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BETTER SHIPS, BLUE OCEANS

Sea Shipping Emissions 2022: Netherlands Continental Shelf, 12-Mile Zone and Port Areas

Final Report

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Sea Shipping Emissions 2022: Netherlands Continental Shelf, 12-Mile Zone and Port Areas

Final Report

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CONTENTS

Page

TABLE OF TABLES iii

TABLE OF FIGURES iv

GLOSSARY OF DEFINITIONS AND ABBREVIATIONS vi

1 INTRODUCTION 1
1.1 Objective 1
1.2 Report structure 1

2 EMISSION DATABASES 2
2.1 General information 2
2.2 Netherlands sea area and Dutch port areas 2

3 PROCEDURE FOR EMISSION CALCULATION 7

4 COMPLETENESS OF AIS DATA 8
4.1 Missing AIS minute files 8
4.2 AIS coverage 8

5 ACTIVITIES FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA 10
5.1 Introduction 10
5.2 Activities of seagoing vessels in the Dutch port areas 10
5.3 Activities of seagoing vessels in the Netherlands sea area (NCS and 12-mile zone) 18
5.4 Overview of ships in the port areas and in the Netherlands sea area 20

6 EMISSIONS FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA 21
6.1 Introduction 21
6.2 Emissions in port areas 21
6.3 Emissions in the Netherlands sea area (NCS and 12-mile zone) 25
6.4 Spatial distribution of the emissions 26

7 EMISSIONS FOR THE FISHING ACTIVITIES IN THE DUTCH PORT AREAS, THE WADDEN SEA AND THE NETHERLANDS SEA AREA 38
7.1 Introduction 38
7.2 Emissions of fishing vessels (EMS type 11) 38

8 SUMMARY AND CONCLUSIONS 46

REFERENCES 47

APPENDIX A: EMISSION FACTORS 1

A1 SAILING AND MANOEUVRING 1
A1.1 Main Engines 1
A1.2 Multiple propulsion engines 3
A1.3 Auxiliary Engines and Equipment 8
A1.4 Engine Emission Factors 8
A1.5 Fuel allocation 12
A1.6 Correction factors of engine Emission Factors 13

A2 EMISSIONS OF SHIPS AT BERTH 17

A3 FISHERIES 19
A3.1 Activity data 19
A3.2 Emission factors 19

TABLE OF TABLES

Table 3-1 Link between AIS data (MMSI number) and IHS data (IMO number) 7
Table 5-1 Number of calls extracted from websites of the ports 10
Table 5-2 Shipping activities per EMS type for the Dutch part of the Western Scheldt 12
Table 5-3 Shipping activities per EMS ships size classes for the Dutch part of the Western Scheldt 12
Table 5-4 Shipping activities per EMS type for the Rotterdam port area 13
Table 5-5 Shipping activities per EMS ships size class for the Rotterdam port area 13
Table 5-6 Shipping activities per EMS type for the Amsterdam port area 14
Table 5-7 Shipping activities per EMS ships size classes for the Amsterdam port area 14
Table 5-8 Shipping activities per EMS type for the Dutch part of the Ems area 15
Table 5-9 Shipping activities per EMS ships size classes for the Dutch part of the Ems area 15
Table 5-10 Shipping activities per EMS type for the port area of Den Helder 16
Table 5-11 Shipping activities per EMS ships size classes for the port area of Den Helder 16
Table 5-12 Shipping activities per EMS type for the port area of Harlingen 17
Table 5-13 Shipping activities per EMS ships size classes for the port area of Harlingen 17
Table 5-14 Shipping activities per EMS type for the Netherlands Continental Shelf and 12-mile zone 19
Table 5-15 Shipping activities per ship size class for the Netherlands Continental Shelf and 12-mile zone 19
Table 5-16 Average number of ships per day, in distinguished areas, excluding fishing vessels. 20
Table 6-1 Total emissions in ton in each port area for 2022, excluding fishing vessels (EMS-type 11) 23
Table 6-2 Emissions in each port area for 2022 as percentage of the emissions in 2021, excluding fishing vessels (EMS-type 11). 24
Table 6-3 Emissions of ships in ton in the Netherlands sea area for 2022 compared with 2021, excluding fishing vessels (EMS-type 11). 25
Table 7-1 Total emissions in ton in each port area for 2022, fishing vessels including trawlers 39
Table 7-2 Emissions in each port area for 2022 as percentage of the emissions in 2021, fishing vessels including trawlers 40
Table 7-3 Total emissions in ton in the 12 mile zone and the NCP for 2021, fishing vessels including trawlers 41
Table 7-4 Emissions in 12 miles and NCP for 2021 as percentage of the emissions in 2020, fishing vessels including trawlers 42

TABLE OF FIGURES

Figure 2-1 Grid points for The Netherlands Continental Shelf, 12-mile zone, The Wadden Sea and six port areas 3
Figure 2-2 Rotterdam and the Western Scheldt: The points indicate the centres of grid cells for which emissions are calculated....4
Figure 2-3 Amsterdam and Den Helder: The points indicate the centres of grid cells for which emissions are calculated....5
Figure 2-4 Harlingen, the Wadden Sea and Ems: The points indicate the centres of grid cells for which emissions are calculated....6
Figure 4-1 AIS base stations in 2022 delivering data to the Netherlands Coastguard. 9
Figure 4-2 June 2022, relative number of signals lost with respect to signals received per grid cell, circles mark the 20 nautical miles zones around the Dutch base stations....9
Figure 5-1 Average number of not moving and moving ships per day for 2017-2022, excluding fishing vessels....20
Figure 6-1 CO_2 emissions in ton in each port area for 2017-2022, excluding fishing vessels. 21
Figure 6-2 NO_x emissions in ton in each port area for 2017-2022, excluding fishing vessels. 22
Figure 6-3 SO_2 emissions in ton in each port area for 2017-2022, excluding fishing vessels....22
Figure 6-4 CO_2, NO_x and SO_2 emissions in ton in the Netherlands sea area for 2017-2022, excluding fishing vessels. 25
Figure 6-5 NO_x emission in 2022 in the Dutch part of the Western Scheldt by ships with AIS. 27
Figure 6-6 Absolute change in NO_x emission from 2021 to 2022 in the Dutch part of the Western Scheldt by ships with AIS....27
Figure 6-7 Relative change in NO_x emission from 2021 to 2022 in the Dutch part of the Western Scheldt by ships with AIS....28
Figure 6-8 NO_x emission in 2022 in the port area of Rotterdam by ships with AIS. 28
Figure 6-9 Absolute change in NO_x emission from 2021 to 2022 in the port area of Rotterdam by ships with AIS. 29
Figure 6-10 Relative change in NO_x emission from 2021 to 2022 in the port area of Rotterdam by ships with AIS. 29
Figure 6-11 NO_x emission in 2022 in the port area of Amsterdam by ships with AIS....30
Figure 6-12 Absolute change in NO_x emission from 2021 to 2022 in the port area of Amsterdam by ships with AIS. 30
Figure 6-13 Relative change in NO_x emission from 2021 to 2022 in the port area of Amsterdam by ships with AIS. 31
Figure 6-14 NO_x emission in 2022 in the Ems area by ships with AIS. 31
Figure 6-15 Absolute change in NO_x emission from 2021 to 2022 in the Ems area by ships with AIS.32
Figure 6-16 Relative change in NO_x emission from 2021 to 2022 in the Ems area by ships with AIS..32
Figure 6-17 NO_x emission in 2022 in the port area of Den Helder by ships with AIS....33
Figure 6-18 Absolute change in NO_x emission from 2021 to 2022 in the port area of Den Helder by ships with AIS. 33
Figure 6-19 Relative change in NO_x emission from 2021 to 2022 in the port area of Den Helder by ships with AIS. 34
Figure 6-20 NO_x emission in 2022 in the port area of Harlingen by ships with AIS....34
Figure 6-21 Absolute change in NO_x emission from 2021 to 2022 in the port area of Harlingen by ships with AIS. 35
Figure 6-22 Relative change in NO_x emission from 2021 to 2022 in the port area of Harlingen by ships with AIS. 35
Figure 6-23 NO_x emission in 2022 in the NCS, the 12-mile zone and the Dutch port areas by ships with AIS....36
Figure 6-24 Absolute change in NO_x emission from 2021 to 2022 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS....36

Figure 6-25 Relative change in NO_x emission from 2021 to 2022 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS. 37
Figure 7-1 CO_2 emission observed in the NCS, fishing vessels including trawlers, based on AIS data of 2022 43
Figure 7-2 Absolute change in CO2 emission from 2021 to 2022 observed in the NCS, fishing vessels including trawlers. 43
Figure 7-3 Relative change in CO2 emission from 2021 to 2022 observed in the NCS, fishing vessels including trawlers. 44
Figure 7-4 CO_2 emission observed in the Dutch Wadden Sea, fishing vessels including trawlers, based on AIS data of 2022 44
Figure 7-5 Absolute change in CO2 emission from 2021 to 2022 in the Dutch Wadden Sea, fishing vessels including trawlers. 45
Figure 7-6 Relative change in CO2 emission from 2021 to 2022 in the Dutch Wadden Sea, fishing vessels including trawlers. 45

GLOSSARY OF DEFINITIONS AND ABBREVIATIONS

Definitions:

Ship characteristics database	IHS-database (Lloyds Register of ships) contains vessel characteristics of over 120,000 seagoing merchant vessels larger than 100 GT operating worldwide. The information includes year of built, vessel type, vessel size, service speed, installed power of main and auxiliary engine.
Netherlands sea area	NCS and 12-mile zone

Abbreviations/Substances:

Methane (CH_4)	Gas formed from the combustion of LNG. Substance number **1011**
VOC	*V*olatile Organic Compounds. Substance number **1237**
Sulphur dioxide (SO_2)	Gas formed from the combustion of fuels that contain sulphur. Substance number **4001**
Nitrogen oxides (NO_x)	The gases nitrogen monoxide (NO) and nitrogen dioxide (NO_2). NO is predominantly formed in high temperature combustion processes and can subsequently be converted to NO_2 in the atmosphere. Substance number **4013**
Carbon Monoxide (CO)	A highly toxic colourless gas, formed from the combustion of fuel. Particularly harmful to humans. Substance number **4031**
Carbon Dioxide (CO_2)	Gas formed from the combustion of fuel. Substance number **4032**
PM	Particulates from marine diesel engines irrespective of fuel type. Substance number **6598**
PM-MDO	Particulates from marine diesel engines operated with distillate fuel oil. Substance number **6601**
PM-HFO	Particulates from marine diesel engines operated with residual fuel oil. Substance number **6602**

Abbreviations/Other:

AIS	Automatic Identification System
EMS	Emissieregistratie en Monitoring Scheepvaart (Emission inventory and Monitoring for the shipping sector)
GT	Gross Tonnage
IHS	IHS Maritime World Register of Ships
IMO	International Maritime Organization
LLI	Lloyd's List Intelligence (previously LLG and LMIU)
m	meter
MMSI	Maritime Mobile Service Identity is a unique number to call a ship. The number is added to each AIS message.
NCS	Netherlands Continental Shelf
nm	nautical mile or sea mile is 1852m
SAMSON	Safety Assessment Model for Shipping and Offshore on the North Sea
TSS	Traffic Separation Scheme

1 INTRODUCTION

1.1 Objective

This study aims to determine the emissions to air of seagoing vessels and fishing vessels for 2022. The results of both the seagoing vessels and the fishing vessels are included in the current document. The totals and the spatial distribution for the Netherlands Continental Shelf, the 12-mile zone, the Wadden Sea and the port areas Rotterdam, Amsterdam, the Ems, the Western Scheldt, Den Helder and Harlingen are all based on AIS data. The emissions for 2022 are determined for CH_4, VOC, SO_2, NO_x, CO, CO_2 and Particulate Matter (PM).

The grid size for the port area emissions, the Wadden Sea and the 12-mile zone is 500 x 500 m, for the Netherlands Continental Shelf area a grid size of 5000 x 5000 m has been used.

1.2 Report structure

Chapter 2 describes the emission databases that were compiled for 2022.
Chapter 3 describes the procedure used for the emission calculation based on AIS data.
Chapter 4 describes the completeness of the AIS data with respect to missing files and to spots that are not fully covered by base stations.
Chapter 5 contains the level of shipping activity in the Dutch port areas and the Netherlands sea area.
Chapter 6 summarises the emissions for 2022 for the Dutch port areas and the Netherlands sea area and makes a comparison with 2021.
Chapter 7 contains the emissions results for 2022 for the fishing activities.
Chapter 8 presents conclusions and recommendations.

2 EMISSION DATABASES

2.1 General information

A set of comma-separated databases with the calculated emissions to air from sea shipping have been delivered for:

- the Netherlands sea area (NCS and 12-mile zone);
- the six Dutch port areas Rotterdam, Amsterdam, the Ems, the Western Scheldt, Den Helder Harlingen and the Wadden Sea.

For the information on what can be found in the databases, refer to [1].

2.2 Netherlands sea area and Dutch port areas

The emissions in the Netherlands sea area and the six Dutch port areas have been delivered in MARIN nextCloud (https://nextcloud.marin.nl):

- db_emissionsresults_12Miles500.txt
- db_emissionsresults_OutOf12.txt
- db_emissionresults_portareas.txt

The emissions have been calculated on a 5000 x 5000 m grid for the NCS and on a 500 x 500 m grid in the 12-mile zone and in the port areas.

The Netherlands sea area and the port areas are presented in Figure 2-1. The different areas are indicated by plotting the centre points of the grid cells with different colours.

The six port areas are illustrated in more detail in Figure 2-2 to Figure 2-4. At some places, there are grid points on land. There are several reasons for this. In general, the detail of the charts presented here is such that not all existing waterways and/or quays are visible, though they do exist. In addition, we noticed that container cranes disturb the determination of the GPS position and therefore the AIS-message is not containing the correct position. When, for whatever reason, AIS signals are disturbed or lost positions are extrapolated and this is done before MARIN receives the data.

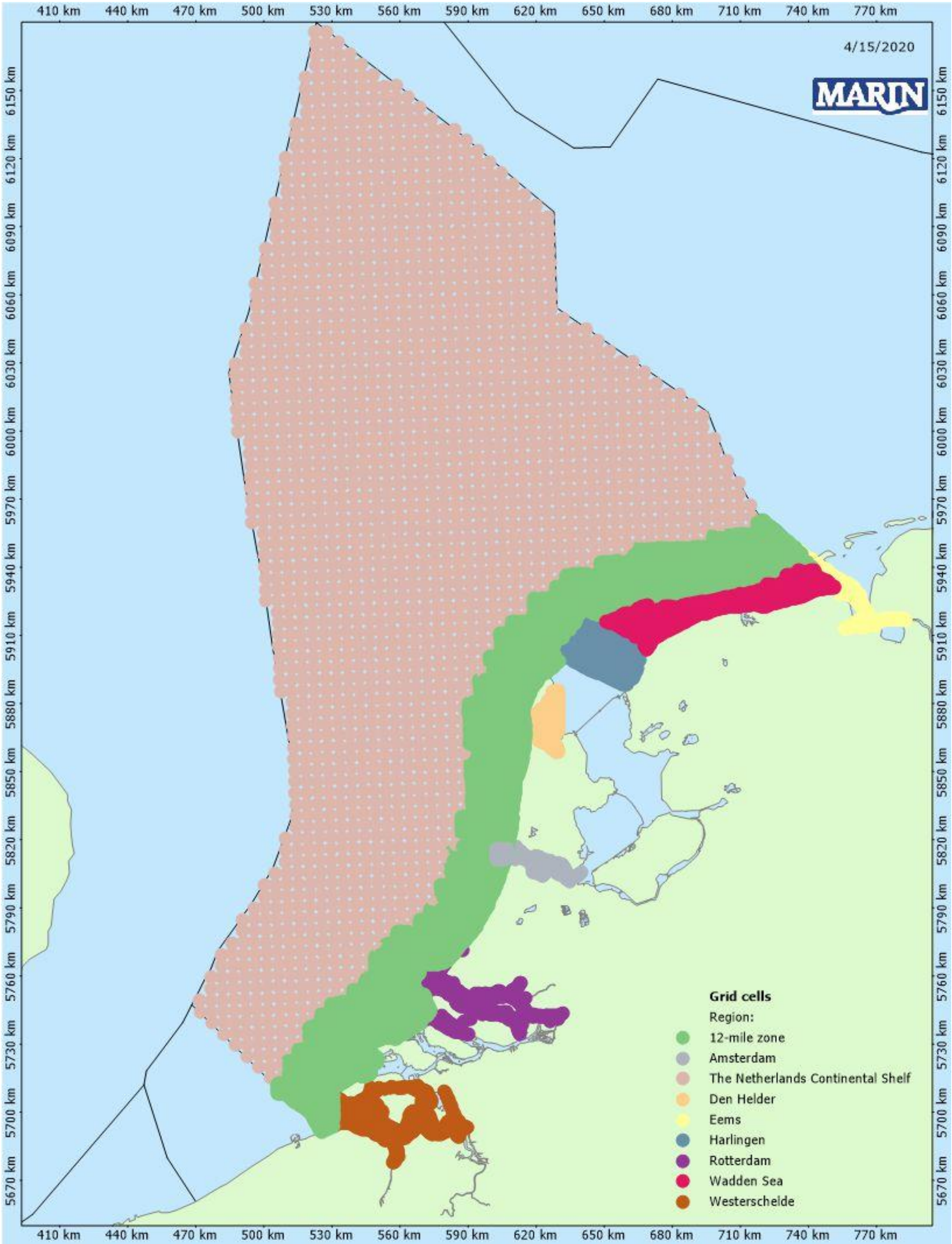

Figure 2-1 **Grid points for The Netherlands Continental Shelf, 12-mile zone, The Wadden Sea and six port areas**

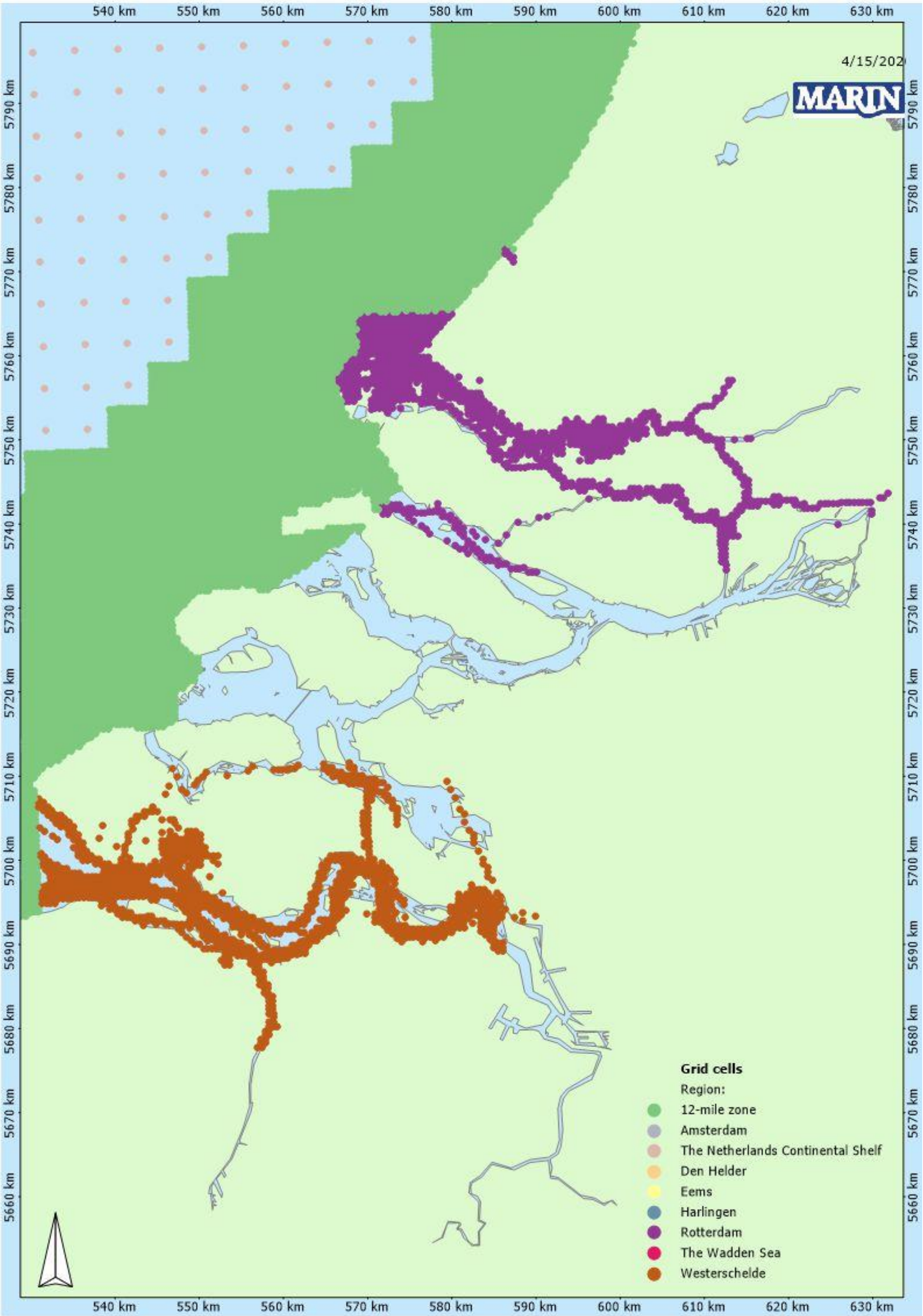

Figure 2-2 **Rotterdam and the Western Scheldt: The points indicate the centres of grid cells for which emissions are calculated**

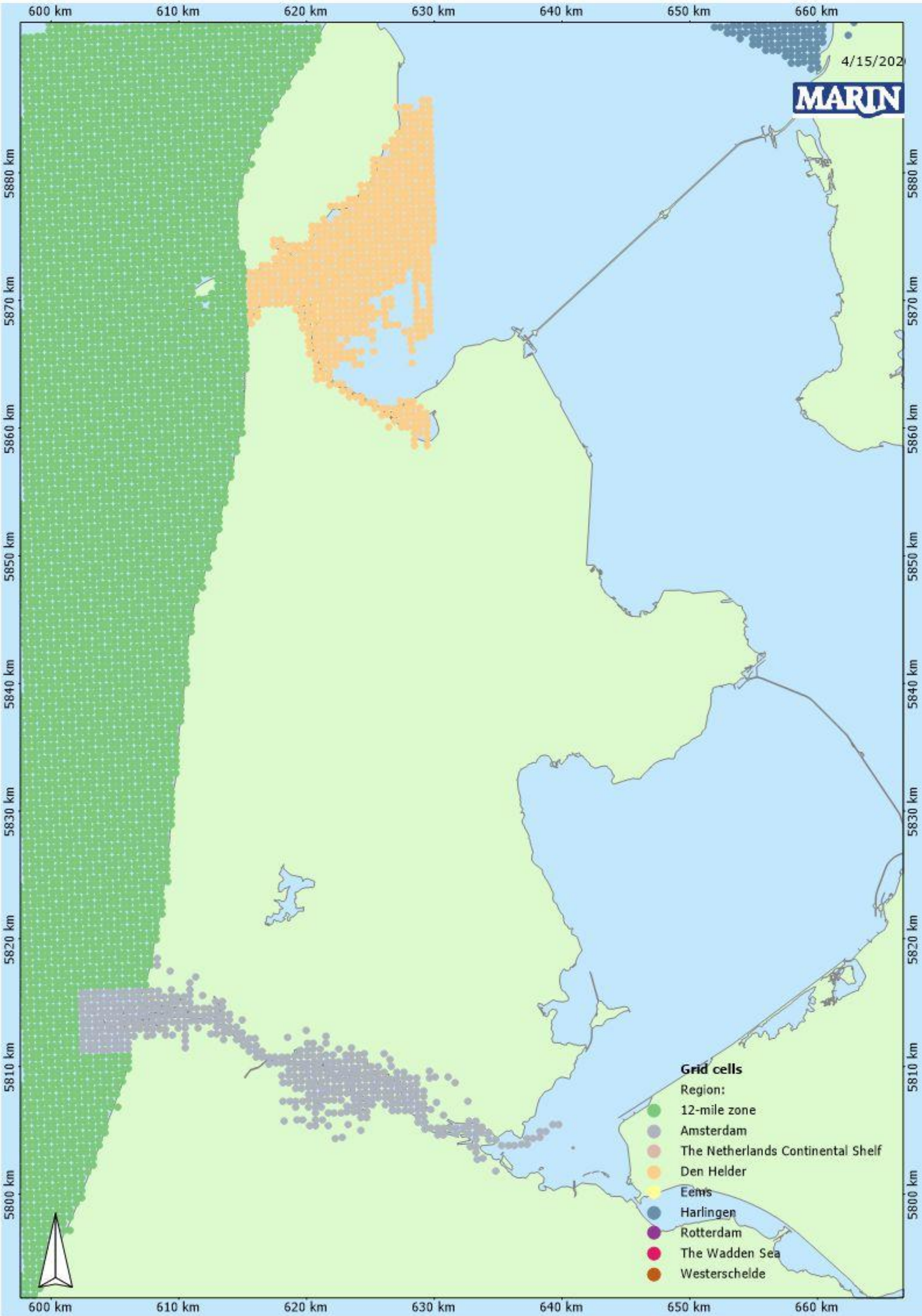

Figure 2-3 Amsterdam and Den Helder: The points indicate the centres of grid cells for which emissions are calculated

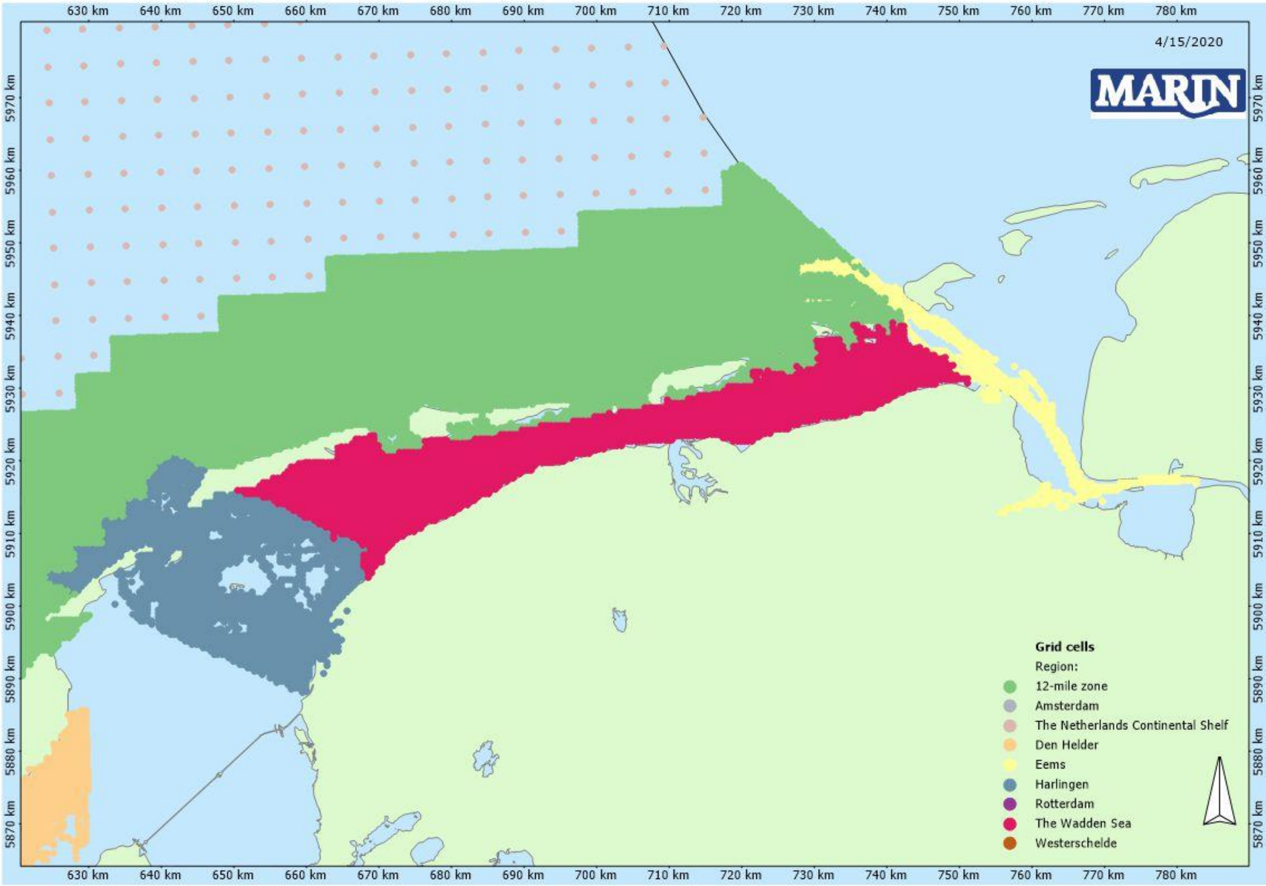

Figure 2-4 **Harlingen, the Wadden Sea and Ems: The points indicate the centres of grid cells for which emissions are calculated**

3 PROCEDURE FOR EMISSION CALCULATION

This chapter describes the procedures for the emission calculation, which is based on AIS data. The AIS data has been used to calculate the emissions for both NCS, the 12-mile zone, the Wadden Sea area and the six Dutch port areas. In the appendix, TNO provides more information about the current calculation method.

AIS data

In this study, AIS data of 2022 received by the Netherlands Coastguard has been used to calculate the emissions. Refer to [1] for background information about the AIS data.

IHS and the Port of Rotterdam

Just like in the previous study, the emission calculation of 2021 [9], TNO has calculated emission factors for the Port of Rotterdam, using ship characteristics provided by IHS Maritime World Register of Ships to the Port of Rotterdam. Since the IHS database was available to TNO, the emissions factors for all ships seen in the areas of interest of this study were based on this database.

In the AIS data the identifier for the ship is the MMSI number, not the IMO-number. The identifier for the emission factor based on the ship database of IHS is the IMO-number of a vessel. Therefore, a link is necessary between the MMSI-numbers in the AIS messages and the emission factors based on the ship database of IHS, identified by IMO-number.
The available AIS-data for the study area in 2022 comprised 44,670 valid MMSI numbers. Based on these MMSI-numbers, 15,709 commercial seagoing vessels could be identified (see Table 3-1). About 47% of all messages obtained, were sent by the 15,709 commercial vessels for which emission factors were calculated.

Table 3-1 Link between AIS data (MMSI number) and IHS data (IMO number)

	Total individual valid mmsi	Total valid mmsi emission factors included	Total valid messages obtained	Total valid messages obtained emission factors included	Valid messages obtained emission factors included [%]
2017	33,612	12,952	733,405,583	328,970,302	45%
2018	36,167	12,797	865,399,825	375,120,674	43%
2019	37,970	13,238	910,441,140	386,801,288	42%
2020	37,321	13,914	946,587,638	442,001,668	47%
2021	39,159	14,376	914,653,016	418,725,035	46%
2022	44,670	15,709	962,616,821	447,947,568	47%

Samples taken of unidentified MMSI - thus without IMO number and emission factor - learned that far most of these MMSI could be attributed to non-commercial small vessels and fixed objects (like aid to navigation, wind turbines and oil and gas installations) or inland vessels near the port areas which are not relevant with respect to sea shipping emissions. Based on experience from earlier studies it is estimated roughly that at maximum 250 commercial seagoing vessels could not be identified, representing about 2% of shipping emissions.

4 COMPLETENESS OF AIS DATA

This chapter describes the completeness of the AIS data. In 4.1 the missing minute files are described and in 4.2 the coverage of the AIS data.

4.1 Missing AIS minute files

The sample frequency of the AIS runs is exactly 2 minutes. In case the gap between the signals is less than 10 minutes, this has no effect on the results, because each ship is kept in the system until no AIS message has been received during 10 minutes. The sum of missing periods, which are larger than 10 minutes is negligible for 2022. The AIS data is practically complete, so there is no need to compensate for this.

4.2 AIS coverage

In the previous section, the number of files received from the Netherlands Coastguard describes the completeness of the data. This does not necessarily mean that the available minute files cover the total area all the time. This is illustrated in Figure 4-1, in which all base stations that deliver data to the Netherlands Coastguard are plotted. The circle with a radius of 20 nautical miles around each base station illustrates the area covered by that base station.

In reality, the covered area varies with the atmospheric conditions. Figure 4-1 shows that some areas are covered by several base stations, while other areas are covered by only one base station and some areas are only covered with favourable atmospheric conditions, when the base stations reach further than 20 nautical miles. This means that there are a few weak spots in the Netherlands sea area and in the Dutch port areas:

- the area in the northern part of the NCS, which is not covered at all. This is not a large shortcoming because the shipping density is very low in this area;
- the Western Scheldt close to the border with Belgium,
- the spot close to the border with the United Kingdom Continental Shelf, southwest of Rotterdam.

For the Netherlands sea area, the weak spots in the collection of the AIS data are identified by the locations where ships lose contact. After 10 minutes without receiving a new AIS message of a ship, the ship is removed from the system. Figure 4-2 show in each cell of 5x5km the number of ships that lose AIS contact with Dutch AIS base stations relative to the total number of observations of ships in this grid cell. Sometimes the data reception of AIS messages is recovered after some time, which is the case in the center area of the Netherlands sea area. However, on most locations near the border of the Netherlands sea area it means that the ship has left the system until its next journey through the Netherlands sea area. Thus, the figure shows more or less the locations where ships are removed from the system. The ideal situation would be if the ships that leave the system were located outside the Netherlands sea area, which is the case on a large part of the west side of the NCS.

The figure show the coverage for June 2022. This month is chosen so that the data can be compared with previous registrations. The overall coverage of AIS data of 2022 seems in most places of the same order of magnitude compared to the AIS coverage of 2021. However, fluctuations in coverage are expected due to the dependency on atmospheric conditions.

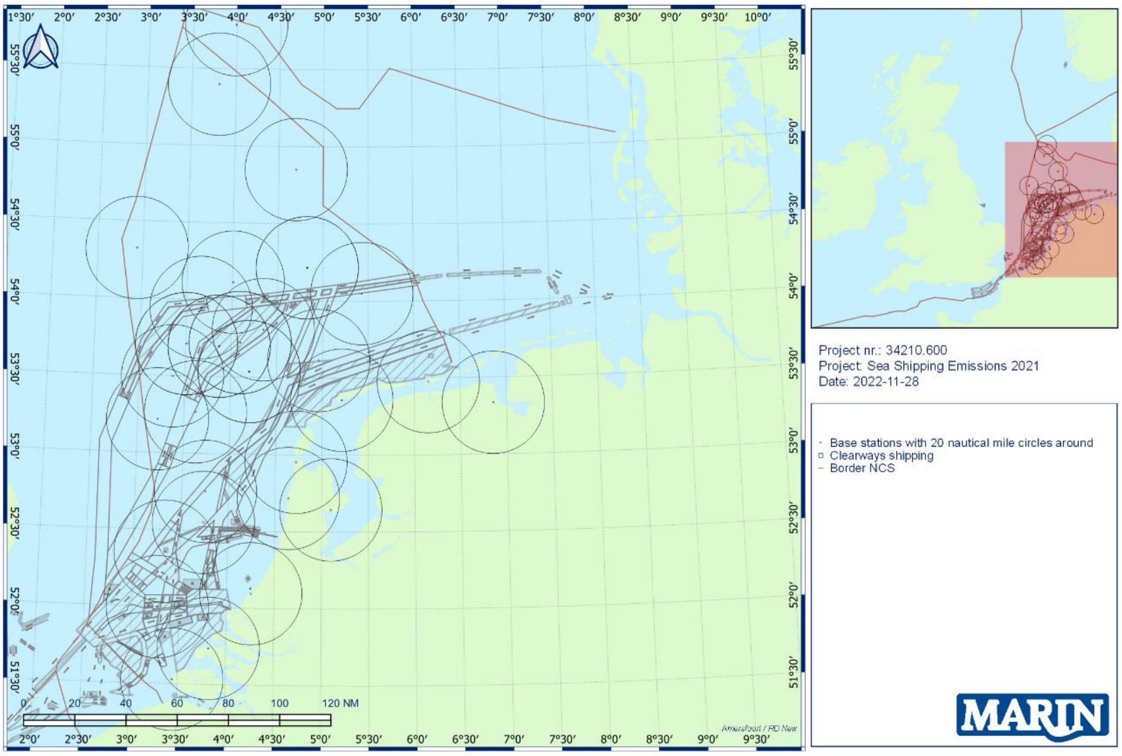

Figure 4-1 AIS base stations in 2022 delivering data to the Netherlands Coastguard.

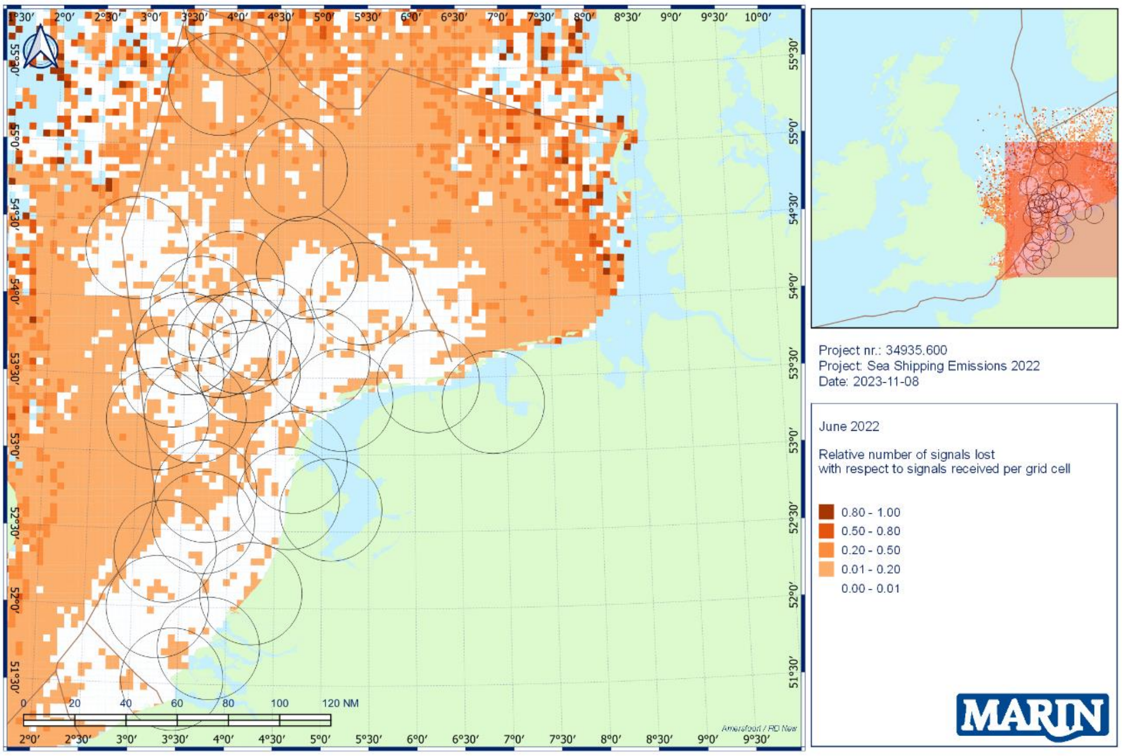

Figure 4-2 June 2022, relative number of signals lost with respect to signals received per grid cell, circles mark the 20 nautical miles zones around the Dutch base stations

5 ACTIVITIES FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA

5.1 Introduction

This chapter presents the activities of seagoing vessels for 2022 in the Dutch port areas and in the Netherlands sea area. The activities of 2022 are compared to those of 2021. Section 5.2 describes the activities in the port areas, Section 5.3 the activity in the Netherlands sea area and Section 5.4 the number of ships in these areas.

5.2 Activities of seagoing vessels in the Dutch port areas

Shipping activities in the six Dutch port areas are determined to calculate the emissions in these areas. The activities extracted from AIS are important explanatory parameters for the total emissions. The other parameter is the emission factor, which has been discussed in [1].

Table 5-1 presents activity numbers that could be extracted from the websites of the ports [10]. These numbers can be used to check the information on activity as derived from the AIS data. The table contains the cargo handling for the main ports in each port area.

Table 5-1 Number of calls extracted from websites of the ports

Port area	Ports	Cargo handling x 1000 tons	
		2021	2022
Amsterdam	Amsterdam	71,3	78,6
Eems	Eems	13,3	13,0
Harlingen	Harlingen	1,9	-
Rotterdam	Rijn- / Maasmond area	468,7	467,4
Western Scheldt	Antwerp-Bruges	288,949	286.953

The shipping activities of 2022 are presented for each port area in a table per ship type and a table per ship size class and compared with the activities observed in 2021. Take into account that some percentages can vary a lot due to the low absolute numbers or that a MMSI number is not linked to an emission factor. Another cause of variation may be due to the AIS responder being turned off or not by the responsible officer upon arrival in the port. Therefore, the (AIS-) methodology for investigating berthed ships may have to be revised.

Western Scheldt
The activity tables, Table 5-2 and Table 5-3, show that the moving hours decreased with 1.0% and the GT.nm (gross tonnage time’s nautical miles) increased with 9%. For berthed ships the hours increased by 3% and GT.hours increased with 24%. The activity numbers that could be extracted from the port websites show an decrease in cargo handling, but cannot be properly compared due to the merger of port areas of Antwerp and Bruges.

Rotterdam
The activity tables, Table 5-4 and Table 5-5, for Rotterdam show that the moving hours decreased with 8% and the GT.nm increased with 3%. Berthed activities, hours and GT.hours, decreased with 16% and 13% respectively. The decrease in berthed and moving hours is in line with the activity numbers that could be extracted from the port websites, they show an downward trend in cargo handling.

Amsterdam
The activity tables, Table 5-6 and Table 5-7, for Amsterdam show that the moving hours and the GT.nm increased by 17% and 79% respectively. The berthed hours increased with 22% and the berthed GT.hours increased with 57%. This is in line with the activity numbers that could be extracted from the port websites, they show an upward trend in cargo handling.

Ems
The activity tables, Table 5-8 and Table 5-9, for the Ems show that the moving hours increased with 1% and the GT.nm increased with 12%. The berthed hours increased with 403% and the berthed GT.hours increased with 607%. The increase in activities in Ems is probably less because the emissions in 2021 based on AIS data are too low and not in line with the annual port report.

Den Helder
The activity tables, Table 5-10 and Table 5-11, for Den Helder show that the moving hours decreased with 5% and the GT.nm decreased with 1%. The berthed hours decreased with 15% and the berthed GT.hours decreased with 28%.

Harlingen
The activity tables, Table 5-12 and Table 5-13, for Harlingen show that the moving hours and GT.nm increased with 5% and 2% respectively. The berthed hours increased with 4% and the berthed GT.hours increased with 87%.

Table 5-2 Shipping activities per EMS type for the Dutch part of the Western Scheldt

Ship type	Totals for Western Scheldt in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	7,305	247,041,560	4,275	1,423,654,666	9.9	128%	171%	109%	123%	99%
Chem.+ Gas tanker	69,172	862,493,968	44,115	5,614,967,807	10.3	95%	108%	93%	102%	99%
Bulk carrier	55,532	1,801,591,731	11,056	2,906,368,914	8.4	133%	150%	123%	134%	100%
Container ship	5,929	147,919,019	25,027	18,076,001,029	12.7	67%	76%	95%	97%	99%
General Dry Cargo	116,755	851,889,324	37,969	1,829,132,212	9.6	117%	138%	98%	104%	102%
RoRo Cargo / Vehicle	15,425	440,314,627	9,716	5,847,630,868	11.2	115%	133%	145%	171%	105%
Reefer	14,297	210,005,187	856	122,598,718	9.7	146%	168%	69%	69%	94%
Passenger	27,502	45,690,822	5,435	96,414,624	10.1	85%	52%	98%	149%	109%
Miscellaneous	253,967	370,830,889	31,744	454,098,101	8.5	105%	87%	91%	100%	106%
Tug/Supply	208,465	680,259,882	25,427	91,875,963	6.9	91%	103%	102%	90%	98%
Total / Average	774,349	5,658,037,009	195,620	36,462,742,902	9.7	103%	124%	99%	109%	101%

Table 5-3 Shipping activities per EMS ships size classes for the Dutch part of the Western Scheldt

Ship size in GT	Totals for Western Scheldt in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	308,137	140,546,573	40,873	162,026,487	7.4	97%	98%	102%	98%	96%
1,600-3,000	102,969	241,759,715	30,893	664,775,383	8.5	105%	105%	90%	91%	101%
3,000-5,000	77,394	298,860,065	21,883	851,741,815	9.2	101%	100%	80%	85%	107%
5,000-10,000	47,814	325,168,970	22,505	1,676,192,336	10.1	89%	90%	100%	100%	104%
10,000-30,000	116,425	2,183,916,881	35,056	7,725,358,131	11.3	101%	99%	101%	101%	103%
30,000-60,000	47,399	1,913,474,966	19,274	9,286,887,522	10.8	179%	185%	104%	101%	99%
60,000-100,000	5,829	452,446,214	9,156	8,430,782,469	11.3	162%	158%	106%	104%	97%
>100,000	824	97,525,199	4,129	7,716,616,438	11.0	785%	584%	204%	210%	107%
Total / Average	774,352	5,658,037,008	195,959	36,523,370,877	9.5	103%	124%	98%	113%	103%

Table 5-4 Shipping activities per EMS type for the Rotterdam port area

Ship type	Totals for Rotterdam in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	23,924	1,834,005,889	3,656	1,779,991,033	8.0	54%	62%	86%	91%	90%
Chem.+ Gas tanker	28,314	1,001,293,108	13,342	1,759,501,795	8.5	67%	100%	100%	118%	99%
Bulk carrier	63,668	3,834,591,450	2,455	775,083,551	7.6	90%	92%	110%	109%	95%
Container ship	160,838	12,214,447,099	18,635	4,972,457,739	8.6	82%	90%	90%	91%	105%
General Dry Cargo	28,005	181,952,140	7,831	388,301,515	9.9	81%	90%	89%	110%	104%
RoRo Cargo / Vehicle	19,878	799,203,637	6,763	2,758,414,939	10.4	74%	77%	99%	98%	98%
Reefer	2	12,209	36	2,601,549	11.3	40%	19%	51%	26%	93%
Passenger	3,192	28,043,428	232	207,713,616	9.6	193%	161%	204%	276%	112%
Miscellaneous	67,602	154,493,092	15,161	464,855,986	7.7	87%	158%	88%	148%	100%
Tug/Supply	175,330	2,016,172,861	35,893	1,195,820,291	6.9	94%	94%	90%	163%	100%
Total / Average	570,753	22,064,214,913	104,004	14,304,742,014	8.0	84%	87%	92%	103%	101%

Table 5-5 Shipping activities per EMS ships size class for the Rotterdam port area

Ship size in GT	Totals for Rotterdam in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average Speed	Hours	GT.hour s	Hours	GT.nm	Average speed
100-1,600	202,959	80,385,842	41,647	97,797,669	6.9	97%	94%	87%	86%	96%
1,600-3,000	17,684	42,267,127	5,842	128,559,467	9.2	65%	66%	84%	84%	100%
3,000-5,000	10,781	42,200,162	9,774	352,648,978	9.4	67%	68%	88%	87%	91%
5,000-10,000	43,951	356,797,784	11,882	835,096,494	9.7	92%	93%	95%	90%	100%
10,000-30,000	89,969	1,537,114,425	16,860	2,711,557,970	9.8	77%	75%	102%	105%	105%
30,000-60,000	63,857	2,796,168,110	6,910	2,656,752,785	9.1	73%	74%	102%	96%	98%
60,000-100,000	57,834	4,787,438,599	5,012	2,872,225,767	7.4	73%	76%	91%	92%	103%
>100,000	72,200	12,421,343,670	4,111	4,649,606,709	6.6	96%	99%	112%	121%	103%
Total / Average	570,755	22,064,214,912	104,004	14,304,742,013	8.2	84%	87%	92%	103%	99%

Table 5-6 Shipping activities per EMS type for the Amsterdam port area

Ship type	Totals for Amsterdam in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	24,931	1,022,171,572	1,059	197,453,695	5.6	117%	113%	104%	100%	95%
Chem.+ Gas tanker	142,454	2,832,980,642	10,836	1,084,803,416	6.2	146%	150%	144%	165%	102%
Bulk carrier	121,515	5,935,351,801	5,565	1,314,677,202	5.5	173%	186%	203%	231%	97%
Container ship	12,887	97,522,307	2,251	187,336,019	6.7	257%	381%	242%	620%	106%
General Dry Cargo	111,932	493,881,483	7,514	171,133,239	6.2	104%	113%	91%	92%	102%
RoRo Cargo / Vehicle	21,672	869,538,753	2,543	563,063,087	5.8	182%	186%	151%	144%	102%
Reefer	22,452	134,949,270	387	10,742,047	5.7	108%	103%	88%	78%	102%
Passenger	24,456	320,618,649	1,385	295,982,858	6.0	114%	139%	192%	957%	113%
Miscellaneous	133,170	194,061,137	7,684	85,567,587	6.3	105%	109%	74%	84%	111%
Tug/Supply	194,985	296,469,814	19,000	46,395,032	6.0	108%	96%	117%	115%	109%
Total / Average	810,454	12,197,545,428	58,224	3,957,154,182	6.1	122%	157%	117%	179%	105%

Table 5-7 Shipping activities per EMS ships size classes for the Amsterdam port area

Ship size in GT	Totals for Amsterdam in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	242,459	96,868,606	22,378	43,133,911	5.9	110%	109%	102%	85%	104%
1,600-3,000	93,034	224,306,017	5,291	87,708,077	6.3	89%	91%	82%	86%	103%
3,000-5,000	57,019	224,162,136	5,050	120,573,936	6.0	97%	94%	89%	88%	103%
5,000-10,000	70,934	513,755,828	4,604	306,793,820	6.7	118%	131%	153%	235%	114%
10,000-30,000	142,770	3,177,196,441	8,651	1,075,386,256	6.0	146%	151%	153%	163%	107%
30,000-60,000	120,551	4,791,149,188	7,079	1,521,778,689	5.5	161%	160%	181%	178%	98%
60,000-100,000	36,155	3,059,696,944	1,648	679,115,457	5.1	171%	179%	222%	244%	98%
>100,000										
Total / Average	810,452	12,197,545,429	58,225	3,957,154,182	6.0	122%	157%	117%	179%	103%

Table 5-8 Shipping activities per EMS type for the Dutch part of the Ems area

Ship type	Totals for Ems in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	8	4,053	86	558,145	8.5	200%	131%	65%	28%	66%
Chem.+ Gas tanker	4,203	12,280,629	2,345	202,285,498	10.3	799%	735%	143%	194%	97%
Bulk carrier	3,448	86,093,076	1,087	212,469,805	9.5	854%	1316%	159%	181%	94%
Container ship	1,439	21,956,994	122	15,106,195	10.5	899%	1882%	305%	337%	86%
General Dry Cargo	26,630	116,505,648	6,130	288,708,987	10.0	296%	384%	80%	99%	96%
RoRo Cargo / Vehicle	8,050	181,353,341	7,329	1,473,233,787	11.9	233%	626%	107%	113%	103%
Reefer	1,370	6,052,206	96	2,688,670	9.3	1631%	953%	204%	121%	90%
Passenger	2,183	331,734,270	271	42,570,699	11.5	2119%	4197%	99%	124%	108%
Miscellaneous	15,292	29,892,324	14,941	223,984,572	9.0	195%	182%	97%	93%	94%
Tug/Supply	85,461	104,334,950	8,525	93,998,883	8.8	1088%	325%	112%	50%	88%
Total / Average	148,084	890,207,491	40,932	2,555,605,241	9.7	503%	707%	101%	112%	95%

Table 5-9 Shipping activities per EMS ships size classes for the Dutch part of the Ems area

Ship size in GT	Totals for Ems in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	83,557	25,603,698	11,733	36,049,352	8.3	969%	477%	111%	79%	93%
1,600-3,000	26,650	63,256,979	13,933	280,474,176	9.0	218%	216%	89%	91%	93%
3,000-5,000	12,551	49,956,682	7,766	248,724,528	9.7	576%	558%	124%	116%	102%
5,000-10,000	6,700	49,199,537	2,178	184,822,467	10.6	141%	161%	61%	68%	96%
10,000-30,000	7,438	137,046,197	2,351	541,616,240	11.0	751%	743%	114%	113%	97%
30,000-60,000	3,921	175,528,155	1,754	920,681,684	10.6	1035%	919%	163%	138%	88%
60,000-100,000	820	57,152,376	316	255,235,486	12.0	789%	828%	94%	92%	81%
>100,000	2,089	332,124,912	78	87,166,646	8.3	5223%	4627%	520%	410%	104%
Total / Average	148,084	890,207,491	40,931	2,555,605,242	9.4	503%	707%	101%	112%	95%

Table 5-10 Shipping activities per EMS type for the port area of Den Helder

Ship type	Totals for Den Helder in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker										
Chem.+ Gas tanker	598	3,768,850	4	169,429	4.7	1087%	1072%	400%	339%	68%
Bulk carrier										
Containership										
General Dry Cargo	2,610	5,073,052	238	6,004,241	7.9	102%	41%	61%	48%	84%
RoRo Cargo / Vehicle	6,421	99,294,960	2,398	303,588,741	8.2	107%	107%	99%	102%	104%
Reefer										
Passenger	10,870	101,103,816	1,845	196,243,801	5.0	66%	87%	94%	99%	91%
Miscellaneous	132,619	118,146,557	3,274	13,255,341	6.2	78%	36%	94%	66%	102%
Tug/Supply	128,244	164,194,927	3,157	34,816,697	6.4	96%	109%	99%	114%	119%
Total / Average	282,406	510,113,334	10,944	559,620,424	6.5	86%	72%	95%	99%	104%

Table 5-11 Shipping activities per EMS ships size classes for the port area of Den Helder

Ship size in GT	Totals for Den Helder in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	141,621	53,613,548	2,893	7,255,345	5.0	85%	75%	90%	93%	85%
1,600-3,000	44,492	99,363,509	1,551	24,746,073	6.7	121%	119%	117%	107%	91%
3,000-5,000	21,228	79,480,846	670	15,135,531	6.3	43%	40%	69%	69%	113%
5,000-10,000	5,716	34,310,531	121	4,037,980	10.5	169%	178%	166%	121%	144%
10,000-30,000	15,201	225,677,568	4,187	503,210,352	7.3	80%	68%	97%	100%	116%
30,000-60,000										
60,000-100,000										
>100,000										
Total / Average	282,404	510,113,333	10,943	559,620,422	6.6	86%	72%	95%	99%	104%

Table 5-12 Shipping activities per EMS type for the port area of Harlingen

Ship type	Totals for Harlingen in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.hours	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker										
Chem.+ Gas tanker	4,511	280,596,043	27	2,752,820	6.5	261%	4324%	93%	325%	88%
Bulk carrier	324	2,351,792	34	1,162,104	6.3	227%	302%	189%	159%	94%
Containership										
General Dry Cargo	37,832	124,457,540	1,272	30,345,761	8.0	125%	115%	79%	85%	101%
RoRo Cargo / Vehicle	33,645	96,560,469	10,219	348,899,486	9.6	94%	98%	98%	101%	91%
Reefer	2,201	12,877,455	152	6,962,662	8.1	95%	119%	94%	112%	103%
Passenger	33,931	12,723,576	1,377	4,979,232	7.8	97%	99%	125%	154%	124%
Miscellaneous	74,848	60,636,079	7,410	39,526,112	7.3	106%	97%	119%	106%	112%
Tug/Supply	48,885	53,577,588	989	4,035,282	6.5	100%	186%	124%	164%	81%
Total / Average	237,885	655,245,533	22,100	479,284,634	8.5	104%	187%	105%	102%	97%

Table 5-13 Shipping activities per EMS ships size classes for the port area of Harlingen

Ship size in GT	Totals for Harlingen in 2022					2022 as percentage of 2021				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.hours	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	130,949	63,070,494	8,834	35,898,031	7.3	95%	105%	108%	128%	100%
1,600-3,000	49,055	115,990,250	5,493	125,870,574	7.2	129%	126%	114%	96%	92%
3,000-5,000	35,744	140,908,292	6,248	254,519,270	8.1	129%	134%	99%	103%	111%
5,000-10,000	10,019	57,922,865	986	58,001,298	9.0	65%	65%	86%	92%	107%
10,000-30,000										
30,000-60,000										
60,000-100,000										
>100,000										
Total / Average	237,884	655,245,534	22,101	479,284,633	7.6	104%	187%	105%	102%	101%

5.3 Activities of seagoing vessels in the Netherlands sea area (NCS and 12-mile zone)

The shipping activities in the Netherlands sea area are presented in Table 5-14 and Table 5-15, where the activities of 2022 are compared to the activities of 2021. The tables contain per ship type and size class:

- hours and GT.hours for not moving ships (at anchor), and
- hours, GT.nm and average speed for moving ships.

The average of the total moving hours increased with 2% and GT.nm for moving vessels increased with 6%.

For ships at anchor, there is an increase for hours by 13% and for GT hours by 21%.

Table 5-14 Shipping activities per EMS type for the Netherlands Continental Shelf and 12-mile zone

Shiptype	Totals for NCS and 12-mile zone in 2022					2022 as percentage of 2021				
	Not moving / at anchor		Moving			Not moving / at anchor		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average Speed
Oiltanker	113,019	7,688,183,998	76,245	48,149,815,246	9.5	71%	80%	100%	112%	97%
Chem.+Gastanker	480,909	7,692,896,174	306,482	50,282,542,256	10.5	103%	130%	99%	112%	98%
Bulkcarrier	230,766	12,336,857,518	124,496	46,949,379,333	9.8	176%	164%	115%	115%	97%
Containership	98,103	9,039,946,352	187,306	123,856,499,854	12.2	99%	124%	96%	96%	98%
GeneralDryCargo	94,849	597,900,929	392,793	18,377,484,151	10.3	148%	177%	95%	98%	99%
RoRoCargo/Vehicle	18,641	372,283,104	118,322	67,762,158,861	12.2	106%	134%	99%	98%	96%
Reefer	4,356	26,558,272	9,521	1,027,676,521	11.5	151%	110%	106%	100%	102%
Passenger	7,861	6,995,534	13,181	13,274,420,265	11.9	154%	2%	257%	408%	114%
Miscellaneous	59,374	487,371,968	130,032	3,211,883,359	7.8	118%	169%	110%	120%	91%
Tug/Supply	160,054	760,833,259	158,872	3,319,289,433	7.4	125%	106%	117%	108%	102%
Total/Average	1,267,932	39,009,827,108	1,517,250	376,211,149,279	10.2	113%	121%	102%	106%	97%

Table 5-15 Shipping activities per ship size class for the Netherlands Continental Shelf and 12-mile zone

Ship size in GT	Totals for NCS and 12-mile zone in 2022					2022 as percentage of 2021				
	Not moving / at anchor		Moving			Not moving / at anchor		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average Speed
100-1,600	96,063	49,701,193	180,712	730,743,746	6.8	145%	115%	119%	98%	96%
1,600-3,000	115,353	277,384,690	298,501	6,281,741,095	8.8	115%	113%	96%	94%	99%
3,000-5,000	169,713	685,522,234	210,942	8,042,804,235	10.0	102%	103%	91%	91%	99%
5,000-10,000	161,623	1,172,465,853	196,194	16,104,465,919	10.6	103%	105%	99%	98%	96%
10,000-30,000	311,497	6,121,191,759	288,585	66,034,429,335	12.0	107%	112%	100%	98%	99%
30,000-60,000	201,193	8,544,582,974	168,238	86,279,134,162	11.3	137%	129%	108%	103%	100%
60,000-100,000	133,556	10,779,748,998	111,552	98,182,987,456	11.3	85%	90%	104%	108%	97%
>100,000	72,812	11,378,803,024	52,454	94,549,611,722	11.7	188%	183%	122%	116%	100%
Total / Average	1,267,936	39,009,827,108	1,517,248	376,211,149,280	10.1	113%	121%	102%	106%	98%

5.4 Overview of ships in the port areas and in the Netherlands sea area

The average number of ships per day, in the port areas and at sea, are presented in Table 5-16. For the port areas, except for Den Helder and Rotterdam, most remarkable is the increase of berthed ships.

For the NCS combined with the 12-miles zone the average number of not moving and moving ships increased by 13% and 2% respectively.

Table 5-16 Average number of ships per day, in distinguished areas, excluding fishing vessels.

Area	In 2022			In 2022 as percentage of 2021		
	Average # ships/day		Speed	Average # ships/day		Speed
	Not moving	Moving	Knots	Not moving	Moving	Knots
Amsterdam	92	7	6	122%	116%	105%
Den Helder	32	1	7	85%	95%	104%
Ems	17	5	10	503%	101%	95%
Harlingen	27	3	8	104%	105%	96%
Rotterdam	65	12	8	84%	91%	101%
Western Scheldt	88	22	10	102%	99%	101%
NCS +12-mile zone	144	173	10	113%	102%	97%

Figure 5-1 shows the average number of ships per day from 2017 up to 2022. The average number of ships per day contains not moving and moving ships excluding fishing vessels. The NCS combined with the 12-miles zone shows a slight increase over time.

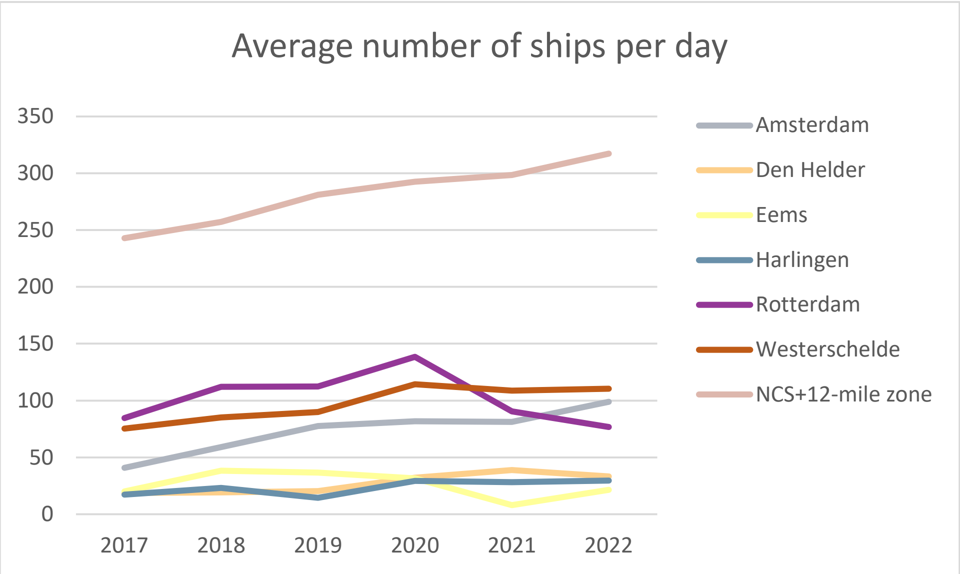

Figure 5-1 Average number of not moving and moving ships per day for 2017-2022, excluding fishing vessels.

6 EMISSIONS FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA

6.1 Introduction

This chapter presents the results of emission calculations for 2022 for the Dutch port areas and the Netherlands sea area. To indicate the change in emissions, all values for 2022 are compared with the values of 2021.

The emissions for the port areas are given in Section 6.2, those for the NCS and 12-mile zone in Section 6.3. Section 6.4 presents the spatial distribution of the 2022 NO_x emissions together with the absolute and relative change compared to 2021.

6.2 Emissions in port areas

Table 6-1 contains the emissions for the six Dutch port areas, calculated for ships berthed and sailing within the port areas. Table 6-2 contains the same emissions expressed as a percentage of the corresponding emissions in 2021. The percentages in grey are based on very low absolute numbers and not very reliable. Similar to the procedure in the previous studies, the values for at berth or at anchor include all vessels with speed below 1 knots.

The substance CO_2 has the largest contribution to the total emissions in ton (98%). For all ports together, there is an overall increase of CO_2 by 4%. Ships at berth have a total increase of CO_2 by 5% and sailing ships increase by 1% (Figure 6-1).

Figure 6-2 and Figure 6-3 show respectively NO_x and SO_2 emissions in ton in each port area from 2017 up to 2022. The emissions in ton contains not moving and moving ships excluding fishing vessels. For all ports together NO_x and SO_2 emissions increased.

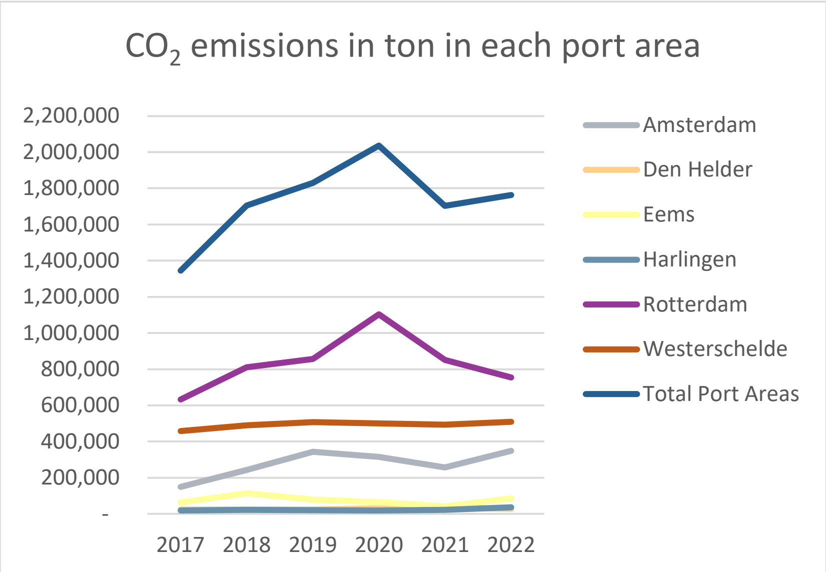

Figure 6-1 **CO_2 emissions in ton in each port area for 2017-2022, excluding fishing vessels.**

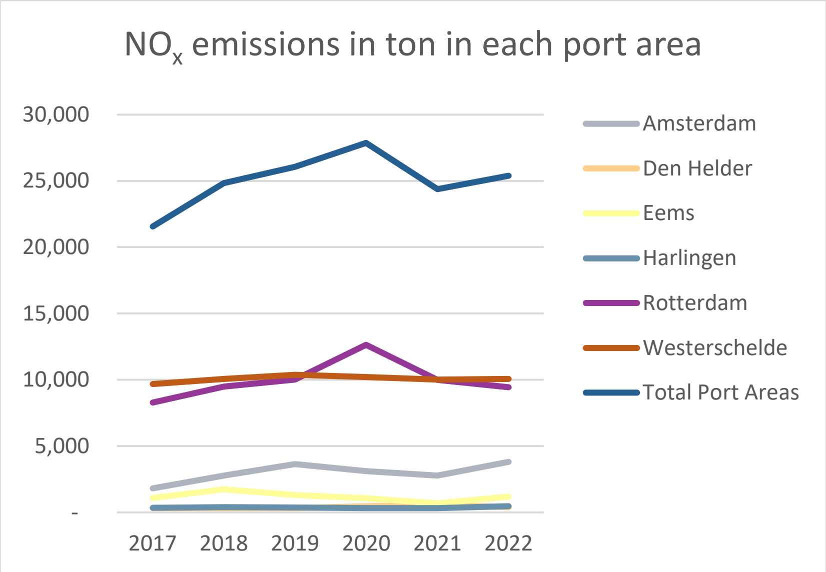

Figure 6-2 **NO_x emissions in ton in each port area for 2017-2022, excluding fishing vessels.**

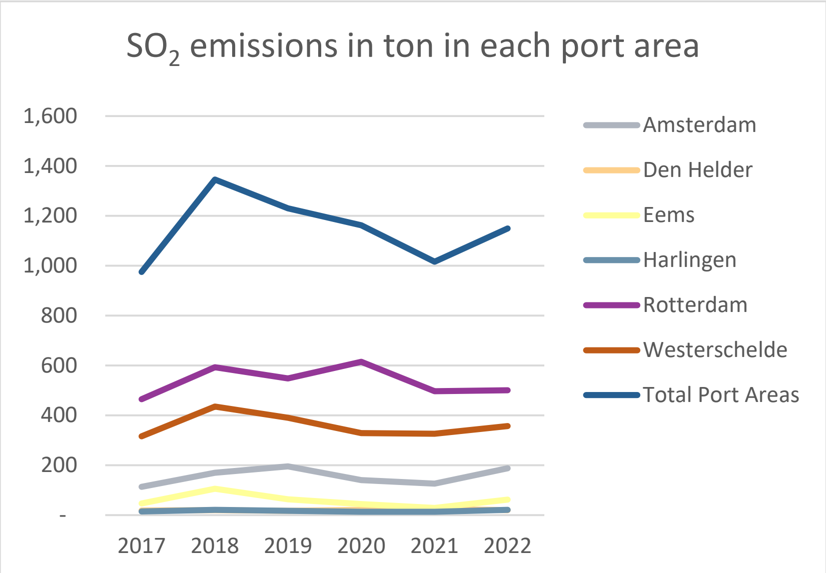

Figure 6-3 **SO_2 emissions in ton in each port area for 2017-2022, excluding fishing vessels.**

Table 6-1 Total emissions in ton in each port area for 2022, excluding fishing vessels (EMS-type 11)

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	44	42	2	26	12	27	153
	Total	44	42	2	26	12	27	153
1237 VOC	Berthed	73	265	126	21	10	11	506
	Sailing	261	122	45	24	6	8	465
	Total	334	387	171	45	15	19	971
4001 SO_2	Berthed	92	389	154	35	13	13	696
	Sailing	265	112	34	27	7	8	453
	Total	357	501	188	62	20	21	1150
4013 NO_x	Berthed	1816	6326	2854	511	262	255	12023
	Sailing	8253	3110	961	681	146	208	13359
	Total	10069	9437	3815	1191	408	462	25382
4031 CO	Berthed	117	463	218	37	15	18	868
	Sailing	508	258	90	53	15	21	945
	Total	625	721	308	89	30	39	1813
4032 CO_2	Berthed	149706	601592	302594	47042	18605	23400	1142939
	Sailing	359687	153043	46430	38720	9506	12579	619965
	Total	509393	754636	349024	85761	28110	35979	1762904
6601 Aerosols MDO	Berthed	36	137	61	11	4	6	256
	Sailing	40	22	9	6	2	4	84
	Total	76	160	70	18	6	10	340
6602 Aerosols HFO	Berthed	0	0	2	0	1	0	4
	Sailing	171	73	19	18	4	1	285
	Total	171	73	21	18	4	1	289

Table 6-2 Emissions in each port area for 2022 as percentage of the emissions in 2021, excluding fishing vessels (EMS-type 11).

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems[1]	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	233%	111%	161%	148%	102%	86%	129%
	Total	233%	111%	161%	148%	102%	86%	129%
1237 VOC	Berthed	113%	90%	132%	1179%	65%	190%	106%
	Sailing	97%	96%	147%	106%	93%	113%	101%
	Total	100%	92%	135%	186%	73%	147%	103%
4001 SO_2	Berthed	124%	100%	148%	1413%	72%	199%	117%
	Sailing	105%	104%	154%	106%	102%	111%	108%
	Total	109%	101%	149%	219%	80%	153%	113%
4013 NO_x	Berthed	112%	93%	134%	1080%	65%	173%	108%
	Sailing	98%	97%	148%	105%	94%	109%	101%
	Total	100%	94%	137%	171%	73%	137%	104%
4031 CO	Berthed	115%	89%	135%	1235%	68%	215%	107%
	Sailing	100%	97%	158%	103%	97%	95%	103%
	Total	103%	92%	141%	165%	80%	127%	105%
4032 CO_2	Berthed	117%	87%	134%	1310%	70%	244%	105%
	Sailing	99%	97%	144%	100%	96%	101%	101%
	Total	103%	89%	136%	203%	77%	163%	104%
6601 Aerosols MDO	Berthed	113%	91%	133%	1358%	77%	180%	107%
	Sailing	101%	99%	126%	90%	96%	111%	102%
	Total	106%	92%	132%	230%	83%	141%	106%
6602 Aerosols HFO	Berthed	82%	26%	280%	266%	43%	136%	83%
	Sailing	96%	96%	157%	107%	94%	85%	99%
	Total	96%	95%	163%	108%	77%	85%	98%

[1] The increase in Ems is probably less because the emissions in 2021 based on AIS data are too low and not in line with the annual port report.

6.3 Emissions in the Netherlands sea area (NCS and 12-mile zone)

The emissions in the NCS and the 12-mile zone are calculated for moving and non-moving ships. Ships are counted as non-moving when the speed is less than 1 knot, just like in the previous studies. Mostly, this concerns ships at anchor in one of the anchorage areas. However, some ships may have such a low speed for a while when waiting for something (for a pilot, for permission to enter a port or for another reason). Based on the observed speed in AIS, the emission has been calculated for the main engine and for the auxiliary engines.

The calculated emissions for 2022 are summarised in Table 6-3. This table also contains a comparison with 2021. The percentages in grey are based on very low absolute numbers and not very reliable.

The substance CO_2 has the largest contribution to the total emissions in ton (98%). For NCS combined with the 12-miles zone there is a total increase of CO_2 emission by 2%. This is due to 10% increase for ships at anchor and 2% increase for sailing ships. For the Netherlands sea area the average number of ships increased by 6%.

Figure 6-4 shows CO_2, NO_x and SO_2 emissions in ton in the Netherlands sea area from 2017 up to 2022. The total emissions in ton contains not moving and moving ships excluding fishing vessels. SO_2 emissions increased by 9% since the previous registration and NO_x remains approximately at the same level.

Table 6-3 Emissions of ships in ton in the Netherlands sea area for 2022 compared with 2021, excluding fishing vessels (EMS-type 11).

No	Substance	Emission in ton in 2022			Emission in 2022 as percentage of 2021		
		Not moving	Moving	Total	Not moving	Moving	Total
1011	Methane		1174	1174		123%	123%
1237	VOC	153	2157	2310	107%	101%	101%
4001	SO_2	227	2397	2624	118%	108%	109%
4013	NO_x	4573	73632	78205	108%	100%	100%
4031	CO	277	4480	4757	112%	105%	105%
4032	CO_2	305249	3337914	3643163	110%	102%	102%
6601	Aerosols MDO	121	272	393	112%	103%	106%
6602	Aerosols HFO	6	1713	1719	88%	101%	101%
Average number of ships present in the area		144	173	317	113%	102%	106%

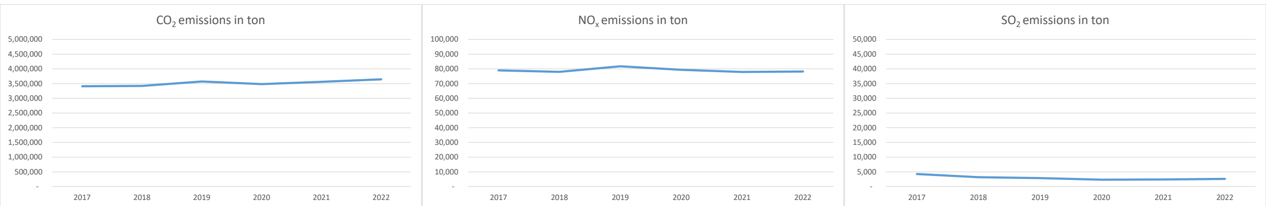

Figure 6-4 CO_2, NO_x and SO_2 emissions in ton in the Netherlands sea area for 2017-2022, excluding fishing vessels.

6.4 Spatial distribution of the emissions

Because of the strong relation between shipping routes and location of the emissions, all substances show more or less the same spatial distribution. Therefore, only the spatial distribution of NO_x is presented for the six Dutch port areas and the Netherlands sea area in Figure 6-5 up to Figure 6-25.

Three figures are presented for each area. The first figure represents the total emission (emissions of auxiliary and main engine of moving and not moving ships together) expressed as NO_x in ton/km^2. The second one shows the *absolute* change in emission between 2021 and 2022 and the third one shows the *relative* change in emission between 2021 and 2022. To make a comparison between areas easier, the same colour table has been used for all areas. Only for the NCS, a different scale has been used to illustrate the absolute difference. This is necessary because at the NCS differences are more smoothed due to the larger grid cells, these are 25 km^2 instead of 0.25 km^2 as used in the port areas.

In the figures, large differences between 2021 and 2022 are visualized by darker colours. Absolute differences are often larger at locations with high traffic intensity, while relative differences are often larger at locations with low traffic intensity. This has to be kept in mind when interpreting the figures.

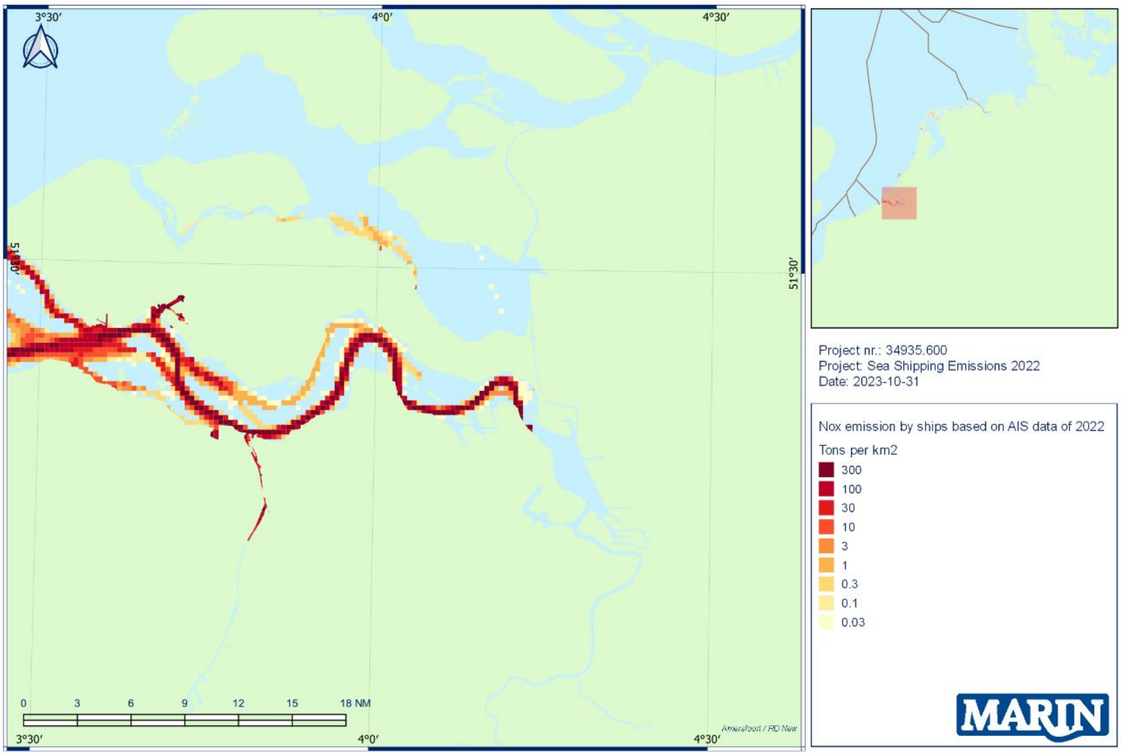

Figure 6-5 NO$_x$ emission in 2022 in the Dutch part of the Western Scheldt by ships with AIS.

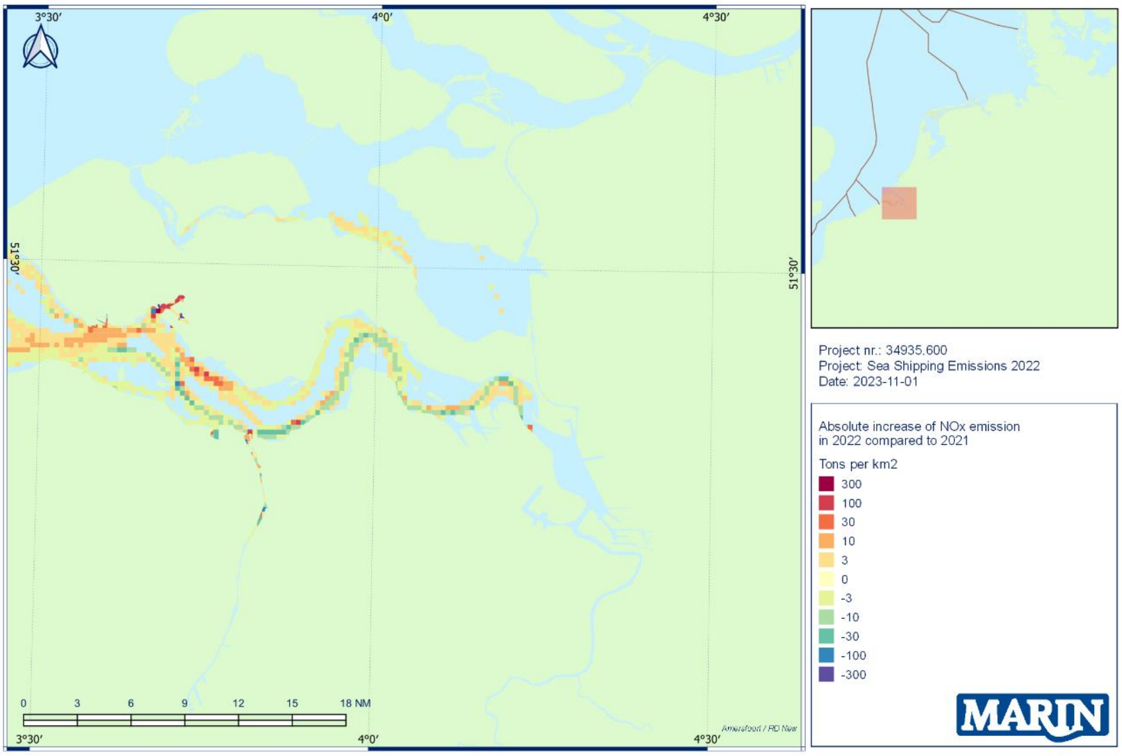

Figure 6-6 Absolute change in NO$_x$ emission from 2021 to 2022 in the Dutch part of the Western Scheldt by ships with AIS.

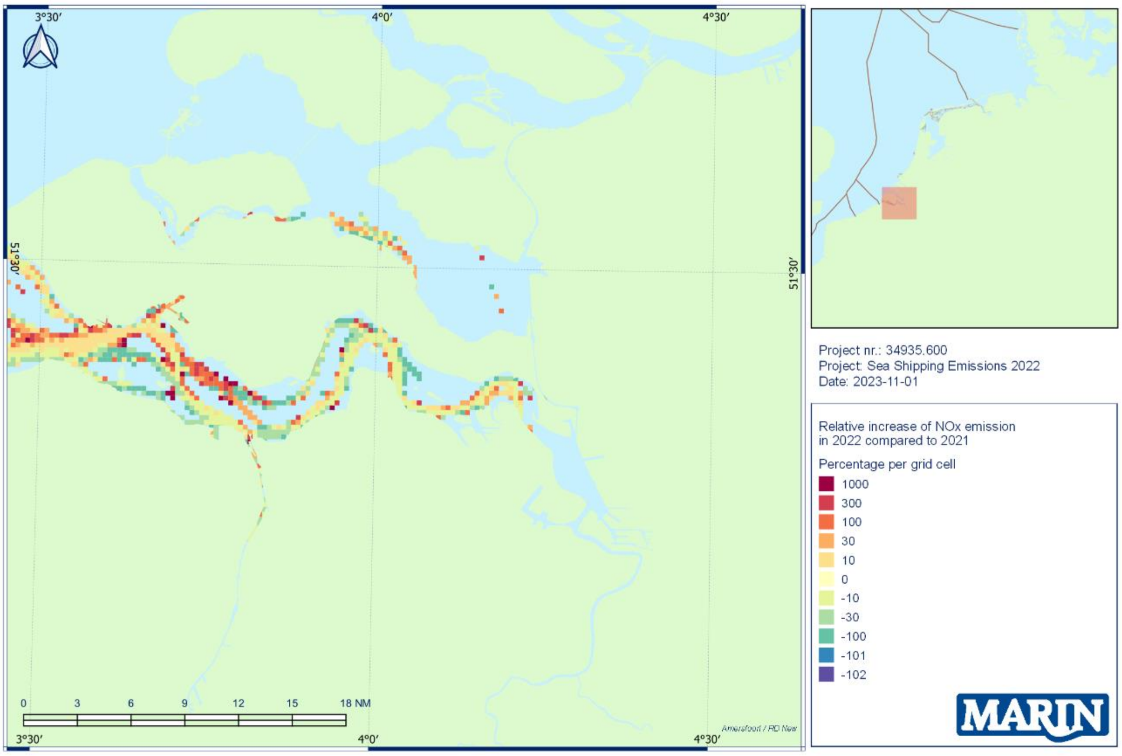

Figure 6-7 **Relative change in NO_x emission from 2021 to 2022 in the Dutch part of the Western Scheldt by ships with AIS.**

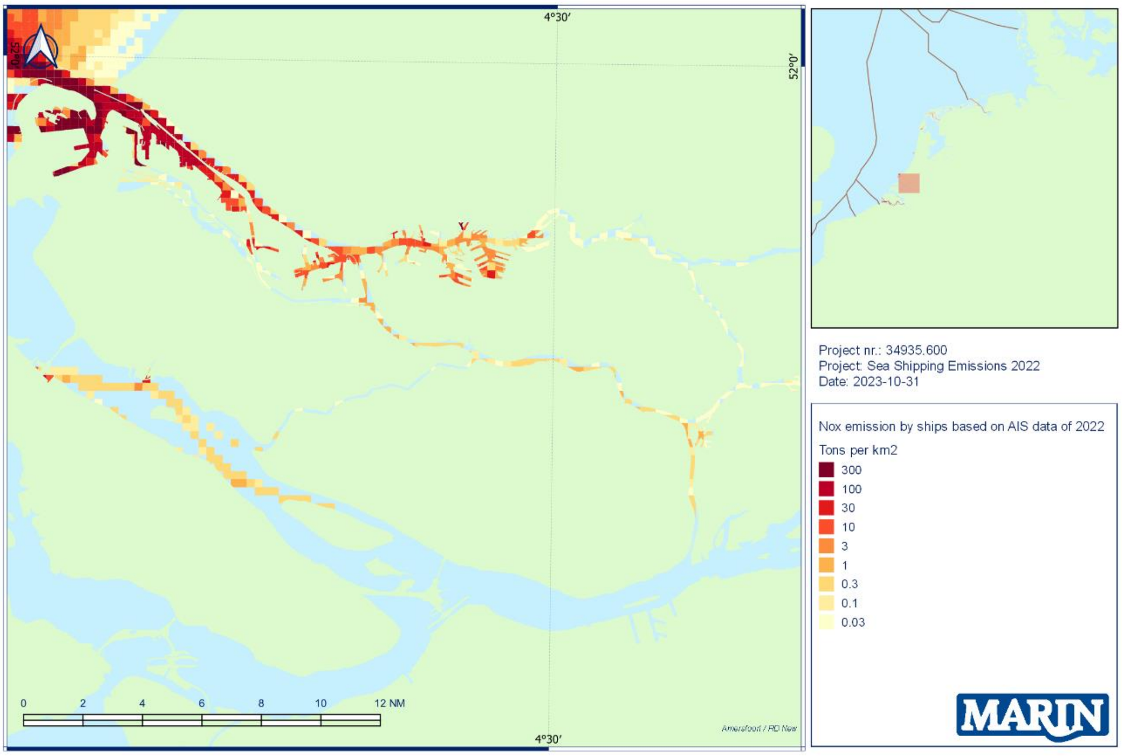

Figure 6-8 **NO_x emission in 2022 in the port area of Rotterdam by ships with AIS.**

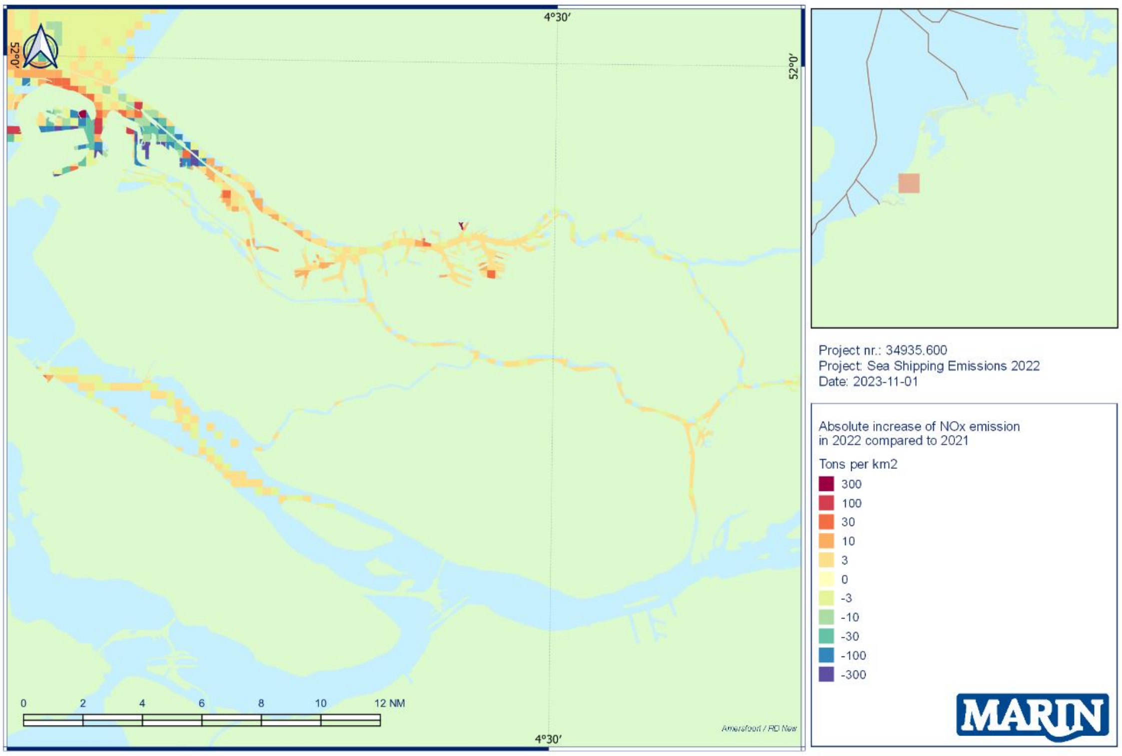

Figure 6-9 Absolute change in NO_x emission from 2021 to 2022 in the port area of Rotterdam by ships with AIS.

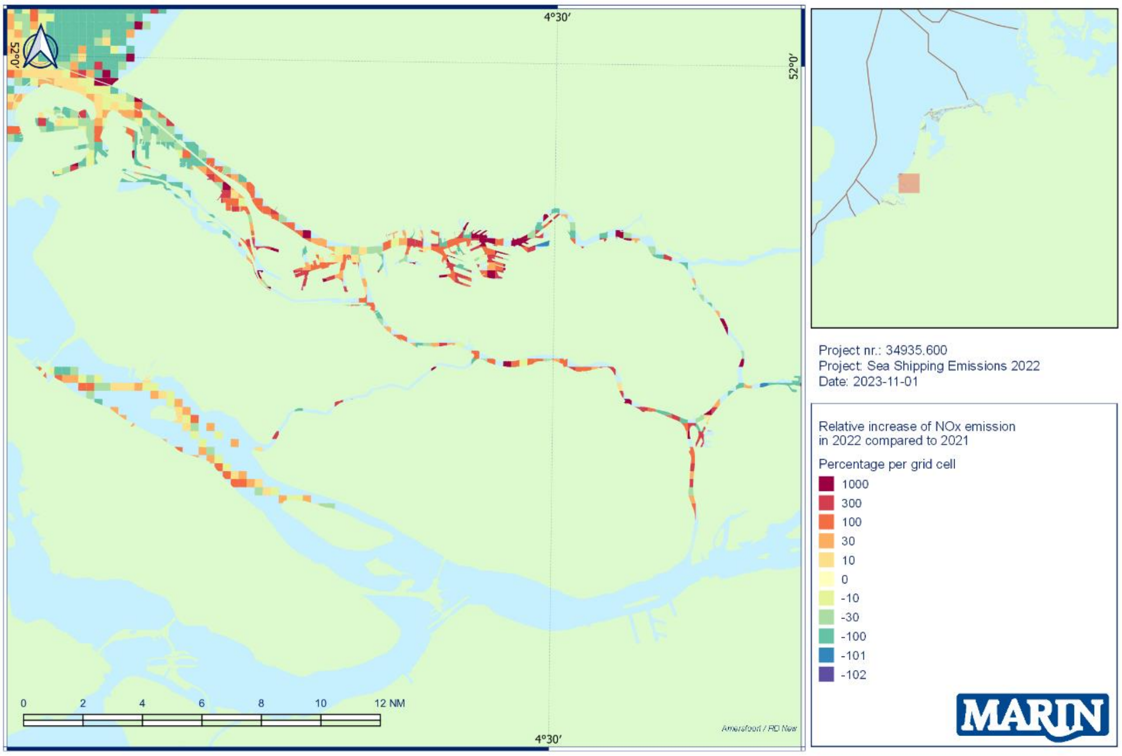

Figure 6-10 Relative change in NO_x emission from 2021 to 2022 in the port area of Rotterdam by ships with AIS.

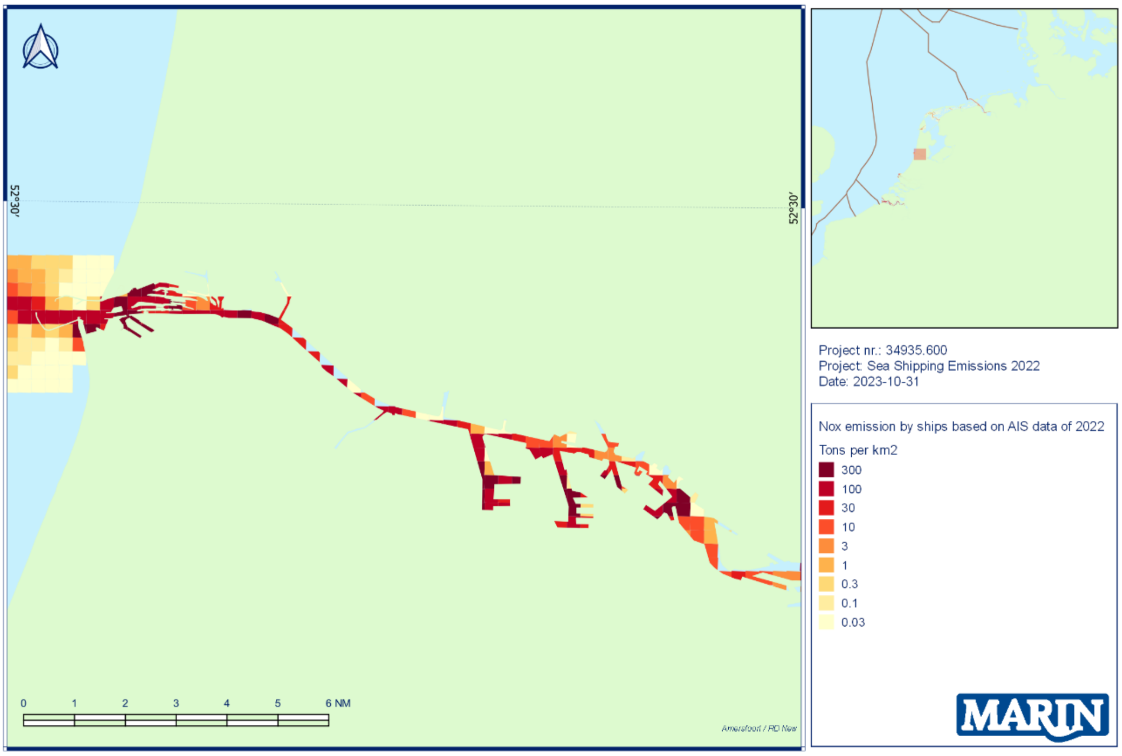

Figure 6-11 NO_x emission in 2022 in the port area of Amsterdam by ships with AIS.

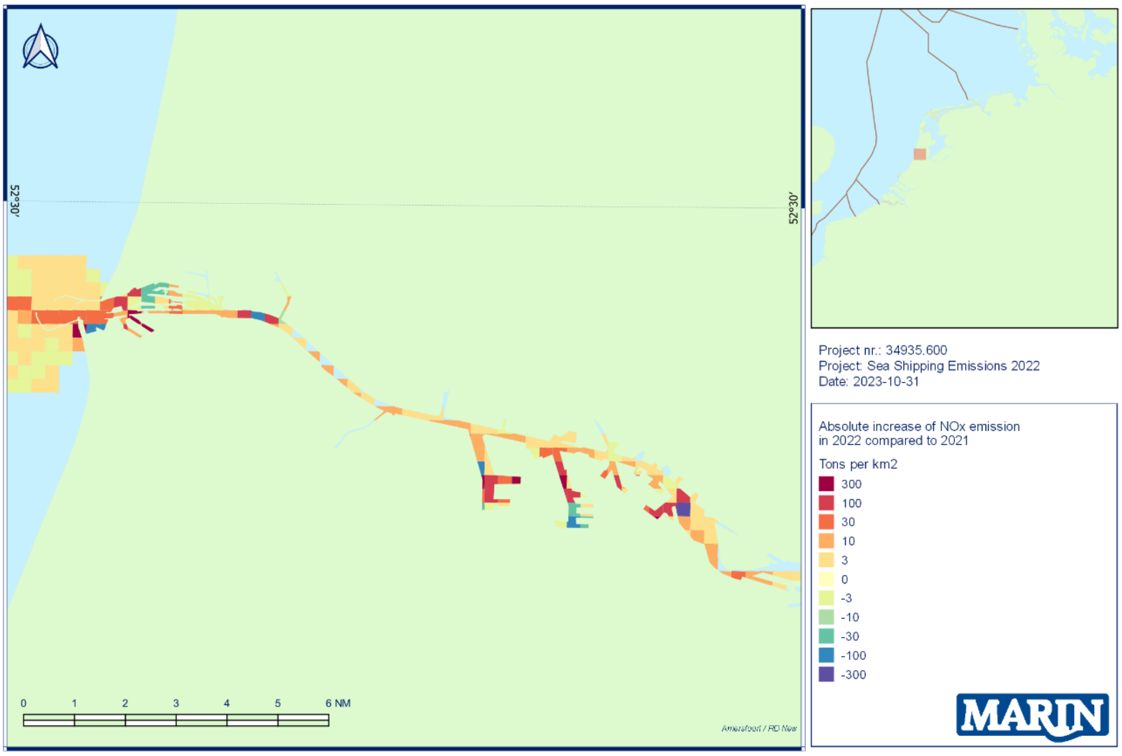

Figure 6-12 Absolute change in NO_x emission from 2021 to 2022 in the port area of Amsterdam by ships with AIS.

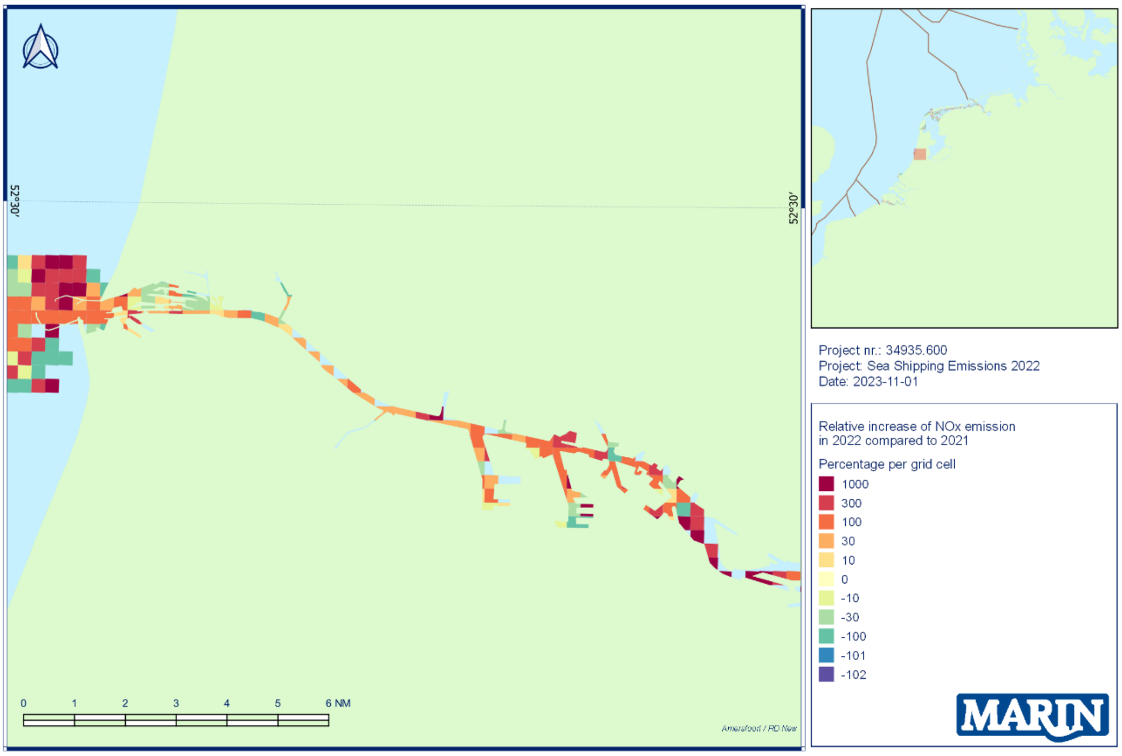

Figure 6-13 Relative change in NO_x emission from 2021 to 2022 in the port area of Amsterdam by ships with AIS.

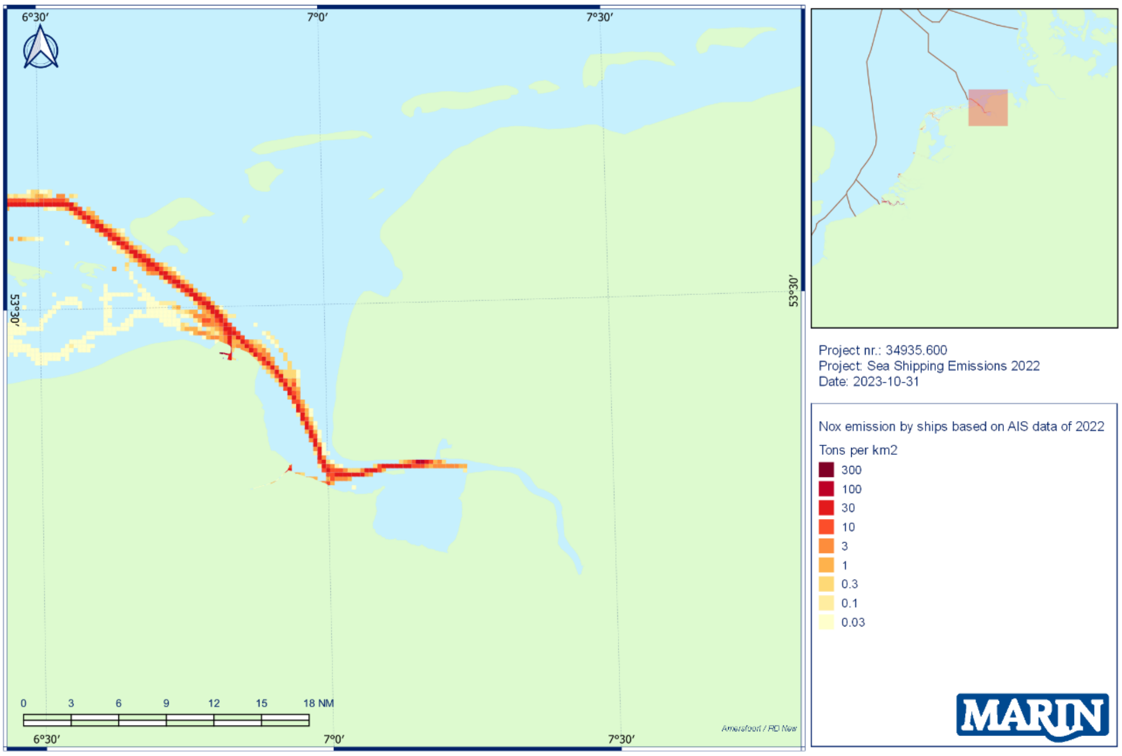

Figure 6-14 NO_x emission in 2022 in the Ems area by ships with AIS.

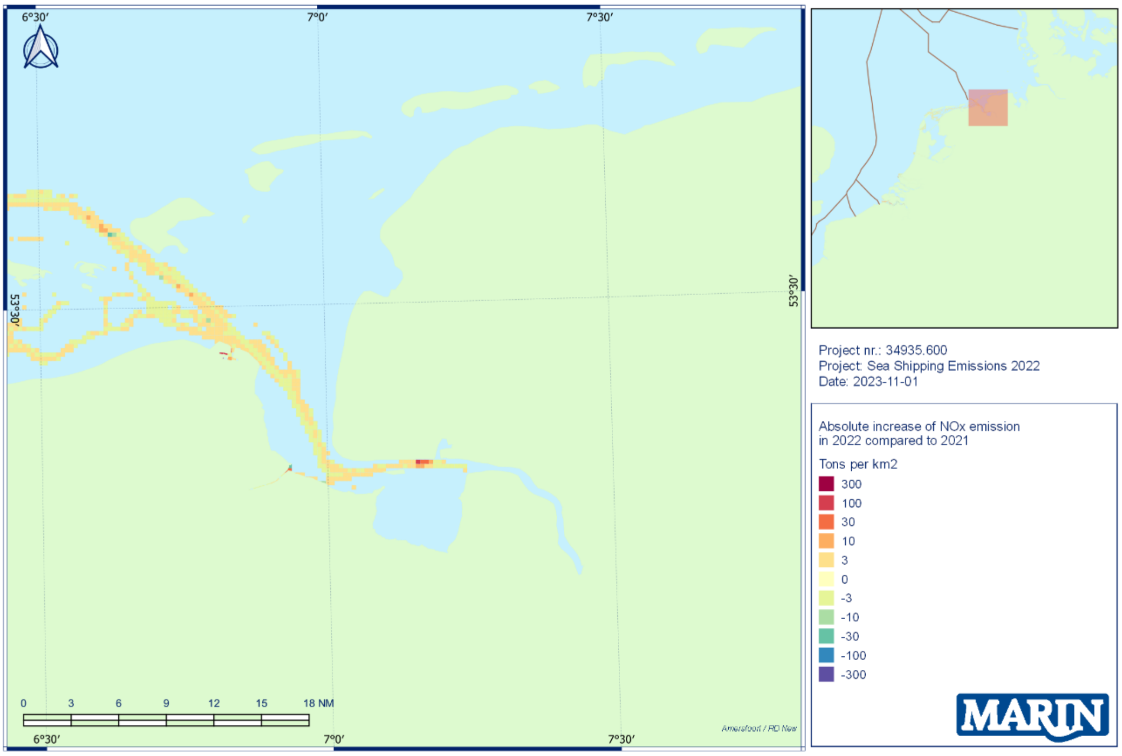

Figure 6-15 **Absolute change in NO_x emission from 2021 to 2022 in the Ems area by ships with AIS.**

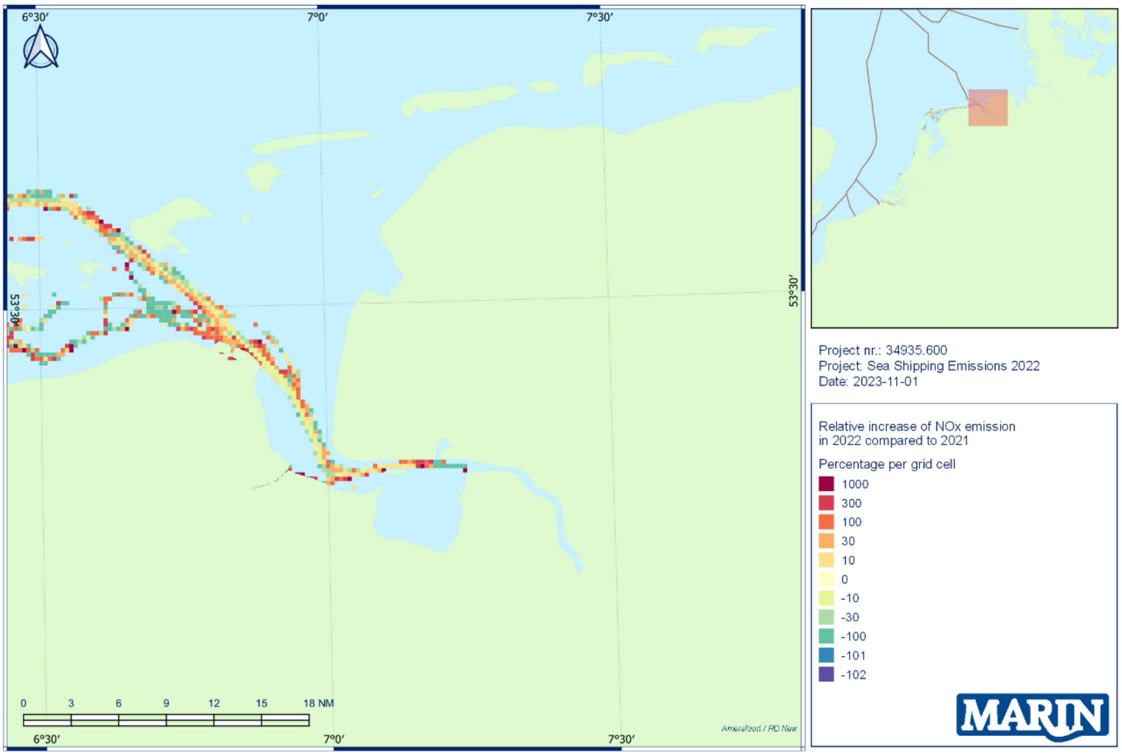

Figure 6-16 **Relative change in NO_x emission from 2021 to 2022 in the Ems area by ships with AIS.**

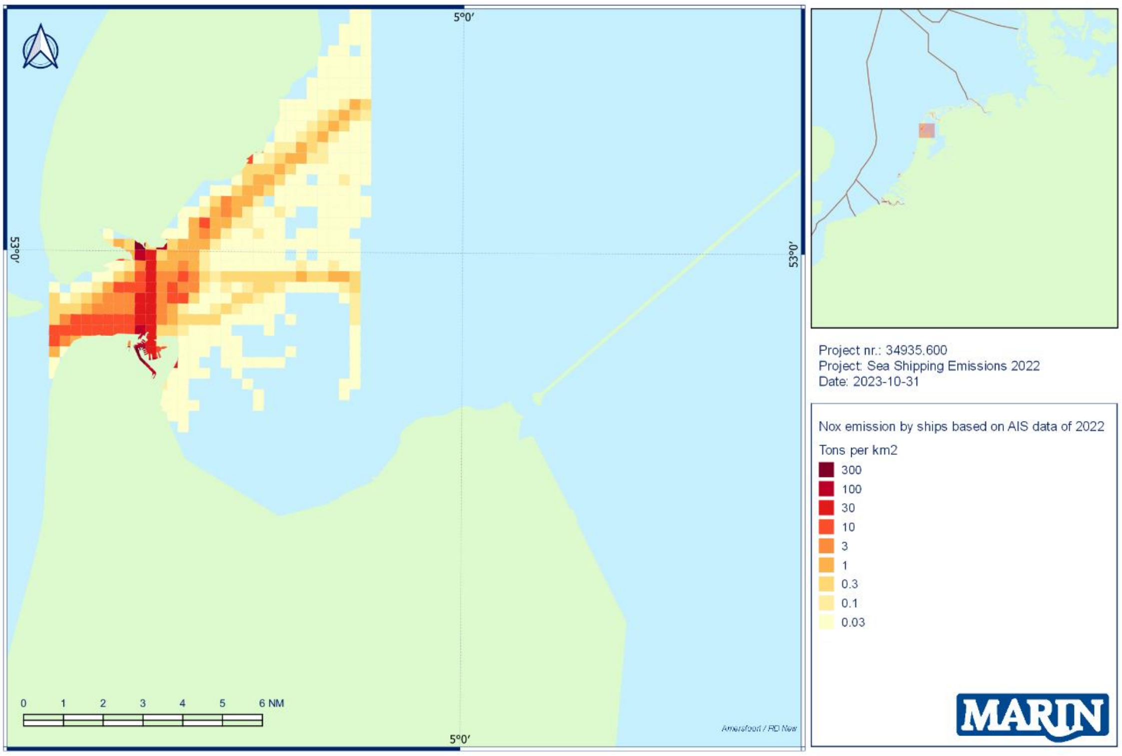

Figure 6-17 NO_x emission in 2022 in the port area of Den Helder by ships with AIS.

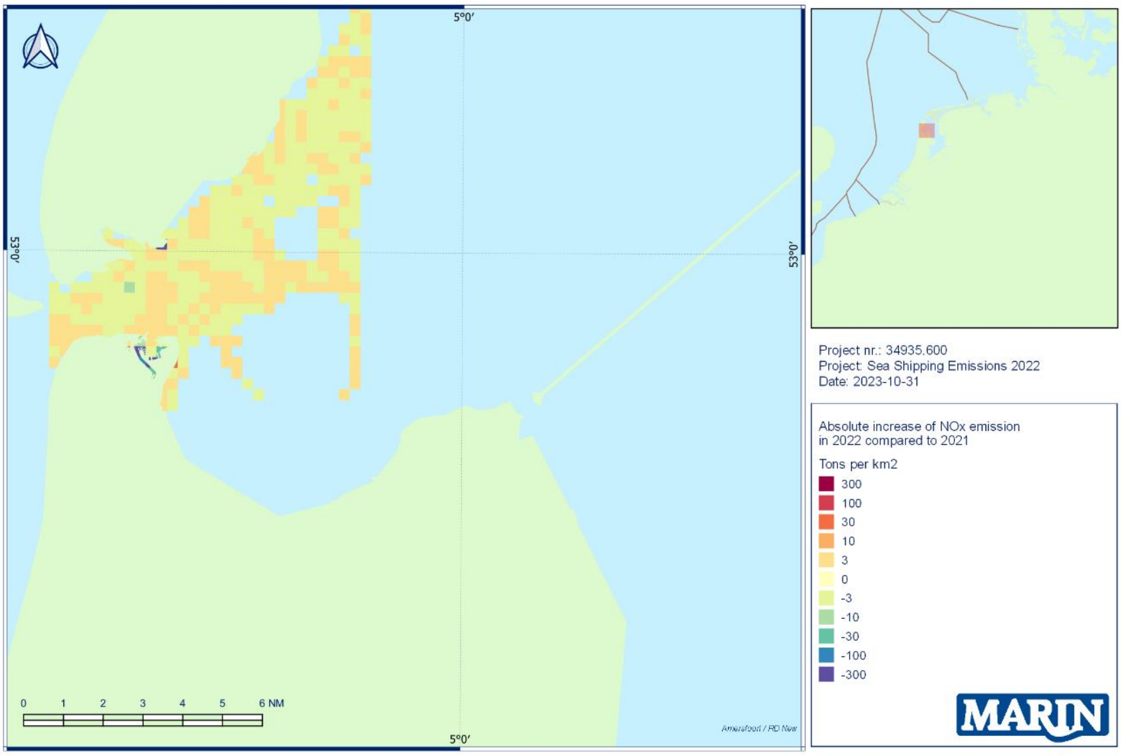

Figure 6-18 Absolute change in NO_x emission from 2021 to 2022 in the port area of Den Helder by ships with AIS.

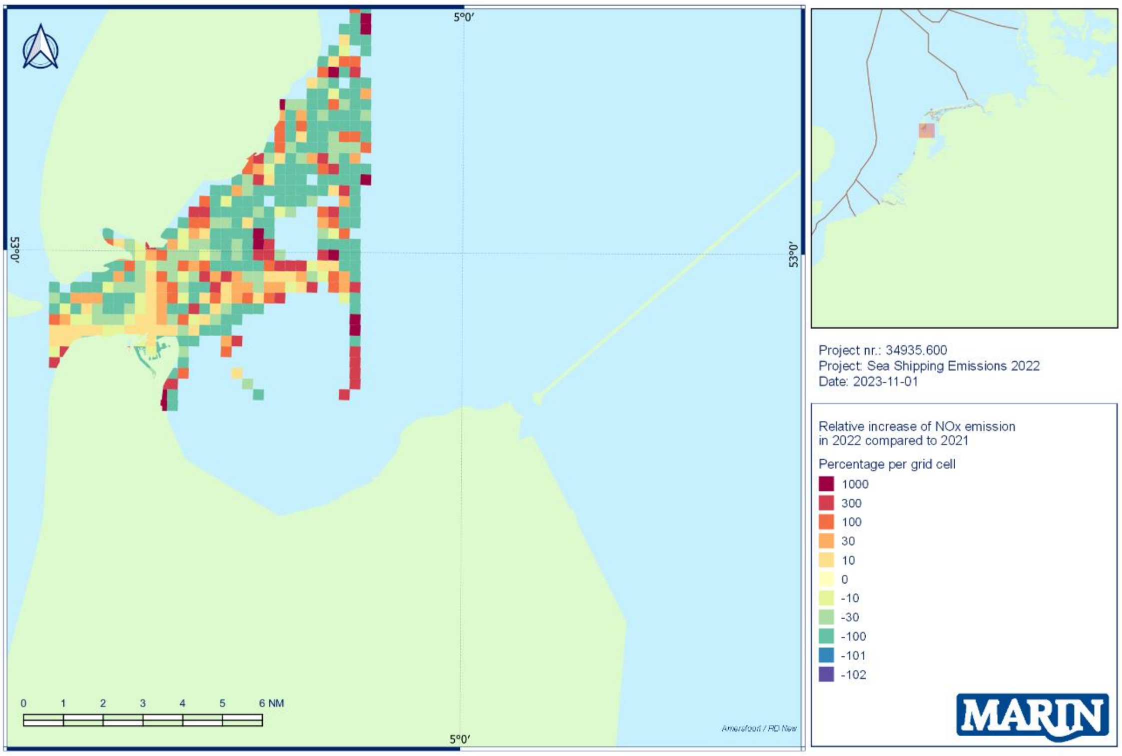

Figure 6-19 **Relative change in NO_x emission from 2021 to 2022 in the port area of Den Helder by ships with AIS.**

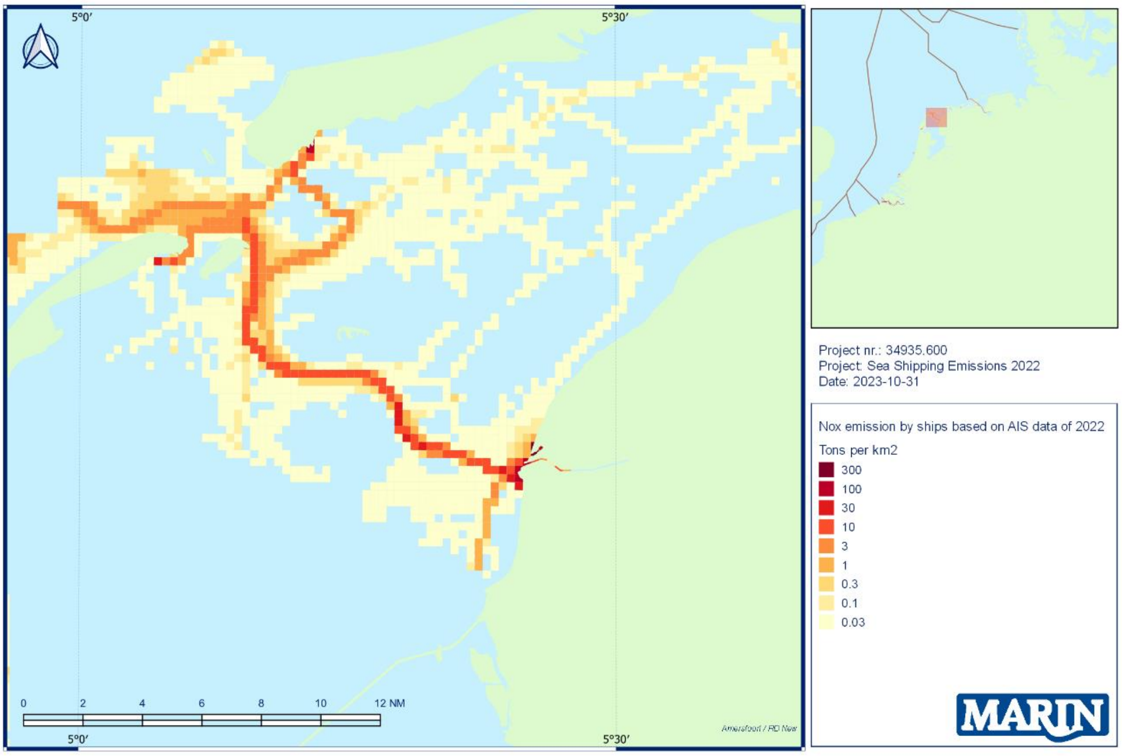

Figure 6-20 **NO_x emission in 2022 in the port area of Harlingen by ships with AIS.**

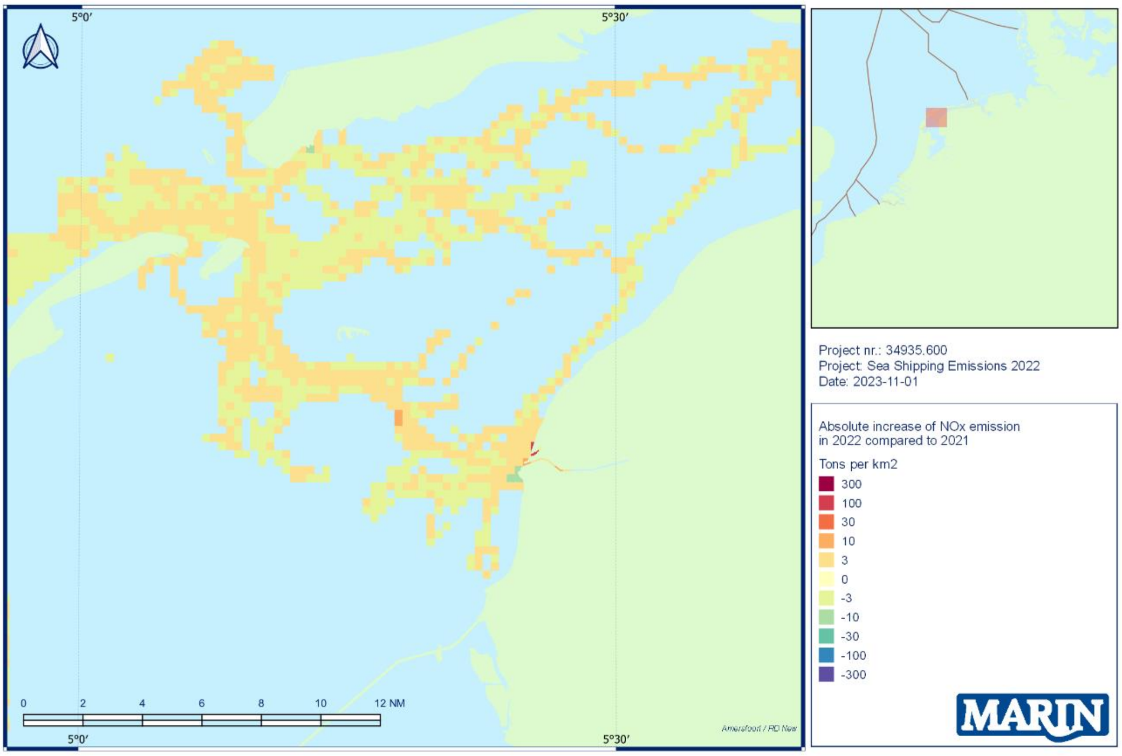

Figure 6-21 **Absolute change in NO_x emission from 2021 to 2022 in the port area of Harlingen by ships with AIS.**

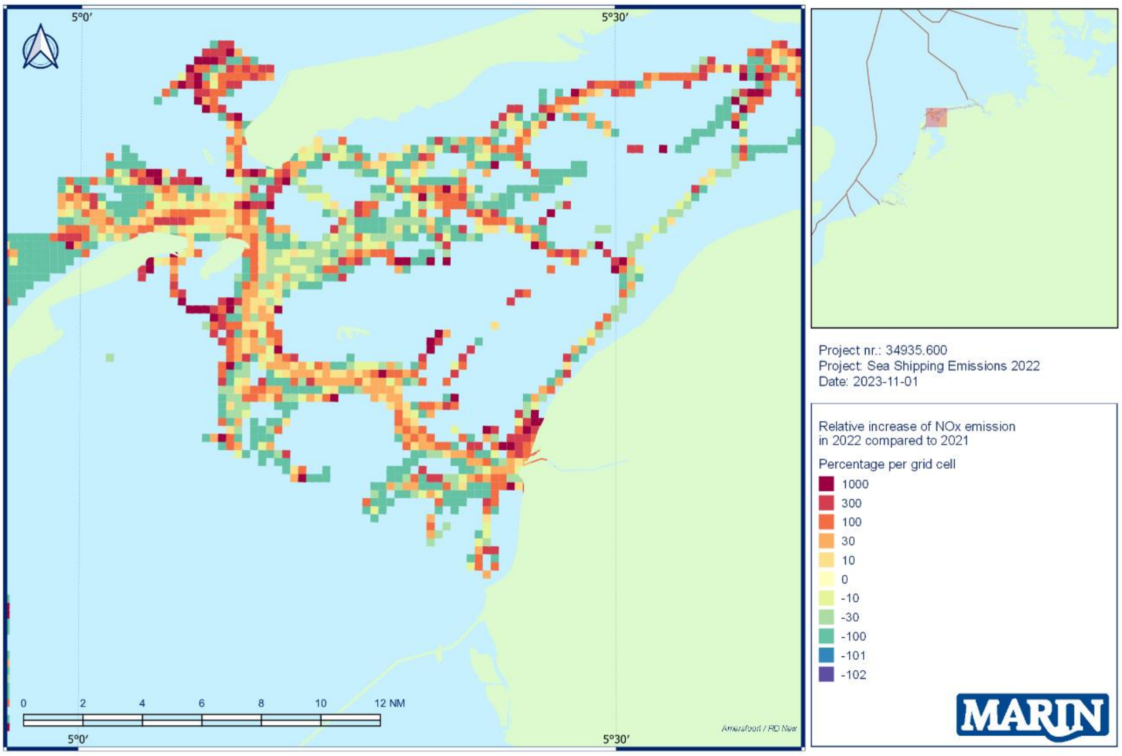

Figure 6-22 **Relative change in NO_x emission from 2021 to 2022 in the port area of Harlingen by ships with AIS.**

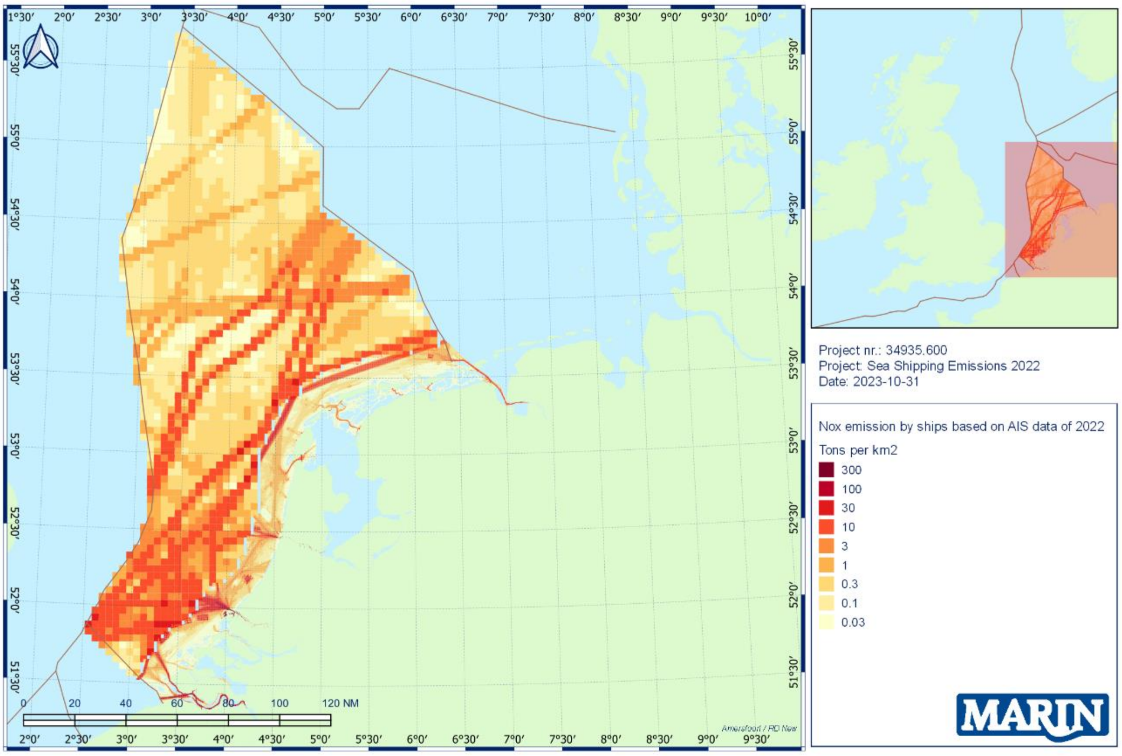

Figure 6-23 NO_x emission in 2022 in the NCS, the 12-mile zone and the Dutch port areas by ships with AIS.

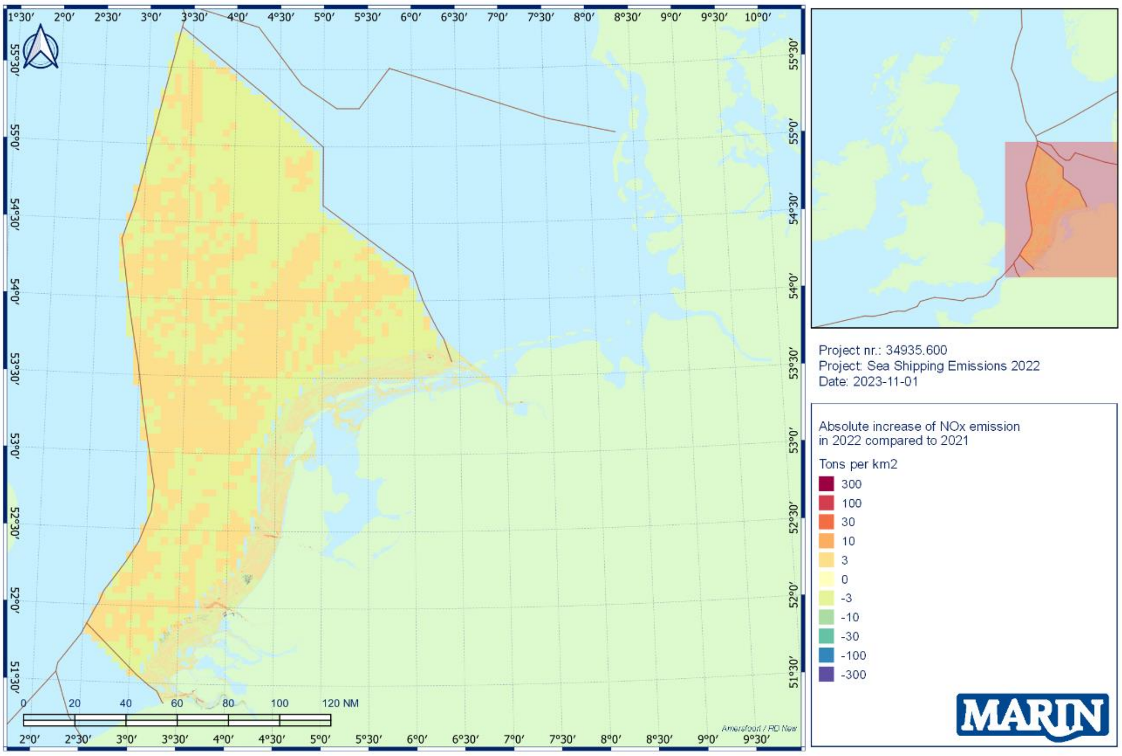

Figure 6-24 Absolute change in NO_x emission from 2021 to 2022 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.

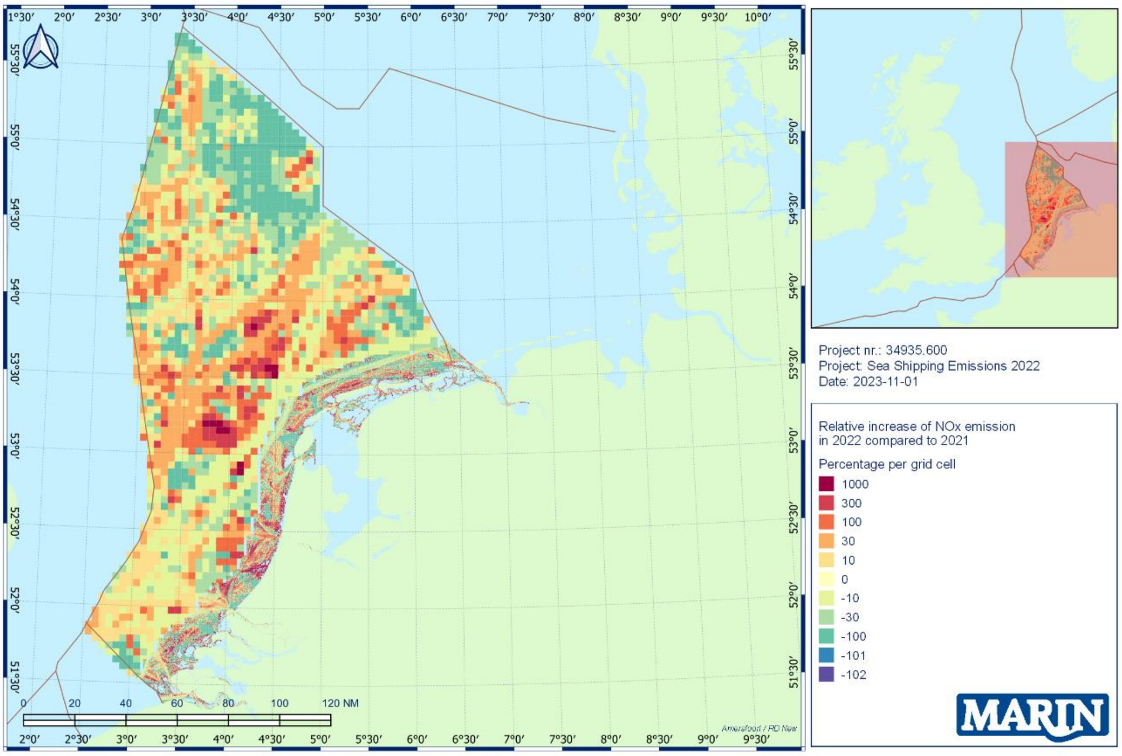

Figure 6-25 Relative change in NO_x emission from 2021 to 2022 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.

7 EMISSIONS FOR THE FISHING ACTIVITIES IN THE DUTCH PORT AREAS, THE WADDEN SEA AND THE NETHERLANDS SEA AREA

7.1 Introduction

This chapter presents the results of the emission calculations for 2022 for the fishing activities in the Dutch port areas, the Wadden Sea and the Netherlands sea area. Its method is explained by TNO in reference [3] and in Appendix A3.

7.2 Emissions of fishing vessels (EMS type 11)

In Table 7-1, the total emissions of fishing vessels are given in ton for each port area and the Wadden Sea. Table 7-2 presents the trend in percentages compared with the results of 2021. Table 7-3 gives the total emissions of fishing vessels for the 12 miles zone and the NCP and Table 7-4 presents the trend in percentages compared with 2021.

The percentages in grey are based on very low absolute numbers and not very reliable.

Figure 7-1 up to Figure 7-6 present the spatial distribution of CO_2 for the NCS and the Dutch Wadden Sea. This substance is most emitted by fishing vessels.

It is clear from both the table and the figures that the absolute contribution of CO_2 emissions by fishing vessels is largest in Harlingen, WesternScheldt and Amsterdam. Compared to the previous year there is a clear increase of CO_2 emissions in the port of Ems (47%), Rotterdam (29%) and Amsterdam (15%). In Harlingen and Wadden there is a decrease of CO_2 emissions, respectively 7% and 11% . For all ports together the CO_2 emissions have been increased by 5%.

For the NCP and the 12-miles zone, the CO_2 emissions by fishing vessels significant decreased by 35 percent, mainly caused by an decrease of moving ships by 35%. In monitor 'Netwerkanalyse Noordzee 2022' [11] where the NCP is monitored annually based on AIS data, a reduction in fishing activity is also observed. This significant decline in actual fishing activity is probably due to high fuel prices, corona aftermath and buyout schemes.

Table 7-1 Total emissions in ton in each port area for 2022, fishing vessels including trawlers

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	6	2	6	1	3	6	0	25
	Sailing	2	0	1	1	2	4	2	11
	Total	7	2	7	2	5	11	2	36
4001 SO_2	Berthed	6	3	7	1	3	7	0	27
	Sailing	2	0	1	1	2	5	1	11
	Total	8	3	8	2	5	11	2	38
4013 NO_x	Berthed	139	63	167	15	65	148	5	602
	Sailing	38	2	17	20	41	101	33	252
	Total	177	65	184	34	106	250	38	854
4031 CO	Berthed	7	3	8	1	3	8	0	30
	Sailing	2	0	1	1	2	5	2	14
	Total	9	3	9	2	6	13	2	44
4032 CO_2	Berthed	9364	4685	10426	1073	4594	10636	354	41133
	Sailing	2533	168	1072	1434	2828	7159	2321	17516
	Total	11896	4853	11498	2508	7422	17796	2675	58648
6598 Aerosols MDO/HFO	Berthed	4	2	3	1	2	5	0	17
	Sailing	1	0	0	1	1	3	1	8
	Total	5	2	3	1	3	8	1	25

Table 7-2 Emissions in each port area for 2022 as percentage of the emissions in 2021, fishing vessels including trawlers

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	107%	128%	117%	2009%	116%	97%	66%	111%
	Sailing	99%	82%	91%	86%	96%	87%	100%	92%
	Total	105%	125%	114%	139%	107%	92%	93%	104%
4001 SO_2	Berthed	111%	132%	121%	1963%	111%	99%	66%	114%
	Sailing	102%	81%	95%	87%	94%	87%	94%	91%
	Total	109%	129%	118%	147%	104%	94%	89%	106%
4013 NO_x	Berthed	110%	131%	116%	1997%	112%	98%	66%	112%
	Sailing	100%	79%	91%	86%	93%	86%	94%	90%
	Total	108%	128%	114%	145%	104%	93%	89%	105%
4031 CO	Berthed	108%	127%	117%	1965%	114%	98%	66%	112%
	Sailing	100%	78%	90%	86%	98%	89%	98%	93%
	Total	106%	124%	113%	140%	107%	94%	92%	105%
4032 CO_2	Berthed	110%	132%	117%	1965%	111%	98%	66%	113%
	Sailing	101%	81%	92%	87%	93%	86%	94%	90%
	Total	108%	129%	115%	147%	103%	93%	89%	105%
6598 Aerosols MDO/HFO	Berthed	104%	136%	124%	2050%	116%	99%	65%	112%
	Sailing	101%	97%	102%	86%	95%	88%	98%	92%
	Total	103%	134%	121%	143%	107%	95%	92%	105%

Table 7-3 Total emissions in ton in the 12 mile zone and the NCP for 2021, fishing vessels including trawlers

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	3	1	4
	Sailing	19	47	66
	Total	22	47	69
4001 SO_2	Berthed	3	1	4
	Sailing	20	49	69
	Total	22	50	72
4013 NO_x	Berthed	75	15	90
	Sailing	439	1130	1568
	Total	514	1144	1658
4031 CO	Berthed	4	1	4
	Sailing	23	58	81
	Total	27	59	86
4032 CO_2	Berthed	4194	892	5086
	Sailing	30416	76329	106744
	Total	34610	77221	111830
6598 Aerosols MDO/HFO	Berthed	1	0	1
	Sailing	14	32	46
	Total	14	32	47

Table 7-4 Emissions in 12 miles and NCP for 2021 as percentage of the emissions in 2020, fishing vessels including trawlers

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	81%	80%	81%
	Sailing	88%	58%	64%
	Total	87%	58%	65%
4001 SO_2	Berthed	83%	81%	83%
	Sailing	86%	60%	65%
	Total	86%	60%	66%
4013 NO_x	Berthed	79%	79%	79%
	Sailing	85%	59%	64%
	Total	84%	59%	65%
4031 CO	Berthed	82%	79%	82%
	Sailing	87%	59%	65%
	Total	86%	59%	65%
4032 CO_2	Berthed	79%	78%	79%
	Sailing	85%	59%	65%
	Total	85%	59%	65%
6598 Aerosols MDO/HFO	Berthed	81%	71%	78%
	Sailing	90%	57%	64%
	Total	89%	57%	64%

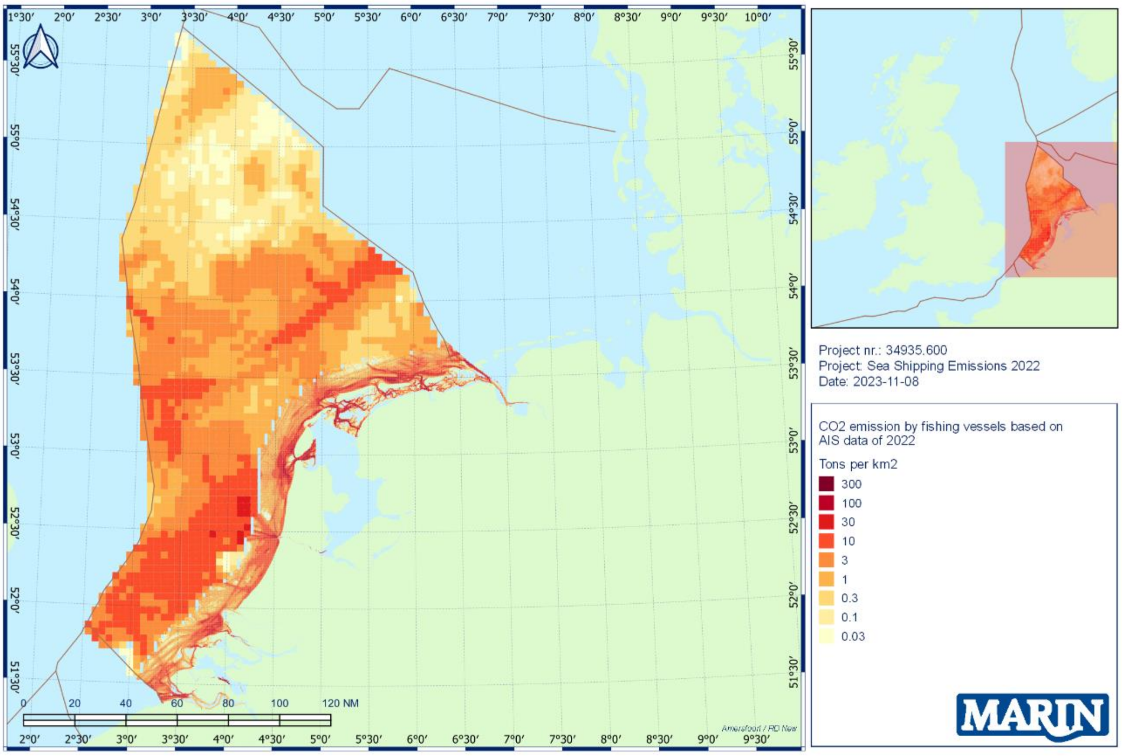

Figure 7-1 **CO_2 emission observed in the NCS, fishing vessels including trawlers, based on AIS data of 2022**

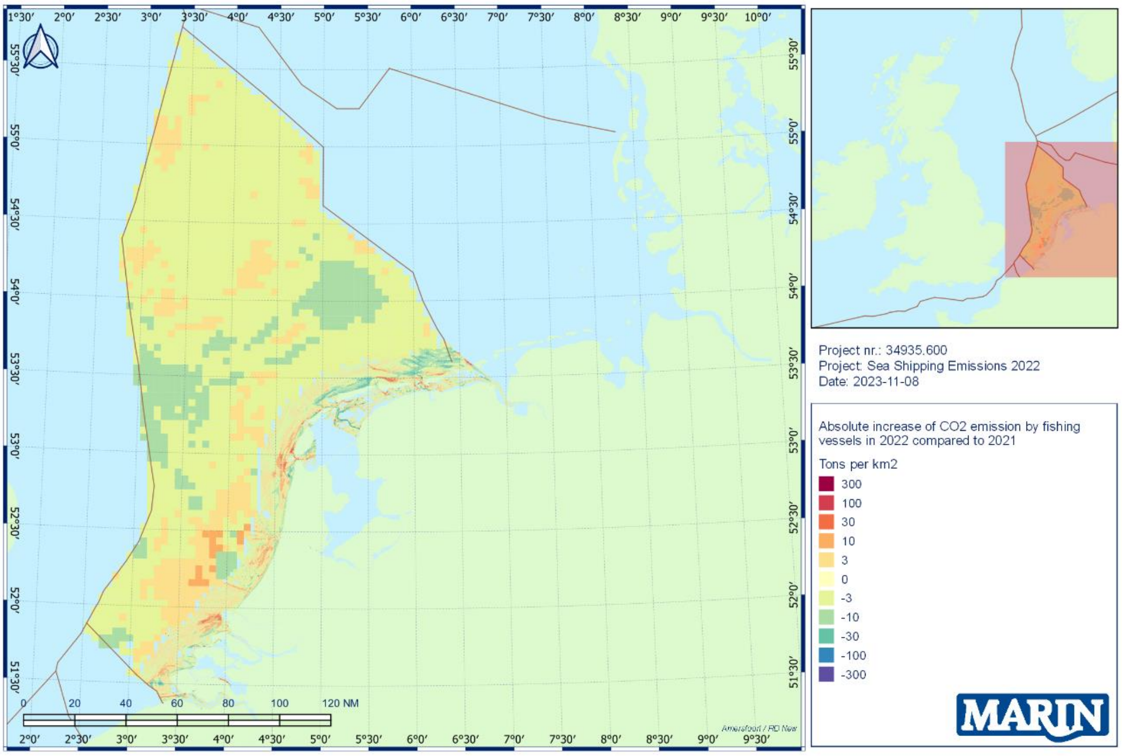

Figure 7-2 **Absolute change in CO2 emission from 2021 to 2022 observed in the NCS, fishing vessels including trawlers.**

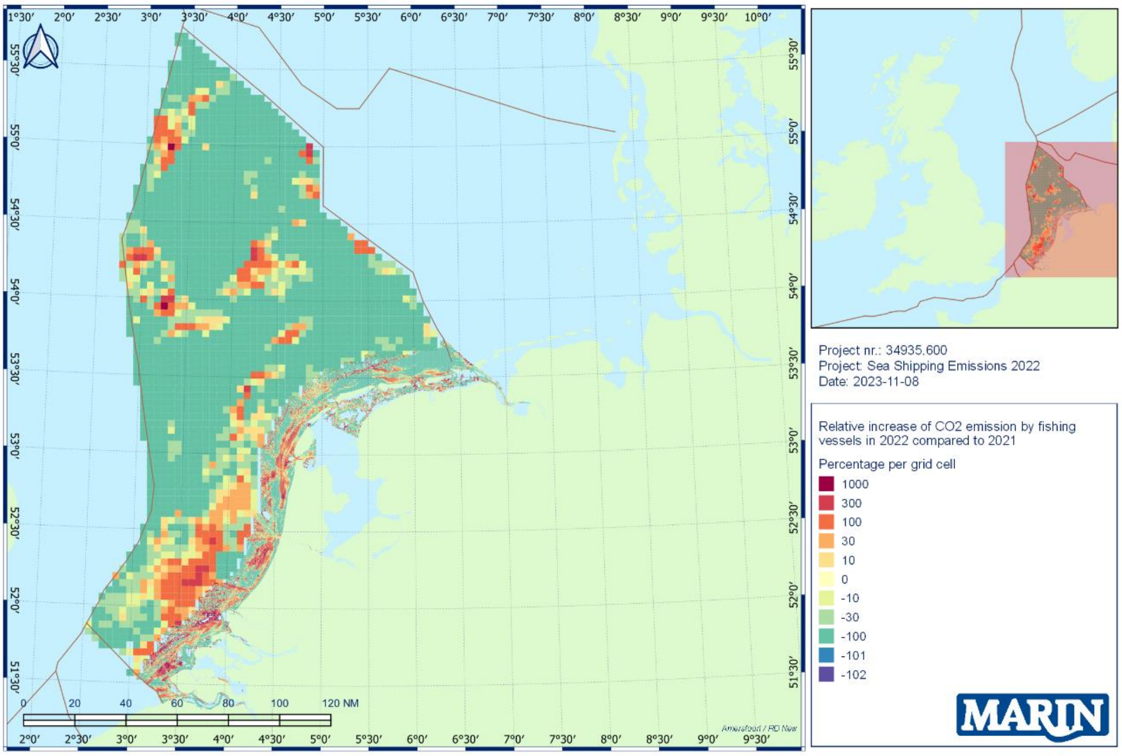

Figure 7-3 **Relative change in CO2 emission from 2021 to 2022 observed in the NCS, fishing vessels including trawlers.**

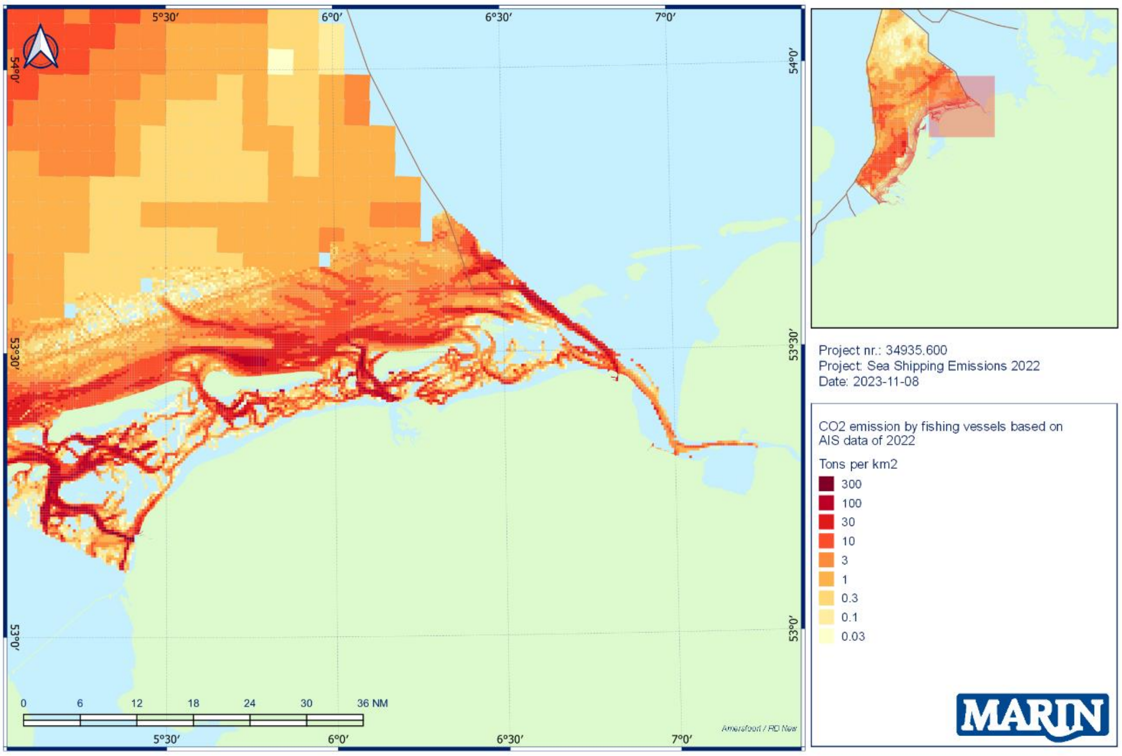

Figure 7-4 **CO_2 emission observed in the Dutch Wadden Sea, fishing vessels including trawlers, based on AIS data of 2022**

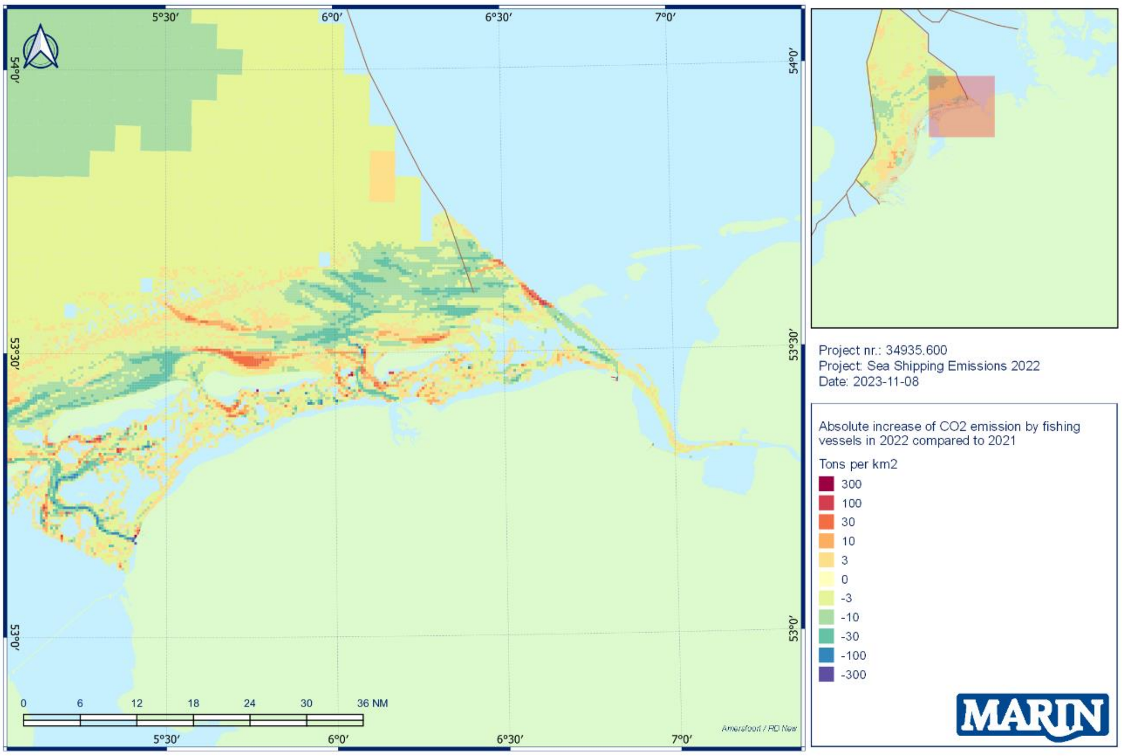

Figure 7-5 **Absolute change in CO2 emission from 2021 to 2022 in the Dutch Wadden Sea, fishing vessels including trawlers.**

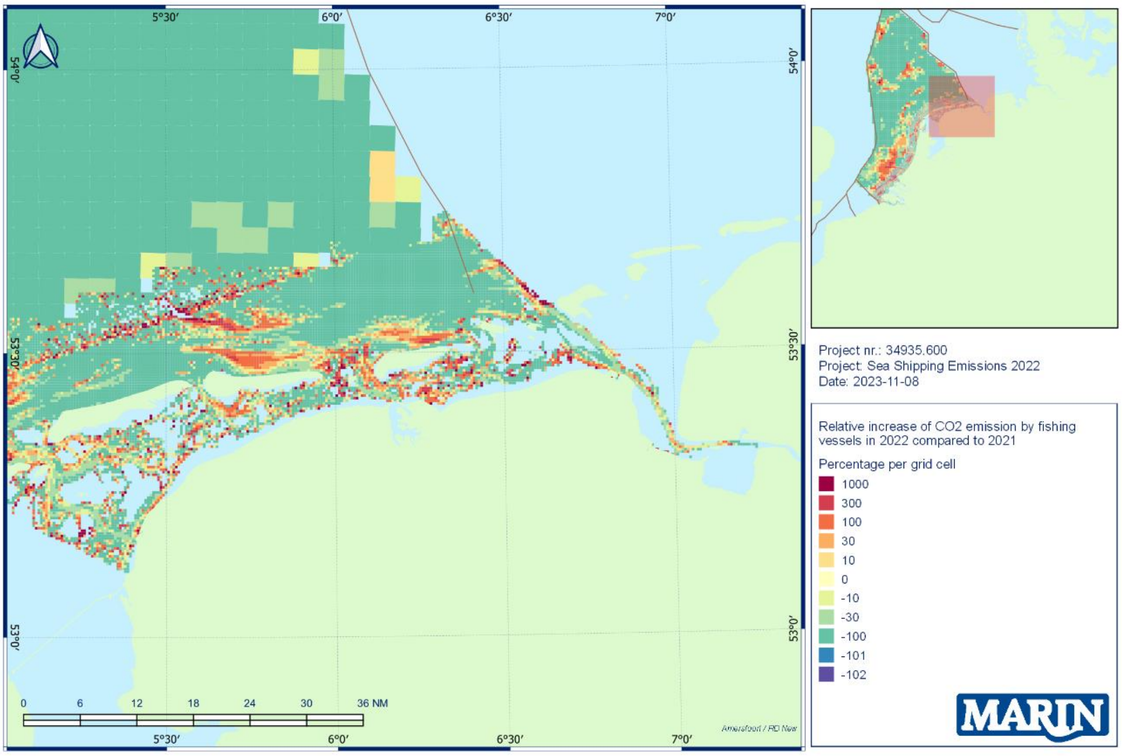

Figure 7-6 **Relative change in CO2 emission from 2021 to 2022 in the Dutch Wadden Sea, fishing vessels including trawlers.**

8 SUMMARY AND CONCLUSIONS

- **Deliveries**
The main delivery of this study is a set of databases containing gridded emissions of seagoing ships, including fishing vessels, both at sea and in the Dutch port areas. These emissions are distinguished into ship type and size. Where applicable, the emissions are also distinguished into moving / not moving. These databases can be used in studies for which a detailed spatial distribution of the emissions is required.

- **Completeness of AIS data**
The sum of missing periods, which are larger than 10 minutes, is negligible for 2022. The AIS data is practically complete, so there is no need to compensate for this.

- **Activity data**
Compared to 2021 there is an increase of activities in the Dutch port areas except for the port of Den Helder and Rotterdam. For the NCS combined with 12-miles zone the average berthed and moving hours increased by 13% and 2% respectively. This can also be seen in the average number of ships per day.

- **Emission results**
The substance CO_2 has the largest contribution to the total emissions in ton (98%). For all ports together, there is an overall increase of CO_2 by 4%. Ships at berth have a total increase of CO_2 by 5% and sailing ships increase by 1%. For all ports together NO_x and SO_2 emissions increased compared to 2021.

  For NCS combined with the 12-miles zone there is a total increase of CO_2 emission by 2%. This is due to 10% increase for ships at anchor and 2% increase for sailing ships. SO_2 emissions increased since the previous registration by 9% and NO_x remains approximately at the same level. For the Netherlands sea area the average number of ships increased by 6%.

- **Emission results fishery**
The absolute contribution of CO_2 emissions by fishing vessels is largest in Harlingen, WesternScheldt and Amsterdam. Compared to the previous year there is a clear increase of CO_2 emissions in the port of Ems (47%), Rotterdam (29%) and Amsterdam (15%). In Harlingen and Wadden there is a decrease of CO_2 emissions, respectively 7% and 11% . For all ports together the CO_2 emissions have been increased by 5%.

  For the NCP and the 12-miles zone, the CO_2 emissions by fishing vessels significant decreased by 35 percent, mainly caused by an decrease of moving ships by 35%. In monitor 'Netwerkanalyse Noordzee 2022' [11] where the NCP is monitored annually based on AIS data, a reduction in fishing activity is also observed. This significant decline in actual fishing activity is probably due to high fuel prices, corona aftermath and buyout schemes.

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APPENDIX A: EMISSION FACTORS

Written by Jan Hulskotte & René Koch of TNO

A1 SAILING AND MANOEUVRING

A1.1 Main Engines

During sailing and manoeuvring, the main engine(s) are used to propel/manoeuvre the ship. Their emission factors per ship, in g per kWh, were determined by TNO according to the EMS protocols [1, 2] (an English report covering the emission calculations in accordance with the EMS protocols is also available [5]. In the emission factor calculation, the nominal engine power and speed are used. For this study, these parameters were taken from the using ship characteristics provided by IHS Maritime World Register of Ships to The Port of Rotterdam. In the case, that only one single main engine is present, it is assumed that a vessel requires 85% of its maximum continuous rating power (MCR) to attain the design speed (its service speed). When multiple main engines are present, some more assumptions have to be made in order to calculate the required power of the main engines. This is described in the next paragraph 0.

The following formula is used to calculate the emission factor per nautical mile.

Formula 1:

$$EF' = EF * CEF * \frac{P * fMCR}{V}$$

where:
EF' Actual emission factor expressed as kg per nautical mile.
EF Basic engine emission factor expressed as kg per kWh (Table A-4/Table A-11).
CEF Correction factors of basic engine emission factors (Table A-14/Table A-16).
P Engine power [KiloWatts].
fMCR Actual fraction of the MCR.
V Actual vessel speed [knots].

The correction factors of basic engine emission factors (CEF) reflect the phenomena that cause the emission factors to change when engines are active in sub-optimal power ranges.

Besides this change in emission factors, ships do not always sail at their designed speed. As such, the actual power use has to be corrected for the actual speed. The power requirements are approximately proportional to the ship's speed to the power of three. For very low speeds, this approximation would underestimate the required power, since manoeuvring in restricted waters increases the required power. Furthermore, engines are not capable of running below a certain load (minimal fuel consumption of 10% compared to full load). To account for this, the cubed relationship between speed and power is adjusted slightly to:

Formula 2:

$$fMCR = CRScor * (1\text{-Sea margin}) = ([(V_{actual}/V_{design})^n + c] / (1+c)) * (1\text{-Sea margin})$$

Following values are used in calculations that are reported:
Sea margin = 15%.
n = 3.2 (value was 3.0 in previous reports).
c = 0.1 (value was 0.2 in previous reports).

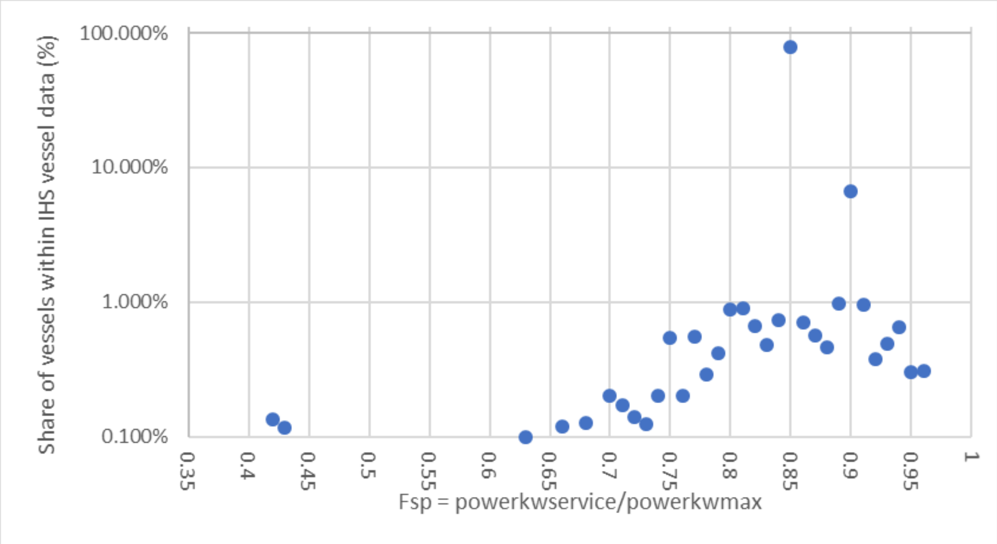

Figure A- 1 Statistics of the Sea-margin.

Figure A-1 shows that of the majority of the IHS vessels (about 80%) the power of reaching the service speed is exact 85% of the maximum rated power (Sea Margin = 15%) and for about 7% of the vessels the power of reaching the service speed is exact 90% of the maximum rated power (Sea margin = 10%). These data justify the application of 15% Sea margin within Formula 2.
Using data of sea trials MARIN (D.R. Schouten & T.W.F. Hasselaar [4]) has advised a value of 3.2 for n in Formula 2. Concerning the choice of a proper value of c no clear data were found in the literature. However, it is obvious that the value of zero (used in many studies) will deliver far too low emission data in the low speed range. In a MAN service letter concerning “low load operation” MAN diesel (Jensen and Jacobsen, 2009) show fuel usage of just below 20% of maximum usage around 55% of the service speed. The result of the parameters chosen in formula 2 confirm this number for the fuel usage around 55% of the service speed.
Note that the Correction Reduced Speed factor CRS_{cor} has to be capped at a maximum of 1.176, since this is the value for which 100% engine power is reached. In Figure A-2, the relationship is shown between the speed relative to the service speed and the power relative to the rated power of the ships single propulsion engine as implied in formula 2.

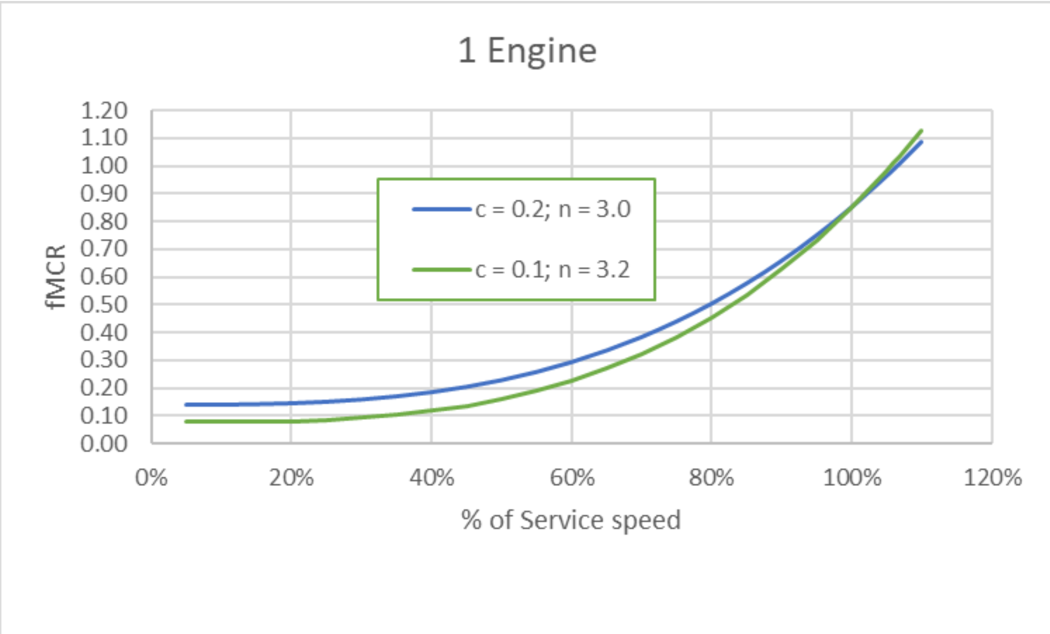

Figure A- 2 **The relationship between service speed and fMCR at ships with one single propulsion engine used in emission calculations.**

A1.2 Multiple propulsion engines

When a ship has multiple main propulsion engines, probably not all of these engines will be used in all situations. For instance, many specialised ships have specialised installations that are only used when these ships are performing their specialised tasks (dredgers, supply ships, icebreakers, tugs, etc.). Other ships may have redundant engine capacity for safety and other reasons (passenger ships, roro-ships). It is rather difficult to account for the usage of multiple engines within emission calculations, since many differences exist between individual ship designs. All kinds of possible situations, which are not known from the AIS-data, may have different influence on emissions from different ships types. Nevertheless, ignoring the existence of multiple engines is not realistic. The presence of multiple engines on some ship types (i.e. passenger and roro-ships) could lead to serious underestimation of total emissions because only the power of the largest engine was taken into account until the emission calculation for 2010.

Before going into an analysis of the usage of main engines when multiple engines are present, it is interesting to analyse which number of engines occurs so often that it has a significant influence on total emissions. In table A-1 it is shown that at ships with multiple engines, only ships with 2 and 4 engines contribute significantly to the total installed power of the whole seagoing fleet. The same conclusion will probably hold with respect to the contribution to total emissions. Therefore, it can be justified to concentrate the analysis on ships with 2 and 4 propulsion engines.

Table A- 1 **World seagoing fleet with number of installed main engines and their total installed power and average installed power per ship.**

Main Engine count	Ships count	Total power installed MW	Average power installed per ship MW	% of total power installed
1	76,135	445,834	5.9	735%
2	40,709	139,118	3.4	22.9%
3	1,866	10,100	5.4	1.7%
4	1,256	8,211	6.5	1.4%
5	56	265	4.7	0.04%
6	84	3,099	36.9	0.5%
8	3	149	49.8	0.02%
	120,109	606,777	5.1	100.0%

As a data source for daily fuel usage the ship characteristic database-item FUEL_CONSUMPTION of the LLI database was analysed. Daily fuel consumption is given for only about 10.000 ships. By far, most of these 10.000 ships are ships with a single main engine. In order to perform a check on the emission calculation, a check on the fuel consumption serves as a very good proxy. When fuel consumption is modelled properly, emission calculation probably will give results with comparable accuracy.

To estimate the daily fuel consumption of a ship (ton/day) we applied a very simple formula:

FC = Active_Engines * MCRss * Power * SFOC * 24/1000.

FC : Daily fuel oil consumption (ton/day).

Active_Engines : number of active engines involved in normal propulsion (-).
MCRss : fraction of power to reach service speed (0.85 for single engine ships, for more engines see table A-2).
Power : power of a single engine (MW).
SFOC : specific fuel oil consumption (kg/MWh).
24/1000 : 24 hours/day;1000 kg/ton.

Note that the calculation of fuel consumption is completely parallel to the calculation of emissions. Instead of EF, approximate values of the SFOC are used. Because (in the LLI database) the service speed is assumed, the values of CEF in the calculation can be ignored because the values will be very close to 1.

The SFOC (specific fuel oil consumption) applied is 0.175 (kg/kWh) for engines above 3 MW and 0.200 (kg/kWh) for engines equal to and below 3 MW. As a reference for these values, see for instance the tables A-4 to A-7.

As a reference for ships with multiple engines, the fuel consumption of ships with 1 main engine is shown. So far, a power setting of 85% MCR is assumed in modelling ship's emissions. It can be seen in Figure A2 that this assumption gives rather accurate results for the majority of ships (but not all ships) with one main engine. The 7918 ships of which data on fuel consumption was available had an average *calculated* fuel consumption of 24.8 ton/day by the main engine while the average *specified* fuel consumption was 26.1 ton/day. This implies that calculated fuel consumption (on average) on the service speed seems to be 5% lower than the specified fuel consumption. Given the number of possible uncertainties, this does not seem to be a major difference.

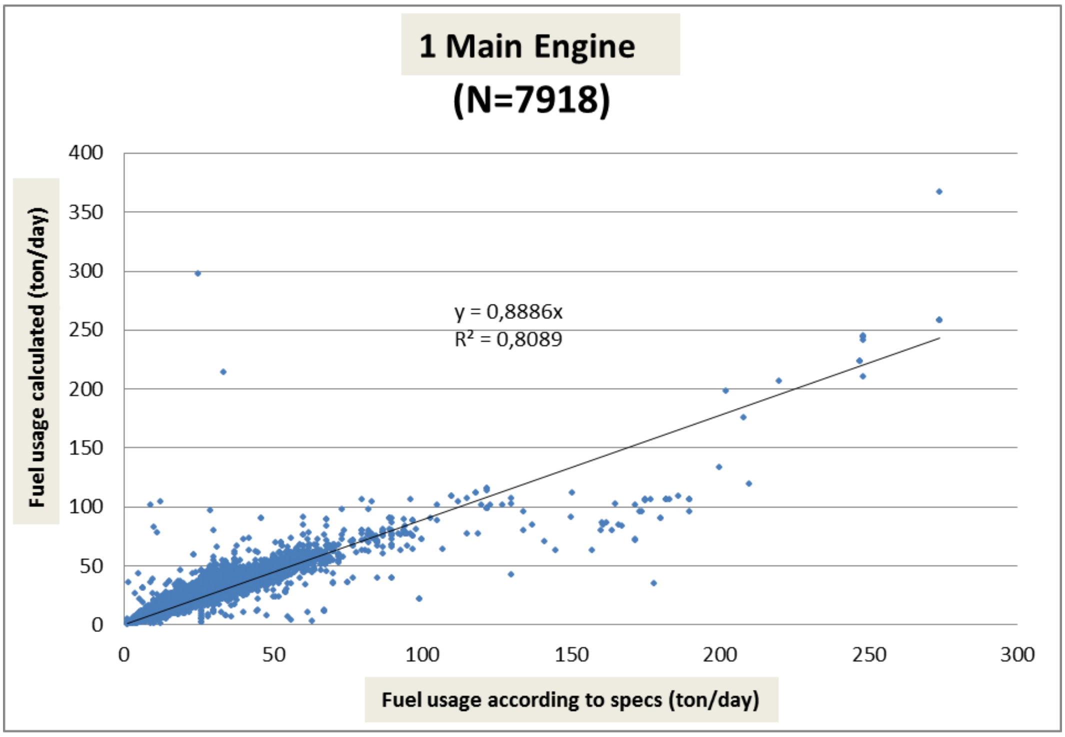

Figure A- 3 Calculated daily fuel usage of one-engine ships compared with specifications.

For ships with two main engines two active engines were assumed and 75% MCR (instead of the standard of 85% [13]) to reach the service speed. It can be seen in Figure A-3 that these assumptions give rather accurate results for the majority of ships with two main engines. The 546 ships of which data on fuel consumption are available show an average calculated fuel consumption of 35.7 ton/day while the average specified fuel consumption is 35.6 ton/day.

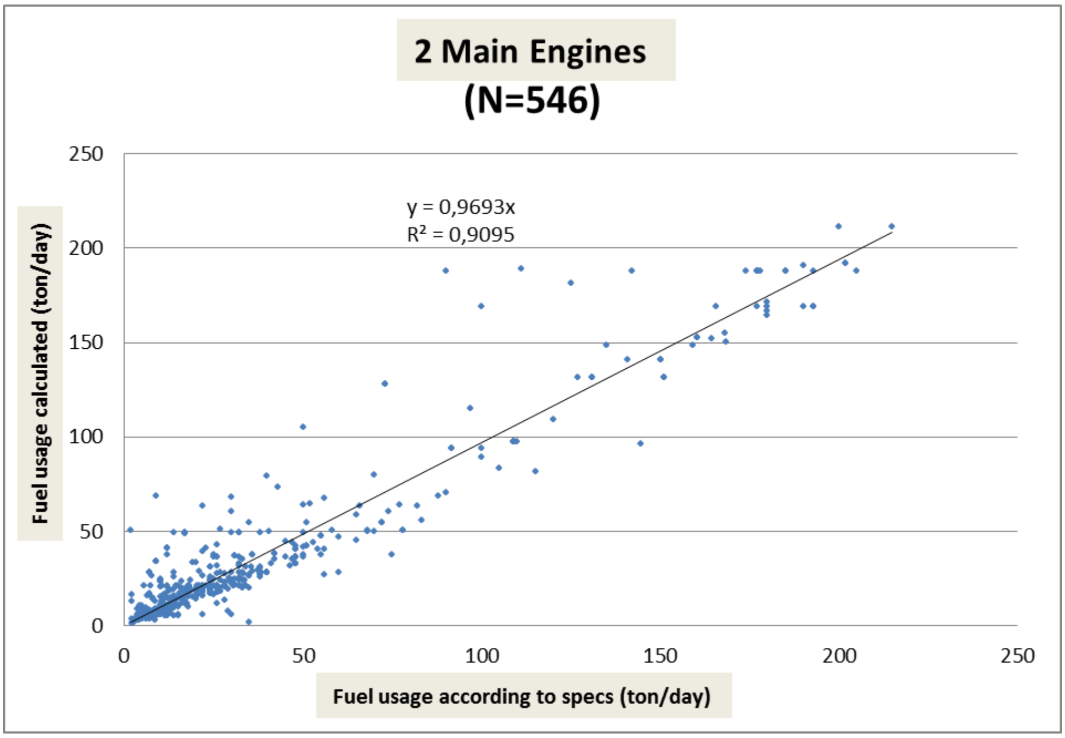

Figure A- 4 Calculated daily fuel usage of two engine ships compared with specifications.

For ships with four main engines, four active engines were assumed and also 75% MCR (instead of the standard of 85%) to reach the service speed. As can be seen in Figure A-5 much less data is available for four engine ships, which causes more scatter in the data. The 29 ships of which data are available show an average *calculated* fuel consumption of 39.2 ton/day while the average *specified* fuel consumption is 32.8 ton/day.

It has to be mentioned that some data filtering was applied to four engine ships. Excluded in the analysis are special cases such as high-speed ferries, supply and service vessels, tugs and fishing ships and one ship mainly propelled by LNG.

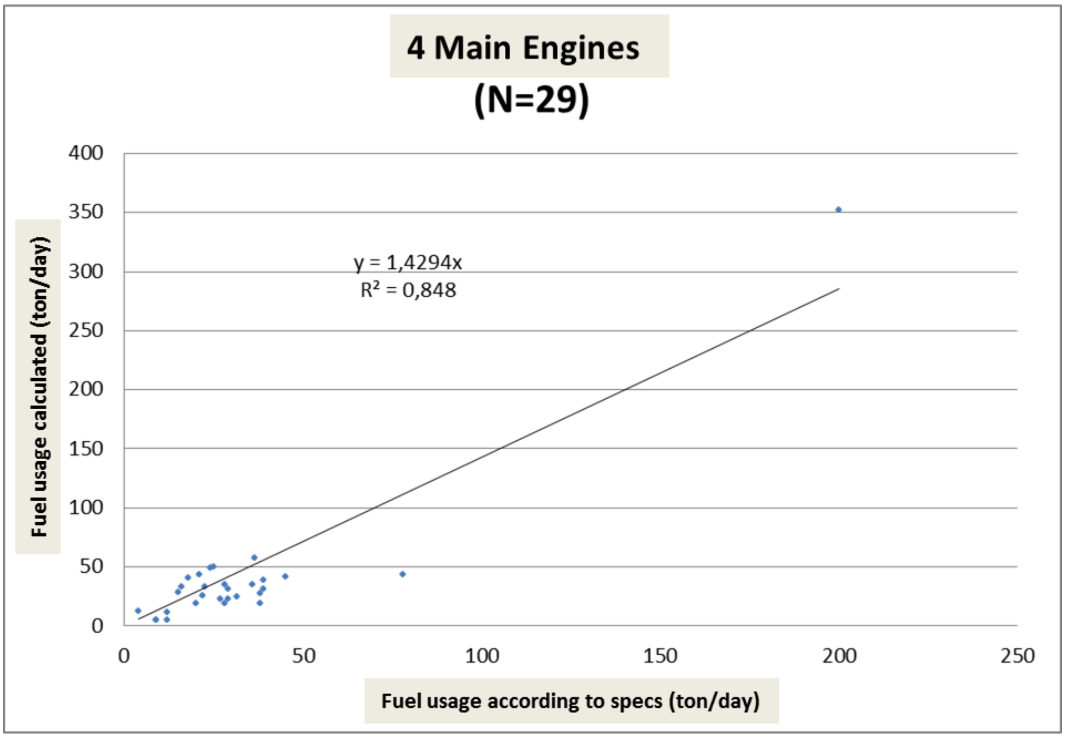

Figure A- 5 **Calculated daily fuel usage of four engine ships compared with specifications.**

It can be argued that energy consumption of four engined ships seems to be overestimated by the assumptions that are applied, but with such a small dataset it is hard to determine whether the assumptions on ships with four main engines are correct or not. Even if there is an overestimation, this will probably not lead to big differences in total emissions, since the contribution of four engine ships in total installed power is below 4% (Table A- 1).

For ships with other numbers of main engines, the available data did not allow any check of possible assumptions on the fuel consumption.

Apart from the check of fuel consumption of two and four engined ships as presented above, for ships with three or five to twelve engines additional assumptions had to made in order to enable calculation of emissions of these ships. These assumptions are shown in Table A-2 and are rather uncertain. However, the total installed power is only 2% and therefore, the influence on total emissions will be minimal.

Table A- 2 Maximum number of engines assumed to be operational for propulsion with multiple engines present and the fraction of MCR assumed (MCR_{ss}) to attain the service speed.

Ship type	Engines Present → / Engines Operational ↓	2	3	4	5	6	7	8	9	10	12
Oil tanker	2	0.75	0.85								
	4			0.75							
Chemical/LNG/LPG tanker	2	0.75	0.85								
	4			0.75		0.75					
	6								0.75		
Bulk carrier	2	0.75	0.85								
	4			0.75	0.75	0.75					
Container ship	2	0.75	0.85								
	4			0.75	0.75	0.75	0.75	0.75			
	6								0.75	0.75	
General Dry Cargo	2	0.75	0.85								
	4			0.75	0.75	0.75		0.75			
RoRo Cargo / Vehicle	2	0.75	0.85								
	4			0.75	0.75	0.75		0.75			
Reefer	2	0.75	0.85								
	4			0.75	0.75						
Passenger	2	0.75	0.85	0.75		0.75			0.75		
Miscellaneous	2	0.75									
	4			0.75							
Tug/Supply	2	0.65	0.85	0.8	0.75	0.85	0.75	0.75	0.75		0.75
Fishing	2	0.75	0.85								
Non Merchant	2	0.5	0.85	0.75	0.75	0.75	0.75	0.75			0.75

The calculation of emissions with multiple engines becomes more complicated because the number of active engines has to be calculated separately. For this reason the calculation of EF' is slightly different from formula 1.

Formula 3:

$$EF' = EF * CEF * \frac{NoEA * P * fMCR}{V}$$

EF' Actual emission factor expressed as kg per nautical mile
EF Basic engine emission factor expressed as kg per KWh (Table A-4/Table A-11)
CEF Correction factors of basic engine emission factors (Table A14/Table A-16)
NoEA Number of active engines (engines that actually are working on a certain moment)
P Engine power of one single engine [Watts]
*f*MCR Actual fraction the MCR of active engines
V Actual vessel speed [knots]

Formula 4:

NoEA =
minimum (Engines Operational, round (CRS_{cor} * Engines Operational * MCR_{ss})+1)

(Note that the Number of active engines depends on the level of CRScor, which depends on the ships speed, and that the maximum number of active engines is equal to Engines Operational).

Formula 5:

*f*MCR= [Engines Operational]/NoEA * CRScor * MCRss

The *f*MCR for individual ship engines is linear inversely related to the Number of active engines (more engines active give lighter work for individual engines). In essence, Formula 3 is the same as Formula 1 except the accounting of Engines Active in the available total Engine power and the application of modified *f*MCR in the selection of the CEF-values (Formula 5).

A1.3 Auxiliary Engines and Equipment

Aside from the main engines, most vessels have auxiliary engines and equipment that provide (electrical) power to the ship's systems. There is limited information available on the use of auxiliary engines. Perhaps the best estimate to date has been made in the *Updated 2000 Study on Greenhouse Gas Emissions from Ships* report (Buhaug et al., 2008, [3]), to which many ship experts contributed. The percentage of the auxiliary power compared to the main engine power as presented in Table 14 of the Buhaug et al report [3] was used in this study. The percentage taken from Buhaug was multiplied with the main power of each individual ship of which no details of auxiliary power are included in the LLI-database. For those ships of which the auxiliary power was included in the LLI-database, the loadfactor of auxiliary engines given by Buhaug specified per ship type was applied on the biggest auxiliary engine of the individual ship as inferred from the LLI-database.

A1.4 Engine Emission Factors

Table A-4 to Table A-11 show the engine emission factors [1], [2] per engine type and fuel type expressed in grams per unit of mechanical energy delivered by ships engines (g/kWh).
Linear relations exist between SFOC and SO_2 and CO_2 depending on fuel quality. SFOC values as such are not used in emission calculations.

Effect of sulphur in calculation of PM-emission factors
PM-reduction is associated with sulphur reduction because a certain fraction of oxidised sulphur is emitted as sulphuric acid, which easily condenses to sulphuric acid particles (PM) in exhaust gases. Based on the sulphur reductions, additional PM reductions were estimated applying a linear relationship between sulphur and PM as demonstrated in [12].

Partial implementation of the SECA according to the MARPOL Annex VI in 2016 has been assumed. Combined surveillance results of EU competent authorities are shared on a website of EMSA. The results are presented in Table A-3.

Table A- 3 Percentage of fuel samples from ships oils services systems with a sulphur content beyond legal limits.

Region	2015	2016	2017	2018	2019	2020	2021
North sea regions	5.34	6.1	7.23	5.72	3.25	1.60	1.49
Baltic sea	2	3.8	3.46	3.1	2.13	0.59	0.57
Calculated average S% North sea regions	0.15	0.15	0.17	0.15	0.13	0.114	0.113

Source: https://portal.emsa.europa.eu/web/thetis-eu/compliance

The calculated average S% in North sea regions is calculated by assuming 0.1 %S for compliant fuel samples and 1% S for non-compliant fuel samples. This results in an estimated sulphur percentage of 0.113% for all areas. It can be concluded that compliance of sulphur legislation is slowly improving since 2015. Surveillance by competent authorities seems to be important as numbers of non-compliance show considerable fluctuation over the years and structural differences between areas.

A sulphur% of 0.113% of HFO and MDO was assumed in all areas in 2021 (see table A-3). According to [12] the contribution of PM from sulphur was calculated as 8% of SO_2 (calculated from S%): 0.08 * 0.113 * 20 = 0.1808 g/kg fuel. For instance having a SFOC value of 210 g/kWh results in PM from sulphur alone in 210/1000 * 0.1808 = 0.038 g/kWh. The PM emission factors in the tables below (table A4 – A11) are the result of the addition part of PM from sulphur and the part produced by the engines.

Table A- 4 Emission factors and specific fuel oil consumption (SFOC) applied on slow speed engines (SP) operated on heavy fuel oil (HFO), (g/kWh).

Year of build	NO_x	PM-HFO NCP[2]	PM-HFO Other[3]	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 – 1973	16	0.44	0.44	0.63	0.63	0.6	0.75	666	210
1974 – 1979	18	0.44	0.44	0.60	0.60	0.6	0.75	635	200
1980 – 1984	19	0.44	0.44	0.57	0.57	0.6	0.75	603	190
1985 – 1989	20	0.44	0.44	0.54	0.54	0.6	0.63	571	180
1990 – 1994	18	0.44	0.44	0.53	0.53	0.5	0.5	555	175
1995 – 1999	15	0.34	0.34	0.51	0.51	0.4	0.5	539	170
2000 – 2010		0.34	0.34	0.50	0.50	0.3	0.5	533	168
2011 –	~rpm[4]	0.23	0.23	0.49	0.49	0.3	0.5	524	165
Tier III		0.23	0.23	0.45	0.45	0.05	0.7	481	151

2 NCP: Dutch Continental Shelf.
3 Other areas: Include harbours areas.
4 Dependant on revolutions per minute (Table A-8).

Table A- 5 Emission factors and specific fuel oil consumption (SFOC) applied on slow speed engines (SP) operated on marine diesel oil (MDO), (g/kWh).

Year of build	NO_x	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 - 1973	16	0.34	0.34	0.63	0.63	0.6	0.75	666	210
1974 - 1979	18	0.34	0.34	0.60	0.60	0.6	0.75	635	200
1980 - 1984	19	0.34	0.34	0.57	0.57	0.6	0.75	603	190
1985 – 1989	20	0.34	0.34	0.54	0.54	0.6	0.63	571	180
1990 – 1994	18	0.34	0.34	0.53	0.53	0.5	0.5	555	175
1995 – 1999	15	0.24	0.24	0.51	0.51	0.4	0.5	539	170
2000 – 2010	~rpm[5]	0.24	0.24	0.50	0.50	0.3	0.5	533	168
2011 –		0.23	0.23	0.49	0.49	0.3	0.5	524	165
Tier III		0.15	0.15	0.44	0.44	0.05	0.7	478	151

Table A- 6 Emission factors and specific fuel oil consumption (SFOC) applied on medium/high speed engines (MS) operated on Heavy fuel oil (HFO), (g/kWh).

Year of build	NO_x	PM-HFO NCP	PM-HFO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 – 1973	12	0.65	0.65	0.68	0.68	0.6	0.75	714	225
1974 – 1979	14	0.65	0.65	0.65	0.65	0.6	0.75	682	215
1980 – 1984	15	0.65	0.65	0.62	0.62	0.6	0.75	651	205
1985 – 1989	16	0.65	0.65	0.59	0.59	0.6	0.63	619	195
1990 – 1994	14	0.64	0.64	0.57	0.57	0.5	0.5	603	190
1995 – 1999	11	0.54	0.54	0.56	0.56	0.4	0.5	587	185
2000 – 2010	~rpm[4] 9[6]	0.54	0.54	0.55	0.55	0.3	0.5	581	183
2011 -	~rpm[4] 7[5]	0.54	0.54	0.53	0.53	0.3	0.5	571	180
TIER III	~rpm[4] 2.2[5]	0,38	0,38	0.49	0.49	0.05	0.7	524	165

[2] applied on auxiliary engines only

Table A- 7 Emission factors and specific fuel oil consumption (SFOC) applied on medium/high speed engines (MS) operated on marine diesel oil (MDO), (g/kWh).

Year of build	NO_x	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 - 1973	12	0.35	0.35	0.68	0.68	0.6	0.75	714	225
1974 - 1979	14	0.35	0.35	0.65	0.65	0.6	0.75	682	215
1980 - 1984	15	0.34	0.34	0.62	0.62	0.6	0.75	650	205
1985 - 1989	16	0.34	0.34	0.59	0.59	0.6	0.63	619	195
1990 - 1994	14	0.29	0.29	0.57	0.57	0.5	0.5	603	190
1995 - 1999	11	0.24	0.24	0.56	0.56	0.4	0.5	587	185
2000 - 2010	~rpm[4] 9[5]	0.24	0.24	0.55	0.55	0.3	0.5	581	183
2011 -	~rpm[4] 7[5]	0.24	0.24	0.53	0.53	0.3	0.5	571	180
TIER III	~rpm[4] 2.1[5]	0,18	0,18	0.48	0.48	0.05	0.7	520	164

[2] applied on auxiliary engines only

[5] Dependant on revolutions per minute (Table A-8).

[6] applied on auxiliary engines only.

Emission factors of CO were reduced by a factor of 4 according to [16]. Emission factors of PM and SO_2 at NCP were lowered based on observations of Chalmers University in commission of the Danish Ministry of Environment and Food concerning the enforcement of IMO SECA [17] .

Table A- 8 Emission factors of NO_X dependant on engines RPM.

Year of build	RPM range	IMO-limits (g/kWh)	Emission factor NO_X (g/kWh)
2000 – 2010 (Tier I)	< 130 RPM	17.0	0.87 x 17.0
	Between 130 and 2000 RPM	$45 \times n^{-0.2}$	$0.87 \times 45 \times n^{-0.2}$
	> 2000 RPM	9.8	0.87 x 9.8
2011 – 2022 (Tier II)	< 130 RPM	14.4	0.93 x 14.4
	Between 130 and 2000 RPM	$44 \times n^{-0.23}$	$0.93 \times 44 \times n^{-0.23}$
	> 2000 RPM	7.7	0.93 x 7.7
(Tier III)	< 130 RPM	3.4	0.95 x 3.4
	Between 130 and 2000 RPM	$9 \times n^{-0.2}$	$0.95 \times 9 \times n^{-0.2}$
	> 2000 RPM	2.0	0.95 x 2.0

The reduction factors for Tier I engines (0.87), Tier II engines (0.93) and Tier III engines (0.95) are based on IAPP-certificate engine data obtained in a project for the Port of London Authority [24].

Table A- 9 Emission factors and specific fuel oil consumption (SFOC) of gas turbines (TB) operated on marine diesel oil (MDO), (g/kWh).

Fuel	NO_x	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
MDO	5.7	0.08	0.08	0.93	0.93	0.1	0.32	984	310

Emission factors of steam turbines were partially adjusted according to Cooper [9].

Table A- 10 Emission factors and specific fuel oil consumption (SFOC) of steam turbines (ST) operated on LNG, HFO or MDO, (g/kWh).

Fuel	NO_x	PM NCP	PM Other	SO_2 NCP	SO_2 Other	CH4	VOC	CO	CO_2	SFOC
LNG	1.94	0.01	0.01	0.0	0.0	0.045		0.06	688	250
HFO	2.0	0.314	0.314	0.92	0.92		0.1	0.15	971	306
MDO	2.0	0.311	0.31	0.87	0.87		0.1	0.15	923	291

Emissions of more modern LNG tanker propelled mostly propelled by medium speed diesel engines fuelled by LNG were calculated by means of emission factors as shown in the table below.

Table A- 11 Emission factors and specific fuel oil consumption (SFOC) of engines operated on LNG, (g/kWh).

Engine type	NO_x	PM	SO_2	CH4	CO	CO_2	SFOC
MS-DF	2.0	0.01	0.003	6.90	1.9	450	162
SP-GDI	12.5	0.01	0.003	0.15	0.2	475	171
SP (TIER III)	3.4	0.02	0.003	0.15	0.2	475	
ST	1.94	0.01	0.004	0.05	0.06	687.8	

The methane (CH_4) emission factor of MS-DF (medium speed dual fuel engines) was adapted according to [22]. Other emission factors were based on preliminary estimations by TNO.

A1.5 Fuel allocation

Fuel allocation has been based on IHS-data primarily and secondly some assumptions have been applied. Table A-12 shows allocation of fuel to main and auxiliary engines depending on the indication of the IHS vessel data. Sulphur legislation introduced in 2015 may have resulted in the usage of less HFO than indicated in table A-12. As a consequence, PM emission factors are possibly a little too high. Sulphur emissions are calculated according to the best estimate prevalent sulphur content of fuels (table A-3).

Table A- 12 Fuel allocation to main engines (Fuel ME) and auxiliary engines dependent on IHS fuel indication.

Enginetype	Number of vessels	Average ME (kW)	IHS: FuelType1First	IHS: FuelType2Second	Fuel_ME_	Fuel_AE
Slow-speed engines	29619	13515	Distillate Fuel	Residual Fuel	HFO	MDO
	3738	1348	Distillate Fuel	Not Applicable	MDO	MDO
	354	3176	Residual Fuel	Not Applicable	HFO	MDO
	192	28170	LNG	Distillate Fuel	LNG	MDO
	53	955	Distillate Fuel	Yes, But Type Not Known	MDO	MDO
	15	5432	Distillate Fuel	Unknown	MDO	MDO
	9	14868	LNG	Not Applicable	LNG	MDO
	9	9498	Methanol	Distillate Fuel	MDO	MDO
	4	42766	Distillate Fuel	LNG	LNG	MDO
	3	1100	Distillate Fuel	Distillate Fuel	MDO	MDO
	3	2280	Residual Fuel	Unknown	HFO	MDO
	2	1618	Residual Fuel	Distillate Fuel	HFO	MDO
	2	9350	Gas Boil Off	Distillate Fuel	LNG	MDO

	1	2795	Yes, But Type Not Known	Residual Fuel	HFO	MDO
	1	970	Residual Fuel	Yes, But Type Not Known	HFO	MDO
Medium-speed engines	16917	2700	Distillate Fuel	Not Applicable	MDO	MDO
	8087	7404	Distillate Fuel	Residual Fuel	HFO	MDO
	668	4034	Residual Fuel	Not Applicable	HFO	MDO
	312	27182	LNG	Distillate Fuel	LNG	MDO
	187	1292	Distillate Fuel	Yes, But Type Not Known	MDO	MDO
	39	3378	Distillate Fuel	Unknown	MDO	MDO
	37	5526	LNG	Not Applicable	LNG	MDO
	35	2981	Distillate Fuel	Distillate Fuel	MDO	MDO
	7	1964	Coal	Not Applicable	HFO	MDO
	6	9731	Residual Fuel	Yes, But Type Not Known	HFO	MDO
	5	6472	Yes, But Type Not Known	Residual Fuel	HFO	MDO
	3	6557	Residual Fuel	Distillate Fuel	HFO	MDO
	2	3430	Residual Fuel	Unknown	HFO	MDO
	1	24000	Methanol	Distillate Fuel	MDO	MDO
Gasturbines	23	59326	Distillate Fuel	Residual Fuel	HFO	MDO
	9	25381	Distillate Fuel	Not Applicable	MDO	MDO
	2	18389	Residual Fuel	Not Applicable	HFO	MDO
	1	44000	LNG	Distillate Fuel	LNG	MDO
	1	13000	Distillate Fuel	Unknown	MDO	MDO
Steamturbines	289	25026	Distillate Fuel	Residual Fuel	HFO	MDO
	51	29469	Residual Fuel	Not Applicable	HFO	MDO
	27	27545	Gas Boil Off	Distillate Fuel	LNG	MDO
	8	19100	LNG	Distillate Fuel	LNG	MDO
	8	57299	Nuclear	Not Applicable	none	MDO
	3	47653	Nuclear	Distillate Fuel	none	MDO
	1	2589	Yes, But Type Not Known	Not Applicable	HFO	MDO

Because there are no specific emission factors for methanol available methanol is treated as marine diesel oil in the calculations.

In cases where no specific fuel type was indicated in the IHS-data, it was assumed that HFO is applied in main engines in case main engine power is more than 3000 kW. In case main engine power is less than 3000 kW MDO was assumed when [Power] - 0.8*[RPM] was lower or equal to 1000 and HFO in case same formula results in a number more than 1000.

The change-over from fuels at LNG-tankers in the model calculations is assumed dependent on the speed of the ships expressed as CRScor. Below a value of CRScor of 0.2, LNG-tankers switch from gaseous LNG to liquid fuel used by main engines according to the scheme presented in the table below. The fuels assumed to be used by the auxiliary engines are also presented in the same table A-13.

Table A- 13 Fuel switch scheme of LNG-tankers in dependence of operational speed.

Engine Type	Main engines		Auxiliary engines	
	0.2 <= CRScor < 1.2	0 <= CRScor < 0.2	0.2 <= CRScor < 1.2	0 <= CRScor < 0.2
MS	LNG	MDO	MDO	MDO
MS	LNG	HFO	HFO	MDO
SP	LNG	MDO	MDO	MDO
SP	LNG	HFO	HFO	MDO
ST	LNG	MDO	MDO	MDO
ST	LNG	HFO	HFO	MDO

A1.6 Correction factors of engine Emission Factors

At speeds around the design speed, the emissions are directly proportional to the engine's energy consumption. However, in light load conditions, the engine runs less efficiently. This phenomenon leads

to a relative increase in emissions compared to the normal operating conditions. Depending on the engine load, correction factors specified per substance can be adopted according to the EMS protocols. The correction factors were extended by distinction of different engine types in order to get more accurate calculations. Three engine groups were discerned: reciprocating engines, steam turbines and gas turbines.
The correction factors used are shown in Table A-14 to Table A-16. The list was extended by some values provided in the documentation of the EXTREMIS model [4].

Table A- 14 Correction factors for reciprocating diesel engines.

Power % of MCR	CO_2, SO_2	CO_2, SO_2	NOx			PM-HFO/ PM-MDO	VOC, CH4	CO
	SP	MS	Tier 0 or I	Tier II	Tier III			
10	1.2	1.21	1.34	1.74	6	1.63	4.46	5.22
15	1.15	1.18	1.17	1.52	3	1.32	2.74	3.51
20	1.1	1.15	1.1	1.36	1.75	1.19	2.02	2.66
25	1.07	1.13	1.06	1.3	1.45	1.12	1.65	2.14
30	1.06	1.11	1.04	1.32	1.45	1.08	1.42	1.8
35	1.05	1.09	1.03	1.34	1.45	1.05	1.27	1.56
40	1.045	1.07	1.02	1.34	1.45	1.03	1.16	1.38
45	1.035	1.05	1.01	1.32	1.45	1.01	1.09	1.23
50	1.03	1.04	1.00	1.3	1.45	1.01	1.03	1.12
55	1.025	1.03	1.00	1.27	1.45	1.00	1.00	1.06
60	1.015	1.02	0.99	1.23	1.4	1.00	0.98	1.00
65	1.01	1.01	0.99	1.13	1.25	0.99	0.95	0.94
70	1.00	1.01	0.98	1.01	1	0.99	0.92	0.88
75	1.00	1.00	0.98	0.95	0.85	0.98	0.89	0.82
80	1.01	1.00	0.97	0.95	0.85	0.98	0.87	0.76
85	1.02	1.00	0.97	0.95	0.85	0.97	0.84	0.7
90	1.03	1.01	0.97	0.95	0.85	0.97	0.85	0.7
95	1.04	1.02	0.97	0.95	0.85	0.97	0.86	0.7
100	1.05	1.02	0.97	0.95	0.85	0.97	0.87	0.7

The correction factors for CO_2 and SO_2 are assumed equal. These newly added factors for CO_2 and SO_2 were derived from two recent publications [10] and [11] by taking interpolated values. A distinction was made for Slow-speed engines (referred as SP) and Medium and high-speed engines (referred as MS). Although correction factors for other substances may differ by engine type also, a numerical distinction was not possible so far.

A differentiation in NOx correction factors between Tier 0 or I versus Tier II engines was considered necessary because of a publication [23]. The Tier II correction factors were estimated by TNO. As a consequence, NOx emissions of vessels with Tier II engines are in the same range of higher than Tier I engine vessels. This is caused by the circumstance that vessels use most energy in lower power ranges between 30 and 50 percent of MCR and even lower power ranges in some harbour areas. The correction factors can be replaced when sufficient measurement data become available.
A further differentiation in NOx correction factors for new vessels is introduced for TIER III engines. This is because the North Sea and the Baltic Sea have become NECA areas (“Nitrogen Oxide Emission Control Area”) as of the 1st of January 2021. See for further information publication [25].

Since steam turbines are predominantly used by LNG-carriers two types of fuels were assumed to be consumed: LNG and HFO. It was assumed that at lower engine loads (up to CRScor = 0.2) steam turbines are operated by HFO. On higher loads (from CRScor = 0.2) usage of LNG (boil-off gas) is assumed. The source of the correction factors of steam turbines was taken from the EXTREMIS model [4].

Table A- 15 Correction factors for steam turbines.

Power % of MCR	CO_2	SO_2	NO_X	PM-HFO	VOC, CH4	CO
10	1.4	3.04	0.3	3	5.44	11.65
15	1.4	3.04	0.34	2.8	5.11	10.83
20	1.4	3.04	0.37	2.8	4.72	9.96
25	1.4	3.04	0.41	2.8	4.39	9.09
30	1.2	2.02	0.44	1.5	4.00	8.26
35	1.00	1.00	0.47	1.00	3.61	7.39
40	1.00	1.00	0.51	1.00	3.28	6.57
45	1.00	1.00	0.54	1.00	2.89	5.7
50	1.00	1.00	0.57	1.00	2.56	4.83
55	1.00	1.00	0.61	1.00	2.17	4
60	1.00	1.00	0.64	1.00	1.83	3.13
65	1.00	1.00	0.68	1.00	1.44	2.26
70	1.00	1.00	0.76	1.00	1.33	1.96
75	1.00	1.00	0.84	1.00	1.22	1.65
80	1.00	1.00	0.92	1.00	1.11	1.30
85	1.00	1.00	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00	1.00	1.00
95	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00

Correction factors for gas turbines were estimated with data from the ICAO Aircraft Engine Emissions Databank [7]. The emission behaviour of the GE CF6-6D (marine derivative: GE LM2500) and the Allison 501 (AN 501) was taken as representative for the two most occurring gas turbines in marine applications. CEF values in the low power ranges have been changed since the 2011 calculation, because an adapted interpolation scheme has been applied.

Table A- 16 Correction factors for gas turbines.

Power % of MCR	CO_2, SO_2	NO_X	PM-MDO	VOC	CO
10	1.26	0.23	0.98	48.71	64.4
15	1.17	0.3	0.95	37.73	51.15
20	1.04	0.41	0.9	22.35	32.6
25	0.96	0.48	0.88	13.02	21.34
30	0.87	0.55	0.85	2.58	8.75
35	0.88	0.58	0.84	2.46	7.98
40	0.89	0.61	0.84	2.33	7.2
45	0.91	0.64	0.83	2.21	6.42
50	0.92	0.67	0.82	2.08	5.65
55	0.93	0.7	0.81	1.96	4.88
60	0.94	0.74	0.8	1.83	4.1
65	0.95	0.77	0.8	1.71	3.32
70	0.96	0.8	0.79	1.58	2.55
75	0.97	0.83	0.78	1.46	1.77
80	0.98	0.86	0.78	1.33	1
85	0.99	0.93	0.89	1.17	1
90	0.99	0.95	0.92	1.1	1
95	1	0.98	0.96	1.05	1
100	1	1	1	1	1

A2 EMISSIONS OF SHIPS AT BERTH

When a ship is berthed, in most cases the main engines are stopped. The auxiliary engines and equipment will be kept in service to provide (electrical) power to the ship's systems, on board cargo handling systems and accommodations.

The procedure for the calculation of emissions from ships at berth is derived from the EMS protocol with some minor modifications. The methodology was published in Atmospheric Environment [8]. In the EMS modelling system, a fixed value is assumed for the length of time at berth, for each ship type. In this study, the length of time at berth was derived for each individual event for each ship on the basis of AIS data. Ships with speeds below 1 knot were considered as ships at berth. Since the year of build of each ship was known, emission factors per amount of fuel dependant on the classification of year of build were applied. The amount of fuel used was calculated from the length of time at berth, ship type and volume in gross tonnage. The amount of fuel used at berth is more accurately determined in two reports on behalf of the CNSS project [14], [15].

Table A- 17 Fuel rate of ships at berth, (kg/1000 GT.hour).

Ship type	Fuel rate
Bulk carrier	2.4
Container ship	6
General Cargo	6.1
Passenger <=30000 GT	8.9
Passenger > 30000 GT	32.4
RoRo Cargo	6.1
Oil Tanker	19.3
Other Tanker	14.5
Reefer	19.6
Other	9.2
Tug/Supply	15.6

Since January 1st 2010, the sulphur content of marine fuels used for ships at berth is regulated to a maximum of 0.1 percent. This implies that only marine gas oil with a sulphur content below 0.1 percent is allowed in harbours. The specification of fuel types at berth is adapted according to this new regulation (Table A- 18).

Table A- 18 Specification of fuel types of ships at berth per ship type (%).

Ship type	HFO	MDO	MGO/ULMF
Bulk carrier	0	0	100
Container ship	0	0	100
General Cargo	0	0	100
Passenger	0	0	100
RoRo Cargo	0	0	100
Oil Tanker	0	0	100
Other Tanker	0	0	100
Fishing	0	0	100
Reefer	0	0	100
Other	0	0	100
Tug/Supply	0	0	100

Table A-19 gives figures about allocation of fuel amount over engine types and apparatus during berth.

Table A- 19 Allocation of fuels usage in engine types and apparatus per ship type at berth (%).

Ship type	Power (MS)	Boiler
Bulk carrier	90	10
Container ship	70	30
General Cargo	90	10
Passenger	70	30
RoRo Cargo	70	30
Oil Tanker	20	80
Other Tanker	50	50
Reefer	90	10
Other	100	0
Tug/Supply	100	0

In following Table A-20 to Table A- 22, the emission factors used for emissions at berth are presented.

Table A- 20 Emission factors of medium/high speed engines (MS) at berth, (g/kg fuel).

Year of build	NO_X	PM-MDO	VOC	CO
Fuel	all	MGO/ULMF	all	all
1900 – 1973	53	1.4	2.7	3,25
1974 – 1979	65	1.5	2.8	3,5
1980 – 1984	73	1.6	2.9	3,75
1985 – 1989	82	1.8	3.1	3,25
1990 – 1994	74	1.3	2.6	2,75
1995 – 1999	59	0.8	2.2	2,75
2000 – 2010	50	0.8	1.6	2,75
2011 – 2022	43	0.8	1.6	2,75
TIER III	12,81	0,91	0,3	1,50

At berth, usage of medium speed engines was assumed.

Table A- 21 Emission factors of boilers of boilers at berth, (g/kg fuel).

Fuel	NO_X	PM-MDO	VOC	CO
MGO/ULMF	3.5	0.7	0.8	1.6

Table A- 22 Emission factors of all engines and apparatus, (g/kg fuel).

Fuel	SO_2	CO_2
MGO/ULMF	2,6	3173

In tanker ships, a reduction factor for boilers (50% for PM and 90% for SO_2) is applied to the emission factors, because gas scrubbers are often applied in order to protect ship internal spaces for corrosion by inert gases produced by boilers.

A3 FISHERIES

Fisheries source category covers emissions from fishing activities in the Netherlands, including inland fishing, coastal fishing and deep-sea fishing. Diesel engines are used to propel fishing vessels such as deep-sea trawlers and cutters, and to generate electrical power on-board fishing vessels. These diesel engines can be fuelled with either diesel oil (distillate) or residual fuel oil. The combustion process that takes place in these diesel engines causes emissions of greenhouse gases and air pollutants.

A3.1 Activity data

Two methodologies based on AIS-data are applied from 2016 onwards. For deep-sea trawlers the same AIS-based methodology as used for maritime navigation is applied (see A1 and 0) because essentially no fishing activities are performed on Dutch national territory, including the Dutch Continental Shelf. This means that these vessels essentially are only sailing towards and from remote fishing grounds. For the other fishing vessel categories (rather small vessels mostly cutters) another AIS-based methodology is described in detail by Hulskotte and ter Brake, 2017 [18]. This is essentially an energy-based method whereby energy-rates of fishing vessels are split up by activity (sailing and fishing) with a distinction in available power of propulsion engine(s). For each fishery segment (combination of gear or catch method combined with power category) a fuel rate (kilogram/hour) for sailing or fishing was assessed by Turenhout et al., 2016 [19]. The distinction for each fishery segment between sailing and fishing is based on the actual speed of the fishing vessels as taken from AIS-data.

A3.2 Emission factors

The emission factors of small vessels (other than deep-sea trawlers) are assumed equal to emission factors of inland navigation because the engine types that are applied in these vessels are essentially the same.

Table A- 23 Emission factors and specific fuel consumption applied on fishing vessels, (g/kWh).

Engine year of build From – To	VOC	NOx	CO	PM	SO_2	SFOC
1959-1973	1.2	10.8	1.1	0.6	0.47	235
1975-1979	0.8	10.6	0.9	0.6	0.46	230
1980-1984	0.7	10.4	0.8	0.6	0.45	225
1985-1989	0.6	10.1	0.65	0.5	0.44	220
1990-1994	0.5	10.1	0.55	0.4	0.44	220
1995-2001	0.4	9.4	0.45	0.3	0.41	205
2002-2007	0.3	9.2	0.4	0.3	0.4	200
2008-2014	0.2	7	0.35	0.2	0.4	200
2015-2022	0.2	7	0.3	0.2	0.4	195

The year of build of the engines of (Dutch and former Dutch) fishing ships were initially purchased from Shipdata (http://www.shipdata.nl) in order to select the emission factors from table A-21. Part of this data concerned the engine type and model and the year of build. Data were enriched with engine changes when indicated on the website http://www.kotterfoto.nl and data of foreign fishing ships (including installing data of new engines) were added from the EU fishing fleet register or the FIGIS database managed by FAO.

As fuel, marine diesel with a sulphur content of 0.1% was assumed.

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