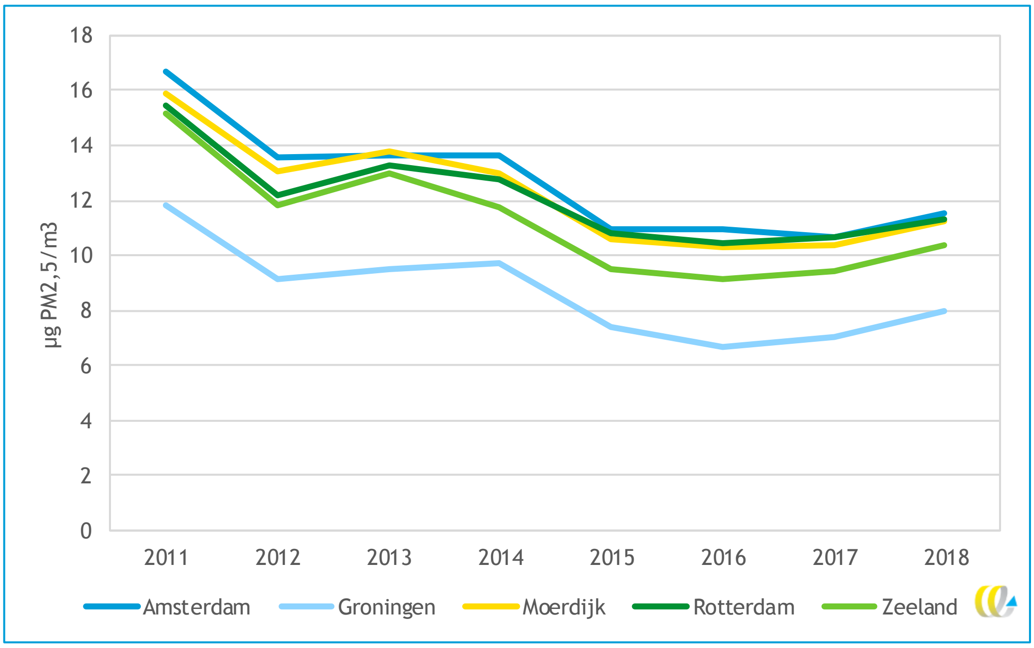
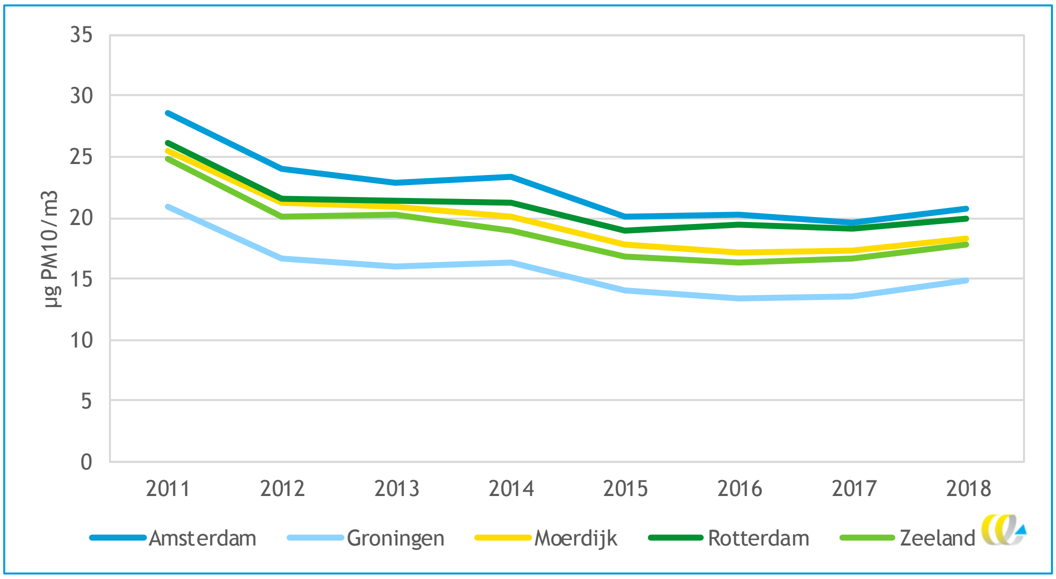



**Figure 15 - Average $PM_{10}$ concentration in port areas the Netherlands**






natuur en milieu federatie zuid-holland

**Text box 8 - Conclusions particulate matter**

| |
|---|
| Ports contribute to about 10% of the total particulate emissions in the Netherlands. The emissions of particulate matter have reduced in absolute terms between 2010 and 2015. Emissions relative to added value have decreased in most ports since 2010, although some ports show increases in the most recent years. The emissions of particulate matter in port areas have not shown major changes between 2015 and 2017. The yearly average particulate matter concentrations have reduced since 2010 as well. Other factors influence the concentrations of particulate matter as well. Particulate matter emission reductions in the port of Amsterdam and Rotterdam between 2015 and 2017 do not necessarily result in lower air concentrations. |

### 3.4.2 Nitrogen oxides

During combustion at high temperatures nitrogen in the air combines with oxygen atoms to create nitric oxide (NO). Nitric oxide itself is relatively harmless in typical ambient concentrations. However, nitric oxide further combines with oxygen ($O_2$) and ozone ($O_3$) to create nitrogen dioxide ($NO_2$). Nitrogen dioxide is harmful for human health. Nitrogen dioxide is an irritant gas, which at high concentrations causes inflammation of the airways. Long term exposure can decrease lung function, increase the risk of respiratory conditions and increases the response to allergens. $NO_x$ also contributes to the formation of fine particulate matter (PM) and ground level ozone, both of which are associated with adverse health effects. $NO_x$ has an ecological effect as well, as the gases react to form acid rain which leads to acidification and damage of buildings.

$NO_x$ emissions arise whenever combustion occurs in the presence of nitrogen, such as in car engines or produced naturally by lightning. The highest contributing sources in the Netherlands are transport, agriculture and industry. According to Emissieregistratie transport contributed 228 kton, agriculture 41 kton and energy production 17 kton in the Netherlands in 2017. DCMR reports the $NO_x$ emissions in the Rotterdam area. The main sources in 2017 are industry (almost 40%), maritime traffic (32%) and road traffic (12%) (DCMR, 2019). The five ports combined contributed almost 35 kton in 2017. Rotterdam, which is also the largest port, is the port with the highest emissions in 2017. It is followed by Zeeland and Groningen. Moerdijk had the lowest emissions in 2017, although $NO_x$ emissions have increased since 2015 due to higher production levels. $NO_x$ emissions have decreased in Amsterdam and Rotterdam since 2015.

**Table 22 – $NO_x$ emissions in port areas the Netherlands**

| kton $NO_x$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | n/a | 4.07 | 3.50 | 3.06 |
| Groningen | n/a | 3.98 | 4.22 | 4.15 |
| Moerdijk | n/a | 1.81 | 2.66 | 2.84 |
| Rotterdam | n/a | 21.62 | 19.82 | 19.43 |
| Zeeland | n/a | 5.26 | 5.87 | 5.42 |
| **Total** | **n/a** | **36.73** | **36.06** | **34.90** |

* 2010 nitric oxide emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to nitric oxide emissions is large. From 2015 onwards data is available on 1x1 km squares. 2010 results are not comparable to 2015 onwards are therefore not included.

The main sources of $NO_x$ emissions are shown in Table 23. Mobility and transport emissions are the largest source, followed by emissions of the energy sector and chemical industry. Maritime vessels emit a lot of $NO_x$ and as a result the emissions of mobility and transport are especially large in the port of Rotterdam as can be seen in Annex C.2. In Rotterdam also significant emissions are the result of energy production (4 kton) and refineries (4.4 kton). Emissions of the sectors transport and refineries have decreased slightly between 2015 and 2017.

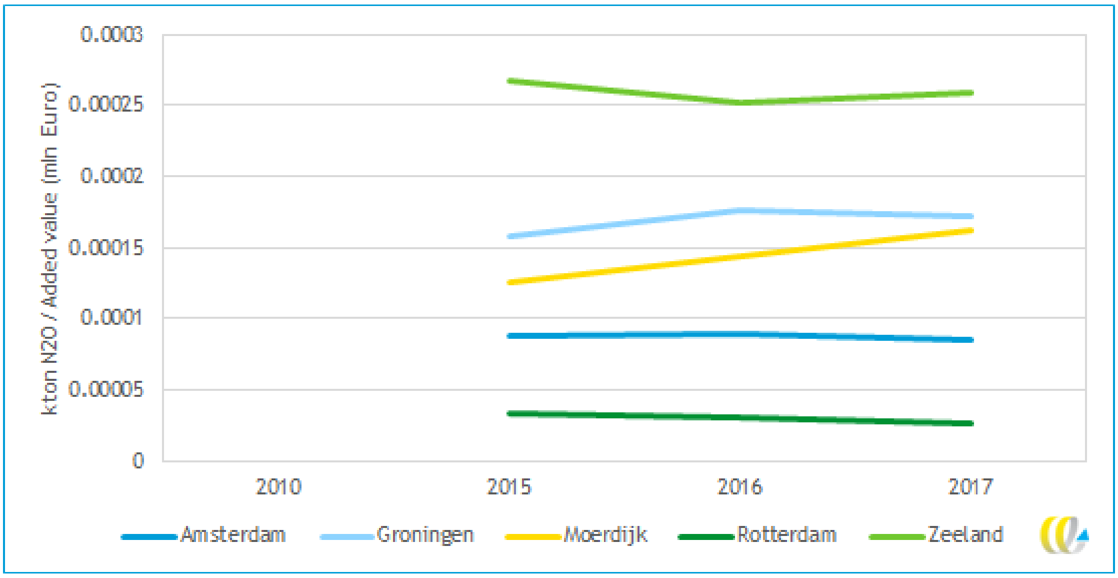
**Table 23 - $NO_x$ emissions in port areas the Netherlands by sector**

| kton $NO_x$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Chemical industry | n/a | 5.1 | 5.7 | 5.4 |
| Energy sector | n/a | 9.1 | 10.0 | 9.2 |
| Mobility and transport | n/a | 13.7 | 11.8 | 11.9 |
| Refineries | n/a | 5.2 | 5.0 | 4.8 |
| Waste disposal | n/a | 2.1 | 2.1 | 2.1 |
| Other sectors | n/a | 3.63 | 3.49 | 3.65 |
| **Total** | **n/a** | **36.73** | **36.06** | **34.90** |

* 2010 nitric oxide emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to nitric oxide emissions is large. From 2015 onwards data is available on 1x1 km squares. 2010 results are not comparable to 2015 onwards are therefore not included.

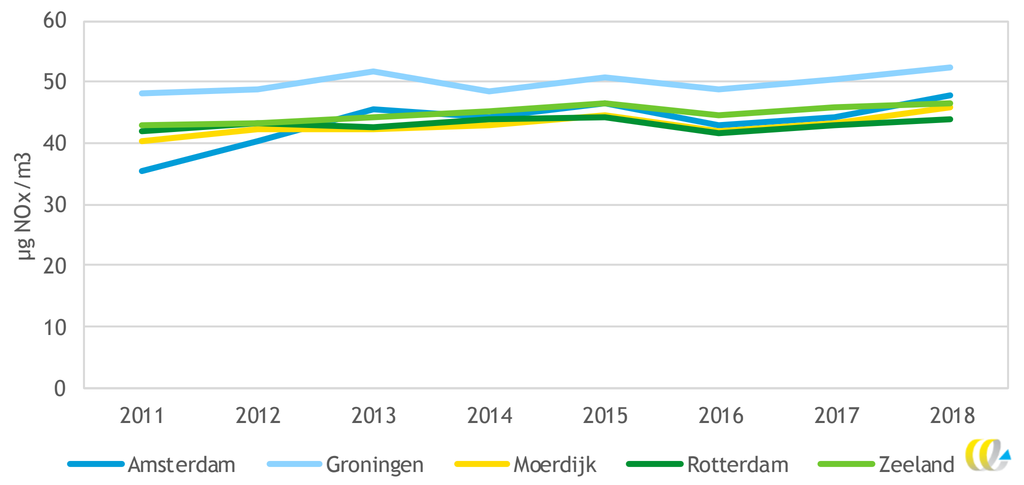
The relative $NO_x$ emissions are highest in Groningen as can be seen in Figure 16. The other ports are comparable in $NO_x$ intensity. Moerdijk is the only port where the $NO_x$ intensity is increasing, according to the Port of Moerdijk (2017) additional emissions are due to higher production levels at several companies. Apparently the higher production levels do not result in sufficient income growth to offset the growth in $NO_x$ emissions.

**Figure 16 - $NO_x$ emissions in port areas the Netherlands relative to added value**



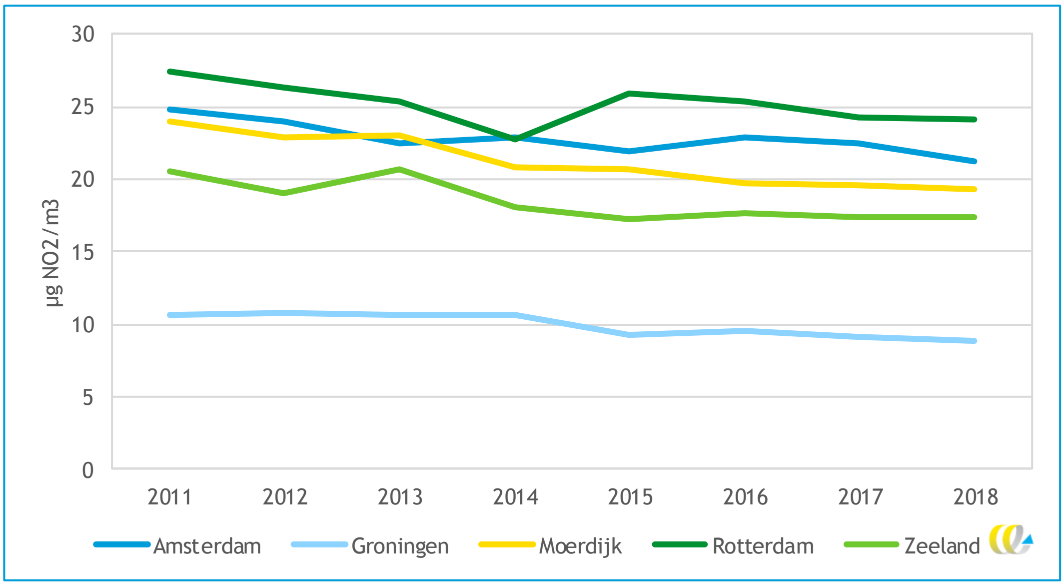

RIVM publishes concentration maps for both $NO_x$ and $NO_2$. The average concentration in port areas of $NO_x$ is shown in Figure 17. The average concentration is highest in Groningen, while the other ports have comparable levels. The $NO_x$ concentrations follow a similar trend in the various port. Between 2011 and 2018 $NO_x$ concentrations have increased slightly in all five ports.

**Figure 17 – Year average $NO_x$ concentration in port areas the Netherlands**



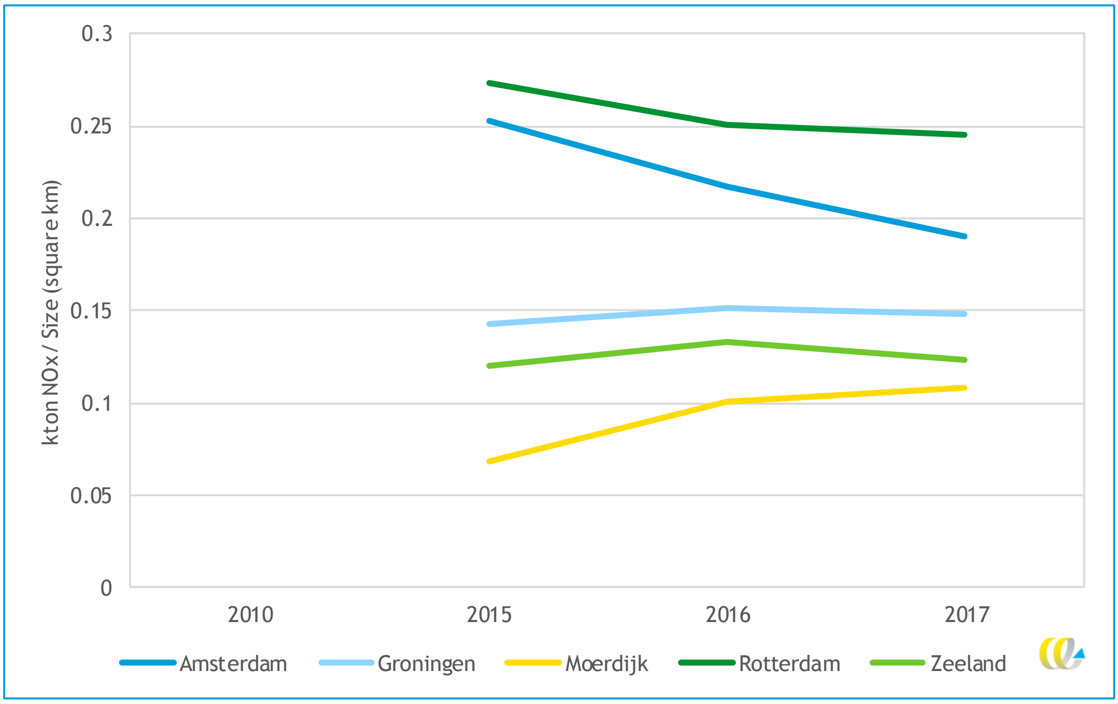

The average $NO_2$ concentrations in ports is shown in Figure 18. The results vary significantly from $NO_x$ concentration. Unlike $NO_x$ concentration the average concentration of $NO_2$ in port areas has decreased between 2011 and 2018. Furthermore Groningen has the highest $NO_x$ concentration while at the same time the lowest $NO_2$ concentration. The $NO_2$ concentrations are modelled based on $NO_x$ concentration and $NO_2/NO_x$ measurements at various locations throughout the Netherlands. According to RIVM (RIVM, 2017) reductions in $NO_2$ concentrations are mostly due to lower direct emissions due to traffic. The reductions in absolute emissions result in lower $NO_2$ concentrations while $NO_x$ concentrations do not seem to be affected. The port with the highest concentrations are Rotterdam and Amsterdam, while Groningen has the lowest concentration.

**Figure 18 - Year average $NO_2$ concentration in port areas the Netherlands**




The low concentration could partly be explained by differences in land use. Figure 19 shows that Rotterdam and Amsterdam have the highest $NO_x$ emissions per square km. The port of Groningen however does not have the lowest $NO_x$ emissions. The port of Groningen is however situated in a relatively rural area in the Netherlands. It is likely that the concentration of $NO_2$ is lower as less $NO_2$ is emitted in surrounding areas. Amsterdam, Rotterdam and Moerdijk are situated in areas with higher populations and more traffic. The port of Zeeland is situated near Ghent and Antwerp.

**Figure 19 - $NO_x$ emissions in port areas the Netherlands relative to size (square kilometre)**



**Text box 9 - Conclusions nitrogen oxides**

| |
|---|
| The five seaports emit about 15% of total $NO_x$ emissions in the Netherlands. Absolute $NO_x$ emissions in port areas have reduced between 2015 and 2017. This is the result of $NO_x$ reductions in Amsterdam and Rotterdam. Absolute $NO_x$ emissions in the ports of Groningen, Moerdijk and Zeeland increased between 2015 and 2017. However, emissions relative to added value have decreased in all ports since 2015 except for the port of Moerdijk. The concentrations of $NO_x$ has increased 2016 and 2017 in all ports, although $NO_x$ emissions reduced in the port areas of Amsterdam and Rotterdam. This indicates that sources outside the port area influence the $NO_x$ concentration in the port area as well. |

### 3.4.3 Other substances

#### *Ammonia*

Ammonia ($NH_3$) emissions in the Netherlands have been greatly reduced since 1990.
The level in 2016 was 127 kiloton which is a reduction of 64% since 1990. Ammonia in the Netherlands is largely emitted by agriculture activities, about 86% is due to agriculture according to Emissieregistratie. Other sources of emissions are non-commercial agricultural activities, transport, households and industry. Ammonia can be harmful to human health in high concentrations. An abundance of ammonia also damages the environment. It is an important contributor to acidification and ammonia leads to eutrophication[14] due to manure pollution. Vegetation that grows well on nitrogen-rich grounds, for example grass and nettles, will become dominant. This leads to a disturbance of ecosystems.

Table 24 shows the ammonia emissions in the Dutch ports. The emissions of ammonia have been greatly reduced since 2010 in all ports. The highest ammonia emissions can be found in Zeeland. This is mostly due to a company which produces fertilizers. In 2017 it emitted about 0.50 kton of ammonia. The spike in 2016 for Zeeland is due to increased production of the same company, resulting in emission of 0.65 kton according to Emissieregistratie. The chemical industry is responsible for about 60% of all ammonia emissions in port areas. Other sectors are agriculture, waste disposal, and mobility and transport as can be seen in Annex C.2. The emissions in the other ports are considerably less, the five ports areas combined contribute less than 1% to all Dutch ammonia emissions.

**Table 24 – Ammonia ($NH_3$) emissions in port areas the Netherlands**

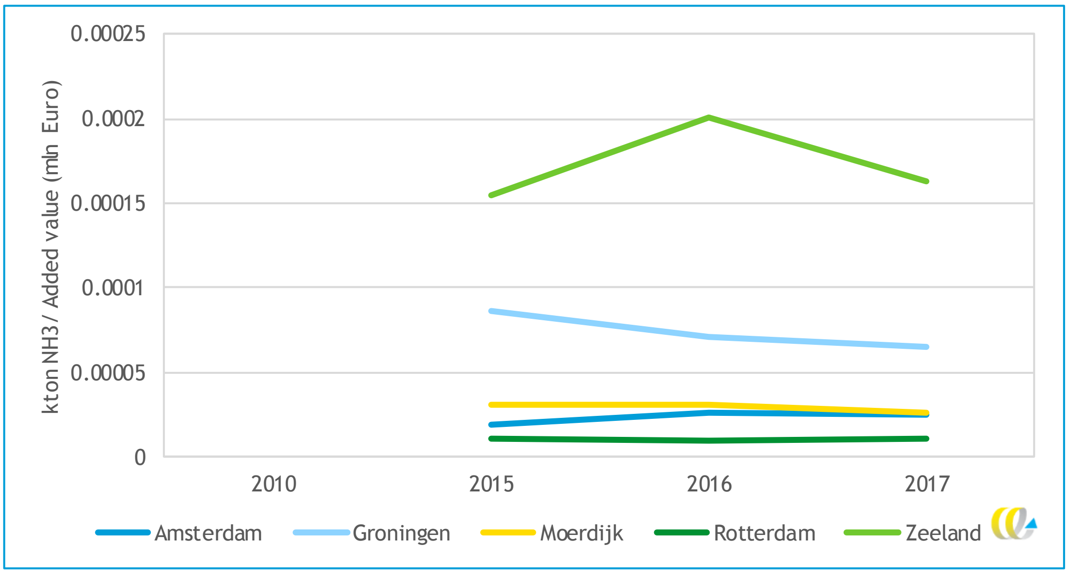
| Kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | n/a | 0.04 | 0.05 | 0.05 |
| Groningen | n/a | 0.09 | 0.09 | 0.09 |
| Moerdijk | n/a | 0.04 | 0.04 | 0.04 |
| Rotterdam | n/a | 0.13 | 0.13 | 0.15 |
| Zeeland | n/a | 0.50 | 0.70 | 0.59 |
| **Total** | **n/a** | 0.80 | 1.02 | 0.91 |

* 2010 ammonia emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to ammonia emissions is large. From 2015 onwards data is available on 1x1 km squares. 2010 results are not comparable to 2015 onwards are therefore not included.

[14] Eutrophication is when a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of algae.

The ammonia emissions relative to added value are shown in Figure 20. Ammonia emissions are relatively highest in the port of Zeeland as well. The increase in ammonia emissions in 2016 is not accompanied by a similar increase in added value. This results in an increase in 2016. The other ports have considerably less ammonia intensive industries, resulting in lower values. The increase of absolute ammonia emissions in Rotterdam in 2017 does not result in an increase of relative ammonia emissions; apparently the added value has increased to a similar extent.

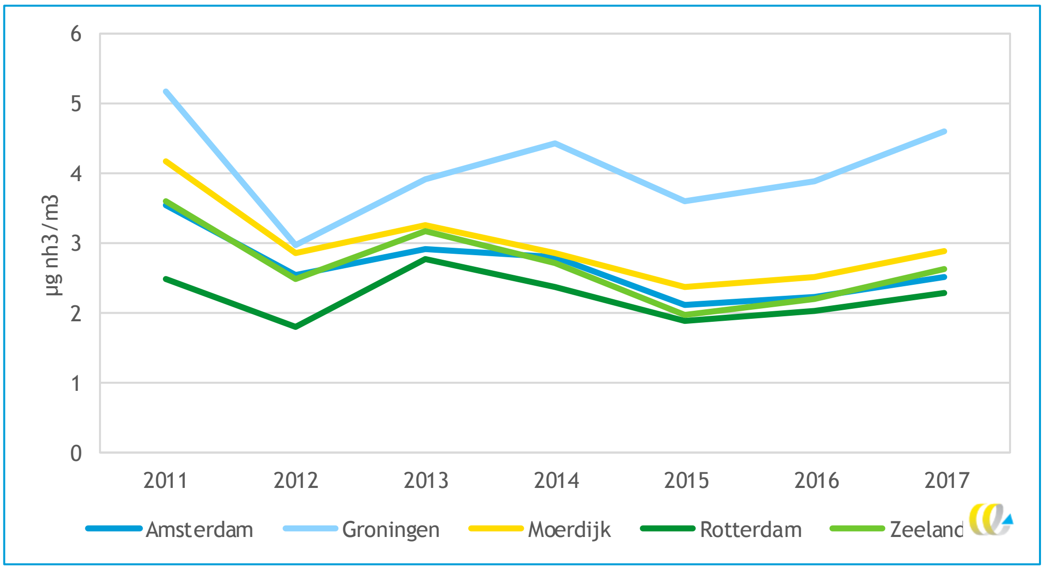
**Figure 20 – Ammonia ($NH_3$) emissions in port area relative to added value**




* 2010 ammonia emissions are only available for 5x5 km squares. This results in a large overestimation of port emissions as the contribution of sources outside port areas to ammonia emissions is large. From 2015 onwards data is available on 1x1 km squares. 2010 results are not comparable to 2015 onwards are therefore not included.

The average ammonia concentration in the port areas are shown in Figure 21. The concentration of ammonia is not directly related to the emissions of ammonia in port areas. The highest emissions (also relative to size) can be found in the port of Zeeland. However, ammonia concentrations are higher in the ports of Groningen and Moerdijk. Apparently sources outside the port area are mainly responsible for the ammonia concentration in ports.

**Figure 21 - Year average Ammonia ($NH_3$) concentrations in port areas the Netherlands**




* 2018 no data available.

## *Benzopyrene*

Benzopyrene ($C_{20}H_{12}$) is the best known polycyclic aromatic hydrocarbon (PAHs), a group of hydrocarbons that are composed of multiple aromatic rings. Emissions are formed by the incomplete combustion or heating of organic material. Sources include exhaust gasses of cars or chimney exhausts. The concentration of PAHs is higher in densely populated areas and during the winter. PAHs can be taken in via food, air or through skin. PAHs is one of the most important causes of cancer. In high concentrations it can also damage skin as well as the eyes and the mucosa. Emissions of PAHs are often measured in benzopyrene emissions, as it is the most occurring version of PAHs. The most important sources of PAHs are households, house fires and bonfires, the contribution of industry is limited.

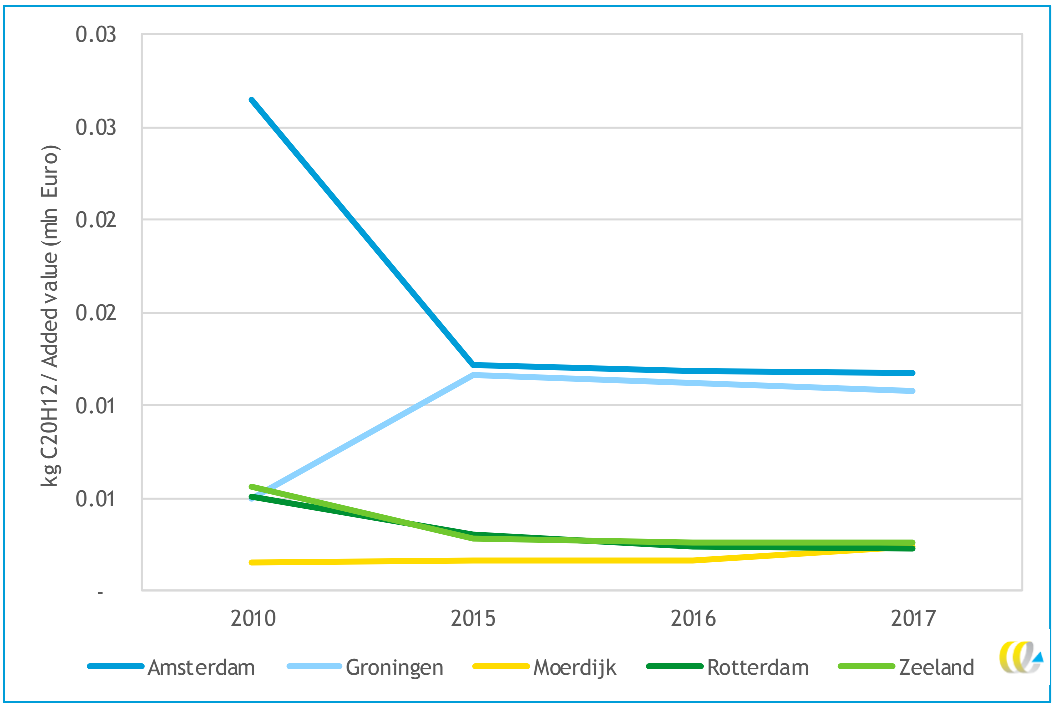
Table 25 shows the benzopyrene emissions in the Dutch ports. The highest emissions can be found in Amsterdam and Rotterdam. Moerdijk and Zeeland have the lowest emissions of benzopyrene. The emissions have reduced in most ports since 2010. Only in Groningen emissions have increased due to higher emissions by consumers as can be seen in Annex C.2. Other sectors that contribute are other industry and mobility and transport. The contribution of ports to PAH emissions is relatively small. In 2017 around 1.975 tons where emitted in the Netherlands. Port areas only contributed 0.085 tons in 2017.

**Table 25 - $C_{20}H_{12}$ emissions in port areas the Netherlands**

| Ton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.044 | 0.025 | 0.025 | 0.025 |
| Groningen | 0.004 | 0.013 | 0.014 | 0.014 |
| Moerdijk | 0.002 | 0.002 | 0.002 | 0.004 |
| Rotterdam | 0.057 | 0.036 | 0.033 | 0.033 |
| Zeeland | 0.018 | 0.009 | 0.009 | 0.009 |
| **Total** | **0.125** | **0.085** | **0.083** | **0.085** |

The benzopyrene emissions relative to added value are shown in Figure 22. Benzopyrene emissions are relatively highest in Groningen, while emissions are lowest in Rotterdam. The high benzopyrene emissions in Groningen can be related to the energy production, which leads to benzopyrene emissions while not producing a lot of added value. The other ports have reduced relative benzopyrene emissions between 2010 and 2015. Between 2015 and 2017 the relative emissions have remained stable.

**Figure 22 - $C_{20}H_{12}$ emissions in port areas the Netherlands relative to added value**




No air concentration data for benzopyrene is available in the Netherlands.

## *Sulphur dioxide*

Sulphur oxides are emitted during the combustion of fossil fuels like crude oil and coals. Sulphur dioxide is a colourless gas that damages human health. It can lead to irritations of airways and hamper respiratory functions of patients with COPD.

Sulphur emissions due to road traffic have reduced significantly as fuel used for road transport contain lower amounts of sulphur. Maritime shipping however still uses fuel with relatively higher sulphur contents. The International Maritime Organisation has recently introduced limitation to the amount of sulphur maritime fuel can contain[15]. In 2017 around 31,710 kton sulphur dioxide have been emitted in the Netherlands according to Emissieregistratie. The majority (11 kton) is due to refineries, other industry (7.6 kton) and energy sector (1.7 kton). Transport is 5.6 Mton, of which 4.15 maritime transport. All of these sectors are generally located in port areas and as a result over 50% of all sulphur dioxide emissions in the Netherlands are emitted in port areas (17.32 kton). Rotterdam is the port with the highest emissions while Amsterdam has the lowest emissions. Most ports show a decline in sulphur dioxide emissions. The port of Groningen is the only port where

[15] IMO: Sulphur oxides ($SO_x$) and Particulate Matter (PM) – Regulation 14

emissions in 2017 where higher than in 2010. This is a result of higher emissions by the energy sector as can be seen in Annex C.2.

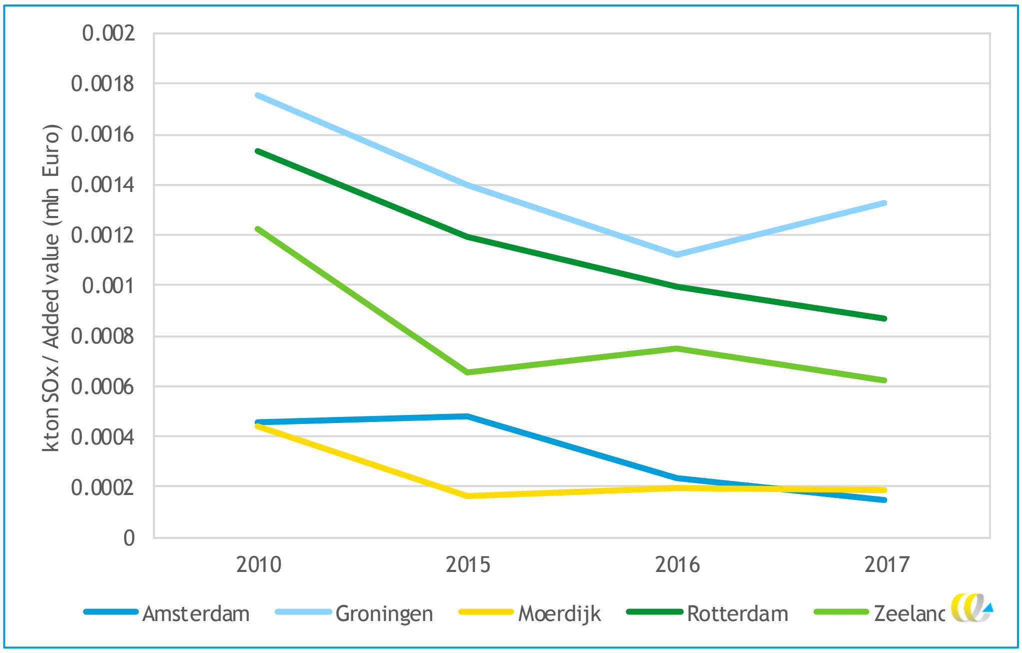
**Table 26 - Sulphur dioxide emissions in port areas the Netherlands**

| Kton $SO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.75 | 0.99 | 0.50 | 0.31 |
| Groningen | 1.43 | 1.52 | 1.39 | 1.76 |
| Moerdijk | 0.56 | 0.22 | 0.27 | 0.27 |
| Rotterdam | 17.09 | 14.27 | 13.67 | 12.73 |
| Zeeland | 3.82 | 2.13 | 2.61 | 2.25 |
| **Total** | **23.65** | **19.12** | **18.43** | **17.32** |

* 2010 sulphur dioxide emissions are only available for 5x5 km squares. This results in an overestimation of port emissions as the contribution of sources outside port areas to sulphur dioxide emissions are included as well. From 2015 onwards data is available on 1x1 km squares offering more precise results.

Sulphur emissions relative to added value are shown in Figure 23. Groningen and Rotterdam are the ports with the highest sulphur emissions relative to the added value it produces. All the ports do show a reduction since 2010. Only Groningen has a significant increase in 2017. Amsterdam and Moerdijk have the lowest emissions of sulphur dioxides relative to the added value.

**Figure 23 - Sulphur dioxide emissions in port areas the Netherlands relative to added value**



The concentration of sulphur dioxides shows a different picture than the emission figures as can be seen in Figure 24. The port of Groningen has the lowest sulphur dioxide concentrations of all five ports, unlike relative emissions. This could be the result of the relative size of the port, if sulphur dioxide emissions are concentrated in certain areas other parts of the ports will have lower concentrations, leading to lower average concentrations. Figure 25 shows that this is possibly the case. When sulphur dioxide emissions are related to the size of the port Groningen scores better. However, there are still ports that have relatively less sulphur dioxide emissions. The low sulphur dioxide concentrations in Groningen are therefore a result of less sulphur dioxide blowing over from surrounding regions.

**Figure 24 – Year average sulphur dioxide concentrations in port areas the Netherlands**

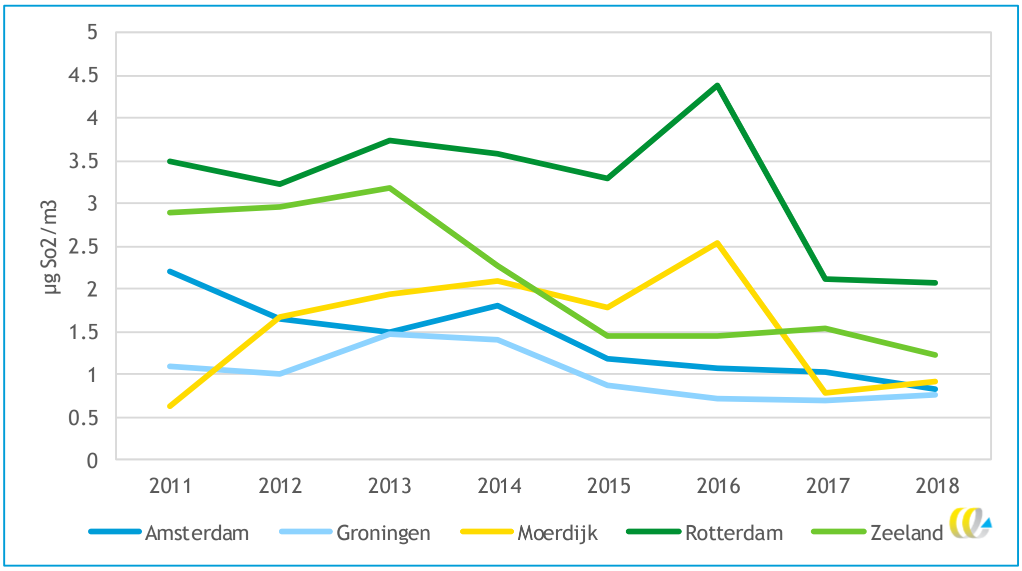
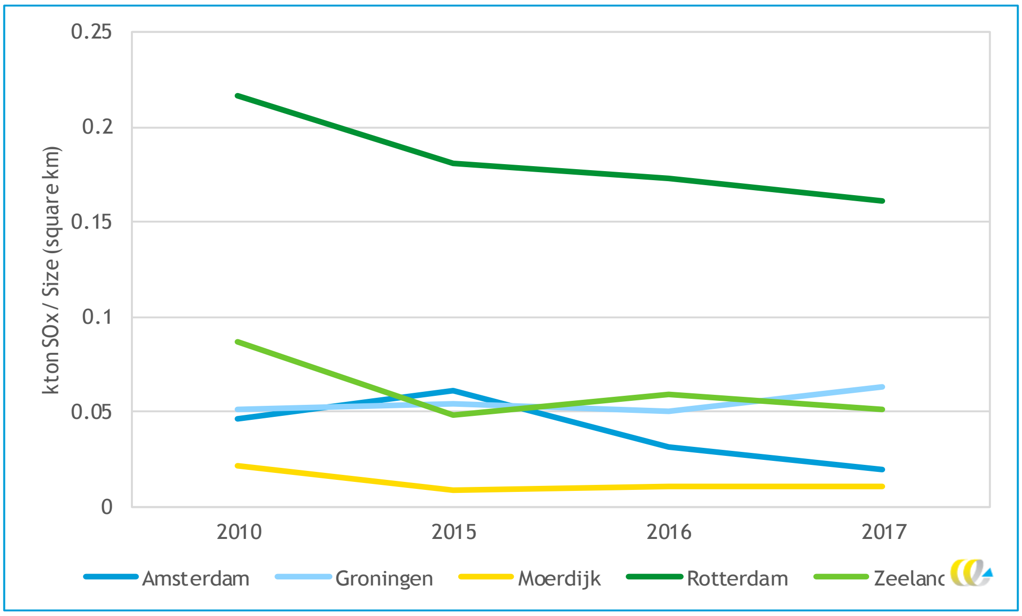



**Figure 25 – Sulphur dioxide emissions in port areas the Netherlands relative to size (square km)**





natuur en milieu federatie zuid-holland

*Carbon monoxide*

Carbon monoxide (CO) is a colourless, odourless, and tasteless flammable gas that is slightly less dense than air. It is toxic to animals that use haemoglobin as an oxygen carrier in the blood (both invertebrate and vertebrate) when encountered in concentrations above about 35 ppm, although it is also produced in normal animal metabolism in low quantities, and is thought to have some normal biological functions. In the atmosphere, it is spatially variable and short lived, and has a role in the formation of ground-level ozone.

Carbon monoxide is emitted by incomplete combustion such as with transport and certain types of industrial processes. The largest global source of carbon monoxide is of natural origin, due to photochemical reactions in the troposphere. In the Netherlands 616 kton was emitted in 2017, of which 400 kton by transport. Consumers (90 kton) and other industry (70 kton) were also main contributors. Port areas emitted about 45 kton in 2017, which is less than 10% of the total in the Netherlands. Rotterdam and Amsterdam have the highest emissions of carbon monoxide. Moerdijk has the lowest emissions of carbon monoxide. The emissions of carbon monoxide in Groningen show a great reduction in 2016, while 2017 levels increase again. According to Emissieregistratie a company melting aluminium is responsible for 3 kton CO emissions in 2017. No emission report is available for 2016 which is probably due to a bankruptcy in August 2017. The firm has been taken over and will increase production levels up to full capacity[16]. The port of Zeeland is the only port where emissions in 2017 are higher than in 2010, which is due to increased emissions at a chemical company. Annex C.2 shows that the chemical industry and mobility and transport are the most important sources of CO emissions in port areas.

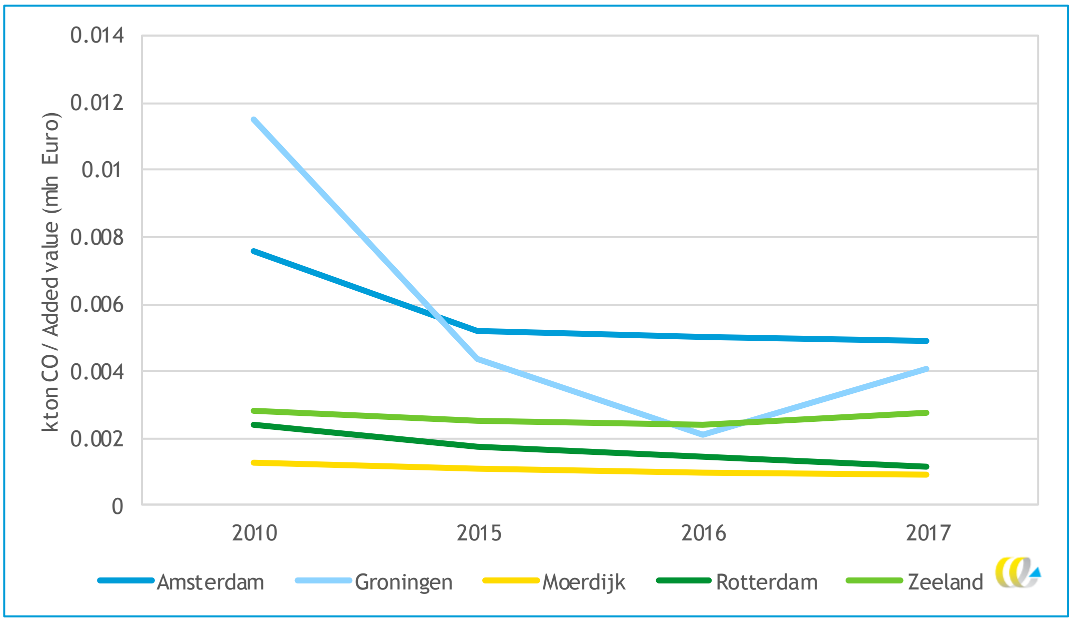
**Table 27 - CO emissions in port areas the Netherlands**

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 12.43 | 10.76 | 10.66 | 10.57 |
| Groningen | 9.38 | 4.77 | 2.58 | 5.42 |
| Moerdijk | 1.62 | 1.50 | 1.33 | 1.33 |
| Rotterdam | 27.06 | 21.21 | 20.05 | 17.14 |
| Zeeland | 8.81 | 8.20 | 8.27 | 9.97 |
| **Total** | **59.3** | **46.44** | **42.89** | **44.43** |

Figure 26 shows the CO emissions relative to added value in port areas. Amsterdam and Groningen have the highest CO intensive industries. Moerdijk and Rotterdam have the relatively lowest carbon monoxide emissions. Most ports show a reduction in the carbon monoxide intensity, only Zeeland is on similar level in 2017 compared to 2010.

16 Groningen Seaports : Opstart totale aluminiumproductie bij Aldel

**Figure 26 – CO emissions in port areas the Netherlands relative to added value**




## *Lead*

Lead (Pb) is a heavy metal that can result in health problems. It can enter the body through inhalation, food, drinks and through the skin. The dangers of lead have been known for some time and many reduction measures have been taken. Historically lead was used in paint and ceramics. Also pipes for drinking water used to be made from lead. Lead also used to be added to petrol as antiknock agent. This has been stopped since 2000 but the ground in areas surrounding busy roads still contain large quantities of lead.

Currently lead is emitted in small amounts by industries. Lead emitted to the air can easily bind itself to particulate matter, thus forming a risk for people living near lead emitting industries. Particulate matter containing lead can also land on crops or grass used by agriculture. Lead can than enter the body through food. Lead entering the body will for the most part be stored in the bones, a smaller portion will end up in blood. It can lead to cardiovascular diseases and kidney failures. Exposure to high quantities can results to lead poisoning. Exposure to lead is especially dangerous for children since they have a higher metabolism and will store higher quantities of lead.

In 2017 8.6 kton of lead was emitted in the Netherlands. The main source of emissions is industry (6.1 kton) and transport (1.9 kton). Emissions have been greatly reduced since 2010 when more than 37 kton was emitted in the Netherlands, of which 31 kton by industries.
In 2010 around 3.9 kton was emitted in port areas, while in 2017 only 1 kton of lead was emitted in port areas.

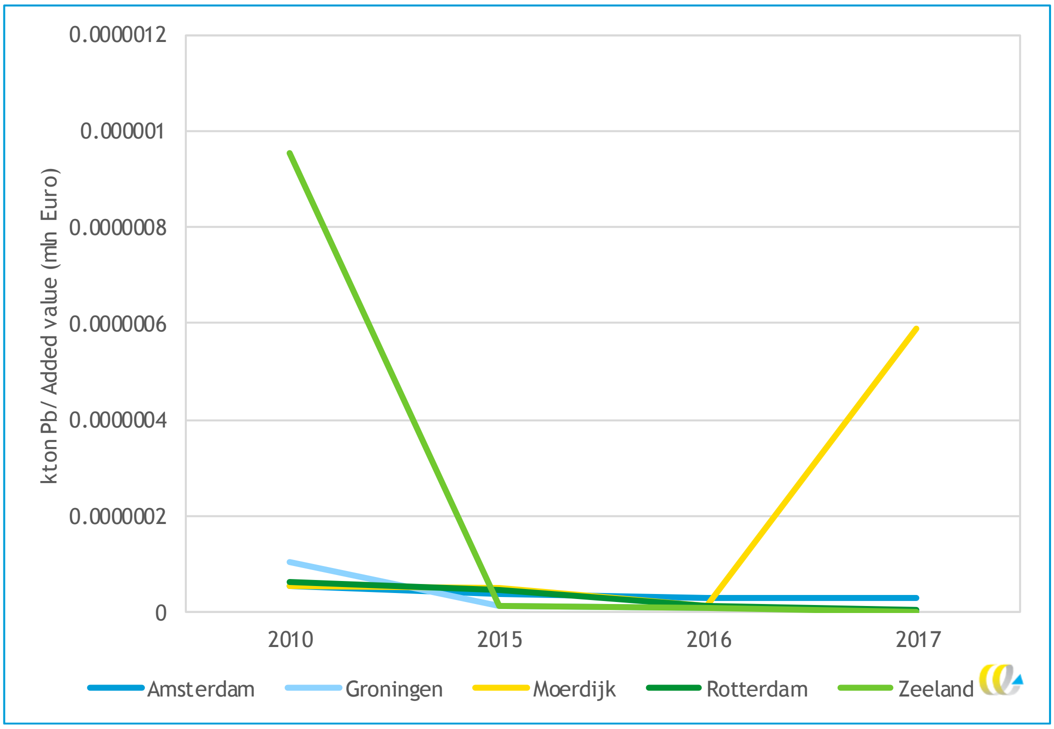
The emissions of lead vary significantly between years in certain ports. Emissions in Zeeland in 2010 are the result of a single company which emitted 2.96 kton. The port of Zeeland located a factory that produced phosphor. This factory stopped production in 2012 due to a bankruptcy. As a result lead emissions in Zeeland for the other years are very low. The increased lead emissions in Moerdijk in 2017 are also the result of a single company. A glass producer that works with lead emitted 0.85 kton in 2017, it is unclear whether this increase is temporary or long term. Lead emissions in the other ports have decreased since 2010. Annex C.2 shows that reductions have occurred in various sectors.

**Table 28 - Lead (PB) emissions in port areas the Netherlands**

| Ton PB | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 0.09 | 0.08 | 0.07 | 0.06 |
| Groningen | 0.08 | 0.01 | 0.01 | 0.01 |
| Moerdijk | 0.07 | 0.07 | 0.02 | 0.87 |
| Rotterdam | 0.68 | 0.57 | 0.15 | 0.06 |
| Zeeland | 2.98 | 0.04 | 0.03 | 0.01 |
| **Total** | **3.90** | **0.77** | **0.28** | **1.01** |

Lead emissions relative to added value are shown in Figure 27. The most notable are the two high values for Zeeland and Moerdijk. Apparently the ports in general are not very lead intensive. The intensity of lead emissions has reduced since 2010 in all ports besides Moerdijk in 2017.

**Figure 27 - Pb emissions in port areas the Netherlands relative to added value**



**Text box 10 - Conclusions other substances**

The emissions of air pollutants has decreased in most ports. The contribution of ports to total national air emissions for most substances is below 10%. Only the contribution to total sulphur dioxide emissions is large. Over 50% of total sulphur dioxide in the Netherlands is emitted in the five seaports. Sulphur emissions have however been reduced greatly during the last decades. [17] The sulphur emissions in port areas are decreasing in all ports except in Groningen. The same applies for benzopyrene emissions. The emissions of ammonia mainly occurs in Zeeland, where a company produces fertilizers. Emissions of certain other pollutants are mainly influenced by large companies as well. Carbon monoxide emissions have increased in Zeeland as result of higher emissions in a single company. Significant amounts of lead where emitted in Zeeland until 2013, when a company producing phosphor went bankrupt. Reducing emissions of air pollutants from large emitters should be done in consultation as the companies have permits to emit maximum amounts of air pollutants.

### 3.4.4 Mitigation measures

Ports can impose several measures to improve the air quality in port areas, for example environmental zones, the supply of onshore power and discounts for more environmental forms of transport. We will discuss the most relevant measures in this paragraph.

#### *Onshore power supply*

Vessels that are docked in the port still require electricity for their operations, such as lighting, communications and household functions. Most vessels rely on auxiliary engines to generate the required electricity. These engines lead to emissions of air quality pollutants like $NO_x$ and PM. Ports have the ability to equip berths with onshore power. Rather than using on-board engines vessels can use an electricity connection from onshore. As a result the auxiliary engines don’t have to run, avoiding emissions and thereby improving air quality.

There are however some difficulties with onshore power supply (OPS). Connecting maritime vessels, especially larger ones, is complex and difficult due to high power demand. (Lakens, 2019). Currently these vessels have to rely on on-board engines. In other situations vessels will prefer to use on-board engines, if this is more convenient or cheaper. The use of onshore power supply is mandatory in certain cases. For example, the ports of Groningen and Rotterdam require inland vessels to use onshore power supply when an inland vessel uses a berth equipped with onshore power supply of sufficient capacity. In Amsterdam the use of generators is prohibited in specific areas.

All ports in the Netherlands do facilitate some form of onshore power supply. Some ports report the number of onshore power supply connections that are available in the port. The results can be seen in Table 29. Groningen and Rotterdam have not reported the number of OPS connections in their ports. Amsterdam has a lot more connections than Zeeland and Moerdijk. Moerdijk only offers a few onshore power supply connections. The number of connections has increased in Amsterdam between 2015 and 2017. The number of connections in Zeeland has remained stable.

[17] KNMI Nieuwsbericht. Zwavel: een voorbeeld voor klimaatbeleid

Table 29 – Number of onshore power supply connection points

| Number of OPS connection points | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Amsterdam | 164 | 166 | 170 | n/a |
| Groningen | n/a | n/a | n/a | n/a |
| Moerdijk | n/a | n/a | n/a | 10 |
| Rotterdam | 1 | 1 | 1 | 1 |
| Zeeland | n/a | 64 | 64 | 68 |

The amount of electricity provided through OPS is a better indicator for the improvement of air quality than the number of connections points. The amount of electricity provided via OPS has a direct relation with the decrease in the use of auxiliary engines. Unfortunately this information is not provided by all ports. Moerdijk and Zeeland do not provide information about the amount of power provided, even though onshore power is available in both ports. The highest amount of on-shore power is provided in Rotterdam, almost 7,000 MWh in 2017. The supply in Groningen was almost 1,000 MWh in 2017, which is about half the amount of Amsterdam. The supply in Groningen increased in 2018.

Table 30 – Onshore power supplied (MWh)

| MWh | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Amsterdam | 2,100 | 2,500 | 2,100 | n/a |
| Groningen | 1,403 | n/a | 968 | 1,114 |
| Moerdijk | n/a | n/a | n/a | n/a |
| Rotterdam | 7,680 | 6,681 | 6,297* | n/a |
| Zeeland | n/a | n/a | n/a | 126 |

* The results of 2017 only include power supplied for maritime shipping

In absolute terms Rotterdam provides the most power via OPS. In relative terms the situation could be different. The total use of onshore power supply depends on the amount of vessel activity in the port. The total throughput can provide some indication for the amount of vessel activity. Table 31 shows the onshore power supplied relative to the total throughput. Rotterdam and Amsterdam provide considerably less onshore power relative to throughput compared to Groningen. Multiple reasons can result in the difference. The most important reason is that OPS is currently mainly provided for inland vessels, while Amsterdam and Rotterdam have high shares of marine traffic as both ports are specialized in trade. A second reason could be that berthing times in Groningen are higher, and as a result OPS connection times are longer, leading to higher amounts of electricity supplied. A third reason could be that the number of OPS connections is not sufficient in Amsterdam and Rotterdam. The exact reason for the differences can't however be traced back based on the data available.

Table 31 – Onshore power supplied relative to total throughput

| MWh/Mton | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Amsterdam | 27 | 32 | 26 | n/a |
| Groningen | n/a | n/a | 145 | 167 |
| Rotterdam | 17 | 14 | n/a | n/a |

Ports can improve the communication regarding onshore power. Data about the number of connection points and the amount of onshore power supplied is incomplete for most ports. Furthermore, it is uncertain which type of vessels use onshore power supply. Providing more information will show which ports make good progress and are able to offer onshore power for inland vessels, cruise vessels and maritime vessels. There is still a large potential group of users, and it is unclear which groups currently use onshore power.

### *Cleaner vessels*

Besides promoting cleaner operation of vessels, ports have the ability to promote cleaner vessels itself. Ports can create an incentive for the purchase of cleaner vessels by reducing the port tariffs for cleaner vessels. For vessels with a Green Award, a discount is offered in all five ports since 2013. The 2018 discounts for inland vessels are shown in Table 32. Green Award uses different types of certificates based on the environmental performance. Amsterdam and Rotterdam are the only ports that differentiates the amount of discount based on the certificate. Rotterdam even exempts the cleanest vessels from paying port charges. Both ports offer additional benefits for the cleanest inland vessels. Groningen offers the lowest discount, 5% for all types of certificates.

**Table 32 – Green Award discounts offered in 2018 for inland vessels**

| Green award | Discount | Criteria |
|---|---:|---|
| Amsterdam | 5/10/15/20% | Certificate |
| Groningen | 5% | |
| Moerdijk | 15% | |
| Rotterdam | 15/30/100% | Certificate and score of engine |
| Zeeland | 10% | |

### *ESI – Environmental Ship Index*

Specifically for maritime vessels a similar program is in place called the Environmental Ship Index (ESI). Vessels receive a score from 0 to 1,000 that reflects their environmental performance. The minimum score to receive a discount differs per port as can be seen in Table 33. In Amsterdam larger vessels receive a higher discount, as well as vessels with a score above 31 points and vessel that use LNG as fuel. In Moerdijk and Rotterdam vessels receive a 10% discount for the first 20 calls if the score is above 31 points, bonuses are awarded if $NO_x$ performance is above a threshold. In Zeeland the discount depends on the ESI score, a higher score results in a higher discount. Groningen offers a 5% discount on port charges for all vessels that score above the minimum of 20 points.

**Table 33 – Minimum ESI score in order to receive discount in 2018**

| Minimum ESI score to receive discount | Discount | Minimum score | Dependent on |
|---|---:|---:|---|
| Amsterdam | € 200-€ 1,400 | 20 | ESI score, type of fuel and size of vessel |
| Groningen | 5% | 20 | |
| Moerdijk | 10% | 31 | Number of calls, $NO_x$ score |
| Rotterdam | 10% | 31 | Number of calls, $NO_x$ score |
| Zeeland | 4.5%-15% | 30 | Score |

Besides offering discounts for environmental friendly vessels ports have to ensure that the infrastructure is ready. For example ports could promote the use of environmentally friendlier fuels by facilitating bunkering of these fuels. Currently it is possible to bunker LNG in all five ports. The Port of Rotterdam reports the number of LNG bunkering.

**Table 34 – Number of LNG bunkering**

| Number of LNG bunkering | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Rotterdam | 58 | 32 | n/a | n/a |

### *Environmental zone*

Besides offering discounts or facilitating infrastructure, port authorities have the ability to impose environmental zones for road traffic and vessels. The port of Rotterdam currently has an environmental zone in place for heavy goods vehicles. Part of the port, the Maasvlakte, is only accessible by trucks with the most recent emission technologies. Only Euro VI trucks can access the Maasvlakte and thus improving air quality. The Port of Rotterdam (2015) is also planning an environmental zone for inland vessels. According to the Havenbeheersverordening (Port of Rotterdam, 2015) from 2025 onwards only inland vessels with at least a type CCR II engine[18] can enter the port of Rotterdam. This will ensure that vessels with older types of engines cannot enter the port, thus improving the air quality in the port.

**Text box 11 - Conclusions mitigation measures**

Ports can impose various measures to improve the air quality in port areas. All ports provide onshore power supply for (inland) vessels. Not all ports report the number of vessels using onshore power or the amount of electricity provided through onshore power supply. It therefore remains difficult to indicate how well onshore power supply is used in ports. Especially since onshore power supply is not available for all vessel types. Another measure is the differentiation of port fees based on environmental performance of vessels. All ports offer discounts for (inland) vessels, although the mechanism differs. Amsterdam and Rotterdam offer a gradual discount for inland vessels. This offers additional incentives for vessels to further improve their environmental performance. Most ports offer differentiated discounts for maritime vessels. This can be through an ESI score, type of fuel, and $NO_x$ performance for example. Another measure to improve the air quality is through an environmental zone for road traffic or vessels. The port of Rotterdam has an environmental zone in place for heavy goods vehicles in part of the port. For 2025 the Port of Rotterdam has planned an environmental zone for inland vessels. The other ports have no environmental zone in place to improve the air quality.

## 3.5 Water quality

This paragraph discusses the water quality in ports.

### 3.5.1 Water quality in ports

The European Union has introduced the Framework Directive Water in 2000 in order to improve the quality of surface and ground water in the European Union. For this reason, a general requirement for ecological protection, and a general minimum chemical standard, was introduced to cover all surface waters. The specific quality requirements can be found in Annexes of the framework. In the Netherlands the results are reported on the website of

[18] CCR II engine is an inland waterway transport specific norm.

Waterkwaliteitsportaal. The results distinguish various elements of water quality as can be seen in Table 35.

The scores range from very good (++), good (+), reasonable (+-), insufficient (-) and bad (--). Ports with a direct connection to sea are not scored on the following aspects: nitrogen, phosphor, salinity, acidity and visibility because these scores are only investigated for fresh water rivers. Most ports have comparable results. Moerdijk and Vlissingen (Zeeland) score less on ecological and biological totals as well as the amount of fish. The quality scores for other water flora in the port of Rotterdam differs per location. The score gets better further downstream towards the North Sea.

While the part of Terneuzen situated at the Gent-Terneuzen canal scores low on the content of nitrogen and phosphor. According to Emissieregistratie 66 ton nitrogen was emitted to surface water in 2017 by the large factory producing fertilizers that is situated alongside the canal. It remains however unclear to what extent this single factory contributes to the negative score. Other industry is located further upstream in Belgium as well and nitrogen can end up in the water due to other reasons, for example through agriculture runoffs. According to Emissieregistratie industry as a whole is only a minor contributor, about 3%, to emissions to surface water of nitrogen and phosphor.

The quality of all water bodies on specific pollutants and chemical quality is insufficient. The waters contain too many pollutants and chemicals to be of sufficient quality according to the European standards. The insufficient scores are not the direct result of the ports, the water entering the five ports already was of not sufficient quality.

**Table 35 – Scores water quality from Waterkwaliteitsportaal in port areas**

| | Delfzijl | Amsterdam | Rotterdam | Moerdijk | Vlissingen/ Terneuzen Seaport | Terneuzen Inland port |
|---|---|---|---|---|---|---|
| Ecological quality total | +/- | +/- | +/- | - | - | +/- |
| Biological quality total | +/- | +/- | +/- | - | - | + |
| Macro fauna | +/- | +/- | + | +/- | + | + |
| Fish | +/- | + | +/- | - | - | + |
| Other water flora | +/- | + | +/-&- & -- | + | + | + |
| Phytoplankton | + | + | + & +/- | n/a | +/- | + |
| Nitrogen | n/a | + | n/a | +/- | n/a | -- |
| Phosphor | n/a | +/- | n/a | + | n/a | -- |
| Salinity | n/a | +/- | n/a | + | n/a | + |
| Acidity | n/a | + | n/a | + | n/a | + |
| Temperature | + | + | + | + | + | + |
| Oxygen | + | + | + | + | + | + |
| Visibility | n/a | + | n/a | n/a | n/a | + |
| Specific pollutants | Not sufficient | Not sufficient | Not sufficient | Not sufficient | Not sufficient | Not sufficient |
| Chemical quality total | Not sufficient | Not sufficient | Not sufficient | Not sufficient | Not sufficient | Not sufficient |

### 3.5.2 Emissions of Substances of Very High Concern to water

The water quality in ports depends on sources outside the port areas as well. This section focuses on a subject which is under influence of ports, namely emissions of pollutants to water within the port area. Emissieregistratie reports the impact on surface water of a selection several Substances of Very High Concern (SVHC or ZZS in Dutch) from companies in the Netherlands. The list of SVHC contains substances with severe environmental and human health impact for which the use should be avoided and minimised according to the minimisation obligation in Dutch environmental law[19]. The use of SVHC will be phased out in the future. The use of SVHC is currently subject to permits and companies have to draft plans to reduce the use of SVHC every five years. The list of SVHC includes heavy metals and several pesticides among other substances. The impact on surface water of pollutants include direct emissions to surface water from companies and discharges from other sources. These other sources include effluent from sewage treatment centres, overflow[20] of sewage and rain water, deposition from emission released to air, and leaching from agricultural and nature soil.

Table 36 shows the accumulated amount of pollutant emissions to surface water in the five port areas. The table shows a very large reduction in the period 2000 until 2010 in the amount of SVHC emitted to water. From 2010 onwards the reduction is less dramatic, and seemingly showing a standstill for the years 2016 and 2017. Even though significant reductions have been made there is still a considerable effort necessary to minimise the remaining portion of SVHC. Currently permits are required to emit substances to surface water. Permits are only possible if no unacceptable effects to the water quality occur.

Rotterdam was the port with the highest amount of SVHC emissions in 2017, followed closely by Amsterdam. Main sources of impact on surface water are the sewage treatment centres located in the port areas. About three quarter of pollutants (in mass) are emitted by sewage treatment companies. Sewage treatment centres are located in the ports of Amsterdam, Groningen, Rotterdam, and Zeeland. In the port of Moerdijk no sewage treatment centre system is located which contributes to the low amount of emissions. It should be noted that companies also emit SVHC via their wastewater which is treated by sewage treatment centres. For some SVHC, particularly persistent substances, it is known that sewage treatment centres are ineffective at removing them leading to significant indirect SVHC emissions to surface water. Other sources of emissions to waters are the chemical industry and waste management industry. The main SVHC emitted are heavy metals, for example cobalt and nickel. The total number of different SVHC that are emitted to surface water in the ports is 47. It should be noted that the SVHC in the emission database (Emissieregistratie) is only a small fraction (less than 10%) of those currently identified (around 1500 ZZS) by the Netherlands[21].

**Table 36 – kg emissions of Substances of Very High Concern to surface water**

| Kg emissions | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|
| Amsterdam | 179 | 302 | 459 | 509 | 526 | 510 |
| Moerdijk | 52 | 53 | 58 | 64 | 42 | 33 |
| Groningen | 980 | 1,932 | 95 | 73 | 76 | 77 |
| Rotterdam | 4,738 | 2,036 | 800 | 833 | 580 | 636 |
| Zeeland | 1,355 | 1,173 | 1,200 | 206 | 238 | 223 |
| **Total** | **7,304** | **5,496** | **2,612** | **1,685** | **1,462** | **1,479** |

[19] Minimalisatie en vijfjaarlijkse informatieplicht

[20] Sewage systems can overflow due to rain fall.

[21] RIVM : Totale lijst van Zeer Zorgwekkende Stoffen

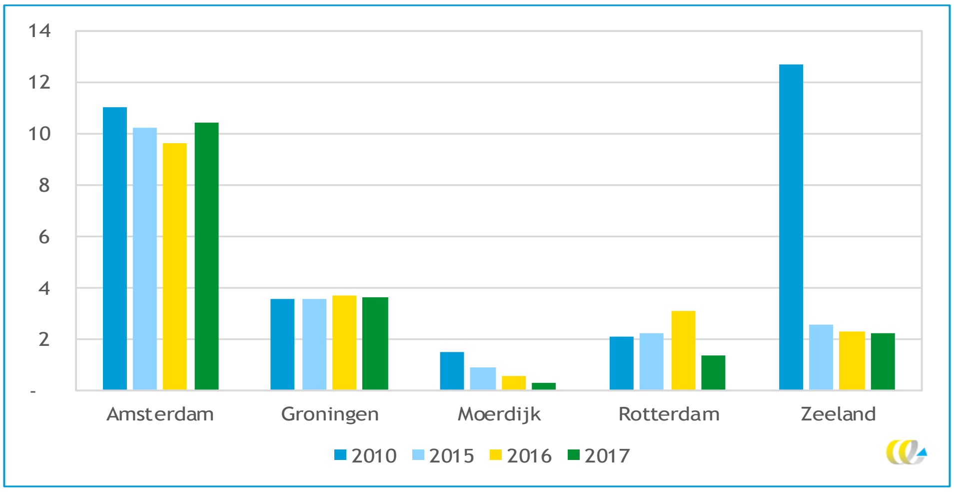
*Substance specific damages of SVHC*

The damage that the emitted SVHC pollutants cause is situation specific and depends among others on the concentration of the substance in the water and the number of species or humans that come in contact with the substance. Furthermore some are more harmful when emitted in water than others. An indication of the potential damage can be provided by using the damage factors used in life cycle analyses. These factors are used to compare the damage of substances relative to each other and to get an indication whether the damage potential of substances is increasing or decreasing. Using damage factors in this way is not an official method and the results do not provide information about the actual damage caused by the emissions.

Ecoinvent is a database that reports the damage factors of various substances to, among others, surface and sewage water. By multiplying the damage factors with the amount of emissions per substance we can create an idea of the potential damage per port due to emissions of SVHC pollutants to water. Ecoinvent distinguishes two types of damage that are relevant for emissions to water; damage to human health and damage to ecosystems. Damage factors of substances differ per type of damage. For example emission to water of nitrogen is harmless for humans but does damage ecosystems.

Figure 28 shows the damage to human health due to discharges of pollutants to water. The method of expression is disability adjusted life years which is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. The number of disability adjusted life years does not provide information about the actual damage done due to discharges of water. This depends on many factors, for example the concentration of the substance, the proximity of water life, or the further uses of the surface water. However, we use this information to show whether the emissions of pollutants harmful to humans has increased or decreased in ports. Figure 28 shows that discharges of pollutants to water that damage health have reduced significantly in the ports of Zeeland and Moerdijk. The results for Amsterdam and Groningen are more or less constant. The reduction in Zeeland is the result of less emissions of lead from the sewage treatment plant situated in the port of Zeeland. The heavy metals lead and mercury as well as the chemical substance carbendazim are the three substances responsible for the high score in the port of Amsterdam. These substances are mainly emitted by sewage treatment centres and a waste incinerator.

**Figure 28 – Disability adjusted life years in port area due to discharges of pollutants to surface water**



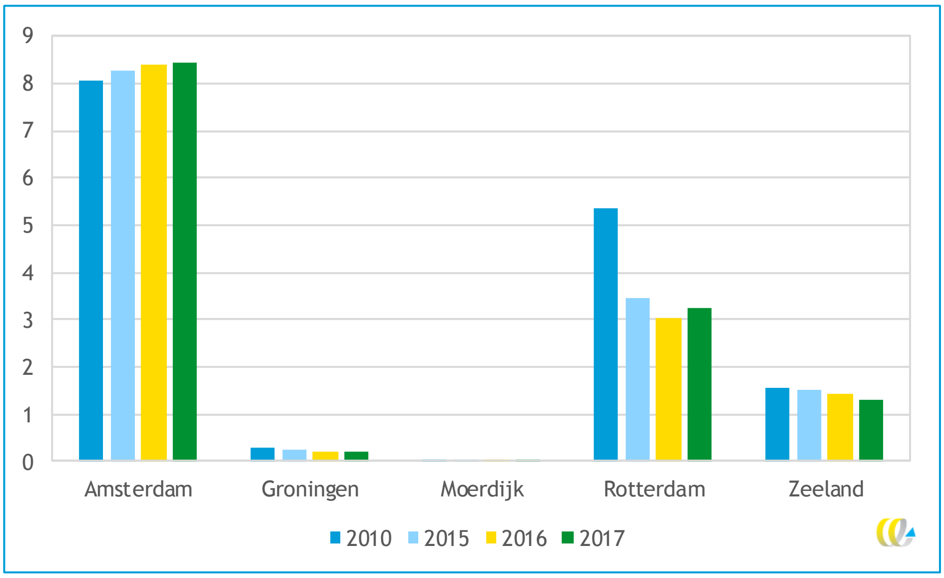



natuur en milieu zuid-holland federatie

Figure 29 shows the damage to ecosystems measured in species-years as a result of the discharges to surface water. This does not reflect the actual damage done by the discharges of pollutants, as this depends on situation specific factors.

Most substances harmful to ecosystems are released in Amsterdam, while the least are released in Moerdijk. The ports of Groningen, Rotterdam and Zeeland show reduction in the impact of pollutants discharges to water. Amsterdam shows a small increase since 2010. Pentachlorophenol, a pesticide, is the pollutant with by far the most damage to ecosystems. Other substances with more damage to ecosystems are the combustion products benzo(a)pyrene and fluoranthene. Pentachlorophenol is released in the ports by wastewater treatment plants located in the port areas. Benzo(a)pyrene and fluoranthene are released by metal companies and oil refineries, as well as sewage treatment plants.

**Figure 29 - Species-years in port area due to discharges of pollutants to surface water**




The main sources, in absolute and relative terms, of discharges SVHC on surface water of pollutants in port areas are the sewage treatment centres located in ports.
Table 37 shows the discharges SVHC of companies situated in port areas to sewage water. Until 2005 more kg of substances were emitted directly to surface water than discharged to sewage water. The emissions of SVHC to sewage water have not been reduced between 2000 and 2017, unlike emissions directly to surface water.

**Table 37 - kg emissions of Substances of Very High Concern to sewage water**

| **kg emissions** | **2000** | **2005** | **2010** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|---|
| Amsterdam | 31 | 5 | 205 | 597 | 599 | 185 |
| Moerdijk | 1,411 | 1,764 | 3,322 | 1,154 | 1,597 | 1,566 |
| Groningen | 0 | - | 1 | - | - | - |
| Rotterdam | 30 | 8 | 7 | 8 | 13 | 8 |
| Zeeland | 20 | 49 | 28 | 67 | 24 | 39 |
| **Total** | 1,492 | 1,825 | 3,562 | 1,826 | 2,232 | 1,797 |

The sewage treatment centres are not able to filter all dangerous substances out of the sewage water. The dangerous substances in the sewage water are partly discharged to the sewage system by companies situated in port areas. Emissieregistratie provides the average efficiency of sewage treatment centres in the Netherlands for heavy metals, as is shown in Table 30. Efficiency for several other substances can be found in (Emissieregistratie, 2018). The efficiency of sewage treatment differs significantly between substances. Some substances can be removed from water relatively well, whereas for other substances they will end up in the effluent of sewage water. No substances can be entirely removed from water.

**Table 38 – Average efficiency sewage treatment of heavy metals in the Netherlands 2017**

| Substance | Sewage treatment efficiency |
|---|---|
| Phosphor | 86% |
| Nitrogen | 84% |
| Arsenic | 53% |
| Cadmium | 69% |
| Chrome | 88% |
| Copper | 94% |
| Mercury | 74% |
| Lead | 94% |
| Nickel | 56% |
| Zinc | 83% |

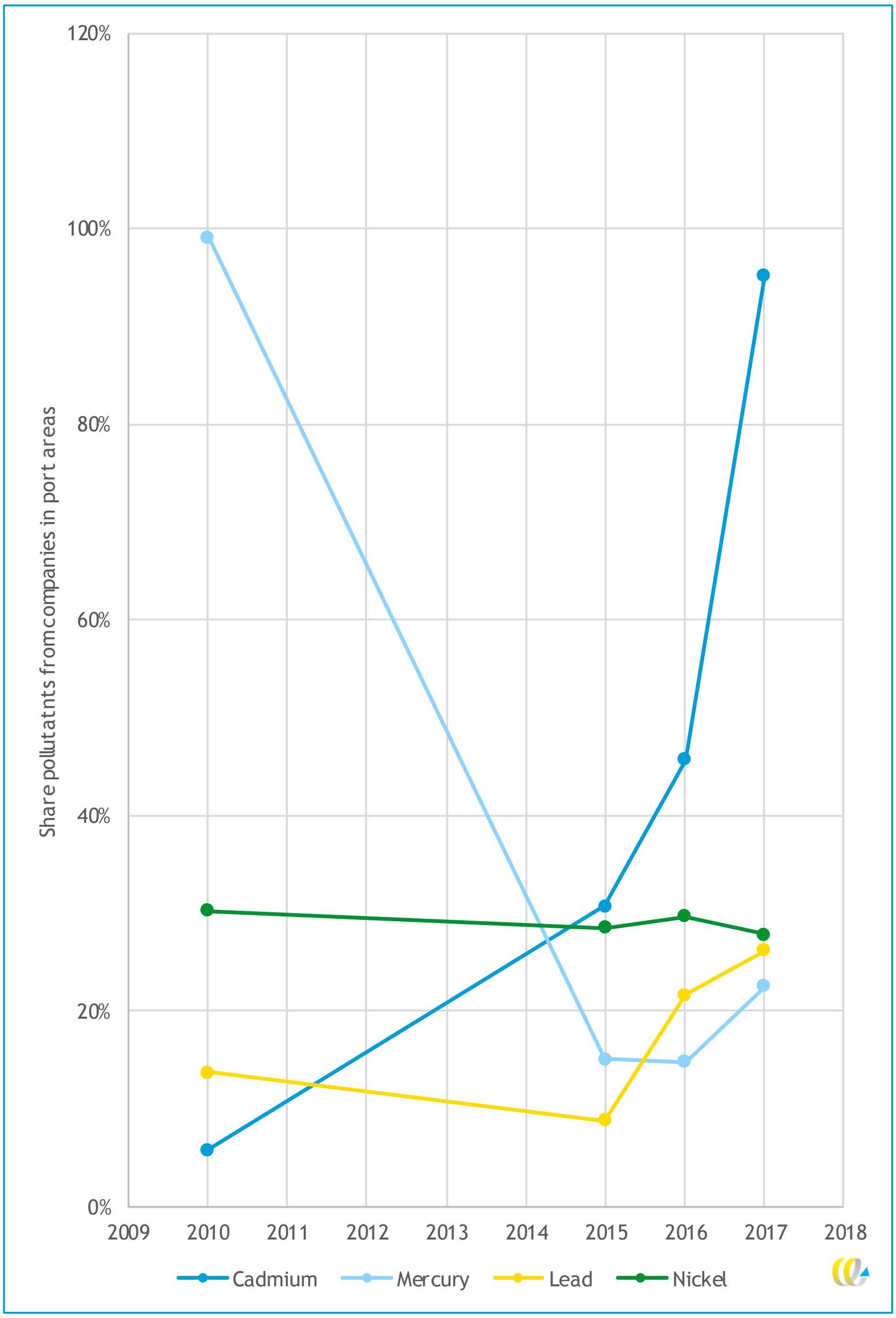
Not all these heavy metals are emitted to sewage systems by companies situated in port areas. Only Cadmium, Lead, Mercury and Nickel are emitted to the sewage in port areas. The amount of discharges of heavy metals have decreased since 2010 as can be seen in Table 39.

**Table 39 – Total emissions to surface water from sewage treatment centre originating from companies situated in Dutch port areas.**

| Kg | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Cadmium | 30 | 20 | 12 | 14 |
| Lead | 10 | 6 | 7 | 5 |
| Mercury | 270 | 147 | 147 | 134 |
| Nickel | 1220 | 527 | 614 | 545 |

Figure 30 shows the share of heavy metal emissions to surface water from sewage treatment centre originating from companies situated in port area. The share of heavy metals emitted inside port areas is increasing since 2010. This shows that the emissions of heavy metals in port areas differs per substance. Mercury is emitted relatively less in port areas, while cadmium emissions from sewage treatment mostly is emitted to sewage inside port areas. The companies in the port significantly contribute to the heavy metals emitted by sewage treatment centres.

**Figure 30 – Share of emissions to surface water from sewage treatment centre originating from companies situated in port area.**




Efforts are required to further reduce the emissions of SVHC to sewage water. Total emissions (in mass) to sewage water have not decreased since 2000 and many SVHC end up in surface water. Emissions of SVHC to surface water are subject to Dutch and European regulation. Rijkswaterstaat, the Dutch waterway manager, issues permits for emissions to national surface water, and inspects and handles offences. Emissions to sewage system are managed by local environmental agencies. The Port of Rotterdam mentions addressing the chemical and thermal quality of water discharges during the construction of new land use plans (Commissie MER, 2013). Moerdijk measures the amount of discharges and discusses it in its environmental report (Port of Moerdijk, 2017). The other ports do not mention discharges of pollutants to water in their communications.

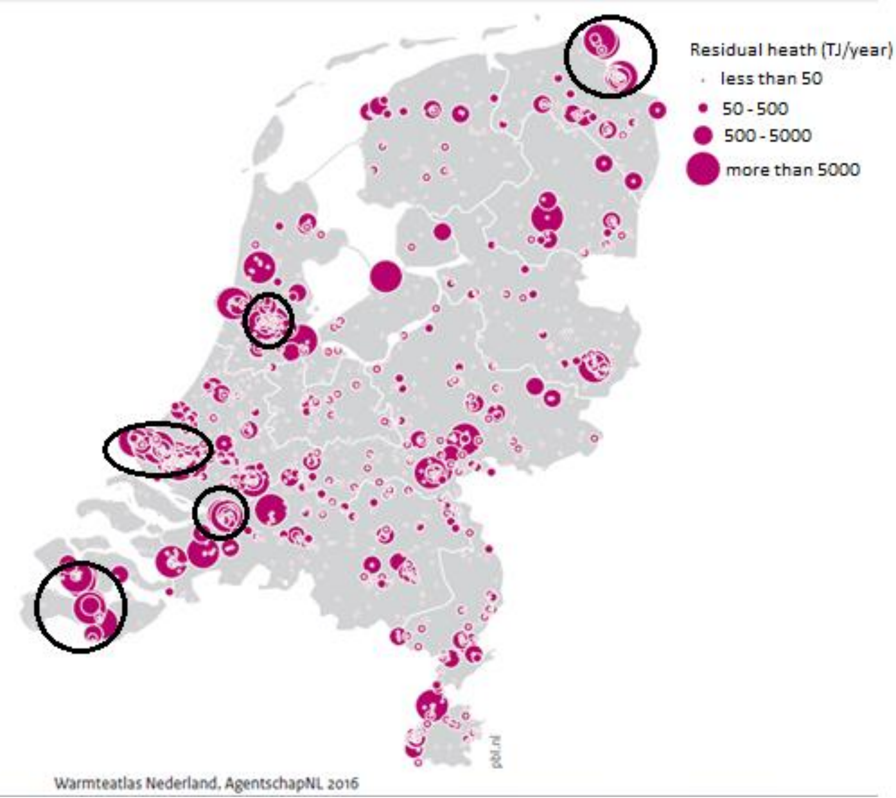
**Text box 12 - Conclusion Substances of Very High Concern**

| |
|---|
| Substances of Very High Concern (SVHC) are emitted to surface water in port areas. The amount of emissions has reduced considerably since 2000 in all ports except in Amsterdam. In Amsterdam the emissions have increased mainly due to more emissions from a sewage treatment centre. Effluences and overflows of sewage treatment are the main source of emissions in all port areas. Ports are partly responsible for the emissions of SVHC to the sewage water. Many substances end up in surface water as efficiencies of sewage treatment are not perfect. Emissions to sewage water have not decreased since 2010, unlike emissions to surface water. In order to reduce the load on the water quality companies within the port area should avoid (by non-regrettable substitution) and minimize the use of SVHC in order to reduce the emissions to surface water and sewage water. Further expanding the monitoring of SVHC (ZZS) use and emission is of importance as currently less than 10% of the substances are tracked by the Emissieregistratie database. Currently ports rarely communicate on this subject. Port authorities could take an active role to reduce the amount of emissions of SVHC by communicating with companies on the importance of a pro-active stance in light of stricter legislation in the near future. |

### 3.5.3 Discharges of cooling water

Pollutants are not the only type of waste that ends up in the surface water in port areas. Water used for cooling is also discharged in port areas, often directly to surface water. This waste water is significantly warmer than the water of the rivers or sea along which the ports are situated. The (sudden) increase of water temperature damages local ecosystems. A portion of this heat has the potential to be reused in a sustainable way according to Deltares and CE Delft (2018). According to the Kaderrichtlijn Water (KRW) the temperature of surface water should not exceed 25 degrees Celsius. Higher temperatures have less ecological potential due to a detrimental decrease in oxygen concentration. This results in blooms of toxic algae and botulism. The temperature of surface waters is expected to increase due to the effects of climate change. As a result the ability to discharge heat to surface water will further decrease. Industry is still a major source of heat discharges in the Netherlands. Seaports still host large complexes of industries and therefore heat discharges often occur in seaports. AgentschapNL (2016) has located major discharges of heat in 2016 in the Netherlands as can be seen in Figure 31. The figure shows that large amounts of heat waste are discharged in the Dutch seaports.

**Figure 31 – Discharges of heat to surface water Netherlands**




In order to improve the quality of surface water ports have to minimize the amount of heat discharges. A first step is to measure the amount of heat discharged to surface water in port areas. The Port of Rotterdam is the only port that has reported the amount of discharges of heat (Port of Rotterdam, 2017). In 2016 over 4,000 MW of heat was discharged, about 300 MW more than in 2015. At this moment this does not have to be problematic as

Table 35 shows that the overall water temperature in the port of Rotterdam still conforms to the KRW goals. However, the local effect of discharged cooling water can still be undesirable. Additionally in specific circumstances like a hot summer, discharges of cooling water can be problematic (CE Delft ; Deltares, 2018). For the other ports no data was found on the amount of cooling water discharged.

**Text box 13 - Conclusions cooling water discharges**

The water quality in the ports does not suffice according to European standards. For example, the total ecological quality is scored bad in all port areas. The same applies for the biological score in ports, only the inland port of Terneuzen, part of the port of Zeeland, scores well. The chemical quality of the water in ports is insufficient, as are the concentrations of specific pollutants. One drawback of the water quality scores is that ports only have limited influence on the water quality as the water quality could have been impacted already upstream. The maps on Waterkwaliteitsportaal show that this in general is the case, the water quality shows no great reduction in and near ports.[22] This does not mean that ports do not impact the water quality. There are still pollutants emitted to surface water in the port areas. Emissieregistratie reports the emissions of Substances

[22] Informatiehuis Water : Waterkwaliteitsportaal

of Very High Concern which can cause serious human health effects or harm ecosystems. The emission of Substances of Very High Concern has been reduced significantly between 2000 and 2010. The possible damage from these substances has not been reduced during the most recent years (2016, 2017) while the goal is to minimise and ultimately phase out these substances. A challenge thus remains for port authorities and companies to further reduce the use of substance of very high concern, especially since more substances are added to the list. Port authorities can communicate on this topic to actively create awareness as well as set up an agreement together with the stakeholders involved to further monitor and reduce emissions of Substances of Very High Concern in port areas. Besides pollutants cooling water is emitted in port areas. The heat contained in the cooling water increases the water temperate which damages local ecosystems. In general the water temperature in the ports is good and discharges of heat are not that problematic. However, during warm summer days discharges of heat can become problematic. And in the future the damages due to cooling water increase due to rising temperatures as a result of global warming. In order to reduce the damage to local ecosystems ports should monitor and minimize the number of heat discharges. The Port of Rotterdam is the only port authority that has reported the amount of heat discharged. The other ports do not report the amount of heat discharged while it is recommended that ports do so. From a climate and circular economy perspective the use of residual heat is preferred to discharges.

## 3.6 Waste management

This paragraph discusses the management of waste released by maritime vessels in seaports. Dutch seaports are obliged to facilitate the collection and management of waste from maritime vessels. The collection, disposal and reception of waste from inland vessels is subject to uniform regulations in the Ship Waste Decree (CDNI). These apply to Germany, Belgium, France, Luxembourg, Switzerland and the Netherlands. In the Netherlands SAB (Stichting Afvalstoffen & Vaardocumenten Binnenvaart), a national institute, is responsible for the network and financing of waste collection from inland vessels. Waste containing oil and grease, waste from cargo and other commercial waste is collected according to regulations.

The five Dutch seaports are visited by about 50,000 maritime vessels each year. These vessels, which have departed from (inter-)continental ports, produce ship-generated waste on their trips. Another type of waste are cargo residues that remain after a ship has discharged its cargo. These residues have to be removed in order to ensure that other cargo types will not be polluted with residues from previous cargo. Seaports have to facilitate the collection of ship-generated waste and cargo residues in order to minimise the disposal of maritime waste in sea waters. During 2002 the European Framework nr. 2000/59/EG concerning port facilities for ship-generated waste and cargo residues came into force. This framework aims to reduce the amount of ship-generated waste and cargo residues disposed in the sea. The European framework is elaborated in the Dutch legislation through the *Wet voorkoming verontreiniging door schepen* (Wvvs). The following paragraph starts with the various types of maritime waste, the facilities in the port areas, and the handling of port waste according to the port plans. The section continues by showing the amounts of waste deposited and the costs of waste management.

### Types of waste

The various types of waste generated by maritime vessels are defined in various annexes of MARPOL, which is the International Convention for the Prevention of Pollution from Ships. These annexes define the various type of waste that are generated by vessels.
Ship-generated waste includes oily waste (Marpol Annex 1), sewage (Marpol Annex 4) and garbage (Marpol Annex 5). Cargo residues include oily waste (Annex 1) and chemicals

(Annex 2) for liquid bulk tanker vessels. Annex VI includes sludge produced by exhaust gas cleaning system[23].

## Facilities

In the port region Rotterdam-Rijnmond 16 designated parties facilitate the reception of waste from maritime ships. Of these parties 15 are able to use mobile means of collection (deploying vessels and vehicles) or stationary facilities (tanks). One terminal is able to collect waste from vessels that have used the terminal for transhipment of goods. Some of the waste collection companies cover multiple areas in the Rijnmond region (Port of Rotterdam, 2018). The various companies focus on different types of waste while others are able to collect all types of waste. Five even collect Annex VI waste produced by scrubbers. In Groningen six companies are able to collect waste from vessels (Groningen Seaports, [2015]). However, no single company is able to collect all types of waste. Some companies specialise in ship specific waste, while others focus on the collection of more general garbage. In the Amsterdam-IJmond area 16 companies collect waste of maritime vessels. Some companies focus on specific types of waste or areas of the port, most companies are however able to collect most types of waste. Some even collect Annex VI waste generated by scrubbers[24]. In Zeeland one company is responsible for the collection and handling of waste, this company is also active in Rotterdam and the port of Antwerp, Gent and Zeebrugge.

## Port waste plans

According to Wvvs the ports are obliged to construct a waste management plan and update it every three years. The Port of Rotterdam has cooperated with the ports in the region such as Dordrecht, Maassluis, Moerdijk, Schiedam and Vlaardingen to generate a waste handling plan for the entire Rotterdam-Rijnmond region. The Port of Amsterdam has combined efforts with the ports of Beverwijk, IJmuiden/Velsen and Zaandam for a waste handling plan for the region. The waste handling plans are constructed in collaboration with various stakeholders, including shipping companies, waste handling companies and the licensing authorities. The waste handling plans discuss the handling of waste in port areas, the tariffs and responsibilities of stakeholders.

## Indirect financing

Article 6a of the Wvvs defines that maritime vessels visiting the port have to contribute financially for the management and handling of ship-generated waste. This mandatory financial contribution is irrespective of the actual amount of waste that is disposed by these vessels. This financial contribution makes disposal of ship-generated waste on sea less attractive as the vessels pay to have their waste handled in any case. The so called indirect financing ensures that vessels can dispose waste up to a certain threshold. However, not all types of waste are included under the indirect financing. The indirect financing applies to ship-generated waste that is irrespective of the type of cargo transported. Ship-waste oils, for example fuel remains or bilge water, falls under indirect financing in all ports. Ship-generated garbage, for example plastics and household waste also falls under indirect financing. The cost of depositing cargo-residues however have to be financed directly.
The Dutch and Flemish ports have introduced similar foundations for the indirect financing

[23] These exhaust cleaning systems are also known as scrubbers.

[24] Aangewezen havenontvangstvoorzieningen in het Noordzeekanaalgebied

in 2017. The financing depends on a fixed contribution and a contribution based on the brute tonnage of a vessel. Vessels using LNG, diesel or gasoil pay reduced tariffs.
The contribution is reduced depending on the amount of waste that is disposed by the vessels which is covered by indirect financing. The more waste a vessel disposes the larger the discount on the total bill (covered by indirect financing). Ports have the ability to set maximum amounts of waste covered by indirect financing. The Rijnmond region currently has no maximum in place, the IJmond region has a maximum amount of garbage that is collected under indirect finance, additional amounts are paid separately. In Groningen the combination (in € costs) of ship-generated waste oils and garbage are included under a threshold while Zeeland has a threshold for both ship-generated waste oils and ship-generated garbage.

## Number of vessels disposing waste

The number of calls by maritime vessels and the share of vessels depositing waste is shown in Table 40. The share of vessels that deposits waste differs substantially between various years. For example in 2017 70% of the vessels that visited Groningen was depositing waste, while in 2018 only 30% of the vessels deposited waste. The number of vessels depositing waste is generally higher in the Rijnmond and IJmond area. In general vessels are obliged to deposit waste when leaving a port. There is however an exception for ships that have sufficient capacity remaining for ship-generated waste for the journey to the destination. More intercontinental vessels visiting a port results in larger share of vessels that deposit waste. Another factor is the type of goods that are carried. For example (liquid-) bulk require cleaning more often to avoid pollution with new cargo volumes. Amsterdam and Rotterdam are ports with high volumes of liquid bulk transport, and as a result a higher portion of their collected waste is cargo residues. In Groningen and Zeeland the share of cargo residues in total waste is minimal.

**Table 40 - Number of calls by vessels and share of vessels depositing waste**

| | 2005 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Amsterdam IJmond | 5,512/30% | 6,609/69% | 6,064/78% | 6,193/76% | 6,466/75% |
| Groningen | 2,483/20% | 7,111/14% | 5,908/71% | 6,336/70% | 7,488/30% |
| Rotterdam and Moerdijk Rijmond | 34,954/28% | 29,122/79% | 29,022/64% | 29,646/80% | 29,646/60% |
| Zeeland | 4,894/15% | 5,784/60% | 6,045/37% | 5,693/41% | 6,169/51% |

* Rotterdam and Moerdijk figures include other smaller ports in the Rijnmond region, Amsterdam IJmond includes other ports in the IJmond region.

Another development is that the share of vessels depositing waste has increased significantly in all ports between 2005 and 2015. The higher shares of vessels depositing waste has also resulted in higher amounts of waste collected in ports. Almost six times more waste was collected in 2015 compared to 2005. The increase is visible in all ports. The most waste is collected in the Rijnmond region, while least waste is collected in Groningen and Zeeland which is not surprising as these are ports with less calls.

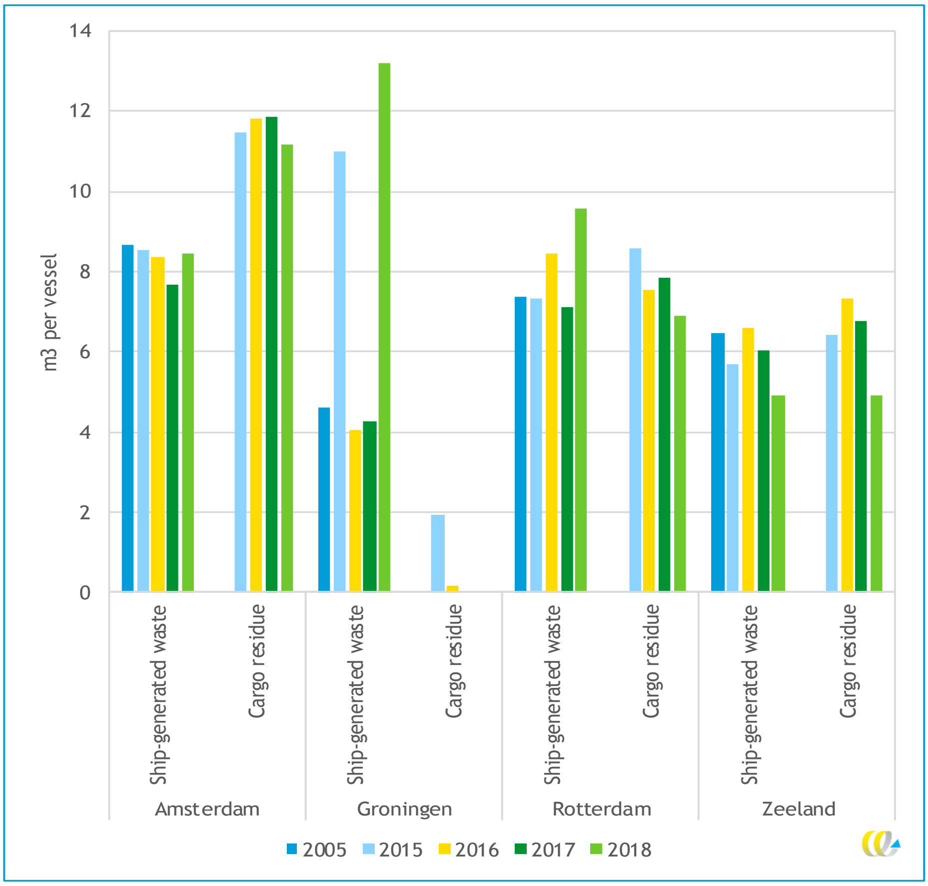
**Table 41 - Volume of ship-generated waste and cargo residues in port areas**

| Volume of waste ($m^3$) | 2005 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Amsterdam IJmond | 14,371 | 68,507 | 74,236 | 67,613 | 64,646 |
| Groningen | 2,354 | 10,865 | 17,211 | 19,103 | 31,823 |
| Rotterdam and Moerdijk Rijmond | 73,185 | 434,647 | 377,666 | 451,521 | 369,667 |
| Zeeland | 4,871 | 26,660 | 15,025 | 14,143 | 15,576 |

* Rotterdam and Moerdijk figures include other smaller ports in the Rijnmond region, Amsterdam IJmond includes other ports in the IJmond region.

The volume of collected waste has increased massively between 2005 and 2015. The amount of ship-generated waste deposited per vessel has however has not changed a lot between 2005 and 2015. This is among other reasons due to differences in European regulations and improved reporting by waste collectors. Cargo residues were not collected in 2005, while in 2015 cargo residues make up a significant share of waste in most ports. Only in the port of Groningen cargo residues are a lot smaller than ship generated waste. In Amsterdam more cargo residues are collected compared to ship generated waste. In Rotterdam and Zeeland the amount of ship generated waste and cargo residues per vessel is comparable. Cargo residues are generally associated with liquid bulk transport. In Amsterdam about 60% of the maritime throughput is liquid bulk, whereas in Groningen less than 10% of the throughput is liquid bulk.

**Figure 32 - Average amount of waste deposited per vessel**

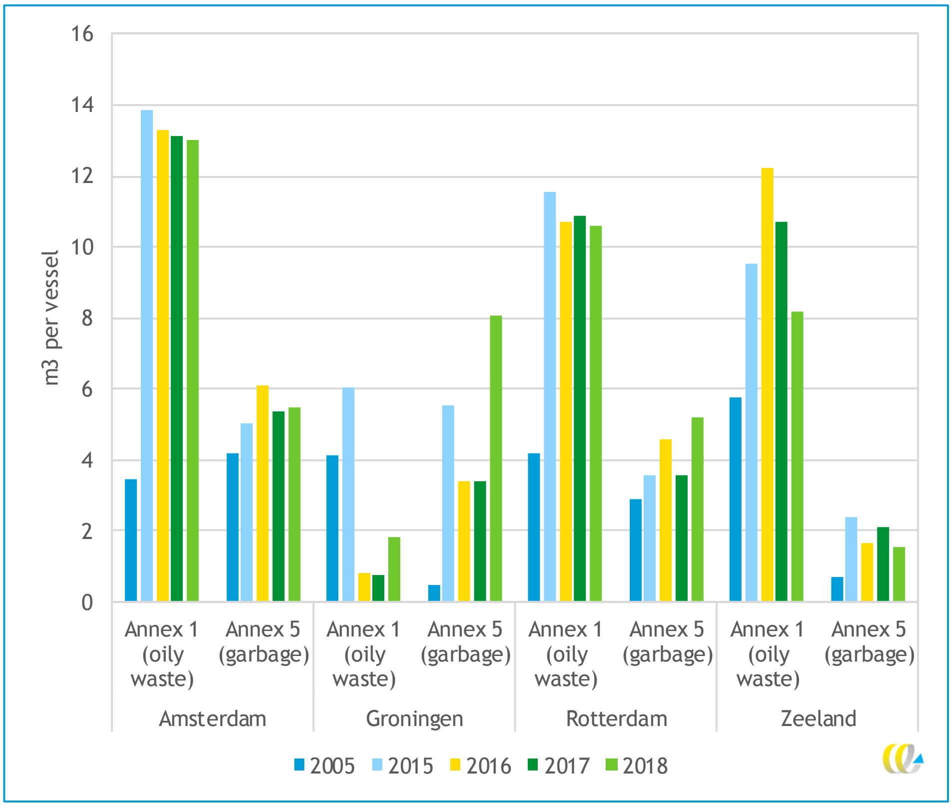



* Rotterdam and Moerdijk figures include other smaller ports in the Rijnmond region, Amsterdam IJmond includes other ports in the IJmond region.

## Type of waste

The two types of waste most collected by seaports are oily waste and garbage. Figure 33 shows the amount of waste collected per vessel. The amount of oily waste collected per vessel increased significantly between 2005 and 2015 since cargo residues are collected as well. In all ports except Groningen the amount of oily waste collected exceeds the amount of garbage.

**Figure 33 - type of waste collected per port region**




* Rotterdam and Moerdijk figures include other smaller ports in the Rijnmond region, Amsterdam IJmond includes other ports in the IJmond region.

## Dumping of waste

There is still potential to collect more waste in seaports. ILT (inspectie leefomgeving en transport) is responsible for the compliance of the waste regulations in the Netherlands. They inspect vessels visiting ports in the Netherlands for compliance to the various regulations. Their results (ILT, 2019) indicate that a portion of the vessels does not comply with the regulation. Based on inspections it is estimated that about 25% of vessels discharges garbage illegally, and 10% of vessels discharge cargo residues illegally. The ability of seaports to influence illegal dumping is limited but nevertheless very necessary to address effectively. In order to simplify waste disposal the Dutch and Flemish ports are working on a uniform system (Groningen Seaports, 2016).

**Text box 14 - Conclusions waste management**

All seaports are required to facilitate the collection of waste according to European and Dutch regulations. In most ports several companies are designated to collect waste. They do this through either vessels or installations on land. Several types of maritime waste are collected in ports, according to the Annex 1 till 5 of the Marpol agreement. Some companies collect all types of waste while other only focus on specific types of waste, for example oily waste or household garbage. The volume of waste deposited increased significantly since 2005. This increase is due to a higher share of vessels depositing waste. The average amount of waste deposited remained more or less constant between 2005 and 2018 except for the port of Groningen. Amsterdam and the Rotterdam region including Moerdijk facilitate the cleaning of scrubbers. The amount of collected waste turned out to have little explanatory power. A future benchmark could investigate the recycling of collected waste. The EU is currently discussing actions to improve the circular use of materials. Part of a proposal (EC, 2018) aims to improve the collection of maritime waste. The current regulation can be improved by further cooperation between member states in the interpretation of the EU regulation and the execution between member states. The Dutch and Flemish ports are adjusting their waste management system to become more uniform.

## 3.7 Modal split

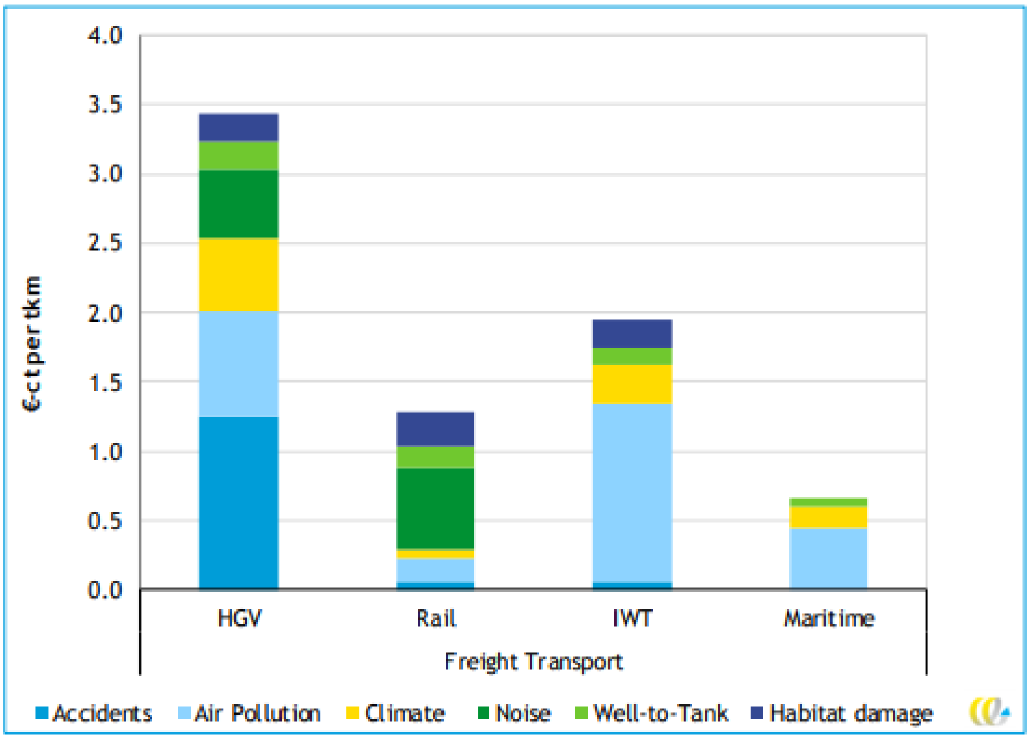
Goods arriving in seaports can be further transported using various modes of transport. The most common modes of transport are heavy goods vehicles (trucks), inland waterway vessels, trains, pipelines and short sea shipping[25]. Certain modes of transport are more environmentally efficient than others, and transport with these modalities is preferred if possible.

### Transport modalities

In general pipelines are a safe and sustainable form of transport for liquid bulk like oil products, chemicals and industrial gasses. Various pipeline networks are available in Europe that connect major (chemical) industries. Pipelines are specially built for certain types of goods; it is not possible to transport all types of liquid bulk with the same pipeline due to contamination issues. The possibility to operate pipelines therefore relies on consistent transport volumes of sufficient amount. In other words, pipeline transport is only suitable for a specific number of goods and locations. The same applies to a certain extent for inland waterway transport and rail transport as destinations have to be accessible by river or rail. All five Dutch seaports are accessible by railways and inland waterways. The road network is very dense and pretty much all goods can be transported by heavy goods vehicles. Unfortunately road transport is not the most sustainable option. The external costs of road transport are considerably higher than for inland waterway transport and rail as can be seen in Figure 34.

[25] 'Short sea shipping' is the movement of cargo. And passengers by sea over short distance where no ocean is crossed.

**Figure 34 - Average external costs in € per tonkm for EU28**[26]




* Well to tank emissions include the environmental impact due to production and transport of fuels.

The external costs to transport one ton of goods over one kilometre is highest for heavy goods vehicles, followed by inland waterway transport and railway transport. In general railway transport and inland waterway transport are preferred over heavy good vehicles, especially for longer distances and heavier goods. The ability to use this mode depends however on the availability and the type of goods transported.

Several large ports in the Netherlands are connected to pipelines in the Netherlands as is shown in Figure 35. The Dutch ports of Amsterdam, Rotterdam, Moerdijk and Zeeland are all part of the network.

[26] (CE Delft; INFRAS ; Ricardo, 2019)

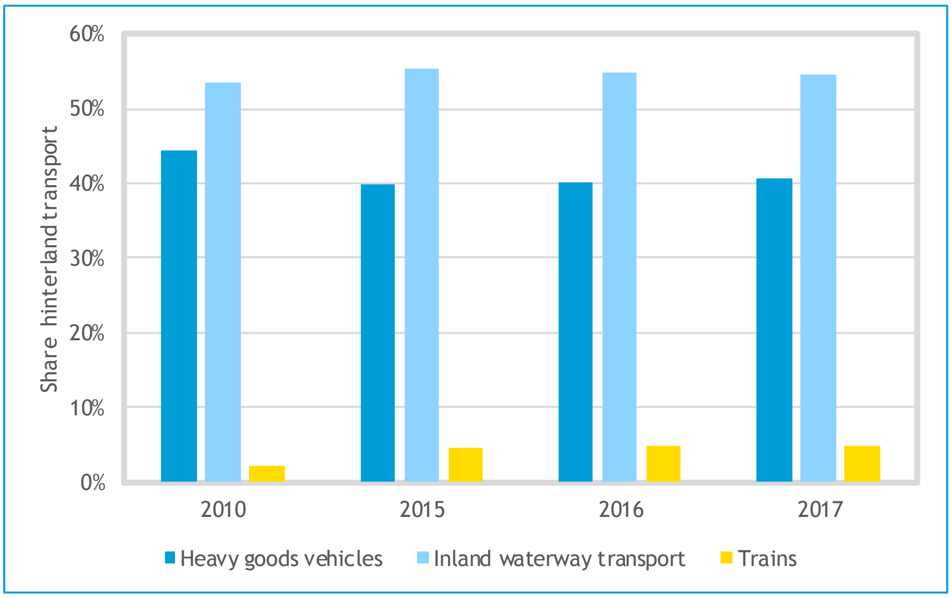
**Figure 35 – Pipelines from port of Rotterdam**


Source: Port of Rotterdam pipeline network

## Modal split results

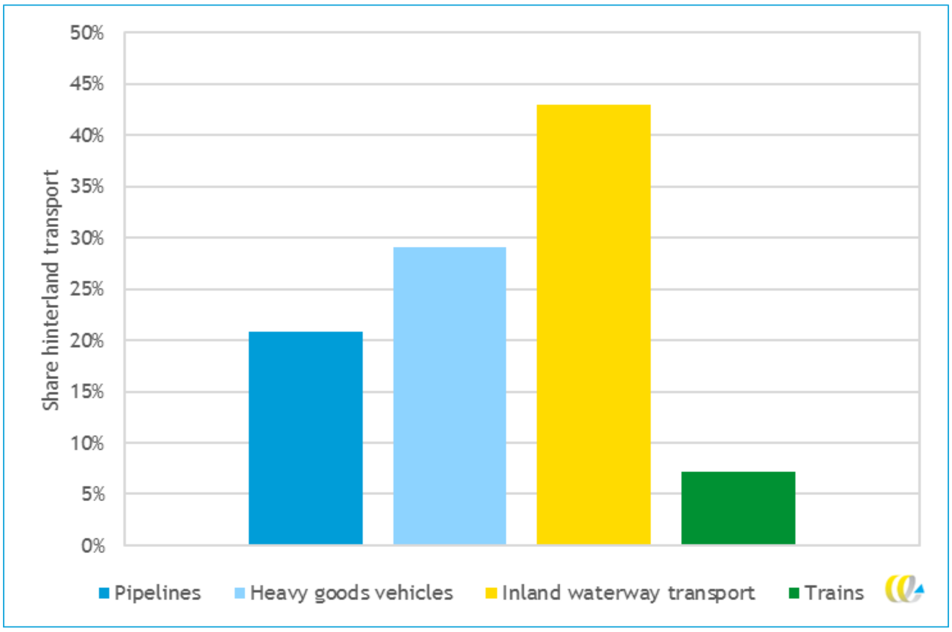
The modal split for Amsterdam is shown in Figure 36. The modal split figures are available for the years 2010 between 2017 on CBS. Pipeline transport and short sea shipping is not included in the scope used by CBS. Most tons of goods are transported from Amsterdam by inland vessel. Due to the large load factors the largest inland vessels can transport the equivalent of 660 heavy goods vehicles. Trains are also able to transport higher loads than heavy goods vehicles, a single freight train will on average transport the equivalent of 40 heavy goods vehicles. The transport share of trains remains limited, this is mostly a result of the limitations of railway infrastructure. Rail transport is not flexible as railway paths have to be reserved up front. The share of heavy goods vehicles has decreased since 2010, while railway transport has increased between 2010 and 2017. Inland waterway transport has remained more or less stable.

**Figure 36 – Amsterdam hinterland transport shares**



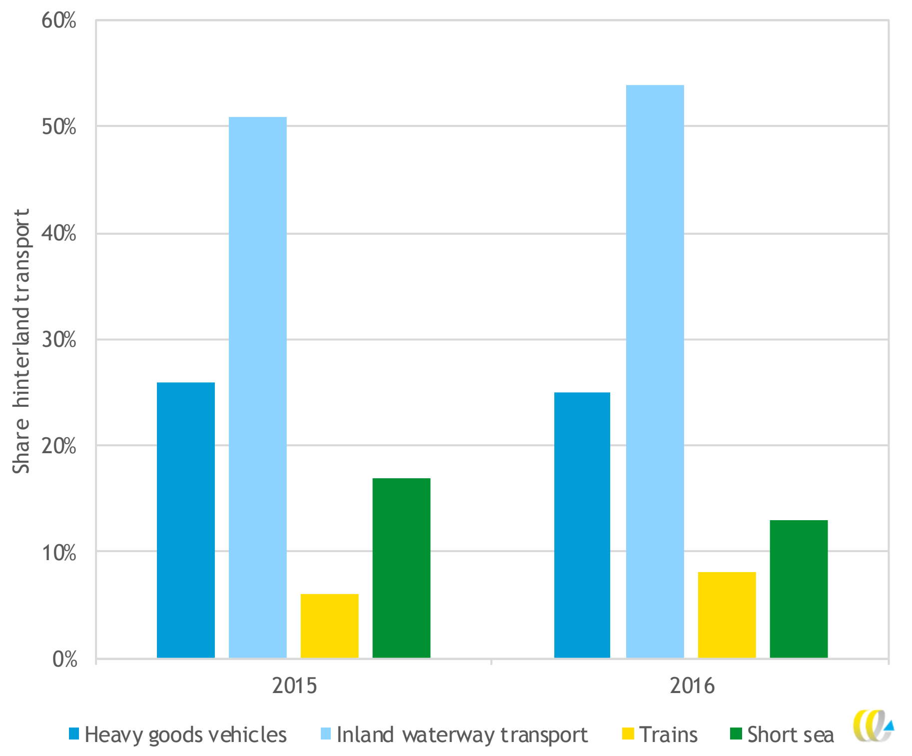

The modal split in Rotterdam is shown in Figure 37. Rotterdam does not include the shares of short-sea shipping in its results. The highest shares are from inland waterways, heavy goods vehicles and pipelines. The share of goods transported by trains is considerably less.

**Figure 37 – Rotterdam hinterland transport shares 2018**




The transport shares for Zeeland are shown in Figure 38. Similar to Amsterdam and Rotterdam the highest share is for inland waterway transport. The least amount of goods are transported by train. Between 2015 and 2016 the amount of shortsea shipping reduced.

**Figure 38 – Zeeland hinterland transport shares 2015 and 2016**




The ports of Moerdijk and Groningen do not publicise modal split figures for all modes. The Port of Moerdijk has provided the number of vessels and trains departing from Moerdijk. Table 42 shows the number of inland vessel, trains and short sea vessels visiting Moerdijk. The number of inland vessels and especially trains visiting Moerdijk has increased significantly between 2015 and 2018. This indicates a possible modal shift away from other the modes, pipelines and trucks. However, since the tonnages transported by all modes are unknown we can't be certain of a modal shift in Moerdijk.

**Table 42 – Number of inland vessels and trains visiting Moerdijk**

| Number of visits | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Inland vessels | 10,974 | 11,383 | 11,734 | 12,183 |
| Trains | 1,810 | 1,990 | 2,790 | 3,000 |
| Short sea vessels | 1,769 | 1,900 | 2.059 | 2,136 |

The ports of Amsterdam, Rotterdam and Zeeland have reported modal split figures with a different scope. The figures in Amsterdam does not include pipeline transport and short sea shipping, the port of Rotterdam includes pipeline transport while Zeeland does include short sea shipping. In order to properly asses changes in modal split it is necessary to monitor the modal split over time, calculated using the same method. This is currently not something done in the Dutch ports, and it could provide valuable information about changes in hinterland transport.

### Influence

The modal split depends on many factors, for instance on the available infrastructure and the demand for certain goods. The ability of port authorities to influence the modal split is limited, as especially in the short term market dynamics play a large roll. Monitoring the modal split can however provide valuable information for port authorities, but does not necessarily reflect the efforts of port authorities to improve the sustainability of hinterland transport. A future benchmark should investigate measures taken by ports that improve the sustainability of hinterland transport. This could identify best practises which can be considered by other ports as well.

**Text box 15 - Conclusions modal split**

Amsterdam, Rotterdam and Zeeland have reported their modal split between 2010 and 2018. The scope the ports use for modal split differs, some ports include pipelines or short sea shipping, while other solely focus on heavy goods vehicles, inland waterway transport and trains. All ports currently rely for over 50% on inland waterway transport for hinterland transport. The ports do not regularly report the modal split results and therefore it is unclear whether there is a shift towards more environmental modes of transport. It is recommended to regularly update modal split figures to notice changes in hinterland transport. The modal split is heavily influenced by market factors outside the influence of port authorities. A future benchmark should investigate measures taken by ports that improve the sustainability of hinterland transport. This could identify best practises which can be considered by other ports as well.

## 3.8 Community relations

This paragraph discusses how the ports ensure a good local environmental quality and maintain contact with the local community. To what extent do the seaports inform and involve local residents? Are the number of nuisances measured and is there a hotline for complaints? These types of questions are discussed in this paragraph. We analysed the community relations based on websites, annual reports and other communications by port authorities.

### Amsterdam

The Port of Amsterdam has taken measures to minimise nuisance from port activities such as noise, smell, light and dust. One of these measures includes the installation of e-noses in 2015, capable of detecting smell nuisances. In 2017 these e-noses detected heightened levels in 419 occasions. Meanwhile the local Environmental Service (Omgevingsdienst NZKG) received 121 smell complaints from local residents, of which 74 could be assigned to specific companies. In the other cases no specific source of the smell could be determined. There is still room to improve the connection with the e-nose notifications to actual complaints. The Port of Amsterdam also researches the quality of life of the residents surrounding the port. Conversations with local residents are conducted in order to better locate the origin of nuisances. In general better information for local residents should improve the understanding of nuisances from port authorities[27]. The Port of Amsterdam also co-finances the noise isolation of houses surrounding the port areas[28].

[27] Leefbaarheidsonderzoek Noordzeekanaalgebied krijgt vervolg (2017)

[28] Nieuwe subsidie geluidsisolerende ventilatie voor woningen rondom HoogTij en Westpoort (2017)

## Groningen

The port of Groningen is a port with a variety of stakeholders surrounding the port, these include local residents, companies, media and the general public. The Port of Groningen communicates with local residents via information evenings, newsletters, door-to-door magazines and working visits. The communication is used to keep the public informed about port activities and to gain support for the activities of the port. The Port of Groningen also supports local relations through methods beside communication. It has researched the ability to isolate houses close to the port against noise. Based on this research 62 houses have been isolated with partial finance of the Port of Groningen and the local industry.[29] The province of Groningen has ordered that the number of complaints cannot increase. E-noses have been installed to quickly notice any emissions that can lead to smell complaints. Complaints should be handled within 24 hours, notifying both the complainer and the company behind the source of the smell.

## Moerdijk

According to the website of the Port of Moerdijk the relations with its local communities are good. The port authority has regular meetings with local residents, companies and municipalities about port activities. The so called ‘Omgevingstafel’ discusses topics like the reduction of nuisances, insight in port activities and the possibilities to cooperate between the port and its local communities. The port of Moerdijk has introduced e-noses to quickly help locate sources of smell nuisances. Since 2015 nuisances have reduced. In 2017 about 150 complaints concerned the air quality. According to models and actual measurements noise disturbances have remained below the threshold of 50 dB(A) in 2017 and years previous. 50 dB(A) is comparable to a quiet street or a quiet conversation. As a result the port only received 10 noise complaints in 2017, a reduction of 13 compared to 2016 (Milieurapportage). The Port of Moerdijk also collects information about certain species of animals and plants sighted in the port area. The port also allows the formation of temporary nature on plots of land currently not in use. In order to support the local and regional communities the Port of Moerdijk has developed a funding scheme. Each year five percent of the revenue from the port authority is reserved for a fund. Local and regional projects that contribute to education, culture, nature and social cohesion can receive financing from the Port of Moerdijk.

## Rotterdam

The port of Rotterdam is situated in the western part of the city of Rotterdam and stretches to the coast. The port area covers almost 80 square km of which large parts are surrounded with nature and urban areas. Approximately 1.3 million people live in the regions around the port of Rotterdam. The relation between the port of Rotterdam and its local communities is therefore of importance. The Port of Rotterdam has several methods to engage its local communities. Local residents are involved in a variety of ways: 4 times a year a port paper is distributed among half a million residents, information evenings are organised on project basis, special focus groups with residents discuss multiple times a year and every year the port organises the port days where about 345,000 visitors get a view of the port operations. The Port of Rotterdam tries to inform people about its operations and tries to improve its reputation actively by measuring the reputation under certain residents and the general public. It has scored more than 80 points out of a 100 for both stakeholder

[29] Havenvisie Groningen Seaports : app voortgangsrapportage

groups (Port of Rotterdam, 2019). The port of Rotterdam also collects the number of noise and smell complaints. Complaints are collected by a regional complaints department[30]. This regional complaints department also uses the e-nose system. The Port of Rotterdam also monitors the nature in the port and its surroundings. Sightings of birds, (sea) animals and specific species of trees and plants are monitored by employees and companies.
The sightings are collected and reported via a website.[31]

### Zeeland

The Port of Zeeland emphasises that a good relation with local communities is important (masterplan 2015). Local residents can issue port related environmental complaints at the province of Zeeland. The hotline is available 7 days a week, 24 hours a day. The Port of Zeeland does not actively report the number of complaints or additional measures to reduce nuisances to its surroundings. The Port of Zeeland does organise port days and it sponsors other events for the local population. The Port of Zeeland also has set up policy concerning nature in the port area. This includes the reduction of port activities affecting the quality of surrounding nature as well as the use of undeveloped ground for temporary nature.

**Text box 16 - Conclusions local communities**

The ports take several measures to ensure a good local environmental quality. Local residents and other people can report nuisances at regional local Environmental Service centres. These centres try to locate the sources of the emissions. E-noses are installed in Amsterdam, Groningen, Moerdijk and Rotterdam to help locate the sources of smell nuisances. Furthermore, ports can reduce noise nuisances of local residents by financing improved isolation of houses. Ports often make room for (temporary) nature in the port and actively monitor existing nature in the port area. Ports ensure good local community engagement as well. Local residents are informed via newsletters, information meetings, websites and Facebook groups. Port days offer people a perspective of the various port operations. The ports use these channels to inform its local communities about port operations and possible sources of nuisances. Furthermore local community projects are financed by the ports or companies situated within the port. There is however some room for improvement. The website from the ports of Zeeland does not have section for local communities and for other ports it is unsure where people can offer complaints as a result of port activities. Furthermore, the amount of reporting differs between ports. It is therefore unclear whether the ports pay sufficient effort to their local communities or whether they do not communicate about their efforts.

## 3.9 Sustainability strategy

This paragraph discusses the main trends that affect seaports and whether the strategy documents anticipate these trends. Seaports are an important stakeholder in global trade and developments. In order to remain relevant seaports have to adapt in response to global and local trends. The most important transition is the transition towards a carbon neutral future and the use of renewable energy. As a result port operations can rely less on the use and trade of fossil fuels in the coming years. A complementary transition is the shift towards a circular economy, where various forms of recycling and reuse can address the issue of sustainable resource management. Ports can anticipate this development by investing in bio based solutions and setting up recycling services. A third trend is the increasing economic power of Asian economies, which is expected to impact the European economy. A fourth trend is the continuous development of increases in scale, leading to ever larger vessels that require specific infrastructure. A fifth trend is the shift towards a

[30] De werkweek van een meldkamer-coördinator, Havenkrant 36
[31] Port of Rotterdam : Webappviewer

knowledge economy with higher use of IT applications increasing the efficiency of trade and transport. In order to remain competitive ports have to focus on innovation and knowledge. The ability to adapt port operations towards these changes will determine the future competitiveness of seaports. Do the visions of seaports anticipate future transitions and are concrete measures mentioned? This paragraph will offer a short discussion of the strategy documents of each port.

## Amsterdam

In 2015 the Port of Amsterdam has constructed a port vision until 2030 (Port of Amsterdam, 2015). Amsterdam wants to improve the clusters in which it currently excels. One of those clusters is energy, as Amsterdam is the largest petrol port in the world. Because of, among other reasons, decarbonisation the Port of Amsterdam will not invest in crude oil or refining. Also the Port of Amsterdam will not approve the expansion of coal or oil infrastructure. The Port of Amsterdam wants to improve the use of alternative energy, recycling and biobased fuels. To do so it will expand current operations and create a centre for the development of biobased energy with other relevant stakeholders. The port visions do not discuss the decreasing importance of Europe in global trade. On the contrary the vision predicts that production will return to Europe due to increasing wages in Asia.
The Port of Amsterdam wants to remain accessible for the latest so called Panamax vessels (large vessels). In 2022 the required sea lock is expected to be finished and the latest Panamax vessels can visit the port of Amsterdam. Amsterdam wants to increase the use of IT in the logistical chain. The initiative ‘Neutraal Logistiek Informatie Platform’ is one example to improve the use of IT. The increased shortage of (technically) knowledgeable workers is mentioned as a challenge for the port of Amsterdam. Overall, the port sustainability strategy discusses the main trends and challenges that affect the port.

## Groningen

Groningen Seaports has drafted its vision for 2030 in 2012 and has released two progress report in 2015 and 2018. The Port of Groningen has an elaborate website discussing the port vision in 2030 (Groningen Seaports NV, -). This website reports the time frame for various measures, discusses the stakeholders involved and the results in recent years. Growth areas are energy and data as well as the biobased economy in combination with the chemical and recycling industry. The shift to a circular economy will be stimulated by improving the use of recycled materials and use of rest flows between companies. Improving the use of renewable energy will ensure that less fossil fuels are required. The Port of Groningen does not mention the shifting patterns in global trade. Nor is mentioned how Groningen will adjust to the increasing size of vessels. The Port of Groningen wants to improve the knowledge of (future) employees by adjusting education programs and research to the needs of companies situated in the port.

## Moerdijk

The Moerdijk Port Strategy 2030, presented in 2014, describes the strategy for the further development of the Moerdijk Port and Industrial Estate until 2030 and is endorsed by the shareholders and stakeholders. The vision acknowledges the shift towards a carbon neutral future. The ambition is to become climate neutral in the future. Several projects have started which are geared towards the energy transition. Re-use of materials and bio based industry are trends considered in the vision as well. Although specific measures do not seem to be mentioned besides improving the use of waste streams. Moerdijk wants to position itself as a leading player in the handling of containers entering Europe via the ports of Rotterdam and Antwerp by becoming an extended gate. This means that Moerdijk will facilitate the hinterland transport of containers transhipped from maritime vessels in Antwerp or Rotterdam. Moerdijk will operate as a sort of buffer between the hinterland and the seaports of Antwerp and Rotterdam. Furthermore, Moerdijk expects more export of luxury goods to Asia. Moerdijk is situated inland and the limited draught (vertical distance between the waterline and the bottom of vessel) does not suffice for large seagoing vessels. Therefore it is difficult to compete with ports with higher draughts like Rotterdam, Antwerp and Zeeland. Moerdijk will therefore specialise on frequent and regular transport with inland vessels between other mainports, as well as vessel types that rely less on draught, for example: Ro-Ro vessels, tankers for chemical industry and heavy lift vessels. IT will be necessary to become an extended gate for other mainports. Furthermore, Moerdijk realises that it is becoming difficult to find employees with sufficient IT knowledge as the operations become more technology driven. It is not mentioned how the port will cope with this.

## Rotterdam

The Rotterdam port vision was published in 2011 and describes the port vision until 2030 (Port of Rotterdam, 2011). In 2019 a new version was released by the Port of Rotterdam which replaced the original version. The revision was necessary due to the various development such as newly defined climate goals. According to the Dutch climate agreement a reduction of $CO_2$ emissions of 49% is required in 2030 compared to 1990. As a result the transition to a carbon neutral future is a key element in the port vision. The switch to a carbon neutral future is divided into three steps. The first step focusses on the expansion and development of infrastructure required for sustainable solutions like use of residual heat and CCUS. Step 2 is the switch to a new energy system by developing green hydrogen among others. The third step focusses on the shift to different fuels and raw materials. The initial years focus on pilot projects and upscaling. After 2030 the circular economy will become more main stream which will be reflected in the port (industrial) operations. Furthermore Rotterdam aims to become the most important hub for production, storage and transport of sustainable transport fuels. The decreasing importance of Europe in global trade flows is also considered in the port vision of Rotterdam. Rotterdam aims to stay an important trade point in Europe by becoming a global hub and thereby linking the global supply chains. This requires investments in logistical chains and the expansion of the rail and inland waterway transport infrastructure. In order to facilitate the largest vessels improvements of the accessibility of Rijnmond and its hinterlands are required. The Port of Rotterdam thus wants to remain an important trade hub, and will invest in infrastructure accordingly. In order to adapt to digitalisation and the knowledge economy the Port of Rotterdam vision aims to create a well-functioning innovative climate where stakeholders from different backgrounds are involved. The sustainability strategy of the Port of Rotterdam thus covers the topics that are to be expected.

## Zeeland

In 2015 the Port of Zeeland has documented its vision until 2022 (Zeeland Seaports, 2015). This vision precedes the merger with the Port of Gent. Focus areas are the mix of industry and logistics, the development of multimodal transport and improved cooperation between stakeholders like companies, government and other ports. The environmental ambitions for 2030 of the port region are given in the 'duurzaamheidsambitie 2030' (CE Delft, 2016a) which is constructed in cooperation with the port industry, the province, the local environmental agency and the environmental NGO 'Zeeuwse milieufederatie'[32]. The port authority wants to actively create clusters in the port where companies use waste streams from other companies in order to prepare for the circular economy. Furthermore, new companies will be invited to settle in the port, hereby complementing existing clusters and residual flows. To reduce the environmental impact additional pipelines and railway connections are planned. Various key performance indicators (KPI's) have been constructed to measure the ambitions. Topics include the improvement of air quality, especially PM and $NO_x$, 15% share of bio based production in 2030 and the reduction of $CO_2$ emissions with at least 40% in 2030. The port vision does not discuss changes in trade patterns or the size increases of vessels. The vision discusses the use of IT to form clusters of companies, and besides cooperation with knowledge institutes, no mention of the knowledge economy is made. Three important trends are not included in the port vision until 2022: shifting trade patterns, scale increases and the knowledge economy. The sustainability ambitions until 2030 are extensively discussed in the environmental report and contain topics, targets and methods to achieve the targets.

## Antwerp

Due to the close proximity and connections with the Dutch ports the sustainability strategy of the Port of Antwerp has been included as well. The Port of Antwerp has drafted a vision report in 2018 (Port of Antwerp, 2018). This report has the timeline from 2018 until 2020, the goal of the report is to clarify how the Port of Antwerp will prepare for a sustainable future. The Port of Antwerp focusses on international projects to reduce $CO_2$ and sets up a fund to finance the energy transition. Circular economy is being investigated in demonstration projects. The Port of Antwerp still aims to grow without expanding the port area. The vision document does not mention changing freight patterns. The accessibility of large maritime vessels is not mentioned in the report. Improved hinterland transport is an element in the vision of Antwerp. Better use of the data and IT systems is part of the vision as well. It has not been mentioned how the workforce will adapt to the knowledge economy. The public sustainability strategy document of the port includes most important subjects. However it lacks an outlook towards the long term and the topics are not discussed extensively. The Port of Antwerp does evaluate their vision each year. It seems likely that a longer term sustainability strategy is available for internal use. Releasing a public document discussing the long term sustainability strategy will ensure support of the stakeholders and help maintain support for the envisioned growth of the port.

**Text box 17 - Conclusions sustainability strategy**

All Dutch ports have reported their strategy for the future, mostly until 2030. Zeeland Seaports has a separate report for their sustainability ambitions. All ports include the energy transition and shift towards a bio based and circular economy. However, differences remain in the level of detail. The ports of Amsterdam, Groningen and Rotterdam mention concrete measures and the Port of Zeeland even mentions KPIs and how to monitor them. The public vision of the Port of Moerdijk only mentions that carbon neutral and bio based production is the future. Rotterdam focuses on CCUS to reduce carbon emissions, while Amsterdam is currently researching CCUS possibilities[33]. Groningen Seaports on the other wants to focus on renewable energy. The ports of Amsterdam and Rotterdam have the highest throughput and therefore focus on managing shifting trade patterns in their vision documents. The port of Antwerp has a high throughput as well, but does not mention shifting trade patterns in their short term outlook. The ports of Amsterdam and Rotterdam want to be able to facilitate the

[32] Eerste resultaten 'Duurzaamheid Ambitie 2030' laten gemengd beeld zien

[33] Noordzeekanaalgebied biedt potentieel voor $CO_2$-infrastructuur (2019)

latest and largest vessels. Moerdijk does not focus on large cargo vessels but on niche markets and hinterland transport. IT and knowledgeable personnel is mostly mentioned as a requirement and challenge for future port operations. The Port of Rotterdam is actively stimulating an environment where IT and innovation are central, thereby actually promoting the use of IT. The visions documents of the ports cover the most important topics. However, differences remain in the level of detail. Some ports mention concrete measures, KPIs monitoring documents whereas other ports only mention that carbon neutral and bio based production is the future. Currently it is uncertain whether more comprehensive sustainability strategy exist within ports for internal use. Nevertheless, it is advised for all ports to publicly describe detailed KPIs goals. This should be combined with close monitoring and regularly reporting on the progress made. In this way ports can better ensure that the efforts they put forth are also seen, recognised and supported by the stakeholders involved.

# 4 Ports outside the Netherlands

Among the selected seaports are the largest seaports in the Netherlands (detailed in Chapter 3) as well as several important European seaports with the addition of three ports in North America. Below the characteristics of the international seaports are described.

## Port of Antwerp

The port of Antwerp is the second largest port in Europe after the port of Rotterdam with a market share of almost 19% in 2018 in terms of freight volume (Port of Rotterdam, 2019). It is located alongside the river Western Scheldt about 80 kilometres land inwards. It is connected by road, rail and inland waterways as well as shortsea and pipeline transport. The main types of freight transhipped in Antwerp are containers and liquid bulk. Antwerp is also a leading breakbulk port in Europe. Antwerp is not only the European market leader for the handling of steel and fruit, but also the largest port in the world for the trade of coffee. Antwerp contains a large industrial sector including a mayor petro (chemical) company cluster. The port also contains a nuclear power plant.

## Port of Le Havre

The port of Le Havre is the most southern port in the Hamburg – Le Havre (HLH) range, a range of the largest seaports situated in North Western Europe. Le Havre is responsible for about 5% of throughput in this range. Le Havre is the second largest port in France, and the largest container port in France. It is situated directly at sea on the outlet of the river Seine. The port of Le Havre hosts an industrial complex besides having a logistical function. The total size of the port is about 100 square km and a large share is available for industry. It contains the largest chemical platform in France and the entire Seine Valley entrance is the largest industrial region in France. Various industrial companies are situated in industrial and logistic area, including a car assembly factory, a refinery, a factory for aviation technologies, a thermal power plant and a waste incineration and recycling plant[34].

## Ports of Bremen

The ports of Bremen, situated in Bremen and Bremerhaven, are situated at the mouth of the river Wezer into the North Sea. The port is connected by road, rail and inland waterways and is able to transport almost every type of cargo. The market share of the ports of Bremen is about 5.8% in the Hamburg – Le Havre range (Port of Rotterdam, 2019). The ports of Bremen mainly transports general cargo: containers and vehicles. It is Europe’s second-largest terminal for automobile transhipment after the port of Zeebrugge. Only a small portion of the transported goods in Bremen are bulk goods. The ports of Bremen do not host a large industrial or chemical industry. It does contain offshore wind industry and is Germany’s industry leader in fish and food processing.[35] With a size of 30 square km the ports of Bremen are among the average.

[34] Industrial-port-area-le-havre

[35] Bremerhaven : Fish and Food Industry

## Port of Hamburg

The port of Hamburg is situated along the river Elbe, about 110 kilometres from its mouth on the North Sea. It is also connected to Scandinavia and the Baltic Sea via the Kiel Canal. The port of Hamburg is the third largest port in the range Hamburg - Le Havre with a market share of over 10% in 2018 (Port of Rotterdam, 2019) The port of Hamburg is the largest port in Germany. Containers is the cargo type most transported in Hamburg, although other types of cargo are handled as well. The port also plays a crucial function in supply and waste disposal logistics for industry in Hamburg and the Metropolitan Region. The port contains industrial enterprises and manufacturing industries including a copper smelter, producers of ships and aircrafts and other machinery. Other important businesses are renowned industrial firms from the energy, raw materials, drive technology, shipbuilding, mechanical engineering and fertiliser industry.

## Port of Barcelona

The port of Barcelona is situated along the Mediterranean Sea and is one of the largest ports in Spain. The port of Barcelona is 110 square kilometres and contains three areas, the Old Port, the commercial/industrial port, and the logistics port. The port of Barcelona is one of the largest ports in terms of passenger transport, it has ferry connections with places across the Mediterranean and is often visited by cruises. Containers are the main cargo type that is transhipped followed by dry cargo. The port of Barcelona is home to manufacturers of textiles, pharmaceuticals, chemicals, electronics, and motors.

## Port of London

The port of London is situated along the River Thames and encompasses the area from London up to the mouth of the North Sea. The port of London today comprises over 70 independently owned terminals and port facilities, including among others the port of Purfleet and Tilbury. The port of London is the second largest port in the United Kingdom after Grimsby & Immingham, and the third largest port in containerized goods in the United Kingdom. Once a major refiner of crude oil, today the port only imports refined products. During much of the 20th century the port of London Authority owned and operated many of the docks and wharfs in the Port, but they have all now been either closed or privatised. Today the Port of London Authority acts mainly as a managing authority for the tidal stretch of the River Thames, ensuring safe navigation, and the well-being of the port and its activities. The Port of London Authority has no shareholders and all profits are reinvested into the river. The organisation does not handle cargo, nor manage land where cargo is handled. The total size of the port of London is 10 square kilometres.

## Port of Felixstowe

The port of Felixstowe is the largest container port in the United Kingdom, and it covers almost half of the British container throughput[36]. The port focusses on container transport and therefore no other cargo types are transported via Felixstowe. The port has two main container terminals and a RO-RO terminal. The port does not contain any heavy or chemical industry. As a result the size of the port is limited to 33 square kilometres.

[36] Port of Felixstowe

## Port of Los Angeles

The port of Los Angeles is situated near the city of Los Angeles and next to the port of Long Beach. The port of Los Angeles is the largest container port in Northern America. The port has a market share of 40% of the West coast market (Port of Los Angeles, 2018). Besides containers, automobiles are often transported via Los Angeles. Bulk goods are less predominant for the port of Los Angeles. The size of the port is about 17 square kilometres of land, reflecting that the port does not hosts a large industrial complex. The port of Los Angeles has good rail and road connections.

## Port of Long Beach

The port of Long Beach is situated in the city with the same name in California, United States. The port is an important transhipment port from goods to and from Asia. Like the port of Los Angeles it is specialised in container transport and car import. The port is about 13 square kilometres. Together with the port of Los Angeles the port of Long Beach is responsible for 40% of containerized trade in the United States (Port of Los Angeles, 2018). The port supports businesses in the trade, logistics and real estate sectors, including trucking firms, customs brokers and freight forwarders, shipping lines, warehouses and other enterprises.

## Port of Vancouver

The port of Vancouver is about the same size as the next five largest Canadian ports combined. Home to 27 major terminals, the port is able to handle the most diversified range of cargo in North America: bulk, containers, breakbulk, liquid bulk, automobiles and cruise vessels. The port of Vancouver is situated along Canada's West Coast and is a key port for trade with Asia. The port of Vancouver is connected by rail and road to the hinterland. It is the third-largest port in North America by tonnes of cargo, and the largest with respect to export.

## Size of ports

The sizes in square kilometre of the ports are shown in Table 43. Antwerp and Le Havre are the largest ports in terms of size, while the ports of Felixstowe, London and Vancouver are the smallest. The Dutch seaports, are not among the smallest ports in terms of size in square kilometres. This is mainly due to the functions of the ports. Ports which mainly have a logistical function, for example Felixstowe, London, Barcelona and the North-American ports, are smaller in size. Ports which also hosts an industrial complex, for example Antwerp, Le Havre and Rotterdam are larger in size.

Table 43 - Size (square km) of ports

| Square km | 2017 |
|---|---|
| Antwerp | 121 |
| Barcelona | 11 |
| Bremen | 31 |
| Felixstowe | 33 |
| Le Havre | 100 |
| London | 10 |
| Hamburg | 71 |
| Vancouver | 10 |
| Long Beach | 13 |
| Los Angeles | 17 |
| Amsterdam | 16 |
| Groningen | 28 |
| Moerdijk | 26 |
| Rotterdam | 79 |
| Zeeland | 44 |

The different functions of the seaports are as well reflected in the total throughput of the ports. For example, the port of Groningen has a size of 28 square kilometres and only a throughput of 6 Mton in 2017, while the port of Felixstowe had a throughput of 29 Mton in 2017 with a size of 33 square kilometres. The majority of the ports have a throughput below 100 Mton. The ports of Antwerp, Hamburg, Vancouver, Los Angeles and Rotterdam have throughput volumes over 100 Mton.

Table 44 - Total maritime throughput of ports (Mton) [37]

| Total throughput | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp | 178 | 208 | 214 | 224 | 235 |
| Barcelona | 43 | 46 | 46 | 60 | n/a |
| Bremen | 69 | 73 | 75 | 74 | 74 |
| Felixstowe | 26 | 28 | 28 | 29 | 28 |
| Le Havre | 70 | 68 | 66 | 73 | 72 |
| London | 48 | 45 | 50 | 50 | 53 |
| Hamburg | 131 | 138 | 138 | 137 | 135 |
| Vancouver | 118 | 138 | 136 | 142 | 147 |
| Long Beach | 74 | 81 | 78 | 84 | 84 |
| Los Angeles | 158 | 177 | 183 | 198 | 195 |
| Amsterdam | 73 | 79 | 79 | 81 | 82 |
| Groningen | 3 | 6 | 6 | 7 | 7 |
| Moerdijk | 6 | 6 | 7 | 7 | 7 |
| Rotterdam | 405 | 461 | 467 | 469 | 469 |
| Zeeland | 34 | 34 | 34 | 34 | 37 |

37 UK Government Statistical data sets : Port and domestic waterborne freight statistics: data tables (PORT)
(Port of Rotterdam , 2013) Reference year 2012.
(Port of Rotterdam, 2016) Reference year 2015.

## Added value

The scale of a port can be measured in kilometres or throughput. Both methods have disadvantages. The physical size of a port does not consider the density of business, while throughput only measures the scale of maritime logistics. Other port functions, for example industrial complexes are not included in the throughput. Added value solves this issue as it is an indication of the economic scale of a port. There are however different methods to calculate added value. For example direct added value includes added value directly resulting from port activities. Port activities also have a broader economic impact in the global economy, by for example by increasing the demand for raw materials. These broader effects are called indirect effects. The direct added value of ports is shown in Table 45. The port of Barcelona has a total added value of 2.2 billion Euro, this however includes indirect added value as well. The added values for the ports of Bremen, Felixstowe, Long Beach and Los Angeles are not available. Due to the many data gaps and differences in scope it is not possible to scale ports based on added value.

**Table 45 – Direct added value (mil €) of ports between 2010 and 2017**

| Mil Euro | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Antwerp | n/a | n/a | n/a | 10,815 |
| Barcelona* | n/a | n/a | n/a | 2,209 |
| Hamburg* | n/a | n/a | 12,700 | 12,800 |
| London | n/a | 2,733 | n/a | n/a |
| Le Havre | 4,800 | n/a | n/a | n/a |
| Vancouver | n/a | 3,636 | n/a | n/a |
| Amsterdam | 1,645 | 2,069 | 2,125 | 2,159 |
| Groningen | € 814 | 1,087 | 1,235 | 1,323 |
| Moerdijk | 1,276 | 1,376 | 1,398 | 1,471 |
| Rotterdam | 11,143 | 11,962 | 13,716 | 14,689 |
| Zeeland | 3,119 | 3,241 | 3,477 | 3,594 |

* Results for Barcelona and Hamburg include indirect added value as well.

## 4.1 Climate

Table 46 shows the greenhouse gas emissions in the selected ports. The results show that GHG emissions are not reported in every port. Barcelona, Bremen, Felixstowe and Hamburg have not publicly reported $CO_2$ emissions in the port area. Barcelona, Bremen and Felixstowe do measure the $CO_2$ emissions produced by the port authority but do not collect $CO_2$ emissions from the other companies and mobile sources in the port. Ports which hosts industrial complexes have higher $CO_2$ emissions. Antwerp, Le Havre and the Dutch ports all have $CO_2$ emissions exceeding 5,000 kton. The port of Antwerp is the only port which has $CO_2$ data available for multiple years for the entire port area. The results show that a small increase of $CO_2$ emissions. The ports of London, Long Beach, Los Angeles and Vancouver report $CO_2$ emissions from a selection of sources. Long Beach and Los Angeles focus solely on emissions from mobile sources, which in most ports are only a small portion of total emissions. The Port of London Authority only includes shipping emissions, and does not consider emissions from stationary (factories) and other mobile sources. The Port of Vancouver does include all transport activities as well energy usage by companies. Emission sources not included by the Port of Vancouver are fugitive emissions associated with dust, vapours, and refrigerants, up/downstream emissions associated with the production or consumption of cargoes, as well as emissions associated with heavy industrial processes on or adjacent to port lands, such as chemical or cement manufacturing, which are processes with large quantities of $CO_2$ emissions.

Table 46 – CO2 emissions in port areas

| Kton $CO_2$ | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp* | 18,070 | 18,335 | 18,464 | 18,711 | n/a |
| Barcelona | n/a | n/a | n/a | n/a | n/a |
| Bremen | n/a | n/a | n/a | n/a | n/a |
| Felixstowe | n/a | n/a | n/a | n/a | n/a |
| Hamburg | n/a | n/a | n/a | n/a | n/a |
| Le Havre | n/a | n/a | About 10,000 | n/a | n/a |
| London** | 210 | n/a | 195 | n/a | n/a |
| Long Beach*** | 817 | 850 | 777 | 819 | 836 |
| Los Angeles*** | 837 | 934 | 885 | 908 | 934 |
| Vancouver**** | 947 | 1,079 | n/a | n/a | n/a |
| Amsterdam | 5,906 | 5,977 | 6,191 | 5,397 | n/a |
| Groningen | 7,424 | 10,533 | 13,875 | 13,323 | n/a |
| Moerdijk | 5,364 | 3,800 | 5,163 | 5,825 | n/a |
| Rotterdam | 29,720 | 31,137 | 32,743 | 30,641 | n/a |
| Zeeland | 14,537 | 10,210 | 10,956 | 10,869 | n/a |

* Shipping emissions are not included.

** London only reports $CO_2$ emissions from shipping.

*** Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

**** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

It is very difficult to compare the $CO_2$ emissions of the various ports due to the differences in scope for which the $CO_2$ emissions are collected. Of the ports that include $CO_2$ emissions from all sources Rotterdam, Antwerp and Groningen have the highest emissions. These three ports have an industrial complex as well as an energy production industry. The emissions in Antwerp have slightly increased between 2010 and 2017. The emissions from mobile sources in Long Beach and Los Angeles have increased as well. At the same time throughput has increased and as a result the carbon intensity relative to throughput has decreased.

## Mitigation measures

Not much information is available about mitigation measures applied in port areas. This is partly due to the fact that certain measures are taken by independent companies inside the port area. The relevant information is therefore not always available for the port authority. Table 47 shows the cumulative annual reduction through mitigation measures taken up to the year 2018. Antwerp reports 0.1 reductions in Mton $CO_2$ due to projects where residual steam is used. In the port of Antwerp about 44 MWe biomass has been used since 2010, it is however uncertain how many $CO_2$ is saved by this. Some ports are doing research in mitigation measures. Antwerp has a carbon capture and usage (CCU) project where sustainable methanol is produced from $CO_2$, that has been captured, and green hydrogen that is produced using renewable energy using an electrolysis installation. Le Havre has several projects related to CCS and hydrogen as well as looking to transform a coal powered plant to a plant running on biomass. In the port of London several companies use residual heat but actual figures are not available. The Dutch Ports seem to be the most involved in mitigation measures, which can partly be explained by the existence of industrial complexes in the Dutch ports.

Table 47 - Most important mitigation measures (cumulative) in port areas

| Annual Mton $CO_2$ reduction | Biomass | Biomass (certified) | Residual heat | Carbon capture and usage | Carbon capture and storage | Steam | Hydrogen pipeline | Estimation 2018 |
|---|---|---|---|---|---|---|---|---|
| Antwerp | | | 0.1* | | | | | 0.1 |
| Amsterdam | | | 0.21** | | | | | 0.21 |
| Groningen | 0.25** | 0.25** | | | | 0.80* | | 1.05 |
| Moerdijk | 0.13** | 0.13** | 2.53* | | | Included in the 2.53* | | 2.66 |
| Rotterdam | 0.43* | Unclear | 0.16** | 0.4*** | | 0.25** | | 1.3 |
| Zeeland | 0.05* | Unclear | 0.25* | Included in the 0.25* | | | 0.01** | 0,31 |

$CO_2$ reduction in Moerdijk estimated based on production of heat (Mw) in Moerdijk relative to Mw and $CO_2$ reduction other ports. Data for year: * 2018 ** 2017, *** 2015.

### 4.1.1 Conclusions climate

Ports can be an important source of greenhouse gas emissions due to amount of transport and industrial activity in port areas. It is surprising that various ports still do not report CO2 emissions. This is also the case in the port of Le Havre which contains a large industrial complex. The ports with do report CO2 emissions do so in different scopes and don't always include all sources of emissions. Ports without an industrial complex focus on emissions from shipping or mobile sources. Many ports mention the ambition to reduce climate emissions. The emissions between 2010 and 2015 in most ports however have not been reduced. Only the ports of Amsterdam and Zeeland show a reduction of CO2 emissions. The climate impact can also reduce through the use of mitigation measures. The data availability on this topic is limited as most ports do not publicise this information. The results seem to indicate that more mitigation measures are applied in the Dutch ports and Antwerp. The CO2 reduction of these measures is however limited compared to the CO2 emissions of the ports.

## 4.2 Renewables

Many ports are involved with some sort of energy production due to their good transport connections. As a result of climate change a shift towards renewable energy is required. Several ports are already involved with renewable energy production. However, this information is not always available or being published. Not many port authorities collect data on renewable energy themselves. As a result the quality of the collected data on renewable energy capacity is limited, and the results displayed in Table 48 should be considered indicative.

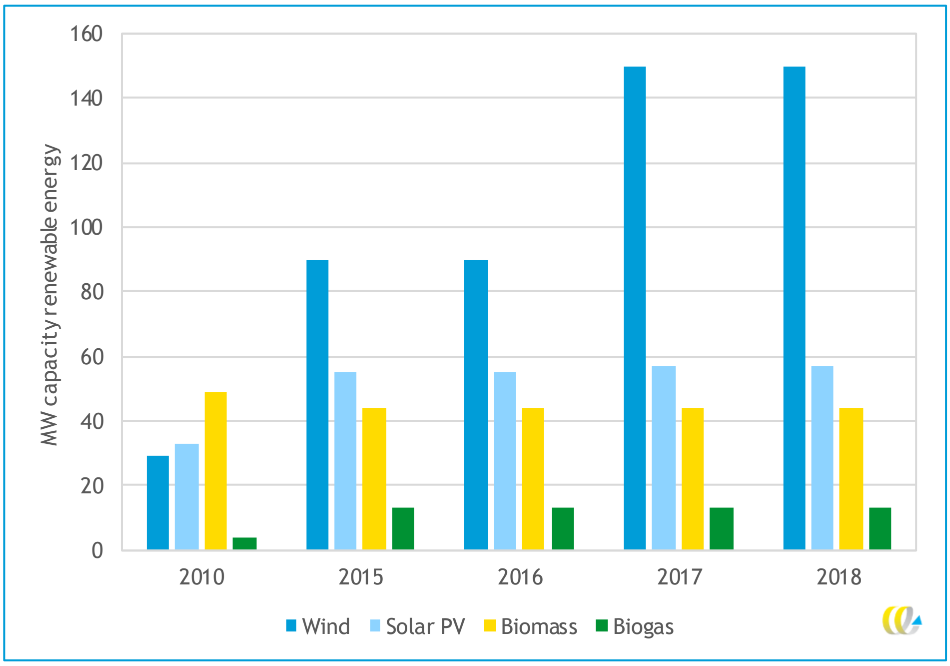
The port of Antwerp produces renewable energy via wind, solar PV, biomass and biogas since 2010. The capacity of wind energy has been increased significantly between 2010 and 2018. The port of Barcelona and Los Angeles have solar PV installed, though the capacity is significantly lower than Antwerp. In 2016 Hamburg has reported 25 MW capacity of wind turbines, in 2018 the capacity increased to 42 MW. In the port of Hamburg geothermal energy is produced, although the capacity of 1.3 MW is relatively small. According to the port authority of Hamburg also renewable energy using solar PV and solar thermal is produced in the port area. The capacity of these production methods is however unknown, only the output (in MWh) is known to the port authority. Some renewable energy production is not included in Table 48 because the capacity is unknown. The port of Bremen has produced 35 MWh in 2016 through solar PV and is considering hydrogen as a future energy source. Felixstowe has solar PV in place as well and produced 435 MWh in 2016. Windmills are situated in the port of London, though the capacity is unknown. In the port of Hamburg and the port of Long Beach there are solar facilities on the roofs of some warehouses and terminals.

**Table 48 - MW renewable energy capacity installed in seaports**

| Port | Type of measure | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Antwerp | Wind | 29 | 90 | 90 | 150 | 150 |
| Antwerp | Solar PV | 33 | 55 | 55 | 57 | 57 |
| Antwerp | Biomass | 49 | 44 | 44 | 44 | 44 |
| Antwerp | Biogas | 4 | 13 | 13 | 13 | 13 |
| Barcelona | Solar PV | 0 | 0 | 0 | 5 | 5 |
| Hamburg | Wind | n/a | n/a | 25 | n/a | 42 |
| Hamburg | Geothermal | n/a | n/a | n/a | 1.3 | 1.3 |
| Los Angeles | Solar PV | n/a | 3 | n/a | 10 | n/a |

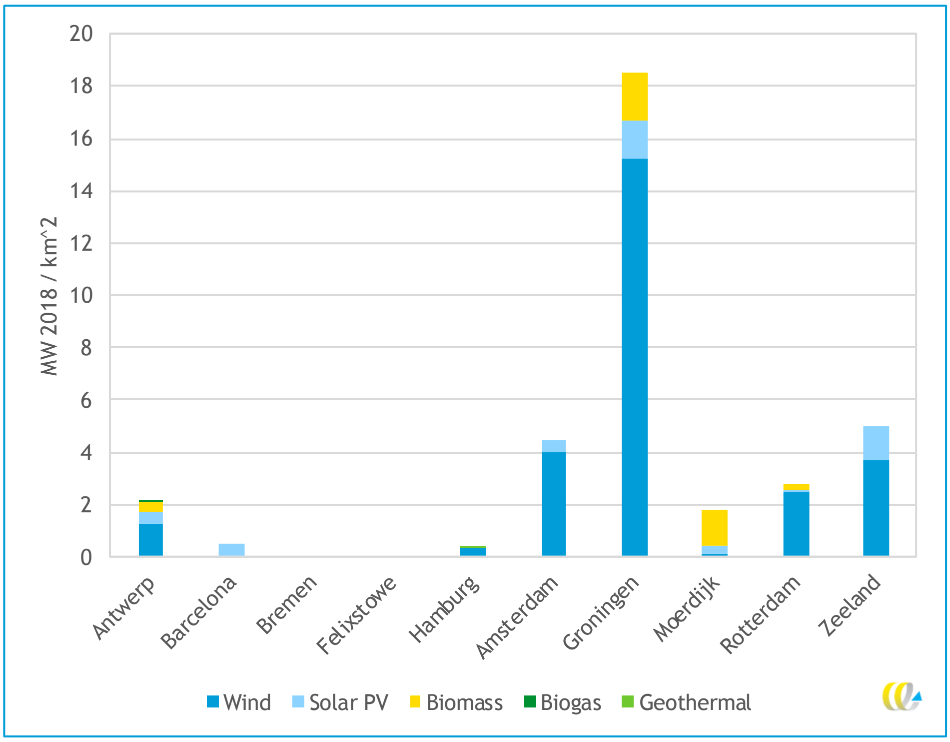
Antwerp has presented the renewable energy capacity for the years 2010, 2016, 2017 and 2018 as is shown in Figure 39. The port of Antwerp has four types of renewable energy: Wind, solar PV, biomass and biogas. In 2010 the most important sources of renewable energy were biomass and solar PV. In 2018 wind energy is the most important source of renewable energy with over 150 MW capacity. The capacities of solar PV and biomass have not changed much between 2010 and 2018. Renewable energy production through biogas has increased between 2010 and 2016.

**Figure 39 - Renewable energy capacity installed port of Antwerp 2010 - 2018**



The renewable energy capacity relative to size is shown in Figure 40. The port of Groningen has the most renewable energy capacity relative to square kilometre. The other Dutch ports, except Moerdijk, have significant amounts of renewable energy capacity compared to the international ports. Only the port of Antwerp and Hamburg are visible in the figure.

**Figure 40 - Renewable energy capacity (average 2015- 2018) relative to size (square km)**




## 4.2.1 Conclusions renewables

The amount of renewable energy capacity installed seems to differ significantly between ports. Some ports have been active longer in renewable energy production whereas others have just started. As a result not all ports collect and report data on renewable energy production. This leads to uncertain results in some cases. The data quality can be greatly improved by a uniform method for monitoring and reporting data. In general we see that ports with a focus mostly on transport have only limited renewable energy capacity. The Dutch and Flemish ports, which also have a function in energy production and industry, have more renewable energy capacity installed compared to the other ports. At the same time the port of Le Havre has similar characteristics as the Dutch ports but currently does not report any production of renewable energy.

# 4.3 Air quality

This paragraph discusses the emissions that influence the air quality in ports, the concentrations of air quality pollutants and the most important measures that improve the air quality.

### 4.3.1 Particulate matter

As discussed in Paragraph 3.4.1 particulate matter (PM) is the term for a mixture of solid particles and liquid droplets found in the air mainly caused by traffic and industry. Two types of particulate matter that generally are measured are $PM_{10}$ and $PM_{2,5}$. $PM_{10}$ are inhalable particles, with diameters that are 10 micrometres and smaller. $PM_{2,5}$ are fine inhalable particles, with diameters that are 2.5 micrometres and smaller.

Table 49 shows the emissions of $PM_{2,5}$ measured in seaports, whereas Table 50 shows the emission of $PM_{10}$. In Vancouver only $PM_{2,5}$ emissions are measured whereas in London only $PM_{10}$ emissions are measured. The Port of London only focusses on shipping emissions since the London port authority only manages the water in the port. Large contributors of particulate matter emissions are (road) traffic and industry. As a result larger ports, have higher emissions of particulate matter. The port of Rotterdam, Zeeland and Antwerp have the highest emissions. The lowest emissions are in Moerdijk, Groningen, Long Beach and Los Angeles. However, in Long Beach and Los Angeles only emissions from mobile sources are included. The ports in North America have shown a significant decrease in emissions from 2010 up to 2015. This is the result of the introduction of the North American Emission Control Area for marine vessels in 2012 by the International Maritime Organisation (IMO). The port of Groningen is the only port with higher emissions in 2017 compared to 2010.

**Table 49 – $PM_{2,5}$ emissions in port areas**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp | 0.7 | 0.58 | 0.6 | 0.6 | n/a |
| Barcelona | n/a | n/a | n/a | 0.25 | n/a |
| Long Beach* | 0.27 | 0.16 | 0.13 | 0.13 | 0.13 |
| Los Angeles* | 0.24 | 0.14 | 0.12 | 0.12 | 0.13 |
| Vancouver | 0.89 | 0.29 | n/a | n/a | n/a |
| Amsterdam | 0.43 | 0.43 | 0.39 | 0.34 | n/a |
| Groningen | 0.12 | 0.12 | 0.11 | 0.13 | n/a |
| Moerdijk | 0.21 | 0.08 | 0.10 | 0.10 | n/a |
| Rotterdam | 1.20 | 1.02 | 0.83 | 0.83 | n/a |
| Zeeland | 0.87 | 0.63 | 0.69 | 0.80 | n/a |

* Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

$PM_{10}$ is measured in several ports as well. Rotterdam, Antwerp, Hamburg and Zeeland have the highest emissions. Interestingly $PM_{10}$ emissions have increased in Antwerp since 2015 while $PM_{2,5}$ emissions haven't. The ports in North-America have lowered their emissions from mobile sources since 2010. The port of London shows a reduction of $PM_{10}$ emissions related to shipping. $PM_{10}$ emissions have increased in the ports of Antwerp, Moerdijk and Zeeland.

**Table 50 – $PM_{10}$ emissions in port areas**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp | 1.1 | 1 | 1.15 | 1.3 | n/a |
| Barcelona | n/a | n/a | n/a | 0.28 | n/a |
| Hamburg | n/a | 0.031 | 0.03 | 0.045 | 0.051 |
| London* | 0.17 | 0.14 | n/a | 0.11 | n/a |
| Long Beach** | 0.32 | 0.17 | 0.14 | 0.14 | 0.14 |
| Los Angeles** | 0.27 | 0.15 | 0.13 | 0.13 | 0.13 |
| Amsterdam | n/a | 0.50 | 0.46 | 0.41 | n/a |
| Groningen | n/a | 0.15 | 0.14 | 0.17 | n/a |
| Moerdijk | n/a | 0.07 | 0.09 | 0.09 | n/a |
| Rotterdam | n/a | 1.35 | 1.25 | 1.24 | n/a |
| Zeeland | n/a | 0.76 | 0.88 | 1.00 | n/a |

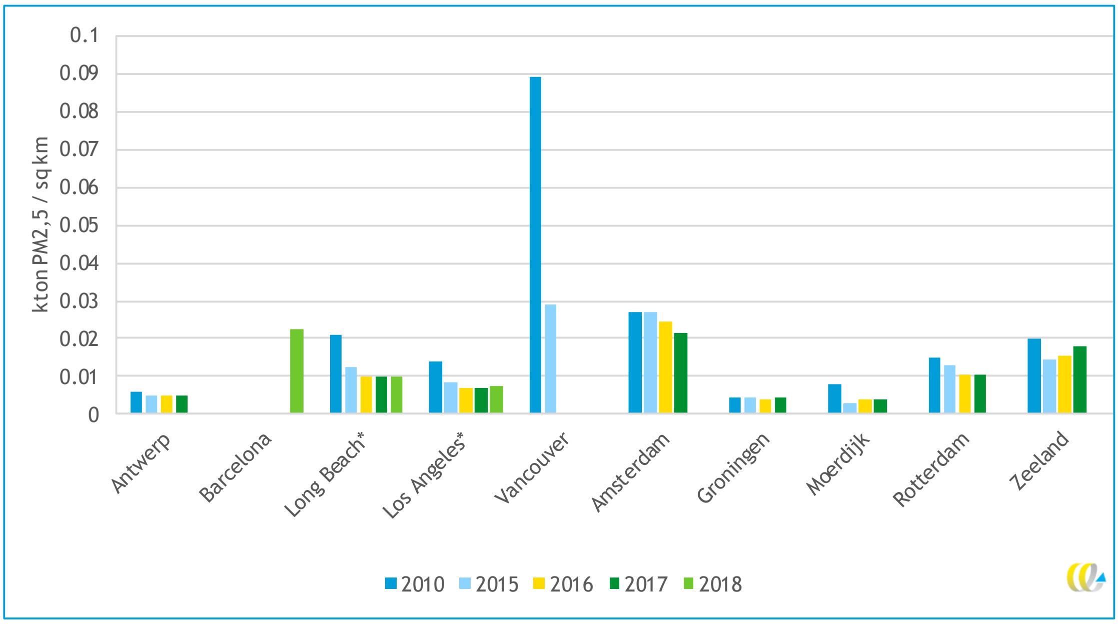
* Only shipping emissions.

** Emissions in the ports of Long Beach and Los Angeles only include mobile sources.

### *Relative particulate matter emissions*

Particulate matter is mainly emitted by transport as well as industrial processes. For this reason it is better to compare the emissions relative to size of the ports, as this better captures both the logistics as well as the industrial complexes than maritime throughput figures do. Figure 41 shows the $PM_{2,5}$ emissions relative to the size in square kilometres of ports. The ports of Vancouver, Amsterdam and Barcelona have relative highest emissions of particulate matter. These three ports are situated in cities where space is scarce and as a result businesses in these ports are more concentrated. The higher concentration of business results in higher emissions per square kilometre. Most ports show a reduction in particulate matter emissions. Only in the port of Moerdijk and Zeeland emissions have increased during recent years.

**Figure 41 – $PM_{2.5}$ emissions relative to size (square kilometre)**

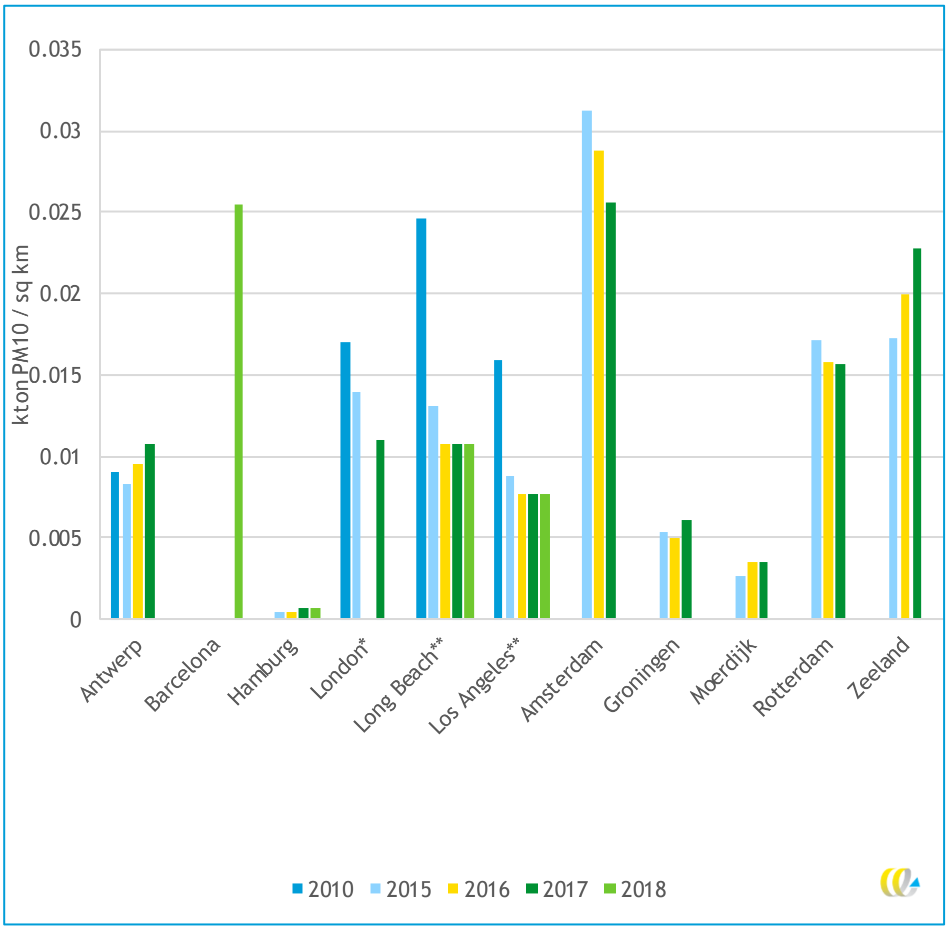



* Only shipping emissions.

** Emissions in the ports of Long Beach and Los Angeles only include mobile sources.

The emissions of $PM_{10}$ relative to size are shown in Figure 42. The highest emissions per square kilometre can be found in Barcelona, Amsterdam and Zeeland. The lowest emissions per square kilometre can be found in Hamburg, Zeeland and Moerdijk.

**Figure 42 – $PM_{10}$ emissions in port areas relative to size (square kilometres)**

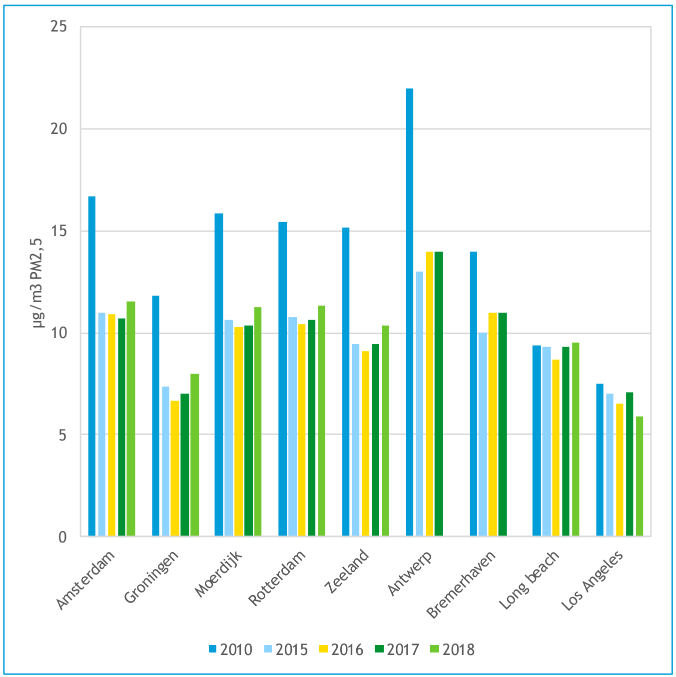


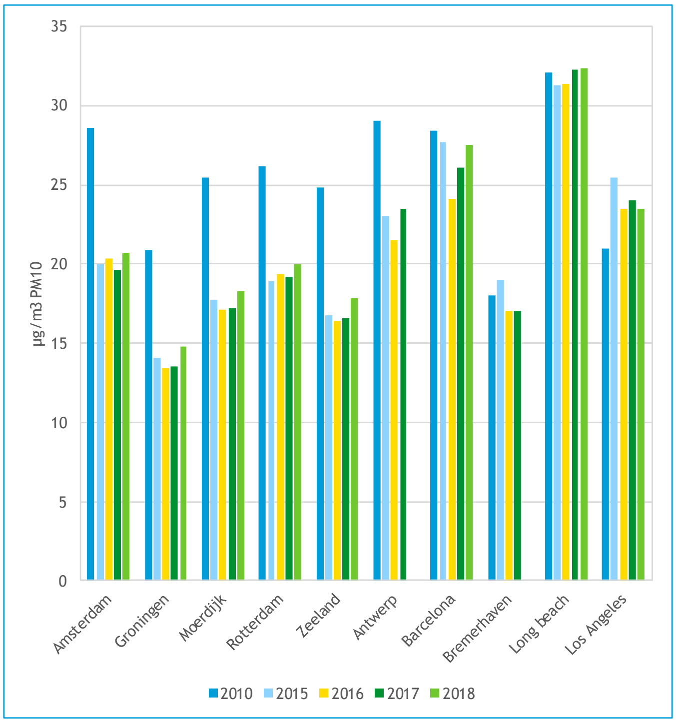

* Only shipping emissions.

** Emissions in the ports of Long Beach and Los Angeles only include mobile sources.

The concentrations of $PM_{2,5}$ and $PM_{10}$ are shown in Figure 43. The concentrations in the port areas are influenced by sources outside the port. As a result ports with the highest emissions per square kilometre, Amsterdam, Zeeland do not have the highest concentration compared with the other ports. Interestingly $PM_{2,5}$ concentrations are among lowest in Long Beach, whereas $PM_{10}$ concentrations are among the highest.

**Figure 43 – $PM_{2,5}$ and $PM_{10}$ concentrations in port areas**




* The 2010 results presented for the Dutch ports are from the year 2011. For certain ports data is only available for a selection of years.

## 4.3.2 Nitrogen oxides

As discussed in Sector 3.4.2 nitrogen dioxide is an irritant gas is mainly emitted by traffic and industry. Nitrogen dioxide is released during combustion at high temperature and can lead to damages to human health and ecosystems.

Table 51 shows the $NO_x$ emissions in port areas between 2010 and 2018. The largest port in terms of throughput, Rotterdam, Antwerp, Los Angeles, Vancouver and Hamburg also have the highest emissions of $NO_x$. The higher throughput of these ports results in more transport movements in the port areas. The ports with lowest throughput, Amsterdam and Groningen, also have low $NO_x$ emissions. The port of London only includes shipping emissions and as a result also reports low $NO_x$ emissions compared to the other ports. Since mobile sources mainly contribute to $NO_x$ the ports of Long Beach and Los Angeles have levels comparable with other ports. Most ports show declining $NO_x$ emissions. Only in Groningen, Moerdijk and Zeeland emissions have increased between 2015 and 2017.

**Table 51 – $NO_x$ emissions in port areas**

| kton $NO_x$ | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp | 22.9 | 22.3 | 21.2 | 19.7 | n/a |
| Barcelona | n/a | n/a | n/a | 5.44 | n/a |
| Hamburg | n/a | 51.09 | 47.84 | 51.32 | 65.68 |
| London* | 3.28 | 2.80 | n/a | 3.05 | n/a |
| Long Beach** | 8.40 | 8.21 | 6.95 | 6.95 | 6.95 |
| Los Angeles** | 8.62 | 7.48 | 6.72 | 6.62 | 6.55 |
| Vancouver*** | 13.29 | 12.97 | n/a | n/a | n/a |
| Amsterdam | n/a | 4.07 | 3.50 | 3.06 | n/a |
| Groningen | n/a | 3.98 | 4.22 | 4.15 | n/a |
| Moerdijk | n/a | 1.81 | 2.66 | 2.84 | n/a |
| Rotterdam | n/a | 21.62 | 19.82 | 19.43 | n/a |
| Zeeland | n/a | 5.26 | 5.87 | 5.42 | n/a |

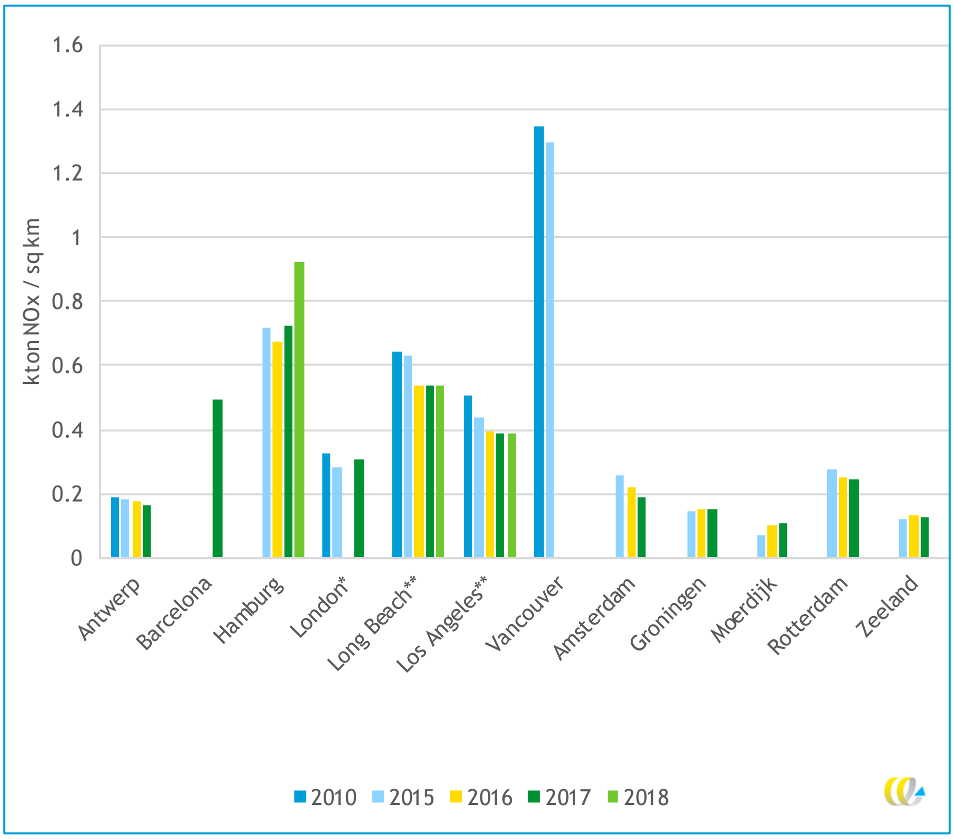
* Only shipping emissions.

* Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

The $NO_x$ emissions relative to size in square kilometre are shown in Figure 44. Most ports show a reduction of relative $NO_x$ emissions. The highest emissions per square kilometre are found in Vancouver while the lowest are found in the Dutch ports. Differences between ports can be the result of different scopes and methods to calculate emissions.

Figure 44 - $NO_x$ emissions in port areas relative to size (square km)



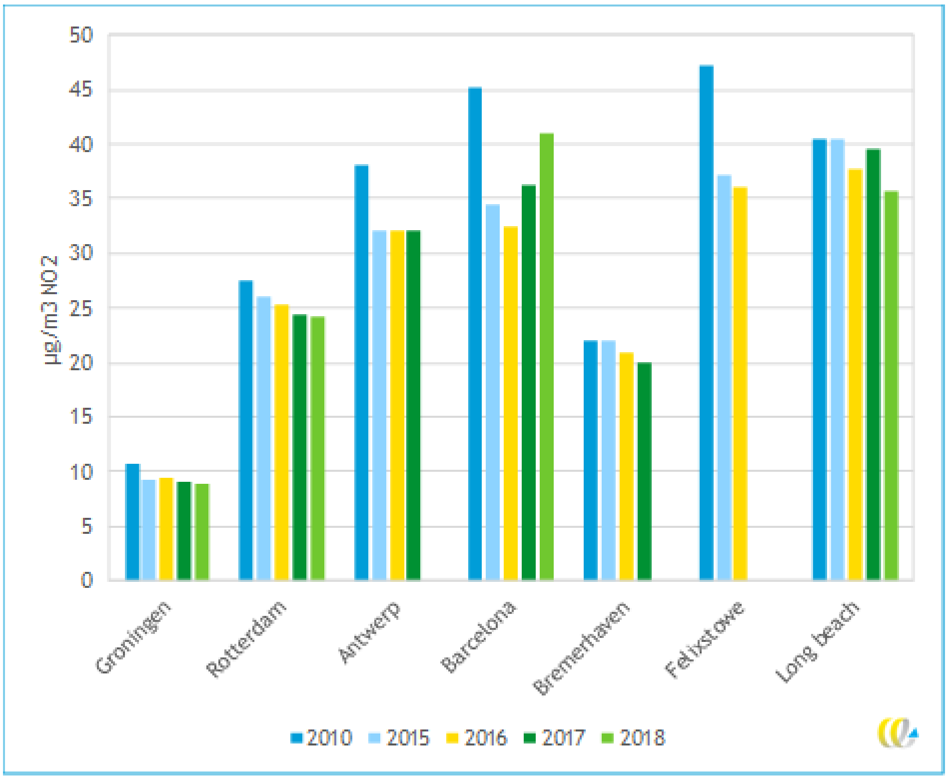

* Only shipping emissions.

* Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

The average concentration of $NO_x$ in the port areas are shown in Figure 45. The lowest concentration can be found in Groningen, the highest in Antwerp, Barcelona, Felixstowe and Long Beach. Most ports show a reduction in $NO_x$ concentrations, only in Barcelona the concentration has increased between 2010 and 2018. It is uncertain whether this increased concentration is the result of higher emissions in the port area.

Figure 45 – Year average nitrous oxide concentration in port areas




* The 2010 results presented for the Dutch ports are from the year 2011. For certain ports data is only available for a selection of years.

### 4.3.3 Other substances

In this subparagraph the air quality relevant substances sulphur oxides and carbon monoxide are discussed.

#### *Sulphur oxides*

As discussed in Subparagraph 3.4.3 sulphur oxides are emitted during the combustion of fossil fuels like crude oil and coals. It can lead to irritations of airways and hamper respiratory functions of patients with COPD. Main sources of emissions are industry, refineries and maritime transport. Maritime shipping however still uses fuel with relatively higher sulphur contents. The International Maritime Organisation has recently introduced limitation to the amount of sulphur maritime fuel can contain (IMO, 2019).

Refineries as well as other industries are also located in the ports of Antwerp, Hamburg, Rotterdam and Zeeland. These ports have the highest emissions of $SO_x$ of the selected seaports. The ports in North America show a significant reduction of $SO_x$ emissions since 2010. From 1st August 2012 onwards an emission control area came into force for ships off the coasts in Canada and the United States. Vessels calling US ports are required to change over to low sulphur fuel oil (LSFO). As a result sulphur emissions are significantly lower. The data from ports of Long Beach, Los Angeles and Vancouver do not include emissions from industrial sources like refineries. The results can therefore not be directly compared with the other ports.

**Table 52 - Sulphur oxide emissions in port areas**

| kton $SO_x$ | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Antwerp | 14 | 11.3 | 11.2 | 10 | n/a |
| Hamburg | n/a | 1.009 | 0.943 | 0.556 | 0.387 |
| London* | 0.444 | 0.379 | 0 | 0.111 | n/a |
| Long Beach** | 1.921 | 0.244 | 0.208 | 0.224 | 0.219 |
| Los Angeles** | 1.338 | 0.132 | 0.114 | 0.121 | 0.118 |
| Vancouver*** | 6.19 | 0.268 | n/a | n/a | n/a |
| Amsterdam | 0.75 | 0.99 | 0.50 | 0.31 | n/a |
| Groningen | 1.43 | 1.52 | 1.39 | 1.76 | n/a |
| Moerdijk | 0.56 | 0.22 | 0.27 | 0.27 | n/a |
| Rotterdam | 17.09 | 14.27 | 13.67 | 12.73 | n/a |
| Zeeland | 3.82 | 2.13 | 2.61 | 2.25 | n/a |

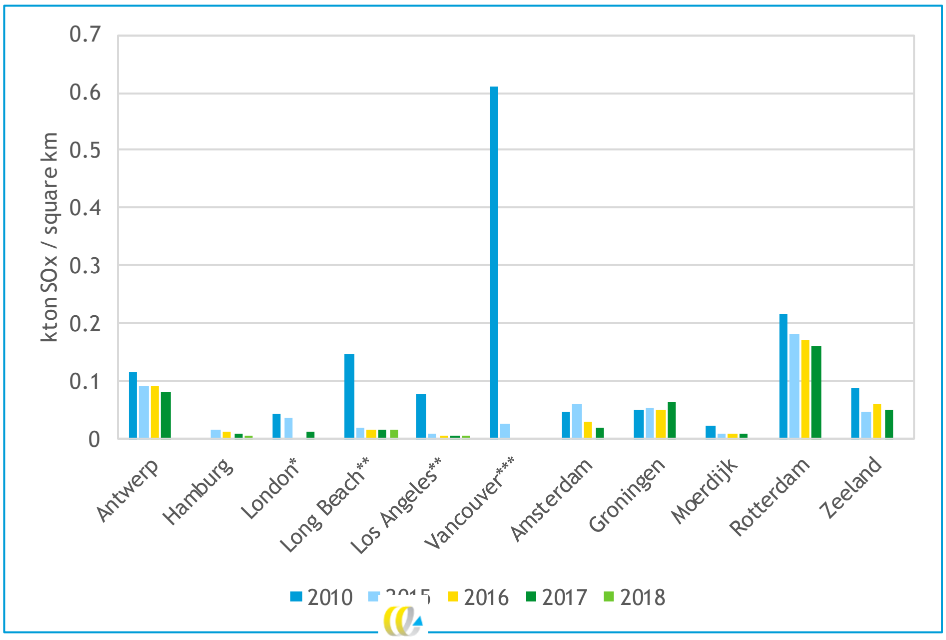
* Only shipping emissions.

** Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

The sulphur oxide emissions relative to size are shown in Figure 46. Relative emissions have decreased significantly in Hamburg, Long Beach, Los Angeles and Vancouver. Emissions are currently highest in Rotterdam, Antwerp and Zeeland. Most ports show a decrease in $SO_x$ emissions, only in Groningen the emissions have increased.

**Figure 46 - Sulphur oxide emissions in port areas relative to size (square kilometre)**



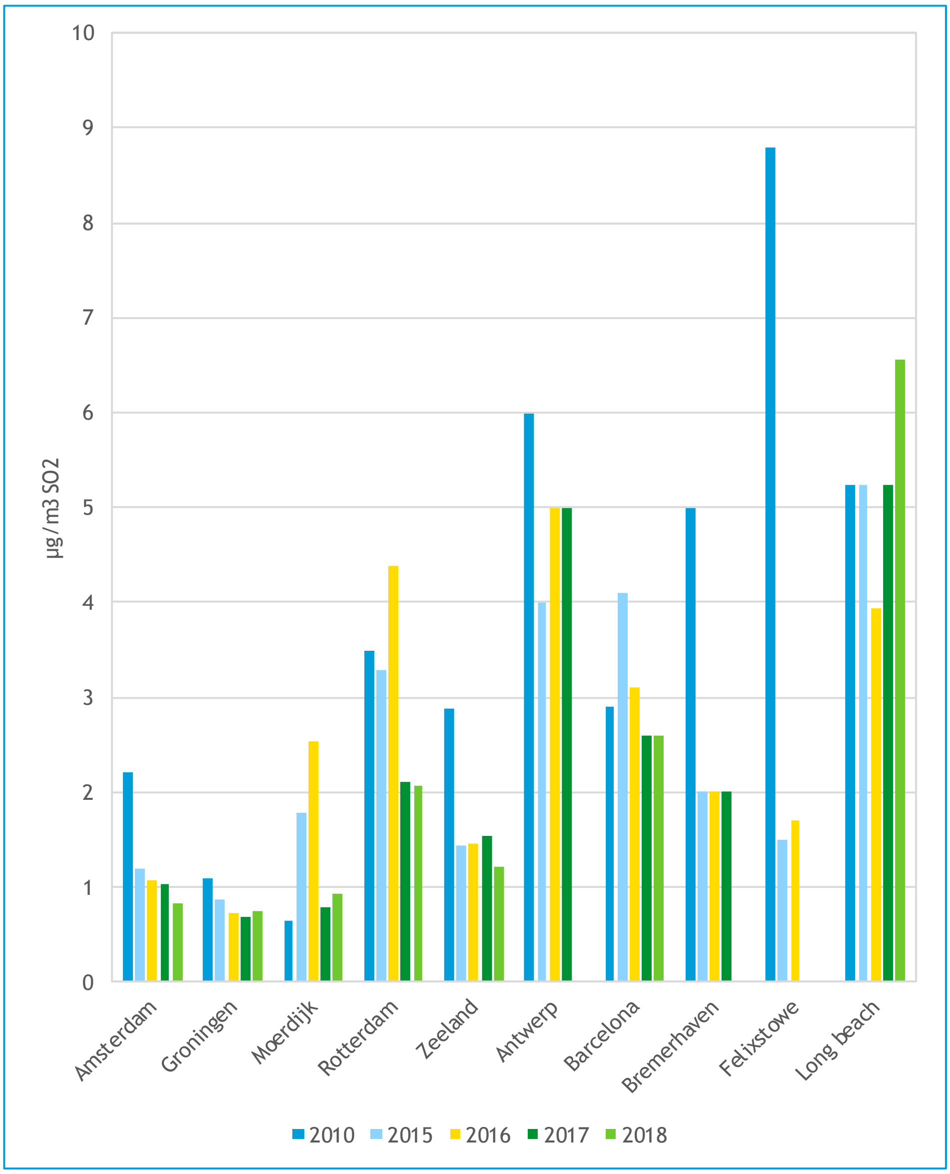

* Only shipping emissions.

** Long Beach and Los Angeles only report $CO_2$ emissions from mobile sources.

*** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

The sulphur oxide concentration in the port areas can be seen in Figure 47. Although the sulphur emissions in the port of Long Beach have reduced dramatically, since 2010 no reduction in the sulphur oxide concentration in the port occurred. Apparently other sources in or outside port, for example industries, influence the concentration in the port as well. Large reductions in the concentration of sulphur oxide are seen in Amsterdam, Rotterdam, Zeeland, Bremerhaven and Felixstowe.

**Figure 47 - Year average sulphur oxide concentration in port areas**




* The 2010 results presented for the Dutch ports are from the year 2011. For certain ports data is only available for a selection of years.

## *Carbon monoxide*

As discussed in Subparagraph 3.4.3 carbon monoxide is a colourless gas emitted by incomplete combustion such as with transport, stoves and certain types of industrial processes. Main sources are transport and industry. Table 53 shows the emissions of carbon oxide in the port areas. The Dutch ports have significantly higher emissions than the ports in North America. However, the ports in North America do not include emissions from all sources and therefore no conclusions can be drawn based on the differences. Emissions in most Dutch ports are decreasing, emissions in the North American ports have increased, as is the case in the port of Zeeland.

**Table 53 – CO emissions in port areas**

| kton CO | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Long Beach* | 1.50 | 1.82 | 1.49 | 1.58 | 1.76 |
| Los Angeles* | 1.74 | 1.90 | 1.89 | 1.99 | 2.13 |
| Vancouver** | n/a | 2.28 | n/a | n/a | n/a |
| Amsterdam | 12.43 | 10.76 | 10.66 | 10.57 | n/a |
| Groningen | 9.38 | 4.77 | 2.58 | 5.42 | n/a |
| Moerdijk | 1.62 | 1.50 | 1.33 | 1.33 | n/a |
| Rotterdam | 27.06 | 21.21 | 20.05 | 17.14 | n/a |
| Zeeland | 8.81 | 8.20 | 8.27 | 9.97 | n/a |

* Long Beach and Los Angeles only report CO emissions from mobile sources.

** Vancouver only includes emissions related to logistical processes: for example, emissions associated with heavy industrial processes are not included.

### 4.3.4 Mitigation measures

Ports can impose several measures to improve the air quality in port areas, for example environmental zones, the supply of onshore power and discounts for more environmental forms of transport. We will discuss the most relevant measures in this paragraph.

#### *Onshore power Supply*

Onshore power supply allows vessels to switch off auxiliary engines during berth. This will reduce the emissions from vessels and improve the air quality in the port area. Onshore power supply is currently offered in most ports. The results in Table 54 show the number of OPS connection points.

**Table 54 – Number of onshore power supply connection points**

| Number of OPS connection points | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Amsterdam | 164 | 166 | 170 | n/a |
| Groningen | n/a | n/a | n/a | n/a |
| Moerdijk | n/a | n/a | n/a | 10 |
| Rotterdam | n/a | n/a | 1 | 1 |
| Zeeland | n/a | 64 | 64 | 68 |
| Antwerp | n/a | n/a | 5 | 39* |
| Bremen | n/a | 25 | n/a | n/a |
| Hamburg | n/a | 1 | 1 | 1 |
| Long Beach | n/a | n/a | n/a | 75 |
| Los Angeles | n/a | n/a | n/a | 75 |
| Vancouver | n/a | n/a | n/a | 3 |

* 30 points are reserved for vessels of the port authority.

These points do not distinguish between maritime and inland waterway transport. The ports in the Netherlands, Belgium and Germany are suited for inland waterway vessels and maritime vessels. The ports in North America are not situated alongside a commercially navigable river and the connection points are designed for maritime vessels. This can be cargo vessels as well as cruise vessels. Onshore power supply for cruise vessels is offered in Hamburg, Los Angeles and Vancouver. Barcelona currently has no OPS connections but is starting a study on the feasibility of providing OPS. The port authority of London is planning to perform a similar study. Table 55 summarizes the type of onshore power provided for a selection of the selected ports.

**Table 55 - Type of onshore power facilities for maritime vessels**

| Year of introduction | Port | Country | Voltage (kV) | Type of vessels |
|---|---|---|---|---|
| 2004 | Los Angeles | USA | 6,6 | Container, cruise |
| 2008 | Antwerp | Belgium | 6,6 | Container |
| 2009 | Vancouver | Canada | 6,6 & 11 | Cruise |
| 2011 | Long Beach | USA | 6,6 & 11 | Container |
| 2012 | Rotterdam | Netherlands | 11 | ROPAX |
| 2015 | Hamburg | Germany | 6,6 | Cruise |

Source: Platform schone scheepvaart (2015); WPSP (2019).

The number of connections does not provide information about the extent to which onshore power supply is used. Onshore power often is more cumbersome and more expensive than the use of auxiliary engines. Therefore the European ports often measure the amount of electricity supplied through onshore power supply. Table 56 shows the amount of electricity provided through onshore power supply for the years available. Information for many ports and years is missing. The limited data availability is partly explained by different methods of data collection used in the North American ports.

**Table 56 - Onshore power supplied (MWh)**

| MWh | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Amsterdam | 2,100 | 2,500 | 2,100 | n/a |
| Groningen | 1,403 | n/a | 968 | 1,114 |
| Rotterdam | 7,680 | 6,681 | 6,297* | n/a |
| Antwerp | 550 | 1100 | 1900 | 1900 |
| Hamburg | n/a | 12 | 12 | 12 |

* Results 2017 only contain maritime vessels.

The ports in North America use different methods to measure the extent to which onshore power supply is used. First of all they measure the number of vessels visiting that are capable of using onshore power. Secondly the number of successful connections is measured and the percentage of capable vessels using onshore power. The port of Vancouver also quantifies the amount of fuel saved and the environmental benefits in tonnes of $CO_2$ saved and air quality improvements[38]. The Californian law requires vessels visiting the ports of Los Angeles and Long Beach to reduce emissions at berth by either switching to onshore power or by using alternative control technologies. In 2020 at least 80% of the fleet calls must use onshore power. Additionally, if a ship is currently equipped for onshore power and an

[38] Port of Vancouver : environment, air-energy-climate-action

onshore power-ready berth is available, the ship must plug in to onshore power.
The regulation applies to container ships, reefer vessels, and cruise ships (California Air Resources Board, 2020).

Table 57 shows the number of successful connections of vessels in the North American ports. The information for the ports of Long Beach and Los Angeles is incomplete. The use of onshore power in the port of Vancouver fluctuates between years. However, in general over 70% of all capable vessels use onshore power. It is unclear what share of all vessels is capable of connecting. In 2018 the port in Los Angeles has a lot more successful connections compared to the port of Vancouver. Unfortunately, similar to Table 56, data for many years is missing. As a result it is unclear whether the usage of onshore power is increasing. A uniform standard for data collection can greatly improve the knowledge about onshore power supply and the impact is can have on improving air quality.

**Table 57 – Number and percentage of successful connections of capable vessels**

| Successful connections (number and %) | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Long Beach | n/a | n/a | n/a | n/a/48% |
| Los Angeles | n/a | n/a | n/a | 615/81% |
| Vancouver | 77/84% | 54/77% | 54/79% | 63/69% |

The seaports do not offer much specifications about the type of vessels that are able to or actually use the onshore power facilities. There seems to be a lot of untapped potential for the use of onshore power. Based on the current data it is often unclear which type of vessels do use onshore power and how the uptake of onshore power can be improved. It looks like the ports of Long Beach and Los Angeles are success stories although it remains uncertain how much energy (in MWh) is actually provided.

### *Environmental discounts*

Specifically for maritime vessels a program is in place called the Environmental Ship Index (ESI). Vessels receive a score from 0 to 1,000 that reflects their environmental performance. Many of the selected ports offer a discount for vessels with a certain ESI score. The ports of Long Beach and Vancouver do offer discounts for environmental friendly vessels but via different program. The port of Felixstowe does not offer environmental discounts while the discount in the port of Le Havre is not part of the standard port tariffs. The discount is only accessible by contacting the port authority. Table 58 shows the minimum score applied in various ports. The minimum scores differ between ports and range from 20 up to 40. The associated discounts differ between ports but have not been investigated further. Additional benefits specific vessel types, e.g. with low $NO_x$-emissions, exist in certain ports as well.

**Table 58 - Minimum ESI score for discount**

| Minimum ESI score to receive discount | Minimum score |
|---|---|
| Antwerp | 31 |
| Bremen | 40 |
| Hamburg | 20 |
| London | 30 |
| Long Beach | n/a[39] |
| Los Angeles | 30 |
| Vancouver | n/a[40] |
| Amsterdam | 20 |
| Groningen | 20 |
| Moerdijk | 31 |
| Rotterdam | 31 |
| Zeeland | 30 |

Several ports mention the number of vessels that receive a discount. Table 59 shows the percentage of visiting vessels that receive a discount. In the port of Le Havre for 326 calls a discount was awarded in 2017, it is unclear what share of vessels this concerns. The results between ports can't be compared due to the different discount mechanism. Also, it is uncertain what influence the discounts of ports have on greening initiatives of vessel owners. In general the number of vessels receiving a discount is increasing in the selected ports. As is shown by the results from the Ports of Bremen, the share of vessels which have an ESI index is increasing as well. Vessels visiting Hamburg and Amsterdam require a lower ESI score in order to receive a discount compared to Antwerp, Rotterdam and Zeeland. As a result more vessels have received a discount in Hamburg and Antwerp. Many ports do not report the number of vessels that have received a discount.

**Table 59 - Share of vessels receiving discount**

| % vessels receiving discount | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Antwerp | 6.2% | 7.9% | 12.2% | 17.1% |
| Bremen | 27%* | 31%* | 38%* | n/a |
| Hamburg | 20% | n/a | 23.3% | 26.5% |
| Vancouver | 16.3% | 22.2% | 29.6% | 33.7% |
| Amsterdam | n/a | 17% | 20% | 27% |
| Rotterdam | 6% | 7% | 9% | n/a |
| Zeeland | n/a | n/a | n/a | 2,5% |

* The results for Bremen show the share of ship arrivals with environmental ship index (ESI). Only the best 25 vessels receive a discount in Bremen.

39 The Green Ship Incentive Program is a voluntary clean-air initiative targeting the reduction of smog-causing nitrogen oxides ($NO_x$). Vessels with main engines meeting 2011 Tier 2 standards established by the International Maritime Organization (IMO) will be eligible for an incentive of $ 2,500 per ship call. For still cleaner vessels meeting 2016 Tier 3 standards, the incentive will increase to $ 6,000 per ship call.

40 EcoAction Program offers discounts on harbour dues to vessels meeting voluntary environmental best practices that reduce emissions and environmental impacts. These practices include the use of cleaner fuels and technologies, and obtaining third-party environmental designations. In 2016, participation in the EcoAction Program grew to 612 vessel calls, representing 24 per cent of all eligible calls for the year. The Blue Circle Award is given to shipping lines with the greatest proportion of participation in the EcoAction Program. In 2016, 15 shipping lines were awarded.

Ports can take additional measures to attract more environmentally friendly vessels. Therefore it is important to have the required facilities for hosting innovative clean vessel types. One example is to offer liquefied natural gas (LNG) bunkering facilities which allows LNG powered vessels to bunker fuel. LNG bunkering is offered in the ports of Antwerp, Barcelona, Bremen and the Dutch ports. The Port of Vancouver is working with industry and government to facilitate the use of LNG as a marine fuel in the port of Vancouver. Based on a study conducted in 2016 they expect to start seeing demand for LNG as a marine fuel as early as 2020, which would increase steadily toward 2030.

Table 60 shows the ports which report the number of vessels bunkering LNG. Several of the ports that offer LNG facilities report the number of bunkering. The number of bunkering is still relatively small to the total number of calls in a port.

**Table 60 – Number of LNG bunkering**

| Number of LNG bunkering | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Antwerp | 13 | 16 | 28 | 25 |
| Barcelona | 0 | 0 | 2 | 18 |
| Rotterdam | 58 | 32 | n/a | n/a |

## *Environmental zone*

Besides offering discounts or facilitating infrastructure, port authorities have the ability to impose environmental zones for road traffic and vessels. The port of Rotterdam currently has an environmental zone in place for heavy goods vehicles and is also planning an environmental zone for inland vessels. The ports of Long Beach, Los Angeles and Vancouver also regulate access for trucks. The Port of Long Beach and the Port of Los Angeles have introduced a clean truck program in 2008, which has progressively banned older heavy polluting diesel drayage trucks[41]. Vancouver has a truck licensing system since 2008. This includes strict environmental requirements for engine age, emission controls and idle reduction. Beginning in 2022, no truck in the fleet older than 10 years will be permitted.

## *Slow steaming*

Another option to improve the air quality in port areas is to reduce the emissions of maritime vessels. One method to reduce the emissions of maritime vessels is by sailing at lower speeds in the port, so called *slow steaming*. The ports of Long Beach and Los Angeles have an active vessel speed reduction program since 2001. Vessels are required to lower speeds on either 20 or 40 nautical miles from the port. This program applies to all ships and via AIS data[42] ships are monitored. Currently 95% of the ships comply with the 20 nautical mile mark, and more than 80% comply with the 40 nautical mile mark. The program has proven to reduce $NO_x$ and PM emissions of maritime vessels. The other selected ports have not implemented a vessel speed reduction program. Slow steaming is a best practise that should be further investigated by other ports.

[41] A drayage truck is a truck used for short distance transport: e.g. from ship to warehouse.

[42] Automatic identification system is a satellite system used for maritime navigation.

### 4.3.5 Conclusions air quality

Air quality has been an important topic in many ports for a long time. Since 2013 it has been mentioned as most important environmental priority by a survey conducted by ESPO under European ports (ESPO, 2018). As a result many ports measure and report the emissions and concentrations of air pollutants. In general the emissions and concentrations of air pollutants in ports have gradually decreased between 2010 and 2018. Additional efforts from ports are required to further reduce the emissions of air quality pollutants. Good examples of measures can be found in various ports. Increased use of onshore power supply can greatly improve air quality in ports. Currently many ports offer onshore power for certain type of vessels. A large challenge remains to expand the share of vessels using onshore power. This can be done by improved facilities and more strict regulation. Improved monitoring and reporting of onshore power can provide more information about successful applications of onshore power in ports. Another method to improve the air quality is to attract and facilitate more environmental friendly vessels. Most ports offer discounts for environmental friendly. LNG bunkering is offered in Antwerp, Barcelona, Bremen and the Dutch ports. More ports could facilitate LNG bunkering to stimulate vessel owners to switch fuels. Environmental zones for trucking exist in Rotterdam and the ports in North America. The ports in North America have vessel speed reductions zones, also known as slow steaming. These measures are not applied in the European ports but should be investigated further as a mitigation measure.

## 4.4 Water quality

The European Union has introduced the Framework Directive Water in 2000 in order to improve the quality of surface and ground water in the European Union. For this reason, a general requirement for ecological protection, and a general minimum chemical standard, was introduced to cover all surface waters. The specific quality requirements can be found in Annexes of the framework. We have collected the water quality scores for the European ports for which these are available. As counties interpret the framework differently, differences exist in the collection and presentation of the results. Therefore the results in Table 61 are on the following general categories; Ecological, chemical and psychical-chemical quality.

**Table 61 – Water quality in European ports**

| | Antwerp | Le Havre | Hamburg | London |
|---|---|---|---|---|
| Ecological quality | Insufficient | Moderate | Moderate | Moderate/Good |
| Chemical quality | Bad | Bad | Insufficient | Insufficient/Good |
| Physical-chemical quality | Bad | Good | n/a | n/a |

Source: (CIW, -; ICPER, 2016).

The port of Antwerp monitors the water quality. The salinity of water, the amount of nutrients as well as the content of oxygen are measured in the port of Antwerp. Furthermore the use of water is monitored. About 2 billion $m^3$ water is used, this includes cooling water. Also more detailed information is available for the sources of water namely rain, ground, and from pipes. The majority of the water is used for cooling, especially by the nuclear reactor situated near the port of Antwerp. The release of heavy metals by point sources and diffusion is also monitored by the port authority (Port of Antwerp, 2019).

Barcelona measures the water quality in six points in the port. It measures the chemical quality and biological quality. The results show a reduction in inorganic nutrients, namely ammonium, phosphates ($PO_4$), nitrates and silicates. This benefits the marine ecosystems, as indicated by the reduction in chlorophyll a (CL a) and the increase in the biodiversity of

benthic communities (organisms that live on the seabed) (Port of Barcelona, 2017).
The port of London does monitor the water quality, however no specific scores are available for the port area due to wide area covered by the port area. The so called Tidal Thames covers the river from West-London up to the mouth of the sea. It exits out of eight separate sections with different scores. For each area the ecological and chemical quality is available. The results for 2016 shows that two out of eight sections do not have sufficient chemical quality, six out of eight sections have good chemical quality, four out of eight sections have moderate ecological quality, and four have good ecological quality (Environment Agency (UK), 2019).

The ports of Long Beach and Los Angeles (2009) have constructed a combined water resources action plan. The water quality was measured in 2009 and the water quality rarely exceeded regulatory criteria. Exceptions are the concentration of copper and the dissolved organic tributyltin. Besides water quality the quality of sediment is researched as well.

The Port of Vancouver provides limited information on its website regarding the water quality. The Port of Vancouver aims to maintain good water quality through project and environmental reviews, storm water management, water discharge rules for vessels, partnerships in emergency management and response, and derelict vessel removal. No recent water quality measurements for the port of Vancouver have been found.

***Emission of substances to water***

Industrial facilities in Europe are required to register releases of pollutants under the European PRTR regulation. The register contains information on releases of pollutants to air, water and land, as well as off-site transfers of pollutants present in waste-water and waste. The register covers 91 pollutants including greenhouse gases, other gases, heavy metals, pesticides, chlorinated organic substances and other inorganic substances. The PRTR emissions released by companies located in the port area provide information about releases of pollutants to water. In the Netherlands the website Emissieregistratie has documented the release of pollutants to water. The Port of Antwerp (2019) monitors the emissions of metals and PAH to water. The PRTR emissions are available in the European database[43]. By selecting the facilities located in the port area an image of the emissions of pollutants to water in port areas can be created. However, assigning facilities to the port proved to be not possible for this edition of the benchmark due to time constraints.

### 4.4.1 Conclusions water quality

The water quality in the European ports is measured according to the European Water Framework. This information is however not available for all ports. Some ports report the results themselves whereas the results for certain other ports is available via local environmental agencies. The data is however not centrally available. This is also the case for emissions to surface water and sewage water. The industry located in ports can emit significant amount of toxic substances to water. This information is however not available at port level, and most ports do not collect this information themselves. A future benchmark can use the European E-PRTR database to visualize the emissions of pollutants to water. This requires specific information about which point sources are located in port areas. The emissions of heat to surface water is only reported by the Port of Antwerp and Rotterdam.

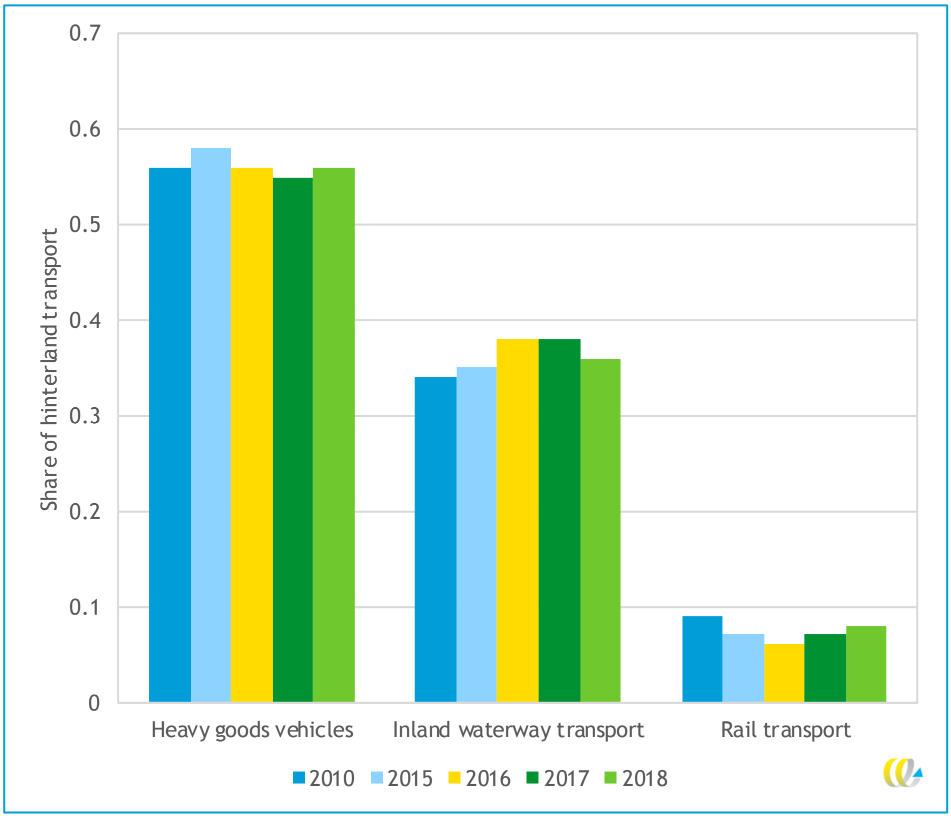
[43] The European Pollutant Release and Transfer Register (E-PRTR)

## 4.5 Modal split

As discussed in Section 3.7 several modes of transport can be used for hinterland transport. In general pipeline, railway and inland waterways are more sustainable forms of transport compared to road transport. The mode of transport used depends however on the type of goods and the existing transport infrastructure. The ports of Antwerp, Bremen, Hamburg, Le Havre and Vancouver have reported the modal split of hinterland transport. For Barcelona, Felixstowe, London, Long Beach and Los Angeles no results are available for the mode of hinterland transport.

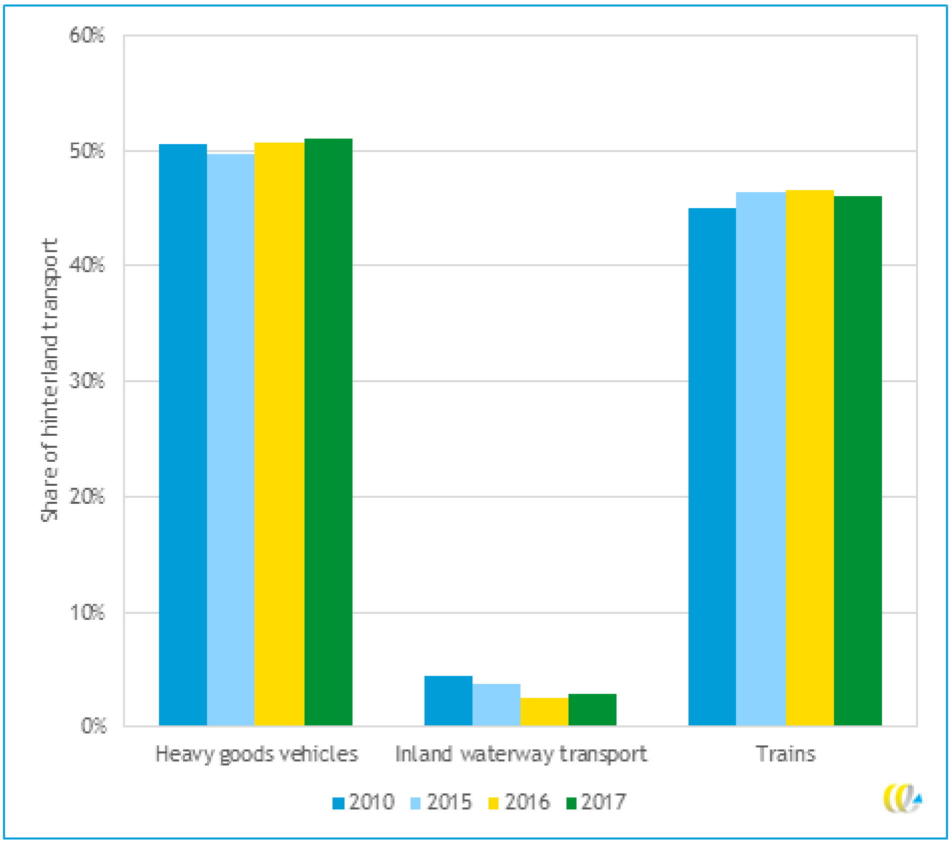
The port of Antwerp is connected by inland waterways, road, rail and pipelines. A large share of goods, about 45%, are transhipped in Antwerp and transported further via short sea shipping. Of the goods that are transported to the hinterland of Antwerp a large section is transported by pipeline. About 60% of the liquid bulk is transported by pipelines, the remainder is transported by other modes of transport. Figure 48 shows the modal split figures for containers for the port of Antwerp in 2015 and 2017 of the modes road, rail and inland waterways. Most containers are transported by heavy goods vehicles, followed by inland waterway transport and trains. In 2018 more goods are transhipped via inland waterways compared to 2010.

**Figure 48 - Modal split Antwerp containers**



The ports of Bremen are connected by road, rail, inland waterways as well as pipeline. The amounts of goods transported via pipelines make up an insignificant proportion, i.e. 2% (Biermann, et al., 2015). Figure 49 shows the modal split for the ports of Bremen in 2010, 2015, 2016 and 2017. The results show a decline of inland waterway transport from 4.5% to less than 3%. Heavy goods transport has increased to a little over 50% while railway transport has increased to about 46%. Overall the modal split has not changed significantly between 2010 and 2017.

**Figure 49 - Modal split ports of Bremen**




The port of Hamburg is connected by road, inland waterways, rail and pipelines. Like the ports of Bremen pipeline transport is very low in the port of Hamburg (Biermann, et al., 2015). The modal split of hinterland transport for the port of Hamburg for 2015, 2016 and 2018 is shown in Figure 50. Heavy goods vehicles transport has decreased from 35% to 32% while railway transport has increased significantly from 26% to 28% in 2018. The share of short sea shipping has increased from 37% to 38% between 2016 and 2018. The results indicate a modal shift towards railway transport away from heavy goods vehicles.

**Figure 50 - Modal split port of Hamburg**

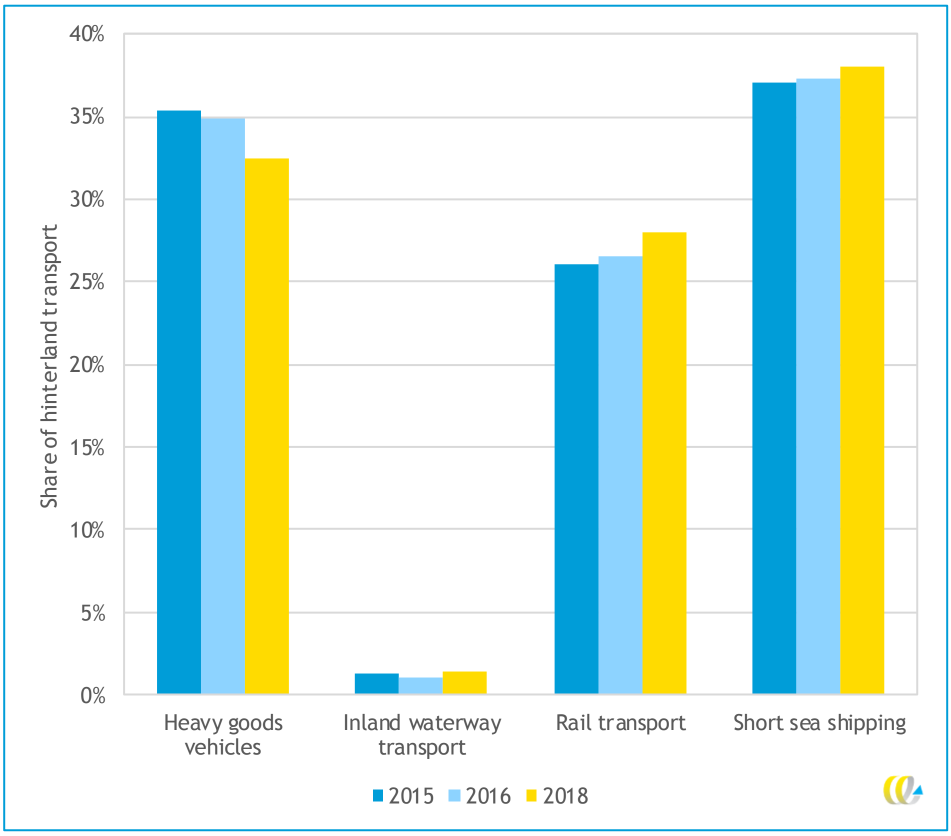
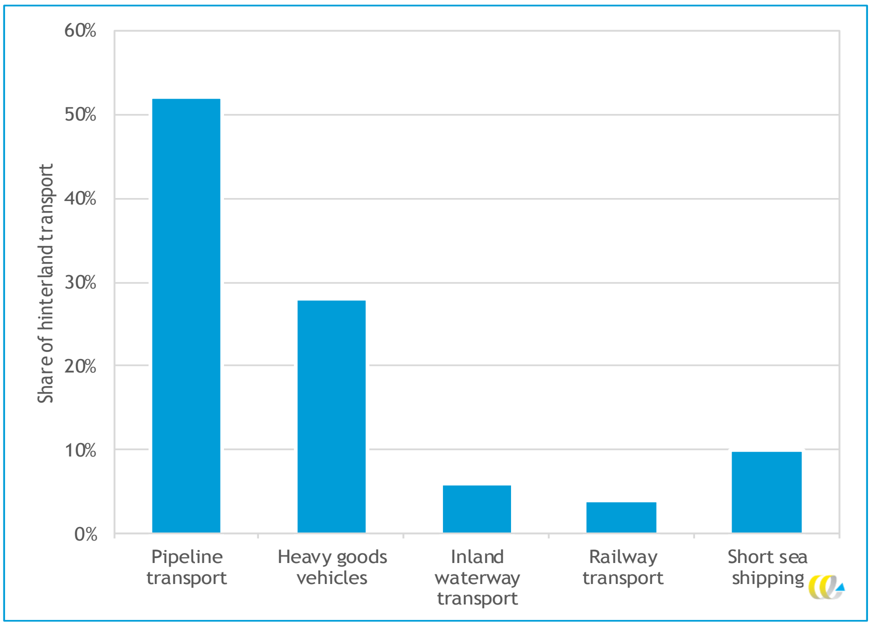


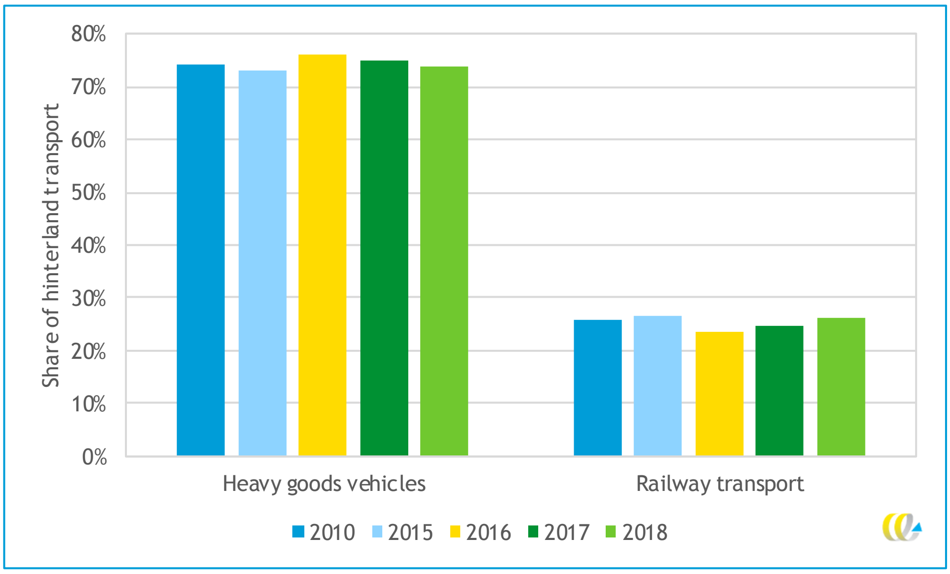

Figure 51 shows the modal split for the port of Le Havre in 2012. Le Havre is connected by road, rail, inland waterways and pipelines. More than 50% of goods are transported by pipelines in Le Havre. Heavy goods vehicles also transport a significant share of goods with 28%. About 10% of the goods are transhipped in Le Havre and transported further via short sea shipping. A smaller share of goods is transported via rail and inland waterways transport.

**Figure 51 – Modal split Le Havre 2012**



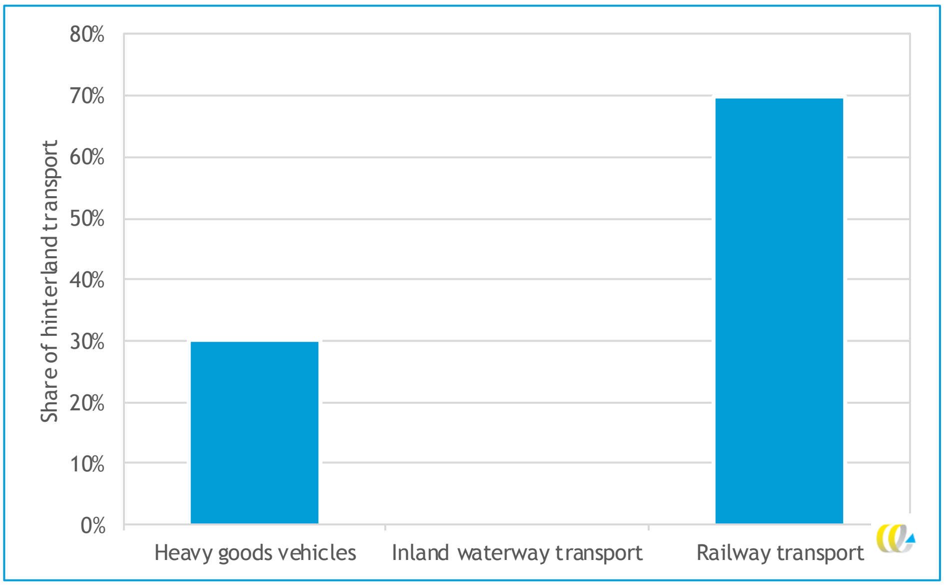

The port of Los Angeles measures the modal split as well, as is shown in Figure 52. The port of Los Angeles is not connected to an inland river. Most goods are transported by heavy goods vehicles. About a quarter of the goods are transported by train. The results do not show growth for a certain mode.

**Figure 52 - Modal split port of Los Angeles**




The port of Vancouver is connected by road, rail, inland waterways as well as pipelines. The commercial possibilities on the river Fraser are limited and pipelines are not included in the modal split figures provided by the port authority. As a result railway transport and heavy goods vehicles are the two modes included in Figure 53. About 70% of all goods are transported further via diesel powered trains, and about 30% of all goods are transported further by road.

**Figure 53 – Modal split port of Vancouver**




The availability of modes of transport depends on the location of ports and the type of goods transported in the port. As a result it is not possible to offer a just comparison of modal split between ports. Measurements over time are necessary to indicate any changes in modal split. Market dynamics play a large role in changes of the modal split, and good actions by port authorities are not always reflected in modal split results. Therefore a future benchmark should investigate measures taken by ports that improve the sustainability of hinterland transport. This could identify best practises which can be considered by other ports as well.

### 4.5.1 Conclusions modal split

This chapter has shown that several ports collect modal split figures. Only for Barcelona, Felixstowe, London, Long Beach and Los Angeles no results are available for the mode of hinterland transport. Antwerp, Bremen and Hamburg regularly update the modal split results. This is essential to notice a modal shift and concurring environmental benefits. Therefore it is to be advised that ports regularly collect and update modal split results. As good actions of port authorities are not always reflected in the modal split a future benchmark should investigate measures taken by ports that improve the sustainability of hinterland transport. This could identify best practises which can be considered by other ports as well.

## 4.6 Community relations

This paragraph discusses how the ports engage their local communities. This can be by improving the local environmental quality by actively reducing nuisances and introducing nature in the vicinity of the port. The engagement with the local communities is analysed based on websites, annual reports and other communications by port authorities.

Not all ports explicitly mention or discuss community relations on their website or in their reports. The ports of Bremen and Le Havre do not mention community relations, local residents or neighbourhood specifically. Other ports only pay limited attention to community relations on their website or reports. For example the Port of Barcelona mentions that a Public Relations area is responsible for organising visits and events of all kinds promoted by the Port of Barcelona. There does not however seem to be a dedicated place on the (English) website where the public can file complaints or get more information. The Port of Felixstowe only offers a general contact information on the website while the Port of London Authority offers the possibility to offer feedback on the work and activities done by the Port authority. The orts of Antwerp, Long Beach, Los Angeles and Vancouver offer more information on community relations, which are discussed in more detail below.

## Antwerp

The Port of Antwerp emphasises the importance of good contact with local residents. The port is coordinating the development of the port area with the surrounding municipalities and residents. Besides this, the port encourages companies to communicate actively with local residents. Some of the initiatives are:

- online communication of companies via up-to-date websites, social media or contact forms;
- incidents are managed with a crisis communication plan;
- several magazines are distributed among local residents and can be viewed online as well;
- companies in the port play an active role in society and offer social, sportive, cultural, educative or ecological initiatives;
- the port community sponsors sportive and cultural events for local community.

## Hamburg

The website of the Port of Hamburg offers a section where all information regarding the port is provided. An online contact centre allows local residents and other stakeholders to easily locate the correct persons. The port of Hamburg discusses the relationship with the city of Hamburg in their sustainability report. The port of Hamburg takes measure to reduce conflicts between the port and the city. For instance the port of Hamburg has drafted six safety reports in 2018 for the handling of dangerous substances. In 2016 an expert report on ambient odour situation in several project areas has been constructed. The close relation between the port and the city can also be used for innovation. For example The Kleiner Grasbrook area is earmarked for urban development but also includes green spaces and office/commercial space. Several stakeholders have signed a letter of intent concerning further development of this area. The main goal is to balance urban development and port-related use in such a way as to ensure that the port companies based in Kleiner Grasbrook can remain there long-term.

## Long beach

There is a special tab on the website called "community" with the following description of the efforts put forth. *"The Port makes an ongoing effort to support activities and school programs and to increase understanding of Port operations through open communication with the local community. Throughout the year the Port offers family-friendly events; provides opportunities to explore the Port by boat with Harbor Tours; sponsors events hosted by local organizations; and has speakers available to share the Port's story.*
*The Port also reaches out to teachers and young people, providing a number of diverse educational programs that allow students to master California content standards while discovering the seaport right in their own backyards. In an effort to encourage young*

*people to continue their education, the Port also offers scholarships to local college students preparing for careers in international trade."* Besides this the port also has a small page for people/organisations who want to send in comments.

### Los Angeles

The Port of Los Angeles has an active Public Relation Department that will attend local neighbourhood meetings in the surrounding residential areas of the Port. The Port of L.A. also has a dedicated Port Police force, were some officers are dedicated to residential community and the commercial interest in the port, like the port tenants. The Governments Affair's division is communicating with local, State and Federal governmental representatives, to inform them on new developments in the port.

### Vancouver

The Port of Vancouver pays special attention to community. Especially as trade continues to grow the port emphasises that communities are approached proactively to identify their concerns, and that port tenants and users minimize negative impacts. The Port of Vancouver has a special section on their website for local community. The Port presents a table with the externalities it causes and their approach to reducing nuisances. For example noise can lead to sleep disturbance or stress. Measures taken by the Port include a community feedback line and a noise monitoring program among others. The Port has a very proactive outreach towards its community and for example briefs mayoral candidates about port operations. The port authority also pays special attention to the relation with aboriginal peoples in the area.

## 4.6.1 Conclusions community relations

Several ports emphasise the importance of having good relations with its local communities. Ports communicate with local residents through various methods, for example websites, local meetings, hotlines or email. Other ports do not offer good communications on their website or emphasize good relations with its local communities. The same applies for initiatives that ports do for or with its surroundings. It is unclear whether some ports do not communicate their efforts or that ports do not have a good relation with its local communities.

# 5 Conclusions and recommendations

## 5.1 Conclusions

The benchmark developed in this study aimed to measure the sustainability performance of several ports situated in the Netherlands, other European countries and North America. The benchmark is mostly focussed on recent years (2015-2018) and an earlier reference point, usually 2010, to get insights in longer term trends. This benchmark does not compare the sustainability of ports but focusses on the sustainable performance on various topics. The scope of data collection and reporting differed significantly between ports, limiting the ability to compare ports along each other. This report however successfully identifies trends and success stories in the sustainability of seaports. The conclusions that were drawn are discussed below per benchmark topic.

### Climate

Climate impact from ports is dominated by the emissions of $CO_2$. Emissions of other greenhouse gasses in the ports is relatively limited. The Dutch ports and Port of Antwerp report the $CO_2$ emissions from all sources on a regular basis. The ports in North America report $CO_2$ emissions for mobile sources. Several (other) ports report emissions of the port authority (as well). The ports which report emissions figures for multiple years do not show a decrease in $CO_2$ emissions. The benchmark showed that ports which have an industrial function tend to have a higher climate impact which is a direct result of the industrial companies situated in these ports. At the same time industrial companies in these ports have taken measures to reduce $CO_2$ impacts like CCU or the use of residual heat, though the impact on the total emission balance is limited at this stage. In the coming years, significant reductions of $CO_2$ emissions or increased use of mitigation measures are required to comply with the climate policy goals such as the Paris agreement.

### Renewable energy

The renewable energy generation capacity in most ports is growing, although the efforts differ widely between ports. This is also reflected by limited data availability on installed capacity in certain ports. Ports which hosts traditional forms of power production, for example coal powered plants, tend to be more active in renewable energy production as well. This could be a consequence of good electricity infrastructure in these ports. Most Dutch ports and port of Antwerp host renewable energy such as wind, solar, biomass and biogas. Hamburg is the only port where geothermal energy is being produced. Other international ports only have limited renewable energy capacity installed. These ports can learn from the successful projects applied in the Dutch ports and the port of Antwerp.

### Air quality

Most ports report air quality emissions and have monitoring stations that measure the concentration of air quality pollutants. The different emission models and concentration measuring systems that are used by the ports make it hard to directly compare air quality between ports. Regardless, tracking the progression of air quality over time for the same port is a valuable way of determining progress for that port. Several ports report air quality emissions for consecutive years. The emissions of particulate matter and nitrous oxides in most ports are decreasing slightly. Sulphur emissions have decreased especially significantly in North America since 2010 due to, among others regulation on low sulphur fuels and slow steaming zones. The air quality thus appears to show a positive trend. However, for further reductions in air quality further facilitating measures like onshore power are important. Currently ports only offer onshore power for certain type of vessels. A large challenge remains to expand the share of vessels using onshore power. This can be done by improved facilities, more strict regulation and incentive programs. Another method to improve the air quality is to attract and facilitate more environment friendly vessels. With exception to the port of Felixstowe, all ports included in this benchmark offer discounts for environment friendly ships. LNG bunkering is offered in the European ports as it is mandatory due to an EU legislative directive (EU, 2014). LNG bunkering is not available in the North American ports. The ports in North America have vessel speed reductions zones, also known as slow steaming, which could be beneficial in Europe as well. Several ports monitor air quality continuously and have implemented measures to improve air quality. Other ports can still improve measuring and reporting emissions.

## Water quality

Water quality in this benchmark is gaged by a scoring system designed by the European Union. These scores are reported by several ports. Ports only have limited influence on the water quality as the much of the water and the contaminations it contains originate elsewhere, upstream or, when a port is not a river port, from the sea. Still, port activities cause emissions of pollutants, waste water and cooling water to surface water. The Dutch ports show a reduction of emissions of pollutants over time, such as the Substances of Very High Concern. Emissions of dangerous pollutants are available at a point emission level (company) via the European E-PRTR system. However, it was beyond the scope of this project to assign emissions to port areas. Ports can develop plans with the emitters to further reduce the emissions of pollutants to water. The ports of Antwerp and Rotterdam are the only ones monitoring discharges of residual heat from cooling water on surface water.

## Modal split

Modal split results are dependent on the situation of the port. Ports with good access to inland waterways have higher shares of inland waterway transport, whereas ports with good railway hinterland connections have higher shares of railway transport. Differences between ports are thus explained by locations and port characteristics and not necessarily due to sustainability efforts. In order to measure a shift to more sustainable forms of transport modal split results have to be updated regularly, which only a few ports currently do. Some ports such as Rotterdam and Antwerp use pipelines to transport liquid goods in high volumes which make for a sustainable method of transport.

## Community relations

The amount of effort ports put into maintaining good relations with the communities in their vicinity differs greatly between ports. The American, Dutch ports and Port of Antwerp offer a dedicated page on their website for the public or surrounding organisations. This can include a section to offer complaints, questions or other feedback towards the port. Ports communicate with local residents through various methods, for example websites, local meetings, newspapers, hotlines or email. Due to differences in size and locations different management strategies for community relations are expected. However some ports do not report about community relations.

### Maritime waste at Dutch ports

Waste produced by maritime vessels is collected in ports. In most Dutch ports, several companies are licensed to collect waste. They do this through either vessels or installations on land. The volume of waste deposited in the Netherlands increased significantly since 2005. This increase is due to a higher share of vessels depositing waste; the average amount of waste deposited per vessel remained more or less constant between 2005 and 2018. The benchmark indicator for waste is still under development and therefore, the results were only collected for Dutch ports. It is presumed that European ports offer similar facilities as Dutch ports since they largely fall under the same regulation. The ports of Long Beach, Los Angeles and Vancouver do have waste management plans as well, but where not investigated in further detail.

### Sustainability strategy

This benchmark has analysed the strategy documents (vision) for the Dutch ports and port of Antwerp. Documents of international ports have not been included in this benchmark due to language and time constraints. The ports include the energy transition and shift towards a biobased and circular economy. However, differences remain in the level of detail. Some ports mention concrete measures, KPIs monitoring documents whereas other ports only mention directions. The ports of Amsterdam and Rotterdam have the highest throughput and therefore focus on worldwide shifting trade patterns in their port vision documents. Both ports want to be able to facilitate the latest and largest vessels. Moerdijk does not focus on large cargo vessels but on niche markets and hinterland transport. The strategy documents of the Dutch ports do include the most important topics but often lack detail. It is unclear what steps are necessary to reach their ambitions and how progress is monitored. It should be noted that recent development amongst Dutch and some international ports are likely to result in more detailed plans that are relevant to the sustainability strategy. Most of these plans are in light of the international climate agreements, such as the ‘*Klimaatakkoord*’ for the Dutch ports.

### Overall conclusion

The level of attention payed to sustainability differs widely between ports. Some ports actively collect data and report information whereas other ports do not. Four ports have not complied to our data request as is discussed in Chapter 2.2. Due to this lack of transparency and open communication it is sometimes uncertain how ports are truly performing and whether sustainability is an important element in their operations. Overall there are some topics where improvement is visible, for example air quality and renewable energy production. There are however also topics, mainly climate, where only limited improvements are visible. This benchmark has proven to be a good tool for gaining insight into the sustainable development of seaports. By improving on the sustainability indicators and performing the benchmark every two years the sustainable development of seaports worldwide can be monitored and optimally stimulated.

## 5.2 Discussion

The results of this benchmark have been influenced by several issues. These include data availability, differences in data collection and characteristics of ports. This paragraph will discuss these issues and their influence on the results.

### Data request

After initially collecting all the publicly available benchmark data in Excel datasheets for each port, we have asked every port authority by telephone and email to firstly verify or correct the data that was collected and secondly to provide additional data that was missed in the initial round of data collection. All the ports have replied to our communication attempts, however the Ports of Groningen, Felixstowe, Bremen and Le Havre ultimately did not manage to give feedback on the data in the Excel datasheets as requested. The Port of Felixstowe explicitly mentioned being restricted by corporate rules which prevents them from sharing data. The data availability has proven to be limited due to various reasons. Some ports do not collect data on certain benchmark topics, some data is not publicly available and some port authorities have not replied adequately to our data request. As a result it is unclear whether certain topics are on the radar of ports.

### Scope collected data

The scope of the data collected by port authorities differs per port. $CO_2$ emissions provide a good example; for the Dutch ports all the sources of emissions are included, the port of Antwerp does not include emissions from shipping, the ports of Long Beach and Los Angeles only include emissions from mobile equipment. This example shows that the collected data can differ significantly between ports. In the case of $CO_2$ emissions the ports have explicitly reported the scope but it raises the question for other benchmark topics whether the same scope is applied between all ports. Similar differences apply for the years for which data is available. This is often fragmented, while data over a longer period of years is necessary to notice trends.

### Function port authorities

The function of port authorities differs between ports. Some port authorities take an active role in policy formation and work in close cooperation with the companies situated in the port area. Other ports take a less active role and may not have the same level of information on sustainability indicators of companies situated in the port area. The port authority of London only manages the waterways and does not manage the terminals and other businesses operating along the river banks. As a result the port authority does not collect information from the companies situated alongside the Thames, and for many sustainability topics no information is available. Simultaneously the functions of ports differ, some ports focus on logistical operations, while others host industry complexes. As a result the scope of data gathering is also different between ports. For example the Port of Long Beach and the Port of Los Angeles focus on transport and as a result emissions are only provided for mobile equipment that is associated with transhipment of goods.

## Scale

This report has used several indicators to measure the scale of a port. Square kilometres provide information about the size in terms of dimensions. Volume of throughput provides information about the scale of logistical activities while value added is used as indication of economic scale. Each indicator has its own benefits but there are also drawbacks. Not all ports report results for value added and the scope differs between ports that do. Maritime throughput does not provide information about the scale of other functions of a port while the size of a port in square kilometre does not consider the density for which the grounds are used. Correcting for these differences is challenging and not always possible.

## Connection with other projects

This benchmark has links with other projects concerning the sustainability of seaports. The ESPO environmental report (ESPO, 2018) has been used to select topics and indicators. Many of the topics mentioned by ESPO are discussed in more detail in this benchmark. The findings of ESPO are based on a selection of ports called EcoPorts. The overarching principle of EcoPorts is to raise awareness on environmental protection through cooperation and sharing of knowledge between ports and improve environmental management. The European project PORTOPIA used insights from EcoPorts in their study which was finished in 2017. The Dutch '*Havenmonitor*' annually reports the economic development of the Dutch seaports. The findings of this study have been used to control for economic development of ports. For the Dutch maritime sector a monitor is released annually[44]. This study consists of a description and analysis of the economic and labour market as well as historic market trends.

# 5.3 Recommendations

This benchmark has been able to show the sustainable performance of seaports located in the Netherlands, Europe and North America. During this process many lessons have been learned resulting in the recommendations described below.

## Uniformity

The data availability differed greatly between ports and the scope of data collection was also not uniform for all ports. To increase uniformity and quality of data the use of uniform reporting guidelines is necessary. For many sustainability topics in this benchmark no international standards apply for the collection and reporting of data. Perhaps one of the most valuable lessons that could be gained from this benchmark would be to move towards a uniform international system for sustainability tracking and reporting. An example of such a system is the Global Reporting Initiative (GRI).

## Centralisation

A lot of data is currently available at various sources, including port authorities, companies and local environmental agencies. This benchmark would improve greatly if the information is reported at a central place. Again this can be supported by a uniform system for tracking and reporting.

[44] Called the Martieme Monitor.

## Cooperation

The available data depends for a large part on the willingness of port authorities or companies to report, share and verify collected data. It is recommended to get in touch with these stakeholders early to ensure their cooperation is not limited by time. The data gathering process can be efficient if the requests are clear. If the data gathering for this benchmark becomes a regular exercise (every two years) the required investment of stakeholders will decrease.

## Developments

The sustainability of a port depends on unique situation and location specific aspects. Long term commitments have a lasting effect on the sustainable performance of a port. As a result it is difficult to compare sustainable performance between ports. Ports can definitely learn from front runners but not all measures are applicable in every situation. Where this benchmark is particularly effective is comparing the sustainability of the same port over multiple years, thus giving insight in the trends. This gives insight to whether the port is improving its sustainability given the restraints and opportunities it has. In order to measure progress, the data on sustainability has to be collected on a regular basis with a uniform scope.

## Organisation

The cooperation of port authorities could be improved by collaborating with industry representatives within the ports. This will benefit the willingness of port authorities to cooperate and improve the credibility of the benchmark as it more closely represents the actual sustainability of the port. Especially if the benchmark is regularly repeated and more ports are included.

## Topics

A few sustainability topics are not included in this benchmark, the most prominent being sustainable land use, safety and nature management. Within the existing topics there is also room for improvement of the indicators. It would be useful if emissions can be specified to sources like industry, shipping and road transport. For renewable energy the energy output (MWh) can be collected in combination with the capacity. Waste management can be researched in more detail while also including international ports. Including the sustainability strategies of international ports and looking at the planned short term investments would increase the quality of the sustainability strategy chapter.

# 6 References

AEB, 2018. *Jaarverslag 2017,* Amsterdam: AEB.
Biermann, F., Teuber, M.-O. & Wedemeier, J., 2015. Bremen's and Hamburg's port position: Transport infrastructure and hinterland connections within the North Range. *International Business and Global Economy,* Volume 34, pp. 78-89.
BMC Moerdijk, 2016. *Biomassacentrale Moerdijk : Van mest naar stroom en mineralen.* [Online]
Available at:
https://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjf8K7WxfHmAhWdwAIHHU15DMMQFjAAegQIARAC&url=https%3A%2F%2Fwww.zlto.nl%2Fstream%2Ffolder-bmc-moerdijk-maart-2016.pdf&usg=AOvVaw2To4zoxrljA4uj1Se8VCKf
[Accessed 2019].
Boerderij.nl, 2018. *BMC Moerdijk hervat verwerking fipronil-mest.* [Online]
Available at: https://www.boerderij.nl/Pluimveehouderij/Nieuws/2018/10/BMC-Moerdijk-hervat-verwerking-fipronil-mest-340922E/
[Accessed 2020].
California Air Resources Board, 2020. *Shore Power for Ocean-going Vessels.* [Online]
Available at: https://ww3.arb.ca.gov/ports/shorepower/shorepower.htm
[Accessed 2020].
CBS, 2018. *CO2-uitstoot in 2017 gelijk aan die in 1990.* [Online]
Available at: https://www.cbs.nl/nl-nl/nieuws/2018/37/co2-uitstoot-in-2017-gelijk-aan-die-in-1990
[Accessed 2019].
CBS, 2019. *StatLine : Zeevaart; overgeslagen gewicht, zeehaven, vervoerstroom, soort lading.* [Online]
Available at: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82850NED/table?dl=21A40
[Accessed 29 juli 2019].
CE Delft ; Deltares, 2018. *Verkenning warmtelozingen en duurzaam hergebruik restwarmte* , Delft: CE Delft.
CE Delft; INFRAS ; Ricardo, 2019. *Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities: Main Findings,* Brussels: European Commission.
CE Delft, 2016a. *Ambitie 2030 Duurzaamheid werkt!,* Delft: CE Delft.
CE Delft, 2016b. *Kansrijk beleid voor CCS,* Delft: CE Delft.
CE Delft, 2017. *LCA of thermal conversion of poultry litter at BMC Moerdijk,* Delft: CE Delft.
CIW, -. *Coördinatiecommissie Integraal Waterbeleid (CIW) : Geoloket stroomgebiedbeheerplannen (Vlaanderen).* [Online]
Available at: https://www.integraalwaterbeleid.be/nl/geoloket/geoloket-stroomgebiedbeheerplannen
[Accessed 2020].
Commissie MER, 2013. *Milieueffectrapport Havenbestemmingsplannen : Hoofdrapport,* Rotterdam: Commissie MER.
DCMR, 2019. *MOI Register - indicatoren,* Schiedam: DCMR.
Doorn, M. v., 2018. Port of Rotterdam Achterland. *Railforum.*
Dutch Government, 2018. *Ontwikkelingen in de maatschappij, indicatoren : Broeikasgas en CO2-intensiteit bedrijven, 1995-2016.* [Online]
Available at: https://www.clo.nl/indicatoren/nl054210-broeikasgasintensiteit-bedrijven
[Accessed 2019].
Dutch Government, 2019b. *Relatie ontwikkelingen emissies en luchtkwaliteit, 1990-2017.* [Online]

Available at: https://www.clo.nl/indicatoren/nl0081-relatie-ontwikkelingen-emissies-en-luchtkwaliteit?ond=20880
[Accessed 2020].
EC, 2018. *Mobilty and Transport, Martime : Proposal for a new directive on port reception facilities aims to tackle sea-based sources of marine litter.* [Online]
Available at: https://ec.europa.eu/transport/modes/maritime/news/2018-01-16-plastic-waste_en
[Accessed 2019].
Emissieregistratie, 2018. *Effluenten RWZI's, regenwaterriolen, niet aangelsoten riolen, overstorten en IBA's,* Den Haag: Rijkswaterstaat.
Environment Agency (UK), 2019. *Catchment Data Explorer ; Tidal Thames, Operational Catchment.* [Online]
Available at: http://environment.data.gov.uk/catchment-planning/OperationalCatchment/3465
[Accessed 2020].
EP, 2015. *Modal Share of Freight Transport to and from EU Ports,* Brussels: European Parliament (EP), Policy Department B: Structural and Cohesion Policies.
Erasmus UPT, 2018. *Havenmonitor : De economische betekenis van Nederlandse zeehavens 2002-2017,* Rotterdam: Erasmus Centre for Urban Port and Transport Economics (UPT).
ESPO, 2018. *ESPO Environmental Report 2018 : EcoPortsinSights 2018,* Brussel: European Sea Ports Organisation (ESPO) .
ESPO, 2019. *Top 10 environmental priorities of European ports for 2019.* [Online]
Available at: https://www.espo.be/media/Top10%20postcard-FINAL.pdf
[Accessed 2020].
EU, 2014. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance. *Official Journal of the European Union,* L307(28.10.2014), pp. 1-20.
Gemeente Moerdijk, 2018. *Milieumonitor 2017 : Haven- en industrieterrein Moerdijk.* [Online]
Available at: https://www.portofmoerdijk.nl/media/1798/milieumonitor-moerdijk-2017-def.pdf
[Accessed 2019].
Gemeente Rotterdam, 2014. *Factsheet : Leefomgevingskwaliteit.* [Online]
Available at: https://www.rotterdam.nl/bestuur-organisatie/stadsontwikkeling/leefomgeving.pdf
[Accessed 2020].
GPMH, 2015. *Suivis de la qualité de l'eau sur la circonscription du GPMH,* Le Havre: Grand Port Maritime du Havre (GPMH).
Green Deal, 2018. *Zeeland vervoert waterstof grootschalig via oude watergasleiding.* [Online]
Available at: https://www.greendeals.nl/nieuws/zeeland-vervoert-waterstof-grootschalig-oude-watergasleiding
[Accessed 2019].
Groningen Seaports NV, -. *Havenvisie 2030 : Doelstellingen en visie Groningen Seaports 2030.* [Online]
Available at: http://havenvisie2030.groningen-seaports.com/de-visie-op-2030/kennis/
[Accessed 2019].
Groningen Seaports, [2015]. *Schone Scheepvaart : adaptief uitvoeringsprogramma = Clean Shipping : adaptive implementation programme,* Delfzijl: Groningen Seaports.
Groningen Seaports, 2016. *Havenafvalplan Groningen Seaports,* Delfzijl: Groningen Seaports.
Groningen Seaports, 2019. *Jaarverslag 2018.* [Online]
Available at: https://www.groningen-seaports.com/wp-content/uploads/JAARVERSLAG-

2018-def.pdf
[Accessed 2019].
Hamburg Port Authority, 2018. *Think Globally : Act Regionally : Sustainability report 2015/2016.* [Online]
Available at: https://www.hamburg-port-authority.de/fileadmin/user_upload/HPA_Sustainability_report_2015_2016_WEB_single.pdf
[Accessed 2019].
ICPER, 2016. *ICPER information sheet 2016 : Water framework directive in the Elbe river basin.* [Online]
Available at: https://www.ikse-mkol.org/fileadmin/media/user_upload/E/06_Publikationen/01_Wasserrahmenrichtlinie/2016_ICPER-Infomation-Sheet_WFD.pdf
[Accessed 2020].
ILT, 2019. *ILT-brede risicoanalyse (IBRA),* Den Haag: Ministerie van Infrastructuur en Waterstaat, Inspectie Leefomgeving en Transport (ILT).
IMO, 2019. *Sulphur oxides (SOx) and Particulate Matter (PM) – Regulation 14.* [Online]
Available at:
http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx
[Accessed 2020].
InfoMil, ongoing. *ZZS beleid.* [Online]
Available at: https://www.infomil.nl/onderwerpen/lucht-water/zeer-zorgwekkende/zzs-beleid/
[Accessed 2020].
ING, 2018. *Utrecht de schoonste economie, Zeeland de meest vervuilende : Grote verschillen in provinciale klimaatscore.* [Online]
Available at:
https://www.ing.nl/media/ING_EBZ_Utrecht_de_schoonste_economie_Zeeland_de_meest_vervuilende_tcm162-139651.pdf
[Accessed 2019].
InterVISTAS, 2017. *Port of Vancouver 2016 Economic Impact Study,* Vancouver: InterVISTAS Consulting Inc.
IPCC, 2013. *Climate Change 2013 : The Physical Science Basis : Fifth Assessment Report: Working Group 1.* Cambridge: The Intergovernmental Panel on Climate Change (IPCC).
Lakens, P., 2019. Zeeschepen aan schone walstroom krijgen is complex en duur. *Financieel Dagblad*, 15 12.
Leidos, 2019. *Air Quality Monitoring Program at the Port of Long Beach Annual Summary 2018',* Long Beach: Port of Long Beach, Environmental Planning Division.
Lugt, L. v. d., Witte, J.-J., Becker, E. & Streng, M., n.d. *Havenmonitor De economische betekenis van Nederlandse zeehavens verschillende edities* , Rotterdam: Erasmus Universiteit Rotterdam – Erasmus Centre for Urban, Port and Transport Economics .
Milieu Centraal, -. *Luchtvervuiling.* [Online]
Available at: https://www.milieucentraal.nl/in-en-om-het-huis/gezonde-leefomgeving/luchtvervuiling/
[Accessed 2019].
Ministry of Infrastructure and Water Management, 2008. *Beleidsbrief Duurzame Zeehavens : Nationaal Zeehavenbeleid 2005-2010, brief aan de Tweede Kamer der Staten-Generaal d.d. 5 november 2008 kamerstnr. 29862, nr. 10,* Den haag: Tweede Kamer der Staten-Generaal.
Nieuwe Oogst, 2017. *OCAP levert weer volledig CO2 aan glastuinbouw.* [Online]
Available at: https://www.nieuweoogst.nl/nieuws/2017/08/22/ocap-levert-weer-volledig-CO2%20-aan-glastuinbouw
[Accessed 2020].

Platform schone scheepvaart, 2015. *Seminar 'Generatorstroom vs. walstroom in de zeevaart*. s.l., s.n.
Port of Amsterdam, 2015. *Visie 2030 : Port of Amsterdam, Port of partnerships*, Amsterdam: Havenbedrijf Amsterdam.
Port of Antwerp, 2017. *Duurzaamheidsverslag 2017*. [Online]
Available at:
https://www.portofantwerp.com/sites/portofantwerp/files/Duurzaamheidsverslag%202017_0.pdf
[Accessed 2020].
Port of Antwerp, 2018. *Ondernemingsplan 2018-2020 : Hefboom voor een duurzame toekomst*. [Online]
Available at:
https://www.portofantwerp.com/sites/portofantwerp/files/imce/Ondernemingsplan%2018-20_executive_summary.pdf
[Accessed 2020].
Port of Antwerp, 2019. *Duurzaamheidsverslag 2019*. [Online]
Available at:
https://www.portofantwerp.com/static/duurzaamheidsverslag/nl/PDF/poa_duurzaamheidsverslag.pdf
[Accessed 2020].
Port of Barcelona, 2017. *Water quality in de Port of Barcelona*. [Online]
Available at:
https://contentv5.portdebarcelona.cat/cntmng/guestDownload/direct/workspace/SpacesStore/9d0eb3cd-f215-49ac-beda-9c1f9ef150c8/diptic4_calidad_agua_2017_en.pdf
[Accessed 2020].
Port of Los Angeles and Port of Long Beach, 2009. *Water Resources Action Plan , final report*. [Online]
Available at: https://www.portoflosangeles.org/pola/pdf/doc/wrap_final.pdf
[Accessed 2020].
Port of Los Angeles, 2018. *2018 Facts and Figures : Fact and Figures Card*. [Online]
Available at: https://www.portoflosangeles.org/business/statistics/facts-and-figures
[Accessed 2020].
Port of Moerdijk, 2017. *Jaarstukken 2016*. [Online]
Available at: https://www.portofmoerdijk.nl/media/1694/havenschap-moerdijk-jaarstukken-2016.pdf
[Accessed 2020].
Port of Rotterdam , 2013. *Port Statistics 2010-2011-2012*. [Online]
Available at: https://www.portofrotterdam.com/sites/default/files/Port-statistics-2012.pdf
[Accessed 2020].
Port of Rotterdam, 2011. *Rotterdam Port Vision Port Compass, Direct the future. Start today*. [Online]
Available at: https://www.portofrotterdam.com/sites/default/files/upload/Port-Vision/Port-Vision-2030.pdf
[Accessed 2020].
Port of Rotterdam, 2015. *Havenbeheersverordening artikel 13 : Schone motoren binnenschepen*. [Online]
Available at:
https://www.portofrotterdam.com/sites/default/files/havenbeheersverordening-rotterdam-2010.pdf
[Accessed 2019].
Port of Rotterdam, 2016. *Port of Rotterdam Stastistics : Wealth of information*. [Online]
Available at: https://www.portofrotterdam.com/sites/default/files/port-statistics-

2015.pdf
[Accessed 2020].
Port of Rotterdam, 2017. *Voortgangsrapportage 2017 Havenvisie 2030,* Rotterdam: Port of Rotterdam.
Port of Rotterdam, 2018. *Havenafvalplan 2018,* Rotterdam: Havenbedrijf Rotterdam N.V.
Port of Rotterdam, 2019. *Jaarverslag 2018,* Rotterdam: s.n.
Port of Rotterdam, 2019. Stakeholderdialoog. In: *Port of Rotterdam Jaarverslag 2018.* Rotterdam: Port of Rotterdam.
Port of Vancouver, 2017. *2015 Port Emissions Inventory Report,* Vancouver: Vancouver Fraser Port Authority.
Port of Vancouver, 2018. *Container ship shore power at Port of Vancouver terminals.* [Online]
Available at: https://www.portvancouver.com/wp-content/uploads/2018/06/2018-05-29-Shore-Power-Container-Qs-and-As-_final.pdf
[Accessed 2019].
Rijksoverheid, 2019a. *Compendium voor de Leefomgeving, indicatoren Emissies broeikasgassen, 1990-2017.* [Online]
Available at: https://www.clo.nl/indicatoren/nl016534-broeikasgasemissies-in-nederland
[Accessed 2019].
RIVM, 2017. *ReCiPe 2016 v1.1 : A harmonized life cycle impact assessment method at midpoint and endpoint level. Report I: Characterization.* [Online]
Available at: https://www.rivm.nl/sites/default/files/2018-11/Report%20ReCiPe_Update_20171002_0.pdf
[Accessed 2019].
RIVM, 2018. *Grootschalige concentratie- en depositiekaarten Nederland : Rapportage 2018,* Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu (RIVM).
RVO, 2011. *Restwarmtekoppeling Moerdijk.* [Online]
Available at:
https://www.rvo.nl/sites/default/files/bijlagen/restwarmte_AZN_Shell_Moerdijk%20AVI%20stoom%20en%20warmte%20(1).pdf
[Accessed 2019].
TNO : Aether, 2017. *Port of London Emissions Inventory 2016* , Oxford: Aether Ltd.
Vitaal sloegebied & Kanaalzone, 2016. *Ambitie 2030 : Duurzaamheid werkt...Verder! (brochure).* [Online]
Available at:
https://www.vitaalsloegebiedenkanaalzone.nl/images/Duurzaamheid_WerktVerder.pdf
[Accessed 2019].
WarmCO2, 2018. *Verdere uitbreiding WarmCO2 : WarmCO2 optimaliseert duurzame energie door uitbreiding 4Evergreen.* [Online]
Available at: https://www.warmco.nl/item/nieuws/4Evergreen
[Accessed 2020].
WPSP, 2019. *Ports using OPS.* [Online]
Available at: https://sustainableworldports.org/ops/ops-installed/ports-using-ops/
[Accessed 6 December 2019].
Zeeland Seaports, 2016. *Winning Combinations : 2015 Strategisch Masterplan.* [Online]
Available at:
http://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwii2uCc5fHmAhWC66QKHc_FBzIQFjABegQIBhAC&url=http%3A%2F%2Fwww.zeelandseaports.nl%2Fen%2Fdownload%2Ffile%3Azeeland-seaports---winning-combinations-gb.htm&usg=AOvVaw3-aUuE
[Accessed 2019].

# A Data sources

Table 62 – Data sources used port of Amsterdam

| Subject | Source |
|---|---|
| Port size | Feiten en Cijfers 2017 |
| Throughput | Feiten en Cijfers 2016 & Feiten en Cijfers 2017 & Jaarverslag 2018 |
| **Climate** | |
| GHG emissions | Emissieregistratie & Jaarverslag 2018 |
| **Climate reduction measures** | |
| Residual heat | Annual report AEB Amsterdam 2017 (Only in Dutch) |
| **Renewables** | |
| Wind | |
| Solar | Solar Magazine: Havenbedrijf Amsterdam en Alliander onderzoeken netcapaciteit voor extra zonnepanelen |
| **Air Quality** | |
| Air quality emissions | Emissieregistratie |
| Air quality concentrations | RIVM |
| **OPS (MWH)** | |
| OPS connections | Jaarverslag 2018 |
| Minimum ESI score for discount | Jaarverslag 2018 |
| Number of vessels receiving discount | Jaarverslag 2018 |
| **Water quality** | |
| Scores | Waterkwaliteitsportaal |
| Emissions to water | Emissieregistratie |
| **Modal split** | |
| Modal split | Feiten en Cijfers 2016 |
| **Public relations** | |
| Consulted websites | Website Port of Amsterdam |

Table 63 – Data sources used port of Groningen

| Subject | Source |
|---|---|
| Port size | Groningen GSP Port HandbookVII |
| Throughput | Jaarrekening 2017 ; CBS Zeevaart overslag |
| **Climate** | |
| GHG emissions | Emissieregistratie ; Jaarverslag 2018 |
| **Climate reduction measures** | |
| Biomass | Golden Raand website |
| **Renewables** | |
| Wind | Jaarverslag 2018 |
| Solar | Jaarverslag 2018 |
| Biomass | Golden Raand website |
| **Air Quality** | |
| Air quality emissions | Emissieregistratie |

| Subject | Source |
|---|---|
| Air quality concentrations | RIVM |
| OPS (MWH) | Jaarverslag 2018 |
| **Water quality** | |
| Scores | Waterkwaliteitsportaal |
| Emissions to water | Emissieregistratie |
| **Modal split** | |
| Modal split | no data |
| **Public relations** | |
| Consulted websites | Port website |

**Table 64 - Data sources used port of Moerdijk**

| Subject | Source |
|---|---|
| Port size | Bijeenkomst Logistiek Platform Roosendaal: presentatie Havenschap Moerdijk Dhr. Van den Oever. |
| Throughput | Jaarverslag 2017 |
| **Climate** | |
| GHG emissions | Emissieregistratie; Milieumonitor Moerdijk 2017 |
| **Climate reduction measures** | |
| Biomass | BMC Moerdijk |
| Heat | Milieumonitor Moerdijk 2017 |
| **Renewables** | |
| Wind | Notitie Windenergie Gemeente Moerdijk 2013-2030 |
| Solar | Milieumonitor Moerdijk 2017 |
| Biomass | BMC Moerdijk |
| **Air Quality** | |
| Air quality emissions | Emissieregistratie |
| Air quality concentrations | RIVM |
| OPS number of connections | Milieumonitor Moerdijk 2017 |
| **Water quality** | |
| Scores | Waterkwaliteitsportaal |
| Emissions to water | Emissieregistratie |
| **Modal split** | |
| Modal split | no data |
| **Public relations** | |
| Consulted websites | Port of Moerdijk |

**Table 65 - Data sources used port of Rotterdam**

| Subject | Source |
|---|---|
| Port size | Feiten en cijfers 2018 |
| Throughput | Feiten en cijfers 2018 |
| **Climate** | |
| GHG emissions | Emissieregistratie; Voortgangsrapportage havenvisie 2030 (2017) |
| **Climate reduction measures** | |
| CCU | OCAP |
| Biomass | Voortgangsrapportage havenvisie 2030 (2017) |

| Subject | Source |
|---|---|
| Heat | Port of Rotterdam- Doing Business- Port of the future- Energy Transition |
| Steam | Port of Rotterdam- Doing Business- Port of the future- Energy Transition |
| **Renewables** | |
| Wind | De kracht van windenergie; consultation port authority |
| Solar | Voortgangsrapportage havenvisie 2030 (2017) ; Port of Rotterdam havenkrant 42: Zonne-energie in de haven |
| Biomass | Petrochemical industry facts and figures |
| Number of LNG bunkerings | Voortgangsrapportage havenvisie 2030 (2017) |
| **Air Quality** | |
| Air quality emissions | Emissieregistratie |
| Air quality concentrations | RIVM |
| OPS number of connections | Voortgangsrapportage havenvisie 2030 (2017 ) |
| OPS (MWh) | Voortgangsrapportage havenvisie 2030 (2017 ) ; Consultation port authority |
| Number of vessels receiving discount | Voortgangsrapportage havenvisie 2030 (2017 ) |
| **Water quality** | |
| Scores | Waterkwaliteitsportaal |
| Emissions to water | Emissieregistratie |
| Discharges cooling water | Voortgangsrapportage havenvisie 2030 (2017 ) |
| **Modal split** | |
| Modal split | (Doorn, 2018) |
| **Public relations** | |
| Consulted websites | Port of Rotterdam; Voortgangsrapportage havenvisie 2030 (2017 ) |

**Table 66 - Data sources used port of Zeeland**

| Subject | Source |
|---|---|
| Port size | Jaarverslag 2015 |
| Throughput | Jaarrekening 2017 |
| **Climate** | |
| GHG emissions | Emissieregistratie; Verduurzaming Havens : Transitie, kansen, bedreigingen |
| **Climate reduction measures** | |
| CCU | De inzet van restwarmte en rest $CO_2$ - de wens van het Kabinet |
| Biomass | Groengas projecten |
| Heat | https://www.warmco.nl/index.php & RVO: Kunstmestfabriek levert restwarmte én $CO_2$ aan glastuinbouw & Sloewarmte |
| Hydrogen pipeline | Vitaal Sloegebied en kanaalzone : Duurzaamheid werkt verder |
| **Renewables** | |
| Wind | Open data portaal from province of Zeeland |
| Solar | PCZ: Ruim twee keer zoveel Zeeuwse zonne-energie (2019) |
| **Air Quality** | |
| Air quality emissions | Emissieregistratie |
| Air quality concentrations | RIVM |

| Subject | Source |
|---|---|
| OPS number of connections | North Sea Port breidt walstroom voor de binnenvaart uit (2019) |
| **Water quality** | |
| Scores | Waterkwaliteitsportaal |
| Emissions to water | Emissieregistratie |
| **Modal split** | |
| Modal split | Strategisch masterplan : Winning combinations |
| **Public relations** | |
| Consulted websites | Zeeland seaports website ; North sea port website |

**Table 67 – Data sources used for Port of Antwerp**

| Subject | Source |
|---|---|
| Port size | Feiten en cijfers 2016, 2017, 2018 |
| Throughput | Cijferboekje 2019 |
| Value added | Nationale Bank Belgie |
| **Climate** | |
| GHG emissions | Duurzaamheidsverslag 2019 - pag 35 |
| **Climate reduction measures** | |
| Biomass | Duurzaamheidsverslag 2017; 2019 |
| Steam | Ecluse.be |
| **Renewables** | |
| Wind | Cijferboekje 2019; Duurzaamheidsverslag 2017 |
| Solar | Duurzaamheidsverslag 2017 & 2019 |
| Biomass | Duurzaamheidsverslag 2019 |
| Biogas | Duurzaamheidsverslag 2017 |
| LNG bunkerings | Duurzaamheidsverslag 2019 |
| **Air Quality** | |
| Air quality emissions | Duurzaamheidsverslag 2019; VMM, Luchtkwaliteit in de Antwerpse haven jaarrapport 2017 |
| Air quality concentrations | VMM, Luchtkwaliteit in de Antwerpse haven jaarrapport 2017 |
| OPS (MWH) | Duurzaamheidsverslag 2019 |
| OPS connections | Port of Antwerp : Walstroom |
| Minimum ESI score for discount | VMM, Luchtkwaliteit in de Antwerpse haven jaarrapport 2017 |
| Percentage of vessels receiving discount | Duurzaamheidsverslag 2019 |
| **Water quality** | |
| Scores | CIW : Geoloket stroomgebiedbeheerplannen |
| Water usage | Duurzaamheidsverslag 2019 |
| **Modal split** | |
| Modal split | Cijferboekje 2019; duurzaamheidsverslag 2019; Port of Antwerp : Binnenvaart |
| **Public relations** | |
| Consulted websites | Duurzame Haven vn Antwerpen : Dialoog; consultation port authortiy |

Table 68 - Data sources used port of Barcelona

| Subject | Source |
|---|---|
| Port size | Port de Barcelona Annual report 2017 |
| Throughput | Port de Barcelona Annual report 2017 |
| Value Added | Port de Barcelona : Economic Motor |
| **Climate** | |
| GHG emissions | No data |
| **Climate reduction measures** | |
| | No data |
| **Renewables** | |
| Solar | Port Stratery Insight for port executives |
| LNG bunkerings | Port de Barcelona Annual report 2017- page 78 |
| **Air Quality** | |
| Air quality emissions | Consultation of port authority |
| Air quality concentrations | Port de Barcelona Annual report 2017 |
| **Water quality** | |
| Scores | Port de Barcelona : Marine environment |
| Residual heat | Consultation of port authority |
| **Modal split** | |
| Modal split | no data |
| **Public relations** | |
| Consulted websites | Port de Barcelona Annual report 2017; Port de Barcelona : Annual report 2018 |

Table 69 - Data sources used port of Bremen

| Subject | Source |
|---|---|
| Port size | Facts and figures 2017 |
| Throughput | Facts and figures 2017 |
| **Climate** | |
| GHG emissions | Environmental report 2018 |
| **Climate reduction measures** | |
| Capacity | No data |
| **Renewables** | |
| Solar | Sustainability report 2016 |
| **Air Quality** | |
| Air quality emissions | No data |
| Air quality concentrations | Environmental report 2018 |
| OPS (MWH) | No data |
| OPS connections | Sustainability report 2016 |
| Minimum ESI score for discount | Environmental report 2018 |
| Percentage of vessels receiving discount | Environmental report 2018 |
| **Water quality** | |
| Scores | No data |
| **Modal split** | |
| Modal split | Facts and figures 2017 |
| **Public relations** | |
| Consulted websites | Port website |

Table 70 – Data sources used port of Felixstowe

| Subject | Source |
|---|---|
| Port size | Port of Felixstowe Journal 2017 |
| Throughput | The Port of Felixstowe's corporate brochure 2019 |
| **Climate** | |
| GHG emissions | Environment Report 2018: reference year 2017 |
| **Climate reduction measures** | |
| | No data |
| **Renewables** | |
| Solar | EEnvironment Report 2018: reference year 2017 |
| **Air Quality** | |
| Air quality concentrations | Environment Report 2018: reference year 2017 |
| **Water quality** | |
| Scores | No data |
| **Modal split** | |
| Modal split | No data |
| **Public relations** | |
| Consulted websites | Port website |

Table 71 – Data sources used port of Hamburg

| Subject | Source |
|---|---|
| Port size | Sustainability report 2015/2016; HPA - facts & figures 2017, 2018 |
| Throughput | HPA - facts & figures 2016, 2017, 2018 |
| Value added | Facts and figures Hamburg port |
| **Climate** | |
| GHG emissions | Sustainability report 2015/2016 |
| **Climate reduction measures** | |
| Heat | Aurubis website: Port of Hamburg Magazine : Focus on Industry (2017) |
| **Renewables** | |
| Wind | Consultation port authority |
| Solar PV | Consultation port authority |
| Geothermal energy | Consultation port authority |
| Solar thermal | Consultation port authority |
| **Air Quality** | |
| Air quality emissions | Sustainability report 2015/2016 ; consultation port authority |
| Air quality concentrations | No data |
| OPS (MWH) | Consultation port authority |
| OPS connections | Consultation port authority |
| Minimum ESI score for discount | Sustainability report 2013/2014 |
| Percentage of vessels receiving discount | Consultation port authority |
| **Water quality** | |
| Scores | Wasserrahmenrichtlinie 2016 ICPER Information Sheet WFD (ICPER, 2016) |
| **Modal split** | |
| Modal split | HPA - facts & figures 2016, 2017, 2018 ; consultation port authority |

| Subject | Source |
|---|---|
| **Public relations** | |
| Consulted websites | Port development plan |

Table 72 - Data sources used port of Le Havre

| Subject | Source |
|---|---|
| Port size | Le Havre Port Guide |
| Throughput | Rapport d'activité 2017; 2018 |
| Value added | Les projets de développement du port" - Pascal Galichon, Grand Port Maritime du Havre (GPMH) |
| **Climate** | |
| GHG emissions | "SET-PLAN TWG9 CCS and CCU Implementation Plan" |
| **Climate reduction measures** | |
| Biomass | No data |
| **Renewables** | |
| Wind | No data |
| **Air Quality** | |
| Air quality emissions | No data |
| Air quality concentrations | No data |
| Percentage of vessels receiving discount | Le Havre : Environmental Ship Index : an incentive to go furtherouillon auto |
| **Water quality** | |
| Scores | Suivis de la qualité de l'eau sur la circonscription du GPMH (GPMH, 2015) |
| **Modal split** | |
| Modal split | Rapport d'activité 2017; 2018 |
| **Public relations** | |
| Consulted websites | Website of port |

Table 73 - Data sources used port of London

| Subject | Source |
|---|---|
| Port size | Port of London Authority annual report & accounts 2018 |
| Throughput | Port of London Authority annual report & accounts 2018 ; 2017 |
| Value added | Port of London Authority : River Thames Economic Prosperity |
| **Climate** | |
| GHG emissions | Port of London Emissions Inventory 2016 - TNO & Aether Study |
| **Climate reduction measures** | |
| Biomass | No data |
| **Renewables** | |
| Wind | No data |
| **Air Quality** | |
| Air quality emissions | Port of London Emissions Inventory 2016 - TNO & Aether Study |
| Air quality concentrations | No data |
| Minimum ESI score for discount | Port of London Authority : Green tariff Scheme |
| **Water quality** | |
| Scores | *ICPER information sheet 2016 : Water framework directive in the Elbe river basin.* (ICPER, 2016) |

| | |
|---|---|
| **Modal split** | |
| Modal split | No data |
| **Public relations** | |
| Consulted websites | Port of London Authority : Feedback, Comments, compliments and complaints. |

**Table 74 - Data sources used port of Long Beach**

| Subject | Source |
|---|---|
| Port size | Port of Long Beach : Facts at a glance |
| Throughput | PoLB Air Emission Inventory 2018, 2017, 2016, 2015, 2010 |
| Value Added | The Port of Long Beach : Economic impacts |
| **Climate** | |
| GHG emissions | PoLB Air Emission Inventory 2018, 2017, 2016, 2015, 2010 |
| **Climate reduction measures** | |
| Biomass | No data |
| **Renewables** | |
| Wind | No data |
| **Air Quality** | |
| Air quality emissions | PoLB Air Emission Inventory 2018, 2017, 2016, 2015, 2010 |
| Air quality concentrations | ''Air Quality Monitoring Program at the Port of Long Beach Annual Summary 2018'' |
| OPS connections | PoLB Air Emission Inventory 2018 - page 50 |
| Minimum ESI score for discount | Port of Long Beach : Green Ship Incentive Program |
| **Water quality** | |
| Scores | No data |
| **Modal split** | |
| Modal split | No data |
| **Public relations** | |
| Consulted websites | Port of Long Beach : Connecting with the Community |

**Table 75 - Data sources used port of Los Angeles**

| Subject | Source |
|---|---|
| Port size | Port of Los Angeles Sustainability report 2014 |
| Throughput | Port of Los Angeles Statistics : Tonnage Data (1971-2018) |
| **Climate** | |
| GHG emissions | POLA EI reports updated with 2018 methodology |
| **Climate reduction measures** | |
| Biomass | No data |
| **Renewables** | |
| Wind | Port of Los Angeles Sustainability report 2014 ; PoLA website |
| Solar | Port of Los Angeles Sustainability report 2014 ; PoLA website<br>Port of Los Angeles : Solar power |
| **Air Quality** | |
| Air quality emissions | POLA EI reports updated with 2018 methodology |
| Air quality concentrations | Port of Los Angeles Air Quality monitoring |
| OPS (MWH) | Port of Los Angeles : AMP Operator Summary Report 2018: January to December Vessel Type: Containership |
| OPS connections | Port of Los Angeles : AMP Operator Summary Report 2018: January to December |

| Subject | Source |
| --- | --- |
| | Vessel Type: Containership ; Port of Los Angeles : Alternative Maritime Power® (AMP®) |
| Minimum ESI score for discount | Port of Los Angeles : environmental ship index |
| **Water quality** | |
| Scores | No data |
| **Modal split** | |
| Modal split | Consultation of port authority |
| **Public relations** | |
| Consulted websites | Port of Los Angeles : partners in community & consultation port authority |

**Table 76 - Data sources used port of Vancouver**

| Subject | Source |
| --- | --- |
| Port size | 2015 Port Emissions Inventory Report |
| Throughput | Financial report 2018 ; Annual report 2010 |
| Value Added | Port of Vancouver : Economic Impact Study |
| **Climate** | |
| GHG emissions | 2015 Port Emissions Inventory Report |
| **Climate reduction measures** | |
| Biomass | No data |
| **Renewables** | |
| Wind | No data |
| **Air Quality** | |
| Air quality emissions | 2015 Port Emissions Inventory Report |
| Air quality concentrations | No data |
| OPS capable vessels | Sustainability Report 2016 |
| OPS connections | (Port of Vancouver, 2018) |
| Percentage of vessels receiving discount | Website Port of Vancouver |
| **Water quality** | |
| Scores | No data |
| Water usage | Sustainability Report 2016 |
| **Modal split** | |
| Modal split | Consultation with port authority |
| **Public relations** | |
| Consulted websites | Port of Vancouver : Good neighbour & consultation port authority |

# B Greenhouse gas emissions in $CO_2$-equivalents

Emissions of greenhouse gasses can be expressed in $CO_2$-equivalents. This is based on the Global Warming Potential of a gas, which is the extent to which a gas contributes to global warming. The emissions of 1 kg of methane ($CH_4$) are the equivalent of 25 $CO_2$-equivalents, nitrous oxide (N20) equals 298 $CO_2$-equivalents. 1 kg emissions of sulphur hexafluoride ($SF_6$) equals 22,800 $CO_2$-equivalents. The emission of methane, nitrous oxide and sulphur hexafluoride expressed in $CO_2$-equivalents are shown in Table 77, Table 78 and Table 79. The total greenhouse gas emissions in the port areas expressed in $CO_2$-equivalents are shown in Table 80. Figure 54 shows the contribution of the other greenhouse gasses relative to total greenhouse gas emissions in port areas. The contribution of other greenhouse gasses in ports is small compared to $CO_2$ emissions. Especially in Groningen and Rotterdam $CO_2$ is the main contributor to global warming. Methane and nitrous oxide contribute relatively more than sulphur hexafluoride.

**Table 77 – $CH_4$ emissions in port areas expressed in $CO_2$-eq.**

| Kton $CO_2$-eq. of $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 95 | 77 | 76 | 72 |
| Groningen | 28 | 45 | 44 | 43 |
| Moerdijk | 80 | 65 | 61 | 57 |
| Rotterdam | 203 | 223 | 240 | 208 |
| Zeeland | 230 | 179 | 171 | 161 |
| **Total** | **635** | **588** | **592** | **542** |

**Table 78 – $N_20$ emissions in port areas expressed in $CO_2$-eq.**

| Kton $CO_2$-eq. of N20 | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 36 | 54 | 56 | 55 |
| Groningen | 3 | 51 | 65 | 68 |
| Moerdijk | 51 | 52 | 60 | 71 |
| Rotterdam | 83 | 119 | 125 | 116 |
| Zeeland | 250 | 258 | 262 | 277 |
| **Total** | **423** | **534** | **567** | **586** |

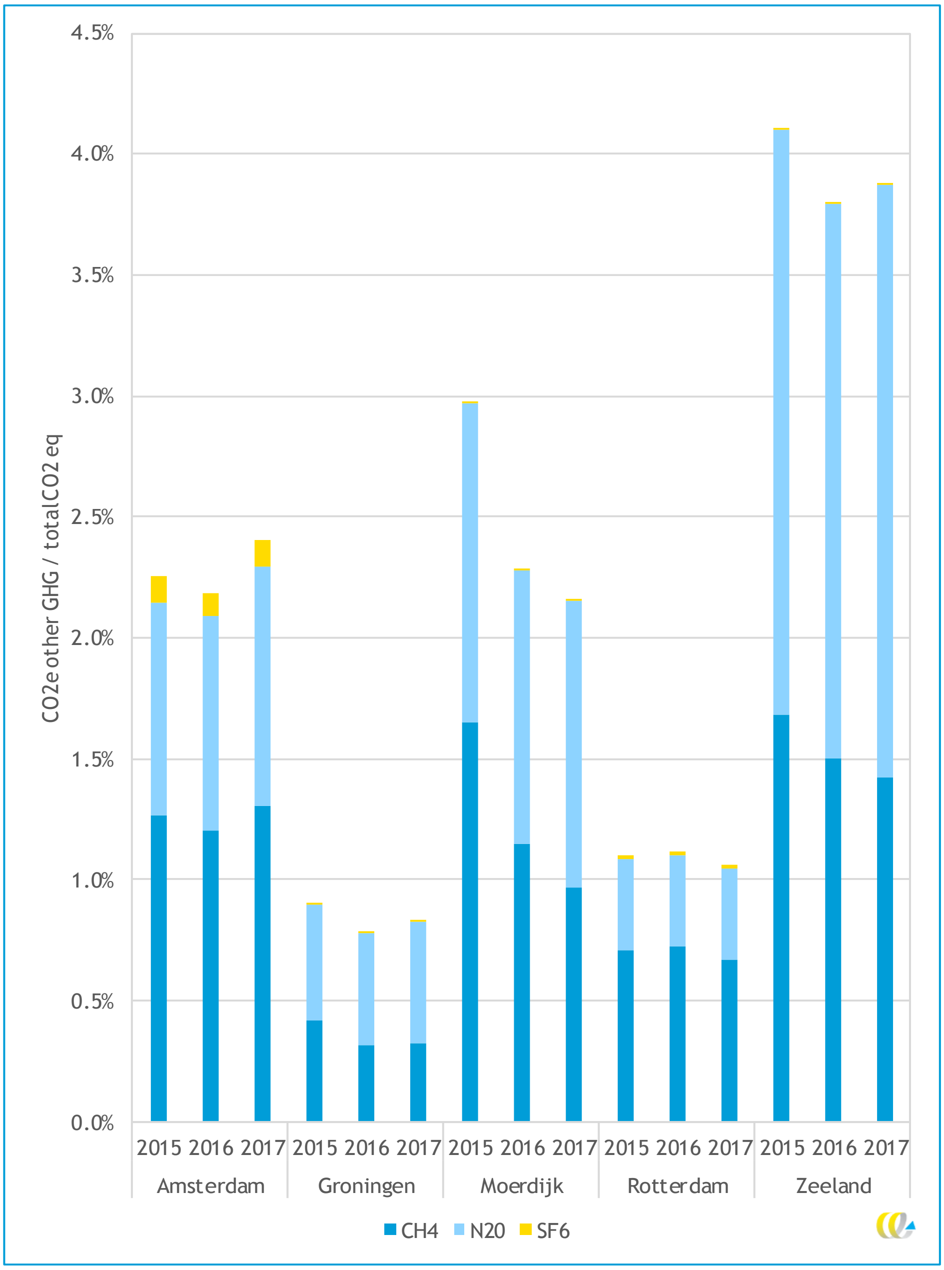
**Table 79 – $SF_6$ emissions in port areas expressed in $CO_2$-eq.**

| Kton $CO_2$-eq. of $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | 7.0 | 6.5 | 6.2 | 6.2 |
| Groningen | 0.3 | 0.4 | 0.2 | 0.2 |
| Moerdijk | 0.1 | 0.1 | 0.1 | 0.1 |
| Rotterdam | 4.5 | 4.2 | 4.0 | 4.0 |
| Zeeland | 0.6 | 0.5 | 0.5 | 0.5 |
| **Total** | **7.0** | **6.5** | **6.2** | **6.2** |

**Table 80 - total greenhouse gas emissions in port areas expressed in $CO_2$ eq.**

| Kton $CO_2$-eq. | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Amsterdam | | 6,115 | 6,330 | 5,530 |
| Groningen | | 10,629 | 13,984 | 13,434 |
| Moerdijk | | 3,917 | 5,284 | 5,953 |
| Rotterdam | | 31,483 | 33,113 | 30,969 |
| Zeeland | | 10,647 | 11,389 | 11,307 |
| **Total** | | 6,115 | 6,330 | 5,530 |

**Figure 54 - $CO_2$-equivalent emissions of other greenhouse gasses relative to total $CO_2$-equivalent emissions in port areas**





natuur en milieu zuid-holland federatie

# C Emissions in Dutch port areas by source

Emissieregistratie reports emissions for a set of various sources including industry, energy production and transport. This Annex shows the results for Dutch ports specified by sector. First the results are shown for greenhouse gas emissions. Secondly the results for air quality emissions are shown.

## C.1 Emission of greenhouse gasses by source

**Table 81 - $CO_2$ emissions port of Amsterdam by source**

| kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 14 | 12 | 12 | 11 |
| Chemical industry | 86 | 73 | 68 | 71 |
| Construction | 24 | 3 | 2 | 3 |
| Consumers | 742 | 4 | 4 | 4 |
| Drinking water supply | - | - | - | - |
| Energy sector | 2,400 | 4,203 | 4,001 | 3,364 |
| Mobility and transport | 667 | 269 | 232 | 197 |
| Nature | - | - | - | - |
| Other industry | 226 | 111 | 108 | 111 |
| Refineries | - | 12 | 10 | 29 |
| Sewage treatment | 25 | 25 | 30 | 30 |
| Trade, services and government | 443 | 71 | 66 | 49 |
| Waste disposal | 1,277 | 1,237 | 1,702 | 1,572 |
| **Total** | **5,906** | **6,020** | **6,235** | **5,441** |

**Table 82 - $CO_2$ emissions port of Groningen by source**

| kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 15 | 3 | 3 | 3 |
| Chemical industry | 532 | 515 | 495 | 620 |
| Construction | 1 | 4 | 4 | 4 |
| Consumers | 56 | 14 | 14 | 15 |
| Drinking water supply | - | - | - | - |
| Energy sector | 6,526 | 9,434 | 12,772 | 12,032 |
| Mobility and transport | 57 | 33 | 27 | 32 |
| Nature | - | - | - | - |
| Other industry | 161 | 61 | 8 | 61 |
| Refineries | 1 | 10 | 12 | 10 |
| Sewage treatment | 1 | 1 | 1 | 1 |
| Trade, services and government | 16 | 18 | 16 | 17 |
| Waste disposal | 62 | 479 | 558 | 564 |
| **Total** | **7,429** | **10,573** | **13,911** | **13,359** |

**Table 83 - $CO_2$ emissions port of Moerdijk by source**

| kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 5 | 0 | 0 | 0 |
| Chemical industry | 2,648 | 1,342 | 2,570 | 2,700 |
| Construction | 5 | 3 | 3 | 4 |
| Consumers | 21 | 1 | 1 | 1 |
| Drinking water supply | - | - | - | - |
| Energy sector | 1,036 | 987 | 1,081 | 1,539 |
| Mobility and transport | 150 | 13 | 12 | 12 |
| Nature | - | - | - | - |
| Other industry | 68 | 68 | 69 | 69 |
| Refineries | 1 | 2 | 1 | 1 |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 8 | 4 | 4 | 4 |
| Waste disposal | 1,422 | 1,383 | 1,424 | 1,496 |
| **Total** | **5,366** | **3,803** | **5,167** | **5,828** |

**Table 84 - $CO_2$ emissions port of Rotterdam by source**

| kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 426 | 24 | 24 | 24 |
| Chemical industry | 2,828 | 3,602 | 3,049 | 2,790 |
| Construction | 19 | 6 | 6 | 9 |
| Consumers | 653 | 55 | 59 | 56 |
| Drinking water supply | 0 | - | - | - |
| Energy sector | 11,852 | 14,642 | 17,059 | 15,193 |
| Mobility and transport | 1,846 | 1,222 | 956 | 999 |
| Nature | - | - | - | - |
| Other industry | 743 | 256 | 190 | 186 |
| Refineries | 9,237 | 9,641 | 9,607 | 8,931 |
| Sewage treatment | 28 | 29 | 29 | 29 |
| Trade, services and government | 316 | 252 | 161 | 780 |
| Waste disposal | 1,774 | 1,467 | 1,663 | 1,705 |
| **Total** | **29,722** | **31,195** | **32,803** | **30,702** |

**Table 85 - $CO_2$ emissions port of Zeeland by source**

| kton $CO_2$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 5 | 9 | 10 | 10 |
| Chemical industry | 5,955 | 6,228 | 6,304 | 6,206 |
| Construction | 5 | 8 | 8 | 8 |
| Consumers | 100 | 3 | 3 | 3 |
| Drinking water supply | - | - | - | - |
| Energy sector | 6,111 | 2,007 | 2,667 | 2,625 |
| Mobility and transport | 293 | 130 | 139 | 145 |
| Nature | - | - | - | - |
| Other industry | 509 | 267 | 266 | 270 |
| Refineries | 1,483 | 1,549 | 1,557 | 1,606 |
| Sewage treatment | 7 | - | - | - |
| Trade, services and government | 35 | 15 | 15 | 15 |
| Waste disposal | 34 | 28 | 25 | 22 |
| **Total** | **14,538** | **10,246** | **10,993** | **10,908** |

**Table 86 - $CH_4$ emissions port of Amsterdam by source**

| kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.2 | 0.2 | 0.2 |
| Chemical industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.6 | 0.4 | 0.4 | 0.4 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.5 | 0.4 | 0.4 | 0.3 |
| Mobility and transport | 0.1 | 0.1 | 0.1 | 0.1 |
| Nature | 0.1 | 0.1 | 0.1 | 0.1 |
| Other industry | 0.1 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | 0.0 |
| Sewage treatment | 0.4 | 0.5 | 0.6 | 0.6 |
| Trade, services and government | 0.2 | 0.1 | 0.1 | 0.1 |
| Waste disposal | 1.8 | 1.3 | 1.2 | 1.2 |
| **Total** | **3.8** | **3.1** | **3.0** | **2.9** |

**Table 87 – $CH_4$ emissions port of Groningen by source**

| kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.8 | 0.7 | 0.7 |
| Chemical industry | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.0 | 0.0 | 0.0 | 0.0 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.3 | 0.4 | 0.4 | 0.4 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | 0.1 | 0.1 | 0.1 | 0.1 |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.5 | 0.4 | 0.4 | 0.3 |
| **Total** | **1.1** | **1.8** | **1.8** | **1.7** |

**Table 88 – $CH_4$ emissions port of Moerdijk by source**

| kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.2 | 0.2 | 0.2 |
| Chemical industry | 0.1 | 0.1 | 0.1 | 0.1 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.0 | 0.0 | 0.0 | 0.0 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | 0.1 | 0.1 | 0.1 | 0.1 |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 3.0 | 2.2 | 2.1 | 1.9 |
| **Total** | **3.2** | **2.6** | **2.4** | **2.3** |

**Table 89 – $CH_4$ emissions port of Rotterdam by source**

| kton $CH_4$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 3.1 | 2.9 | 3.2 |
| Chemical industry | 0.2 | 0.3 | 0.4 | 0.2 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.5 | 0.4 | 0.4 | 0.4 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.8 | 1.2 | 2.2 | 1.0 |
| Mobility and transport | 0.1 | 0.1 | 0.1 | 0.1 |
| Nature | 0.2 | 0.2 | 0.2 | 0.2 |
| Other industry | 0.1 | 0.1 | 0.0 | 0.0 |
| Refineries | 2.1 | 0.5 | 0.6 | 0.4 |
| Sewage treatment | 0.3 | 0.3 | 0.3 | 0.3 |
| Trade, services and government | 0.1 | 0.1 | 0.0 | 0.1 |
| Waste disposal | 3.6 | 2.7 | 2.5 | 2.4 |
| Total | 8.1 | 8.9 | 9.6 | 8.3 |

**Table 90 – $CH_4$ emissions port of Zeeland by source**

| kton $CH_4$ | 2010* | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.4 | 0.4 | 0.4 |
| Chemical industry | 0.5 | 0.4 | 0.2 | 0.2 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.1 | 0.1 | 0.1 | 0.1 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.1 | 0.1 | 0.1 | 0.1 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | 0.3 | 0.3 | 0.3 | 0.3 |
| Other industry | 0.0 | 0.0 | 0.2 | 0.2 |
| Refineries | - | - | 0.0 | 0.0 |
| Sewage treatment | 0.1 | 0.1 | 0.1 | 0.1 |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 8.1 | 5.9 | 5.5 | 5.1 |
| **Total** | **9.2** | **7.1** | **6.8** | **6.4** |

**Table 91 – N20 emissions port of Amsterdam by source**

| kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 2.0 | 1.9 | 0.6 |
| Chemical industry | 0.4 | 0.4 | 0.5 | 0.6 |
| Construction | 1.4 | 1.5 | 1.6 | 1.5 |
| Consumers | 1.8 | 0.8 | 1.8 | 1.4 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 1.5 | 0.6 | 0.7 | 0.6 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | 2.5 | 3.3 | 3.3 | 3.3 |
| Other industry | 1.6 | 1.4 | 1.5 | 1.7 |
| Refineries | - | - | - | 0.0 |
| Sewage treatment | 0.0 | 1.4 | 1.4 | 1.5 |
| Trade, services and government | 2.3 | 3.6 | 3.4 | 3.5 |
| Waste disposal | 0.0 | 0.3 | 0.4 | 0.4 |
| **Total** | **11.5** | **15.4** | **16.4** | **15.0** |

**Table 92 – N20 emissions port of Groningen by source**

| kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.1 | 0.1 | 0.1 |
| Chemical industry | 0.8 | 1.0 | 0.1 | 0.2 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 1.9 | 1.6 | 1.5 | 1.9 |
| Drinking water supply | - | - | - | - |
| Energy sector | 1.0 | 1.4 | 0.6 | 1.1 |
| Mobility and transport | 2.3 | 1.9 | 0.8 | 2.2 |
| Nature | 1.7 | 1.5 | 1.5 | 1.5 |
| Other industry | 1.1 | 0.4 | 0.9 | 1.5 |
| Refineries | - | - | - | - |
| Sewage treatment | 1.5 | 1.9 | 1.5 | 1.5 |
| Trade, services and government | 1.6 | 0.9 | 1.3 | 1.2 |
| Waste disposal | 0.0 | 0.1 | 0.0 | 0.1 |
| **Total** | **11.8** | **10.7** | **8.3** | **11.4** |

**Table 93 - N20 emissions port of Moerdijk by source**

| kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.0 | 0.0 | 0.0 |
| Chemical industry | 0.8 | 0.0 | 0.0 | 0.1 |
| Construction | 0.2 | 0.2 | 0.2 | 0.2 |
| Consumers | 0.7 | 0.4 | 0.7 | 0.7 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 1.8 | 0.9 | 0.9 | 0.9 |
| Nature | 1.5 | 1.6 | 1.6 | 1.6 |
| Other industry | 1.2 | 1.2 | 0.4 | 1.1 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.9 | 0.9 | 0.8 | 0.8 |
| Trade, services and government | 0.3 | 1.4 | 1.3 | 1.3 |
| Waste disposal | 0.5 | 0.4 | 0.5 | 0.5 |
| **Total** | **8.0** | **7.0** | **6.4** | **7.2** |

**Table 94 - N20 emissions port of Rotterdam by source**

| kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 3.5 | 3.2 | 1.9 |
| Chemical industry | 2.7 | 3.3 | 2.8 | 2.5 |
| Construction | 3.3 | 2.2 | 2.6 | 2.6 |
| Consumers | 4.4 | 3.9 | 4.4 | 4.6 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.6 | 1.9 | 1.4 | 1.1 |
| Mobility and transport | 2.8 | 1.9 | 1.1 | 1.7 |
| Nature | 4.9 | 5.4 | 5.4 | 5.4 |
| Other industry | 2.1 | 3.1 | 3.3 | 2.6 |
| Refineries | 0.1 | 0.1 | 0.1 | 0.1 |
| Sewage treatment | 4.7 | 5.4 | 4.9 | 5.3 |
| Trade, services and government | 4.2 | 7.1 | 7.2 | 6.3 |
| Waste disposal | 1.9 | 1.8 | 1.9 | 0.9 |
| **Total** | **31.7** | **39.8** | **38.3** | **35.0** |

**Table 95 - N20 emissions port of Zeeland by source**

| kton $N_2O$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.1 | 0.9 | 0.9 |
| Chemical industry | 1.2 | 1.4 | 1.5 | 1.0 |
| Construction | 0.7 | 0.6 | 0.5 | 0.6 |
| Consumers | 5.7 | 5.0 | 4.7 | 5.0 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 4.4 | 2.8 | 2.1 | 1.8 |
| Nature | 2.5 | 3.2 | 3.2 | 3.2 |
| Other industry | 0.8 | 1.6 | 1.7 | 2.0 |
| Refineries | 0.0 | 0.0 | 0.0 | 0.0 |
| Sewage treatment | 2.8 | 3.2 | 2.7 | 2.6 |
| Trade, services and government | 1.6 | 2.4 | 1.4 | 1.6 |
| Waste disposal | 0.8 | 1.5 | 1.7 | 0.9 |
| **Total** | **20.6** | **21.7** | **20.3** | **19.6** |

**Table 96 - $SF_6$ emissions port of Amsterdam by source**

| kton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | - | - | - | - |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | - | - | - | - |
| Nature | - | - | - | - |
| Other industry | 1.7 | 2.7 | 2.6 | 2.6 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | - | - | - | - |
| Waste disposal | - | - | - | - |
| **Total** | **1.7** | **2.7** | **2.6** | **2.6** |

Table 97 – $SF_6$ emissions port of Groningen by source

| kton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | - | - | - | - |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | - | - | - | - |
| Nature | - | - | - | - |
| Other industry | 1.1 | 0.9 | 1.0 | 1.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | - | - | - | - |
| Waste disposal | - | - | - | - |
| **Total** | **1.1** | **0.9** | **1.0** | **1.0** |

Table 98 – $SF_6$ emissions port of Moerdijk by source

| kton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | - | - | - | - |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | - | - | - | - |
| Nature | - | - | - | - |
| Other industry | 0.5 | 0.5 | 0.5 | 0.5 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | - | - | - | - |
| Waste disposal | - | - | - | - |
| **Total** | **0.5** | **0.5** | **0.5** | **0.5** |

**Table 99 - $SF_6$ emissions port of Rotterdam by source**

| kton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | - | - | - | - |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | - | - | - | - |
| Nature | - | - | - | - |
| Other industry | 6.1 | 5.4 | 5.2 | 5.2 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | - | - | - | - |
| Waste disposal | - | - | - | - |
| **Total** | **6.1** | **5.4** | **5.2** | **5.2** |

**Table 100 - $SF_6$ emissions port of Zeeland by source**

| kton $SF_6$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | - | - | - | - |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | - | - | - | - |
| Nature | - | - | - | - |
| Other industry | 1.2 | 1.6 | 0.7 | 0.7 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | - | - | - | - |
| Waste disposal | - | - | - | - |
| **Total** | **1.2** | **1.6** | **0.7** | **0.7** |

## C.2 Emissions of air quality pollutants by source

**Table 101 – $PM_{2,5}$ emissions port of Amsterdam by source**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 2.9 | 2.9 | 2.3 | 2.7 |
| Chemical industry | 0.7 | 0.0 | 0.0 | 0.4 |
| Construction | 1.7 | 1.8 | 1.9 | 2.0 |
| Consumers | 0.6 | 0.7 | 0.6 | 0.6 |
| Drinking water supply | 0.1 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.5 | 0.5 | 0.4 | 0.3 |
| Mobility and transport | 0.2 | 0.1 | 0.1 | 0.1 |
| Nature | - | - | - | - |
| Other industry | 0.9 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | 0.0 |
| Sewage treatment | 0.4 | 1.0 | 0.5 | 0.5 |
| Trade, services and government | 1.4 | 0.8 | 0.8 | 0.2 |
| Waste disposal | 0.7 | 0.4 | 0.3 | 0.5 |
| **Total** | **10.1** | **8.2** | **6.9** | **7.2** |

**Table 102 – $PM_{2,5}$ emissions port of Groningen by source**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 2.9 | 2.4 | 3.1 | 3.6 |
| Chemical industry | 0.0 | 0.0 | 0.0 | 0.4 |
| Construction | 1.6 | 1.7 | 2.5 | 1.7 |
| Consumers | 2.0 | 1.9 | 1.2 | 1.9 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.2 | 0.1 | 1.0 | 1.0 |
| Mobility and transport | 0.0 | 1.5 | 1.1 | 1.2 |
| Nature | - | - | - | - |
| Other industry | 0.8 | 1.5 | 1.5 | 1.0 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 3.2 | 3.0 | 3.3 | 2.6 |
| Waste disposal | 0.6 | 0.2 | 0.2 | 0.3 |
| **Total** | **11.4** | **12.4** | **13.8** | **13.4** |

**Table 103 – $PM_{2,5}$ emissions port of Moerdijk by source**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.8 | 0.7 | 0.9 | 0.7 |
| Chemical industry | 0.6 | 0.1 | 0.6 | 0.3 |
| Construction | 0.6 | 0.9 | 0.9 | 1.1 |
| Consumers | 0.7 | 0.4 | 0.6 | 0.6 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.2 | 0.1 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.0 | 0.0 | 0.5 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 1.1 | 1.1 | 1.2 | 1.2 |
| Waste disposal | 0.7 | 0.6 | 0.8 | 0.0 |
| **Total** | **4.5** | **4.1** | **5.3** | **4.4** |

**Table 104 – $PM_{2,5}$ emissions port of Rotterdam by source**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 5.0 | 4.6 | 5.4 | 6.1 |
| Chemical industry | 1.2 | 2.2 | 1.4 | 1.3 |
| Construction | 2.7 | 3.9 | 3.4 | 3.8 |
| Consumers | 0.5 | 1.9 | 2.0 | 1.9 |
| Drinking water supply | 0.3 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.3 | 0.2 | 0.2 | 0.5 |
| Mobility and transport | 0.8 | 1.4 | 0.5 | 0.5 |
| Nature | - | - | - | - |
| Other industry | 1.0 | 0.5 | 0.6 | 1.6 |
| Refineries | 0.2 | 0.2 | 0.2 | 0.2 |
| Sewage treatment | 1.1 | 1.4 | 1.3 | 1.3 |
| Trade, services and government | 4.9 | 5.1 | 4.9 | 3.9 |
| Waste disposal | 0.5 | 1.0 | 0.4 | 0.6 |
| **Total** | **18.4** | **22.3** | **20.2** | **21.8** |

**Table 105 – $PM_{2,5}$ emissions port of Zeeland by source**

| kton $PM_{2,5}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 2.0 | 4.3 | 4.4 | 4.5 |
| Chemical industry | 0.5 | 0.4 | 0.5 | 0.6 |
| Construction | 5.1 | 5.1 | 6.0 | 6.2 |
| Consumers | 2.1 | 2.2 | 2.9 | 2.9 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 0.1 | 0.1 | 0.1 | 0.1 |
| Nature | - | - | - | - |
| Other industry | 1.5 | 2.1 | 1.8 | 1.7 |
| Refineries | 0.0 | 0.0 | 0.0 | 0.0 |
| Sewage treatment | 0.3 | 0.8 | 1.0 | 1.0 |
| Trade, services and government | 2.2 | 3.0 | 2.2 | 2.3 |
| Waste disposal | 0.3 | 0.4 | 0.5 | 0.4 |
| **Total** | **14.1** | **18.2** | **19.4** | **19.7** |

**Table 106 – $PM_{10}$ emissions port of Amsterdam by source**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.00 | 0.00 | 0.00 |
| Chemical industry | - | 0.02 | 0.01 | 0.01 |
| Construction | - | 0.00 | 0.00 | 0.00 |
| Consumers | - | 0.00 | 0.00 | 0.00 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | 0.06 | 0.05 | 0.05 |
| Mobility and transport | - | 0.06 | 0.05 | 0.04 |
| Nature | - | - | - | - |
| Other industry | - | 0.07 | 0.08 | 0.08 |
| Refineries | - | - | - | 0.00 |
| Sewage treatment | - | 0.00 | 0.00 | 0.00 |
| Trade, services and government | - | 0.25 | 0.24 | 0.21 |
| Waste disposal | - | 0.04 | 0.02 | 0.01 |
| **Total** | **-** | **0.50** | **0.46** | **0.41** |

**Table 107 – $PM_{10}$ emissions port of Groningen by source**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | 0.00 | 0.00 | 0.00 |
| Chemical industry | - | 0.05 | 0.05 | 0.04 |
| Construction | - | 0.00 | 0.00 | 0.00 |
| Consumers | - | 0.00 | 0.00 | 0.00 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | 0.05 | 0.07 | 0.05 |
| Mobility and transport | - | 0.01 | 0.01 | 0.01 |
| Nature | - | - | - | - |
| Other industry | - | 0.04 | 0.01 | 0.06 |
| Refineries | - | - | - | - |
| Sewage treatment | - | 0.00 | 0.00 | 0.00 |
| Trade, services and government | - | 0.00 | 0.00 | 0.00 |
| Waste disposal | - | 0.00 | 0.00 | 0.00 |
| **Total** | **-** | **0.15** | **0.14** | **0.17** |

**Table 108 – $PM_{10}$ emissions port of Moerdijk by source**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.00 | 0.00 | 0.00 |
| Chemical industry | | 0.01 | 0.04 | 0.04 |
| Construction | | 0.00 | 0.00 | 0.00 |
| Consumers | | 0.00 | 0.00 | 0.00 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.00 | 0.00 | 0.00 |
| Mobility and transport | | 0.00 | 0.00 | 0.00 |
| Nature | | - | - | - |
| Other industry | | 0.05 | 0.04 | 0.04 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 0.00 | 0.00 | 0.00 |
| Waste disposal | | 0.01 | 0.01 | 0.01 |
| **Total** | | **0.07** | **0.09** | **0.09** |

**Table 109 – $PM_{10}$ emissions port of Rotterdam by source**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.00 | 0.00 | 0.00 |
| Chemical industry | | 0.08 | 0.05 | 0.03 |
| Construction | | 0.00 | 0.00 | 0.00 |
| Consumers | | 0.01 | 0.01 | 0.01 |
| Drinking water supply | | 0.00 | 0.00 | 0.00 |
| Energy sector | | 0.06 | 0.09 | 0.09 |
| Mobility and transport | | 0.33 | 0.25 | 0.25 |
| Nature | | - | - | - |
| Other industry | | 0.09 | 0.15 | 0.15 |
| Refineries | | 0.27 | 0.22 | 0.23 |
| Sewage treatment | | 0.00 | 0.00 | 0.00 |
| Trade, services and government | | 0.50 | 0.48 | 0.49 |
| Waste disposal | | 0.00 | 0.00 | 0.00 |
| **Total** | | **1.35** | **1.25** | **1.24** |

**Table 110 – $PM_{10}$ emissions port of Zeeland by source**

| kton $PM_{10}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.00 | 0.00 | 0.00 |
| Chemical industry | | 0.56 | 0.70 | 0.81 |
| Construction | | 0.00 | 0.00 | 0.00 |
| Consumers | | 0.00 | 0.00 | 0.00 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.02 | 0.00 | 0.00 |
| Mobility and transport | | 0.04 | 0.04 | 0.04 |
| Nature | | - | - | - |
| Other industry | | 0.09 | 0.09 | 0.10 |
| Refineries | | 0.01 | 0.00 | 0.00 |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 0.04 | 0.05 | 0.05 |
| Waste disposal | | 0.00 | 0.00 | 0.00 |
| **Total** | | **0.76** | **0.88** | **1.00** |

**Table 111 – $NO_x$ emissions port of Amsterdam by source**

| kton $NO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 8.9 | 9.1 | 8.9 |
| Chemical industry | | 1.2 | 1.5 | 1.0 |
| Construction | | 2.4 | 2.8 | 2.4 |
| Consumers | | 4.3 | 4.2 | 4.2 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | - | - |
| Mobility and transport | | 16.3 | 13.1 | 15.5 |
| Nature | | - | - | - |
| Other industry | | 5.6 | 4.9 | 4.6 |
| Refineries | | 0.0 | 0.0 | 0.0 |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 3.5 | 3.6 | 3.9 |
| Waste disposal | | 0.2 | 1.0 | 0.3 |
| **Total** | | **42.5** | **40.1** | **40.8** |

**Table 112 – $NO_x$ emissions port of Groningen by source**

| kton $NO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 13.6 | 15.1 | 14.4 |
| Chemical industry | | 1.6 | 0.7 | 1.0 |
| Construction | | 2.3 | 2.5 | 3.6 |
| Consumers | | 6.8 | 6.8 | 5.9 |
| Drinking water supply | | - | - | - |
| Energy sector | | 4.0 | 3.9 | 3.6 |
| Mobility and transport | | 7.0 | 6.1 | 7.9 |
| Nature | | - | - | - |
| Other industry | | 3.6 | 2.5 | 3.1 |
| Refineries | | 0.0 | 0.0 | 0.0 |
| Sewage treatment | | 0.1 | 0.0 | 0.0 |
| Trade, services and government | | 1.2 | 1.6 | 1.6 |
| Waste disposal | | 1.5 | 1.1 | 1.7 |
| **Total** | | **41.8** | **40.4** | **42.9** |

**Table 113 – $NO_x$ emissions port of Moerdijk by source**

| kton $NO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 3.6 | 2.8 | 3.6 |
| Chemical industry | | 1.7 | 2.5 | 2.5 |
| Construction | | 4.0 | 3.9 | 3.0 |
| Consumers | | 1.1 | 1.9 | 1.9 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.6 | 0.7 | 0.8 |
| Mobility and transport | | 3.3 | 4.1 | 3.3 |
| Nature | | - | - | - |
| Other industry | | 3.3 | 3.5 | 3.9 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 1.5 | 1.4 | 1.8 |
| Waste disposal | | 1.1 | 1.9 | 1.6 |
| **Total** | | **20.1** | **22.7** | **22.5** |

**Table 114 – $NO_x$ emissions port of Rotterdam by source**

| kton $NO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 11.8 | 9.6 | 9.1 |
| Chemical industry | | 3.6 | 1.8 | 3.2 |
| Construction | | 25.2 | 22.2 | 25.2 |
| Consumers | | 17.4 | 17.8 | 18.0 |
| Drinking water supply | | 0.0 | 0.2 | 0.2 |
| Energy sector | | 11.6 | 12.0 | 11.1 |
| Mobility and transport | | 12.1 | 11.9 | 14.1 |
| Nature | | - | - | - |
| Other industry | | 11.4 | 12.0 | 12.7 |
| Refineries | | 4.7 | 4.5 | 4.4 |
| Sewage treatment | | 0.1 | 0.1 | 0.1 |
| Trade, services and government | | 7.8 | 7.8 | 9.8 |
| Waste disposal | | 4.9 | 4.8 | 4.1 |
| **Total** | | **110.6** | **104.6** | **112.0** |

**Table 115 – $NO_x$ emissions port of Zeeland by source**

| kton $NO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 20.1 | 18.6 | 19.8 |
| Chemical industry | | 3.7 | 4.1 | 3.0 |
| Construction | | 7.8 | 7.6 | 7.6 |
| Consumers | | 9.5 | 8.0 | 7.5 |
| Drinking water supply | | - | - | - |
| Energy sector | | 2.1 | 1.3 | 1.7 |
| Mobility and transport | | 4.1 | 4.2 | 4.5 |
| Nature | | - | - | - |
| Other industry | | 5.1 | 4.6 | 4.9 |
| Refineries | | 0.5 | 0.5 | 0.3 |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 5.5 | 4.5 | 5.2 |
| Waste disposal | | 1.6 | 2.3 | 1.7 |
| **Total** | | **60.0** | **55.8** | **56.3** |

**Table 116 – $SO_2$ emissions port of Amsterdam by source**

| kton $SO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.0 | 0.0 | 0.0 |
| Chemical industry | | 0.9 | 0.9 | 0.6 |
| Construction | | 1.3 | 1.2 | 1.8 |
| Consumers | | 3.0 | 3.0 | 3.2 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.8 | 0.4 | 0.2 |
| Mobility and transport | | 10.2 | 8.6 | 9.4 |
| Nature | | - | - | - |
| Other industry | | 6.8 | 6.3 | 5.3 |
| Refineries | | - | - | 0.0 |
| Sewage treatment | | 0.3 | 0.6 | 0.6 |
| Trade, services and government | | - | - | - |
| Waste disposal | | 3.2 | 2.4 | 2.9 |
| **Total** | | **26.5** | **23.3** | **24.1** |

**Table 117 – $SO_2$ emissions port of Groningen by source**

| kton $SO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 4.7 | 5.5 | 4.6 |
| Chemical industry | | 0.8 | 0.8 | 1.1 |
| Construction | | 0.0 | 0.0 | 0.0 |
| Consumers | | 3.2 | 3.3 | 3.0 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.7 | 1.0 | 0.9 |
| Mobility and transport | | 8.9 | 11.8 | 6.5 |
| Nature | | - | - | - |
| Other industry | | 2.7 | 2.3 | 1.7 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | - | - | - |
| Waste disposal | | 1.1 | 0.8 | 1.5 |
| **Total** | | **22.1** | **25.6** | **19.3** |

**Table 118 – $SO_2$ emissions port of Moerdijk by source**

| kton $SO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.0 | 0.0 | 0.0 |
| Chemical industry | | 0.4 | 1.0 | 1.5 |
| Construction | | 0.9 | 0.3 | 1.1 |
| Consumers | | 0.4 | 0.4 | 0.4 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | 0.0 | 0.0 |
| Mobility and transport | | 2.4 | 3.3 | 2.8 |
| Nature | | - | - | - |
| Other industry | | 2.5 | 2.7 | 2.3 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | - | - | - |
| Waste disposal | | 0.7 | 0.4 | 1.0 |
| **Total** | | **7.3** | **8.1** | **9.1** |

**Table 119 – $SO_2$ emissions port of Rotterdam by source**

| kton $SO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.4 | 0.5 | 0.4 |
| Chemical industry | | 4.1 | 2.6 | 3.7 |
| Construction | | 0.2 | 0.3 | 0.9 |
| Consumers | | 12.6 | 12.1 | 12.5 |
| Drinking water supply | | 0.6 | 0.4 | 0.2 |
| Energy sector | | 3.7 | 3.5 | 2.8 |
| Mobility and transport | | 32.8 | 35.3 | 39.5 |
| Nature | | - | - | - |
| Other industry | | 7.2 | 6.9 | 7.2 |
| Refineries | | 9.1 | 8.7 | 9.0 |
| Sewage treatment | | 1.5 | 1.0 | 1.0 |
| Trade, services and government | | - | - | - |
| Waste disposal | | 1.6 | 2.1 | 2.4 |
| **Total** | | **73.7** | **73.4** | **79.6** |

**Table 120 – $SO_2$ emissions port of Zeeland by source**

| kton $SO_2$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 0.4 | 0.3 | 0.4 |
| Chemical industry | | 0.7 | 0.3 | 0.9 |
| Construction | | 0.7 | 0.6 | 0.2 |
| Consumers | | 2.0 | 2.1 | 2.1 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | 0.0 | 0.0 |
| Mobility and transport | | 11.0 | 11.1 | 12.8 |
| Nature | | - | - | - |
| Other industry | | 2.4 | 3.1 | 4.3 |
| Refineries | | 2.0 | 2.5 | 2.1 |
| Sewage treatment | | - | - | - |
| Trade, services and government | | - | - | - |
| Waste disposal | | 1.4 | 1.2 | 1.1 |
| **Total** | | **20.6** | **21.2** | **23.8** |

**Table 121 – $NH_3$ emissions port of Amsterdam by source**

| kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 3.1 | 3.7 | 3.4 |
| Chemical industry | | 0.8 | 0.9 | 0.0 |
| Construction | | 2.3 | 1.7 | 2.2 |
| Consumers | | 7.2 | 6.7 | 7.5 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | 0.0 | - |
| Mobility and transport | | 16.3 | 16.0 | 15.4 |
| Nature | | - | - | - |
| Other industry | | 6.2 | 5.3 | 4.2 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 11.5 | 11.7 | 11.2 |
| Waste disposal | | 1.1 | 1.2 | 0.3 |
| **Total** | | **48.6** | **47.2** | **44.2** |

**Table 122 – $NH_3$ emissions port of Groningen by source**

| kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 9.9 | 9.1 | 7.6 |
| Chemical industry | | 0.0 | 0.0 | 0.0 |
| Construction | | 0.2 | 0.2 | 0.2 |
| Consumers | | 8.6 | 7.7 | 7.9 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | 0.0 | 0.0 |
| Mobility and transport | | 13.4 | 14.5 | 14.8 |
| Nature | | - | - | - |
| Other industry | | 0.3 | 0.3 | 0.2 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 3.4 | 4.0 | 3.7 |
| Waste disposal | | 0.0 | 0.0 | - |
| **Total** | | **35.8** | **35.8** | **34.5** |

**Table 123 – $NH_3$ emissions port of Moerdijk by source**

| kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 4.6 | 4.8 | 4.3 |
| Chemical industry | | 0.7 | 0.0 | 0.0 |
| Construction | | 0.0 | 0.0 | 0.0 |
| Consumers | | 1.3 | 1.7 | 1.6 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.0 | 0.0 | 0.0 |
| Mobility and transport | | 5.7 | 5.4 | 5.2 |
| Nature | | - | - | - |
| Other industry | | 0.6 | 0.6 | 0.8 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 2.1 | 2.6 | 2.8 |
| Waste disposal | | 0.0 | 0.0 | 0.0 |
| **Total** | | **15.1** | **15.1** | **14.7** |

**Table 124 – $NH_3$ emissions port of Rotterdam by source**

| kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 15.0 | 11.7 | 12.1 |
| Chemical industry | | 1.7 | 0.9 | 1.0 |
| Construction | | 1.4 | 1.6 | 2.4 |
| Consumers | | 18.6 | 19.5 | 19.4 |
| Drinking water supply | | - | - | - |
| Energy sector | | 0.1 | 0.0 | 0.0 |
| Mobility and transport | | 48.8 | 52.0 | 47.7 |
| Nature | | - | - | - |
| Other industry | | 4.0 | 4.1 | 5.6 |
| Refineries | | - | 0.0 | 0.0 |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 19.0 | 20.0 | 18.7 |
| Waste disposal | | 0.7 | 0.7 | 0.0 |
| **Total** | | **109.2** | **110.5** | **107.0** |

**Table 125 – $NH_3$ emissions port of Zeeland by source**

| kton $NH_3$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | | 14.2 | 15.3 | 14.4 |
| Chemical industry | | 1.0 | 1.3 | 0.9 |
| Construction | | 0.1 | 0.2 | 0.3 |
| Consumers | | 8.1 | 8.0 | 8.0 |
| Drinking water supply | | - | - | - |
| Energy sector | | - | - | - |
| Mobility and transport | | 22.0 | 18.8 | 20.8 |
| Nature | | - | - | - |
| Other industry | | 1.4 | 1.3 | 1.9 |
| Refineries | | - | - | - |
| Sewage treatment | | - | - | - |
| Trade, services and government | | 7.6 | 9.3 | 9.7 |
| Waste disposal | | 0.6 | 0.7 | 0.7 |
| **Total** | | **55.1** | **54.9** | **56.5** |

**Table 126 – PB emissions port of Amsterdam by source**

| kton PB | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | 0.7 | 0.6 | 0.7 | 1.0 |
| Construction | - | - | - | - |
| Consumers | 0.6 | 0.5 | 0.5 | 0.2 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | 1.2 | 2.5 | 2.5 | 1.8 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.0 | 0.0 | 0.1 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.0 | 0.0 | 0.2 |
| **Total** | **2.5** | **3.6** | **3.7** | **3.3** |

**Table 127 – PB emissions port of Groningen by source**

| kton PB | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | 1.0 | 0.5 | 0.6 | - |
| Construction | - | - | - | - |
| Consumers | 0.0 | 0.0 | 0.0 | 0.0 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.7 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.1 | 0.5 | 0.0 |
| **Total** | **1.7** | **0.6** | **1.1** | **0.0** |

**Table 128 – PB emissions port of Moerdijk by source**

| kton PB | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | - | - | - | - |
| Construction | - | - | - | - |
| Consumers | 0.0 | 0.0 | 0.0 | 0.0 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | - |
| Mobility and transport | 0.3 | 0.2 | 0.3 | 0.3 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.5 | 0.0 | 0.9 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.1 | 0.1 | 0.1 |
| **Total** | **0.3** | **0.9** | **0.4** | **1.2** |

**Table 129 – PB emissions port of Rotterdam by source**

| kton PB | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | - | - | - | - |
| Chemical industry | 1.2 | 0.7 | 0.7 | 0.5 |
| Construction | - | - | - | - |
| Consumers | 0.4 | 0.0 | 0.1 | 0.1 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | - | - | - |
| Mobility and transport | 1.8 | 2.3 | 2.4 | 2.2 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.5 | 0.1 | 0.1 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.6 | 0.0 | 0.0 | 0.0 |
| **Total** | **4.0** | **3.5** | **3.3** | **3.0** |

**Table 130 – CO emissions port of Amsterdam by source**

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.6 | 1.0 | 1.3 | 1.3 |
| Chemical industry | 0.2 | 0.3 | 0.3 | 0.9 |
| Construction | 1.2 | 0.4 | 1.0 | 1.1 |
| Consumers | 2.1 | 1.1 | 1.1 | 1.1 |
| Drinking water supply | 0.4 | 0.3 | 1.1 | 0.6 |
| Energy sector | 0.4 | 1.8 | 1.0 | 1.1 |
| Mobility and transport | 9.6 | 8.8 | 8.6 | 8.6 |
| Nature | 1.9 | 1.9 | 1.9 | 1.9 |
| Other industry | 0.1 | 0.2 | 0.2 | 0.2 |
| Refineries | - | - | - | 0.0 |
| Sewage treatment | 0.8 | 1.1 | 0.4 | 0.4 |
| Trade, services and government | 0.1 | 0.1 | 0.1 | 1.1 |
| Waste disposal | 0.9 | 0.6 | 0.5 | 0.8 |
| **Total** | **18.4** | **17.5** | **17.3** | **19.1** |

**Table 131 – CO emissions port of Groningen by source**

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 1.6 | 3.4 | 1.8 | 2.7 |
| Chemical industry | 0.6 | 0.6 | 0.5 | 0.5 |
| Construction | 2.2 | 1.2 | 1.7 | 2.0 |
| Consumers | 0.2 | 0.3 | 0.3 | 0.3 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.8 | 1.2 | 1.1 | 0.8 |
| Mobility and transport | 0.7 | 0.6 | 0.6 | 0.6 |
| Nature | 0.0 | 0.0 | 0.0 | 0.0 |
| Other industry | 8.8 | 4.7 | 2.9 | 4.8 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 1.6 | 1.6 | 2.0 | 2.8 |
| Waste disposal | 0.1 | 0.2 | 0.2 | 0.4 |
| **Total** | **16.7** | **13.9** | **11.1** | **14.9** |

**Table 132 – CO emissions port of Moerdijk by source**

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 1.2 | 1.5 | 1.8 | 1.1 |
| Chemical industry | 1.4 | 0.4 | 0.2 | 0.1 |
| Construction | 1.3 | 0.6 | 0.6 | 0.7 |
| Consumers | 0.1 | 0.1 | 0.1 | 0.1 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 1.0 | 0.9 | 0.9 | 0.9 |
| Nature | 0.0 | 0.0 | 0.0 | 0.0 |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.7 | 0.6 | 0.6 | 0.6 |
| Waste disposal | 0.2 | 0.1 | 0.2 | 0.2 |
| **Total** | **6.1** | **4.4** | **4.4** | **3.8** |

Table 133 – CO emissions port of Rotterdam by source

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 2.2 | 2.4 | 2.2 | 2.4 |
| Chemical industry | 4.2 | 3.6 | 3.5 | 3.3 |
| Construction | 3.5 | 4.8 | 4.9 | 5.0 |
| Consumers | 2.0 | 1.3 | 1.3 | 1.3 |
| Drinking water supply | 0.3 | 0.8 | 0.7 | 0.6 |
| Energy sector | 4.3 | 2.0 | 2.2 | 2.0 |
| Mobility and transport | 13.3 | 10.6 | 10.3 | 10.3 |
| Nature | 3.5 | 4.2 | 4.2 | 4.2 |
| Other industry | 5.7 | 1.2 | 1.8 | 0.8 |
| Refineries | 5.7 | 4.9 | 4.3 | 1.5 |
| Sewage treatment | 1.4 | 0.9 | 0.1 | 0.1 |
| Trade, services and government | 2.5 | 2.0 | 1.4 | 2.1 |
| Waste disposal | 1.8 | 2.1 | 2.2 | 1.6 |
| **Total** | **50.4** | **40.8** | **38.9** | **35.1** |

Table 134 – CO emissions port of Zeeland by source

| kton CO | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 3.2 | 2.8 | 2.7 | 2.8 |
| Chemical industry | 5.1 | 5.0 | 5.5 | 7.5 |
| Construction | 2.9 | 3.6 | 4.1 | 2.9 |
| Consumers | 0.4 | 0.4 | 0.4 | 0.4 |
| Drinking water supply | - | - | - | - |
| Energy sector | 1.9 | 0.7 | 0.7 | 1.4 |
| Mobility and transport | 2.0 | 1.8 | 1.8 | 1.8 |
| Nature | 0.1 | 0.1 | 0.1 | 0.1 |
| Other industry | 2.4 | 1.5 | 1.7 | 1.3 |
| Refineries | 0.5 | 0.7 | 0.5 | 0.5 |
| Sewage treatment | 1.0 | 1.0 | 0.3 | 0.3 |
| Trade, services and government | 1.9 | 3.7 | 3.6 | 3.6 |
| Waste disposal | 0.4 | 0.7 | 0.6 | 0.0 |
| **Total** | **21.6** | **22.0** | **22.0** | **22.4** |

**Table 135 – Benzopyrene emissions port of Amsterdam by source**

| kton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.0 |
| Chemical industry | - | - | - | - |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 1.3 | 2.0 | 2.0 | 2.0 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **1.3** | **2.0** | **2.0** | **2.0** |

**Table 136 – Benzopyrene emissions port of Groningen by source**

| kton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.0 |
| Chemical industry | - | 0.0 | 0.0 | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.3 | 0.3 | 0.5 | 0.5 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.4 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | - | - | - |
| **Total** | **0.3** | **0.4** | **0.9** | **0.5** |

**Table 137 – Benzopyrene emissions port of Moerdijk by source**

| kton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.0 |
| Chemical industry | - | - | - | - |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.0 | 0.0 | 0.2 | 0.2 |
| Drinking water supply | - | - | - | - |
| Energy sector | - | - | - | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.0 | 0.0 | 0.0 | 0.0 |
| Refineries | - | - | - | - |
| Sewage treatment | - | - | - | - |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **0.0** | **0.0** | **0.2** | **0.2** |

**Table 138 – Benzopyrene emissions port of Rotterdam by source**

| kton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.0 |
| Chemical industry | 0.0 | - | - | 0.0 |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 3.0 | 1.7 | 1.7 | 2.0 |
| Drinking water supply | 0.0 | 0.0 | 0.0 | 0.0 |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.1 | 0.7 | 0.4 | 0.2 |
| Refineries | - | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | - | - | - | - |
| **Total** | **3.1** | **2.4** | **2.1** | **2.1** |

**Table 139 – Benzopyrene emissions port of Zeeland by source**

| kton $C_{20}H_{12}$ | 2010 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.0 |
| Chemical industry | - | - | - | - |
| Construction | 0.0 | 0.0 | 0.0 | 0.0 |
| Consumers | 0.4 | 0.5 | 0.5 | 0.5 |
| Drinking water supply | - | - | - | - |
| Energy sector | 0.0 | 0.0 | 0.0 | 0.0 |
| Mobility and transport | 0.0 | 0.0 | 0.0 | 0.0 |
| Nature | - | - | - | - |
| Other industry | 0.2 | 0.0 | 0.0 | 0.0 |
| Refineries | 0.0 | - | - | - |
| Sewage treatment | 0.0 | 0.0 | 0.0 | 0.0 |
| Trade, services and government | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste disposal | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **0.7** | **0.5** | **0.5** | **0.5** |