Sea Shipping Emissions 2020: Netherlands Continental Shelf, 12-Mile Zone and Port Areas

Final Report

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Sea Shipping Emissions 2020: Netherlands Continental Shelf, 12-Mile Zone and Port Areas

Final Report

Ordered by : RIVM/Emissieregistratie
P.O. Box 1
3720 BA BILTHOVEN
The Netherlands

Gerapporteerd door : K.F. Kauffman, J. Hulskotte

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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	Volatile 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 2020. 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 2020 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 2020.
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 2020 for the Dutch port areas and the Netherlands sea area and makes a comparison with 2019.
Chapter 7 contains the emissions results for 2020 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.

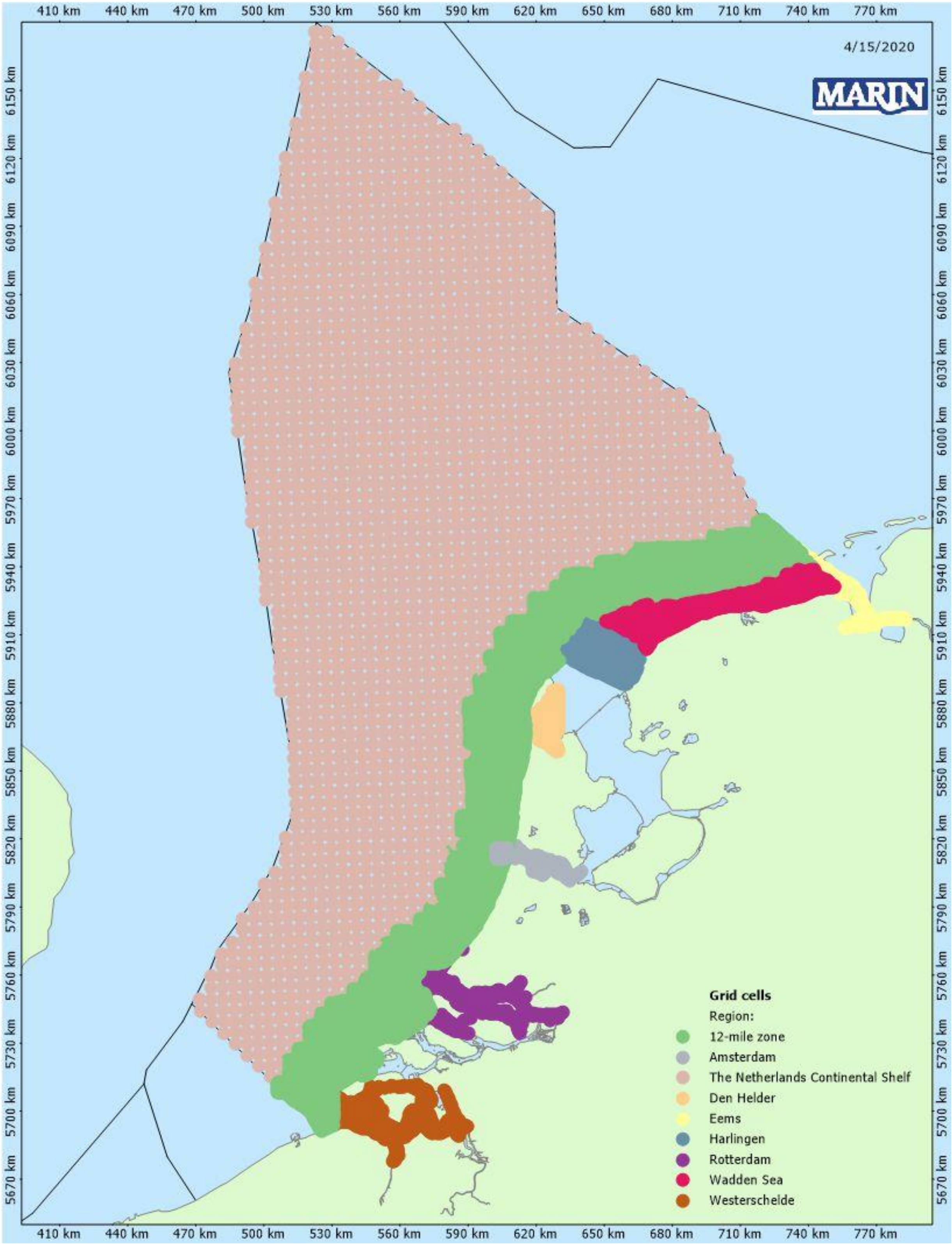

Figure 2-1 **Grid points for The Netherlands Continental Shelf, 12-mile zone, The Wadden Sea and six port areas**

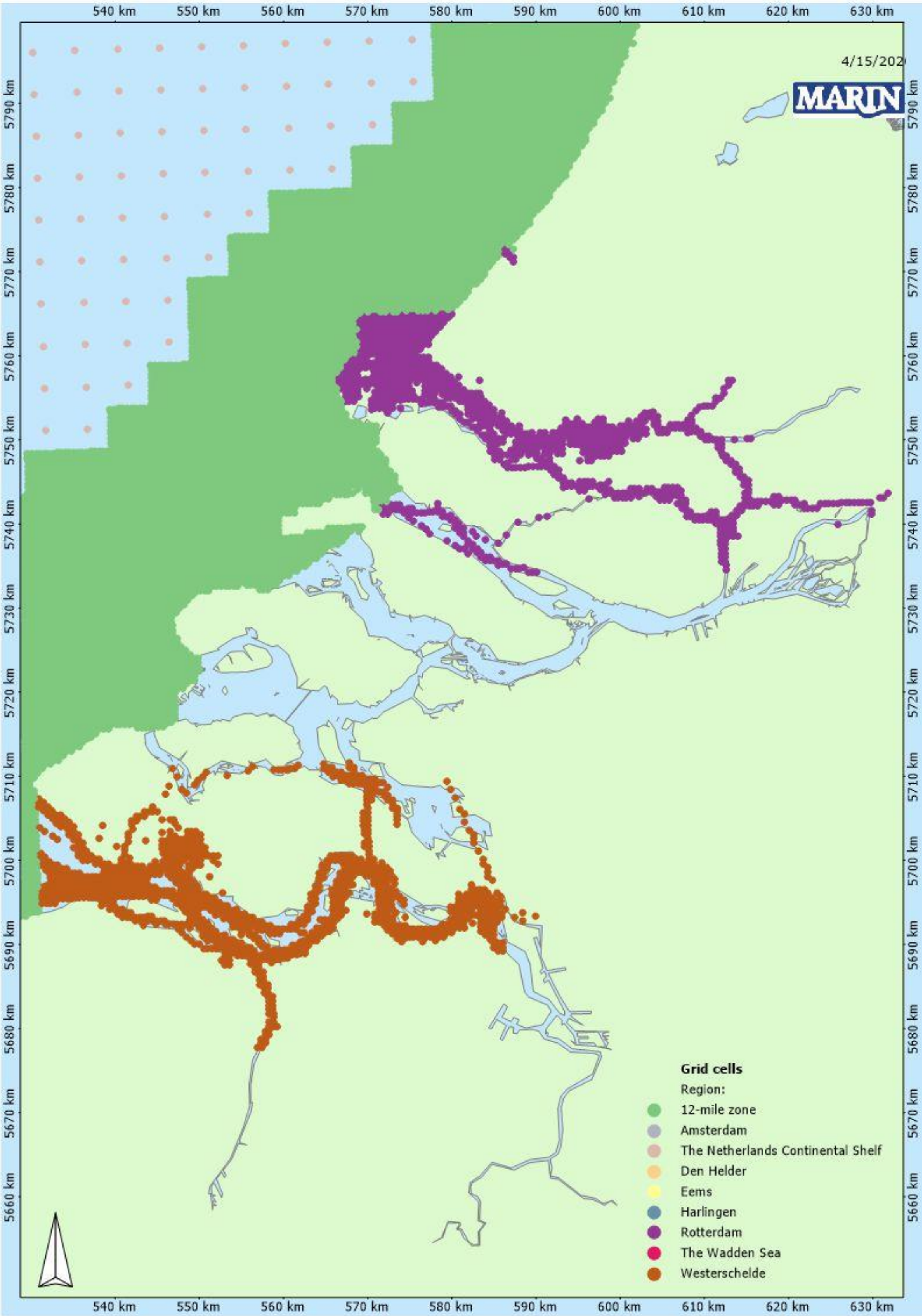

Figure 2-2 Rotterdam and the Western Scheldt: The points indicate the centres of grid cells for which emissions are calculated

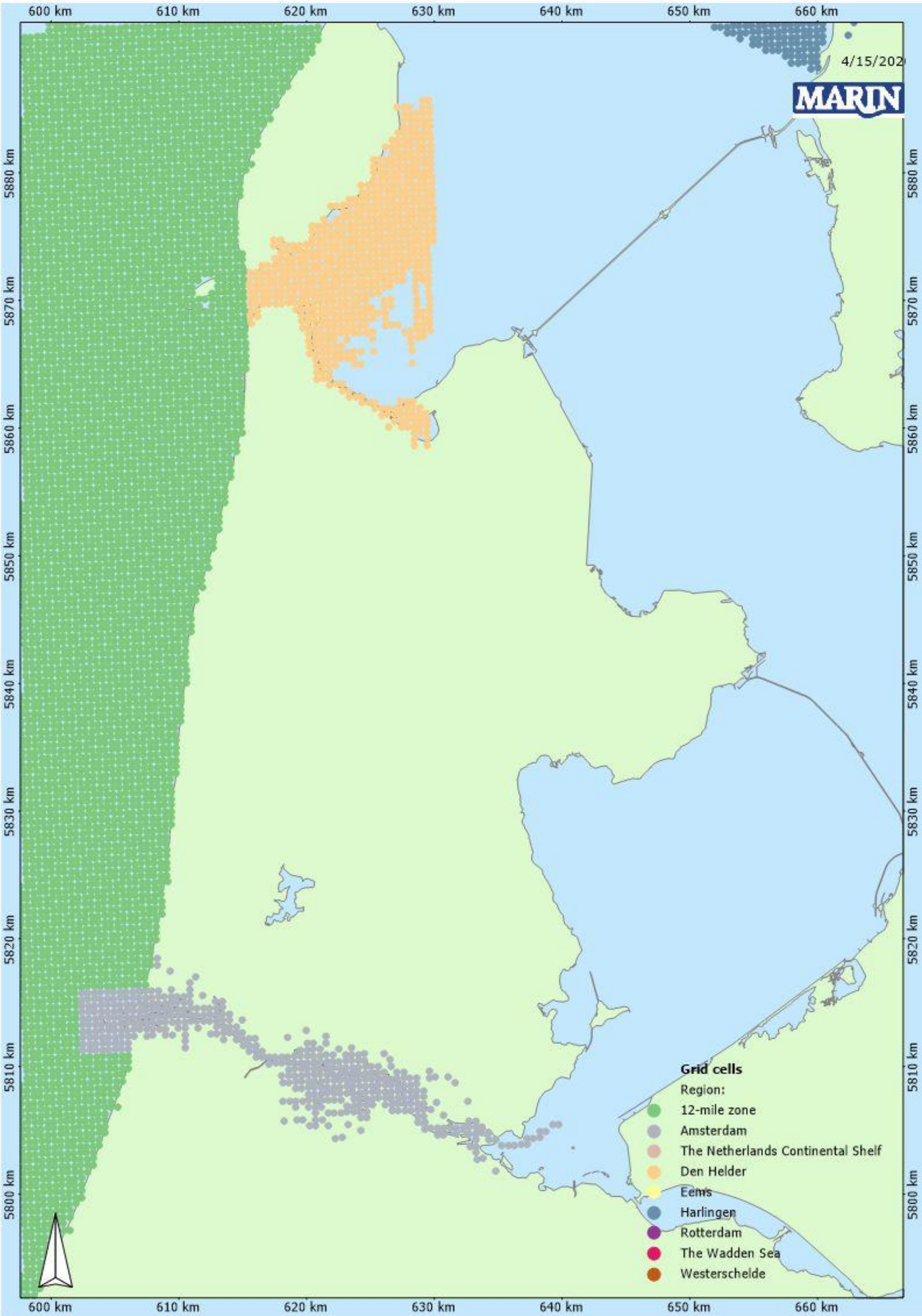

Figure 2-3 **Amsterdam and Den Helder: The points indicate the centres of grid cells for which emissions are calculated**

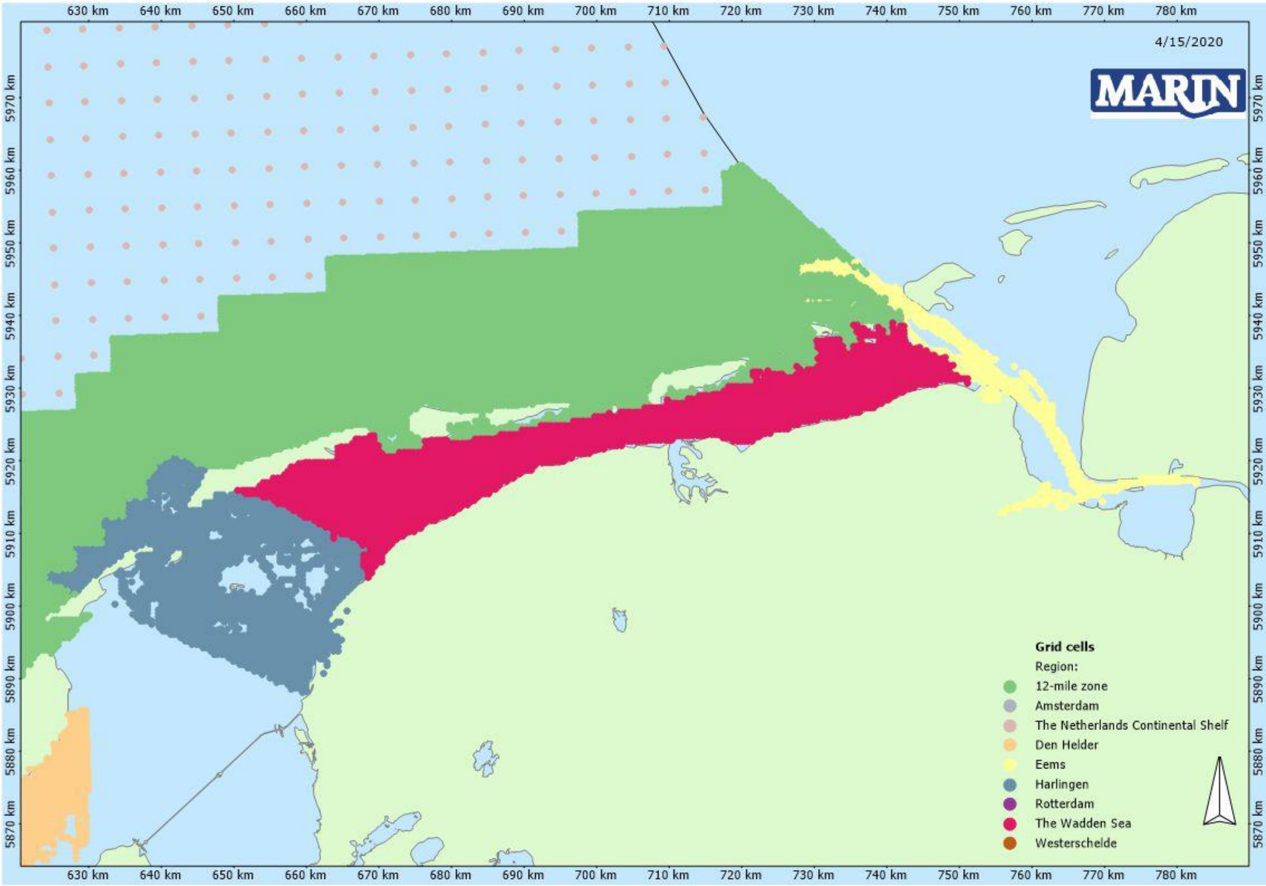

Figure 2-4 Harlingen, the Wadden Sea and Ems: The points indicate the centres of grid cells for which emissions are calculated

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 2020 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 2019, 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 2020 comprised 37,321 valid MMSI numbers. Based on these MMSI-numbers, 13,914 commercial seagoing vessels could be identified (see Table 3-1). About 47% of all messages obtained, were sent by the 13,914 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%

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 (ATON), wind turbines and oil and gas installations), which are not directly relevant with respect to shipping emissions. Based on experience from earlier studies it is estimated roughly that at maximum 250 commercial 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 about 28 minutes for 2020. 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.

The overall coverage of AIS-data of 2020 is in most places of the same order of magnitude compared to the AIS coverage of 2019.

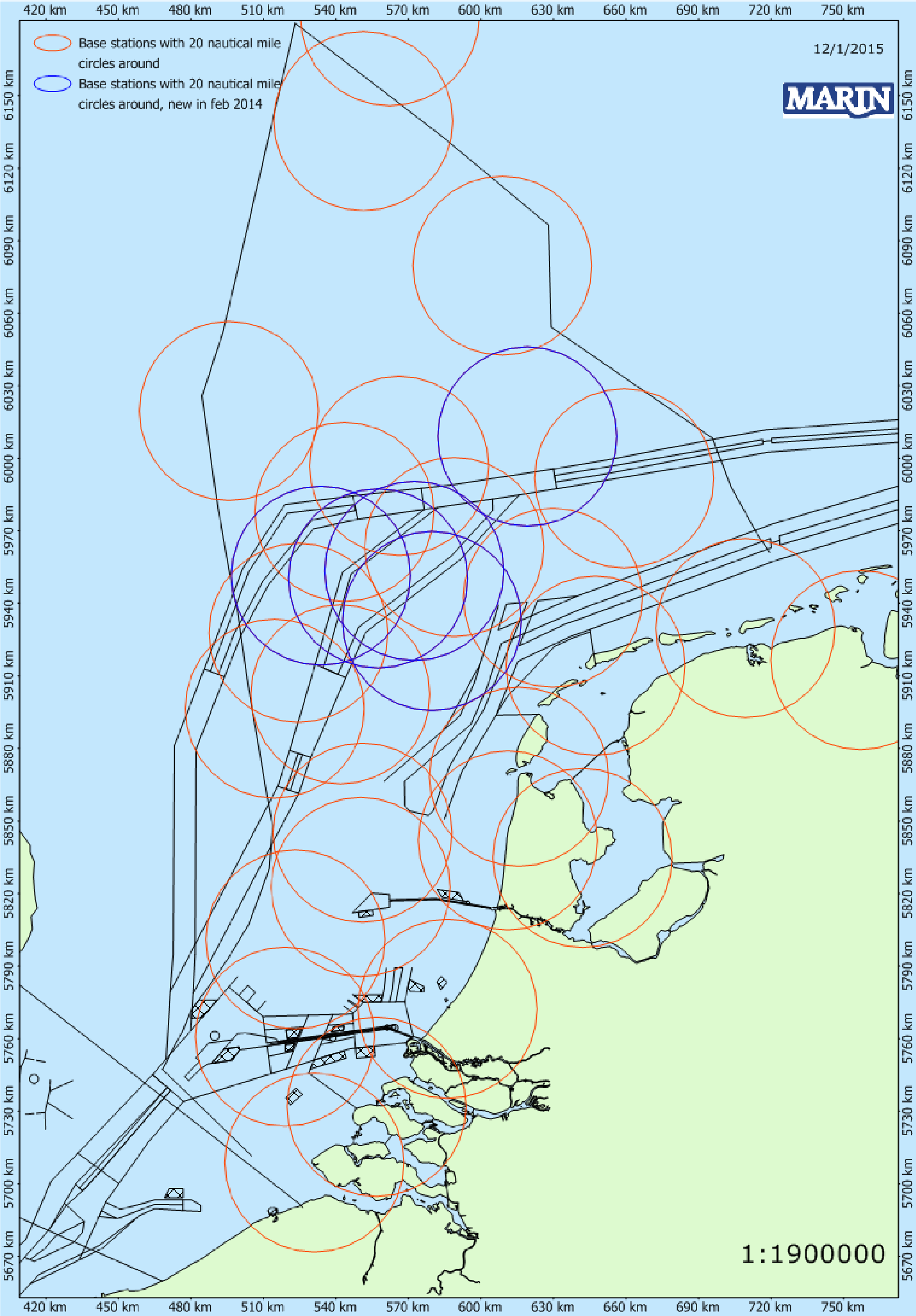

Figure 4-1 AIS base stations in 2020 delivering data to the Netherlands Coastguard.

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

5.1 Introduction

This chapter presents the activities of seagoing vessels for 2020 in the Dutch port areas and in the Netherlands sea area. The activities of 2020 are compared to those of 2019. 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 [7]. For the port of Harlingen, Den Helder and Ems no figures are available, therefore, only the activities for the ports Western Scheldt, Rotterdam and Amsterdam are given here. These numbers can be used to check the information on activity as derived from the AIS-data. The table contains the number of calls and the cargo handling for the main ports in each port area.

Table 5-1 show an overall decrease in cargo handling in the port of Amsterdam, Western Scheldt and Rotterdam. The port of Amsterdam reports that not only the corona crisis led to a decline in cargo handling, but the energy transition in particular caused a significant decrease of coal in 2020. The port of Rotterdam indicates that the economic impact of the corona crisis is the main explanation for the decline in cargo handling for the first half year.

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

Port area	Ports	Number of calls		Cargo handling x 1000 tons	
		2019	2020	2019	2020
Western Scheldt	Antwerp	14,391	13,655	238,179	230,972
Rotterdam	Rijn- / Maasmond area	29,491	28,170	469,402	436,800
Amsterdam	North Sea channel area	-	-	105,000	91,000

The shipping activities of 2020 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 2019. Take into account that some percentages can vary a lot due to the low absolute numbers. 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.

Western Scheldt
The activity tables, Table 5-2 and Table 5-3, show that the moving hours increased with 4.0% and the GT.nm (gross tonnage time's nautical miles) decreased with 6%.

For berthed ships the hours increased by 35% and GT.hours remains on average at the same level.

Rotterdam
The activity tables, Table 5-4 and Table 5-5, for Rotterdam show that the moving hours increased with 5% and the GT.nm decreased with 6%.

Berthed activities, hours and GT.hours, increased with 27% and 15% respectively. The high percentages for passenger ships are striking. This is probably due to the fact that crew and guests on cruise ships were no longer welcome anywhere because of COVID-19 and therefore stayed in the anchor area.

Amsterdam
The activity tables, Table 5-6 and Table 5-7, for Amsterdam show that the moving hours decreased with 14% and the GT.nm decreased with 29%. The decrease in the port of Amsterdam is in line with their annual report in Table 5-1.

The berthed hours increased with 7% and the berthed GT.hours decreased with 12%.

Ems
The activity tables, Table 5-8 and Table 5-9, for the Ems show that the moving hours decreased with 8% and the GT.nm decreased with 14%.

The berthed hours decreased with 15% and the berthed GT.hours decreased with 6%.

Den Helder
The activity tables, Table 5-10 and Table 5-11, for Den Helder show that the moving hours increased with 32% and the GT.nm increased with 23%.

The berthed hours increased with 59% and the berthed GT.hours increased with 59%.

Harlingen
The activity tables, Table 5-12 and Table 5-13, for Harlingen show that the moving hours and GT.nm decreased with 11%.

The berthed hours increased with 50% and the berthed GT.hours increased with 54%.

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

Ship type	Totals for Western Scheldt in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	6,648	167,390,810	4,710	1,393,286,826	10.2	106%	63%	98%	86%	100%
Chem.+ Gas tanker	74,235	849,163,564	42,007	4,725,588,203	10.7	101%	99%	93%	97%	101%
Bulk carrier	30,635	873,397,056	7,072	1,688,726,738	8.2	96%	91%	89%	86%	104%
Container ship	11,357	217,983,618	29,298	20,017,429,338	12.4	107%	92%	99%	97%	96%
General Dry Cargo	88,905	635,636,292	34,517	1,629,291,286	9.5	88%	91%	98%	94%	100%
RoRo Cargo / Vehicle	14,389	321,141,937	9,249	5,388,726,709	11.4	109%	107%	87%	89%	92%
Reefer	8,691	107,870,354	922	117,157,956	9.9	101%	102%	123%	128%	98%
Passenger	32,305	93,921,207	4,998	49,791,522	10.1	172%	164%	100%	58%	100%
Miscellaneous	258,951	435,357,605	34,887	440,177,895	7.2	205%	150%	161%	93%	110%
Tug/Supply	281,954	571,544,450	28,890	159,741,247	6.6	134%	112%	101%	127%	104%
Total / Average	808,070	4,273,406,893	196,550	35,609,917,720	9.4	135%	100%	104%	94%	98%

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 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	379,811	160,082,266	42,597	162,590,250	7.8	139%	124%	102%	96%	99%
1,600-3,000	99,303	239,008,014	31,713	679,686,383	8.4	121%	119%	98%	96%	100%
3,000-5,000	77,582	306,338,389	25,887	976,511,474	9.4	116%	117%	106%	105%	97%
5,000-10,000	58,423	412,130,348	21,683	1,582,270,714	9.9	125%	131%	96%	99%	98%
10,000-30,000	99,799	1,883,815,531	32,904	7,167,388,505	10.8	103%	104%	94%	96%	106%
30,000-60,000	26,043	1,019,186,868	18,423	9,410,469,211	10.9	84%	79%	89%	90%	105%
60,000-100,000	2,782	208,477,845	7,628	7,085,620,117	10.9	87%	84%	97%	97%	94%
>100,000	327	39,993,157	2,369	4,163,545,175	8.5	242%	275%	93%	94%	83%
Total / Average	808,070	4,273,406,897	194,446	31,235,399,342	9.3	135%	100%	104%	94%	99%

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

Ship type	Totals for Rotterdam in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	57,099	3,930,536,445	4,777	1,659,084,821	7.4	118%	114%	102%	96%	101%
Chem.+ Gas tanker	115,716	1,920,543,022	23,045	2,047,081,395	7.7	132%	124%	98%	96%	100%
Bulk carrier	73,609	3,532,441,581	2,866	680,061,932	7.7	96%	88%	97%	89%	99%
Container ship	218,909	11,786,973,674	28,974	5,788,574,822	8.1	107%	105%	92%	89%	105%
General Dry Cargo	86,443	585,021,438	19,314	682,517,541	8.7	146%	144%	107%	103%	98%
RoRo Cargo / Vehicle	60,938	2,118,840,702	10,033	3,301,870,406	9.1	111%	113%	94%	103%	98%
Reefer	1,356	13,597,818	148	15,711,833	9.1	211%	197%	100%	106%	96%
Passenger	8,597	670,732,844	310	104,937,277	8.5	456%	965%	56%	32%	98%
Miscellaneous	103,732	439,656,672	28,081	513,027,175	6.7	202%	161%	139%	108%	99%
Tug/Supply	312,592	2,432,626,695	59,703	305,540,802	6.3	134%	231%	105%	127%	96%
Total / Average	1,038,991	27,430,970,891	177,251	15,098,408,004	7.3	127%	115%	105%	94%	98%

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

Ship size in GT	Totals for Rotterdam in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average Speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	314,243	135,557,883	76,357	179,802,604	7.8	137%	145%	113%	110%	104%
1,600-3,000	49,790	120,752,094	14,574	303,554,236	8.7	147%	146%	107%	103%	101%
3,000-5,000	53,195	207,734,694	19,144	655,775,083	9.0	139%	137%	106%	106%	100%
5,000-10,000	124,455	947,346,186	23,307	1,599,357,489	8.8	123%	120%	94%	95%	99%
10,000-30,000	215,070	3,976,623,826	24,935	3,635,374,795	8.1	122%	122%	92%	90%	98%
30,000-60,000	128,016	5,330,979,902	8,372	2,790,010,161	7.6	111%	108%	98%	97%	103%
60,000-100,000	74,973	5,744,499,016	5,486	2,876,889,526	6.2	113%	109%	103%	104%	93%
>100,000	65,979	10,966,566,677	3,263	3,056,845,567	5.3	115%	118%	79%	84%	95%
Total / Average	1,038,992	27,430,970,892	177,251	15,098,408,003	8.1	127%	115%	105%	94%	101%

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

Ship type	Totals for Amsterdam in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	32,492	1,554,496,312	1,329	311,806,152	6.0	110%	126%	79%	79%	95%
Chem.+ Gas tanker	103,015	2,115,477,768	8,131	741,876,667	6.0	88%	90%	83%	85%	102%
Bulk carrier	64,960	2,694,110,701	2,505	493,115,444	5.7	75%	71%	77%	76%	104%
Container ship	7,479	77,853,840	505	17,173,740	5.7	218%	352%	114%	100%	93%
General Dry Cargo	105,105	415,874,067	7,936	165,105,647	6.0	100%	98%	80%	91%	107%
RoRo Cargo / Vehicle	15,775	544,824,172	1,122	245,555,486	6.3	152%	144%	94%	82%	105%
Reefer	19,451	112,072,428	458	13,470,575	5.5	97%	99%	78%	90%	115%
Passenger	11,672	119,064,305	905	16,761,654	5.1	68%	44%	36%	5%	82%
Miscellaneous	112,034	320,137,906	7,589	93,517,429	5.0	210%	50%	149%	40%	100%
Tug/Supply	198,935	435,856,996	17,734	37,074,880	5.8	109%	155%	82%	71%	142%
Total / Average	670,918	8,389,768,495	48,214	2,135,457,674	5.7	107%	88%	86%	71%	113%

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

Ship size in GT	Totals for Amsterdam in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	199,537	84,462,892	21,490	41,425,496	5.8	115%	126%	87%	92%	104%
1,600-3,000	109,270	252,386,181	6,305	93,491,412	5.8	105%	105%	78%	80%	98%
3,000-5,000	54,727	210,723,653	5,333	123,869,010	5.9	128%	125%	116%	120%	100%
5,000-10,000	71,490	462,198,584	3,065	136,014,755	5.9	123%	114%	83%	94%	104%
10,000-30,000	115,142	2,522,981,797	6,205	734,432,480	5.5	97%	94%	83%	86%	104%
30,000-60,000	75,557	2,946,356,776	3,142	664,985,450	5.1	74%	75%	51%	57%	93%
60,000-100,000	26,214	1,895,662,728	871	335,156,194	5.3	101%	96%	65%	63%	100%
>100,000	123	13,986,930	20	5,380,898	2.4	33%	31%	23%	9%	44%
Total / Average	670,918	8,389,768,497	48,213	2,135,457,674	5.8	107%	88%	86%	71%	103%

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

Ship type	Totals for Ems in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	126	193,485	216	2,159,517	9.2	67%	120%	74%	95%	96%
Chem.+ Gas tanker	4,573	22,970,777	1,665	106,731,488	10.3	93%	86%	104%	99%	100%
Bulk carrier	3,467	57,287,815	662	83,406,759	9.2	84%	87%	87%	76%	102%
Container ship	8,093	128,731,786	46	5,582,474	10.2	864%	989%	96%	127%	95%
General Dry Cargo	54,513	268,569,506	7,255	298,009,157	9.9	92%	95%	101%	93%	100%
RoRo Cargo / Vehicle	11,497	464,976,534	6,462	1,292,859,772	12.1	78%	91%	86%	83%	106%
Reefer	1,029	5,720,968	52	2,008,174	9.4	85%	62%	87%	70%	90%
Passenger	503	2,653,406	246	30,904,696	11.0	59%	7%	19%	65%	75%
Miscellaneous	32,571	43,659,329	14,879	232,485,956	7.3	142%	139%	125%	112%	109%
Tug/Supply	121,940	170,497,628	7,553	160,288,536	9.5	71%	64%	64%	74%	109%
Total / Average	238,312	1,165,261,234	39,036	2,214,436,529	9.2	85%	94%	92%	86%	101%

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 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hour s	Hours	GT.nm	Average speed
100-1,600	115,937	34,774,620	9,986	38,255,856	8.6	77%	74%	75%	70%	78%
1,600-3,000	41,944	100,739,780	13,780	273,783,996	9.3	85%	85%	101%	97%	95%
3,000-5,000	18,118	72,923,953	6,831	238,852,789	9.4	51%	53%	97%	93%	101%
5,000-10,000	23,302	162,970,214	4,266	307,253,170	9.8	94%	87%	91%	85%	102%
10,000-30,000	18,065	327,587,474	2,155	467,936,455	10.4	163%	165%	114%	115%	104%
30,000-60,000	6,651	350,827,991	1,024	628,810,666	10.2	95%	93%	72%	73%	102%
60,000-100,000	1,668	112,919,269	294	245,610,113	12.4	78%	80%	75%	77%	101%
>100,000	9	1,693,619	8	13,481,494	9.6	4%	5%	42%	59%	133%
Total / Average	238,312	1,165,261,234	39,036	2,214,436,528	9.3	85%	94%	92%	86%	92%

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

Ship type	Totals for Den Helder in 2020					2020 as percentage of 2019				
	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	329	2,486,639	12	393,476	4.5	153%	269%	200%	176%	76%
Bulk carrier										
Containership										
General Dry Cargo	1,924	2,937,018	303	8,195,365	6.9	678%	491%	1443%	2945%	85%
RoRo Cargo / Vehicle	6,168	94,507,422	2,614	331,906,111	7.3	116%	115%	112%	125%	128%
Reefer										
Passenger	16,383	125,340,245	1,384	132,585,355	5.1	160%	123%	113%	111%	76%
Miscellaneous	120,603	236,550,200	2,935	20,919,940	6.1	355%	836%	275%	334%	120%
Tug/Supply	126,392	128,779,307	2,758	25,695,698	6.2	104%	81%	93%	86%	103%
Total / Average	271,799	590,600,831	10,006	519,695,945	6.3	159%	159%	132%	123%	107%

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 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	155,503	67,229,371	3,140	10,094,195	5.7	142%	154%	132%	155%	97%
1,600-3,000	38,611	87,702,602	1,583	25,520,216	6.7	103%	99%	110%	119%	129%
3,000-5,000	26,775	104,961,914	445	9,082,376	4.5	329%	317%	184%	164%	56%
5,000-10,000	2,094	13,372,175	68	2,712,033	5.8	75%	76%	133%	143%	102%
10,000-30,000	18,498	316,094,344	3,954	472,143,596	6.4	139%	167%	113%	122%	100%
30,000-60,000										
60,000-100,000										
>100,000										
Total / Average	271,799	590,600,832	10,007	519,695,946	6.3	159%	159%	132%	123%	104%

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

Ship type	Totals for Harlingen in 2020					2020 as percentage of 2019				
	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	530	2,378,524	29	876,144	7.3	61%	71%	145%	179%	95%
Bulk carrier	104	530,261	11	277,775	8.5	347%	748%	220%	872%	102%
Containership										
General Dry Cargo	23,953	71,246,163	1,488	30,790,505	7.8	108%	120%	83%	101%	104%
RoRo Cargo / Vehicle	40,117	102,377,009	8,980	268,718,851	10.4	153%	196%	87%	95%	93%
Reefer	1,963	12,459,536	113	5,316,498	8.4	87%	100%	65%	76%	96%
Passenger	37,185	13,928,297	1,141	3,688,344	7.6	189%	144%	44%	10%	46%
Miscellaneous	86,613	75,378,516	6,258	46,746,656	7.2	171%	216%	119%	107%	106%
Tug/Supply	48,435	29,540,167	489	1,984,179	7.8	131%	99%	63%	31%	104%
Total / Average	239,244	310,150,757	18,582	362,381,182	8.8	150%	154%	89%	89%	86%

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

Ship size in GT	Totals for Harlingen in 2020					2020 as percentage of 2019				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.hours	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	161,999	79,067,287	8,197	35,107,662	7.5	148%	147%	81%	53%	71%
1,600-3,000	38,592	95,717,218	4,887	112,956,296	7.8	109%	114%	78%	71%	95%
3,000-5,000	22,932	85,739,445	4,473	178,144,630	7.9	206%	197%	118%	119%	98%
5,000-10,000	7,601	47,855,125	673	35,689,247	8.4	216%	233%	105%	111%	99%
10,000-30,000										
30,000-60,000										
60,000-100,000										
>100,000										
Total / Average	239,244	310,141,106	18,581	362,381,184	7.7	150%	154%	89%	89%	83%

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 2020 are compared to the activities of 2019. 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 remains at the same level and GT.nm for moving vessels decreased with 4.0%.

For ships at anchor, there is an increase for both hours (10%) and GT.nm (14%).

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

Ship type	Totals for NCS and 12-mile zone in 2019					2019 as percentage of 2018				
	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
Oil tanker	144,853	8,378,945,475	73,360	41,417,790,129	9.4	118%	117%	101%	103%	100%
Chem.+Gas tanker	462,073	6,663,953,673	310,199	45,913,382,941	10.8	108%	116%	101%	103%	103%
Bulk carrier	79,129	3,565,377,573	107,391	37,603,640,908	10.0	68%	67%	99%	98%	102%
Container ship	92,980	3,499,719,707	196,412	130,898,834,556	12.5	137%	139%	99%	97%	98%
General Dry Cargo	100,095	558,429,203	405,044	18,070,734,760	10.3	113%	113%	102%	101%	99%
RoRo Cargo / Vehicle	23,864	580,776,962	116,750	65,076,641,605	12.4	540%	281%	89%	91%	96%
Reefer	2,918	22,319,065	9,398	1,165,080,345	11.9	121%	133%	102%	120%	97%
Passenger	12,941	1,066,252,595	4,570	2,689,204,038	9.1	15406%	56148%	43%	26%	74%
Miscellaneous	48,287	558,743,384	107,989	2,730,488,480	7.2	111%	185%	111%	134%	103%
Tug/Supply	127,793	834,298,277	144,032	3,513,372,210	8.0	108%	111%	101%	111%	104%
Total / Average	1,094,933	25,728,815,914	1,475,145	349,079,169,972	10.3	110%	114%	100%	96%	100%

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 2019					2019 as percentage of 2018				
	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	63,652	34,910,423	167,244	750,555,765	7.2	88%	82%	97%	90%	96%
1,600-3,000	98,182	243,291,523	307,554	6,531,032,842	8.7	98%	99%	99%	98%	95%
3,000-5,000	161,018	655,767,577	206,063	7,957,530,570	10.0	114%	115%	106%	103%	97%
5,000-10,000	174,788	1,248,213,842	198,539	16,355,979,728	10.6	115%	114%	102%	100%	94%
10,000-30,000	345,831	6,926,830,427	295,188	66,819,725,125	11.5	119%	123%	99%	95%	98%
30,000-60,000	124,729	5,432,527,845	157,681	84,069,398,280	11.1	99%	101%	99%	97%	97%
60,000-100,000	100,367	7,370,631,906	93,226	78,295,344,470	10.9	113%	110%	97%	93%	101%
>100,000	25,896	3,816,618,552	46,705	88,298,272,221	11.6	127%	130%	96%	96%	97%
Total / Average	1,094,933	25,728,815,911	1,475,147	349,079,169,972	10.0	110%	114%	100%	96%	97%

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 Ems, most remarkable is the increase of berthed ships.

Also, for the NCS combined with the 12-miles zone the average number of not moving ships increased.

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

Area	In 2020			In 2020 as percentage of 2019		
	Average # ships/day		Speed	Average # ships/day		Speed
	Not moving	Moving	Knots	Not moving	Moving	Knots
Amsterdam	76	5	6	107%	86%	113%
Den Helder	31	1	6	158%	132%	107%
Ems	27	4	9	85%	92%	101%
Harlingen	27	2	9	150%	89%	86%
Rotterdam	118	20	7	127%	105%	98%
Western Scheldt	92	22	9	135%	104%	98%
NCS +12-mile zone	125	168	10	110%	100%	100%

Figure 5-1 shows the average number of ships per day from 2017 up to and including 2020. The average number of ships per day contains not moving and moving ships excluding fishing vessels.

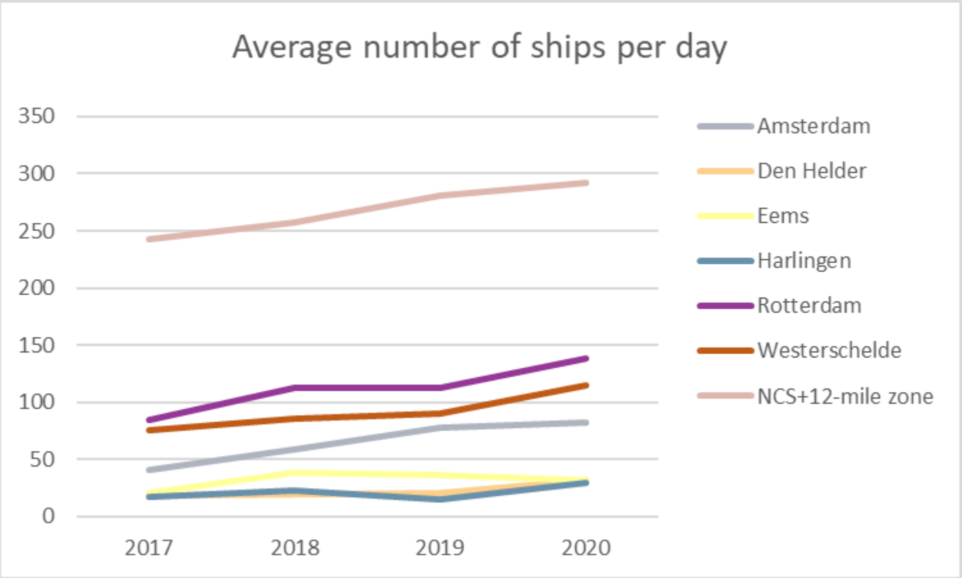

Figure 5-1 Average number of not moving and moving ships per day for 2017-2020, excluding fishing vessels.

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

6.1 Introduction

This chapter presents the results of emission calculations for 2020 for the Dutch port areas and the Netherlands sea area. To indicate the change in emissions, all values for 2020 are compared with the values of 2019.

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 2020 NO_x emissions together with the absolute and relative change compared to 2019.

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 2019. 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 11%. Ships at berth have a total increase of CO_2 by 22% and sailing ships decrease by 6%. The increase in CO_2 emissions for ships at berth is mainly caused by not moving / anchored ships in the port of Rotterdam since this port has a significant influence in an absolute sense.

Figure 6-1 to Figure 6-3 show respectively CO_2, NO_x and SO_2 emissions in ton in each port area from 2017 up to and including 2020. The emissions in ton contains not moving and moving ships excluding fishing vessels. For all ports together NO_x and SO_2 emissions increased and decreased respectively.

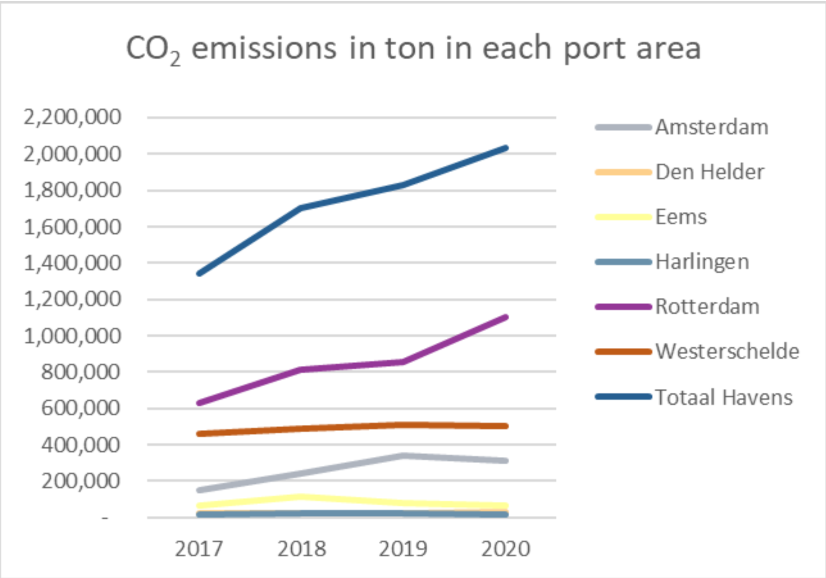

Figure 6-1 **CO_2 emissions in ton in each port area for 2017-2020, excluding fishing vessels.**

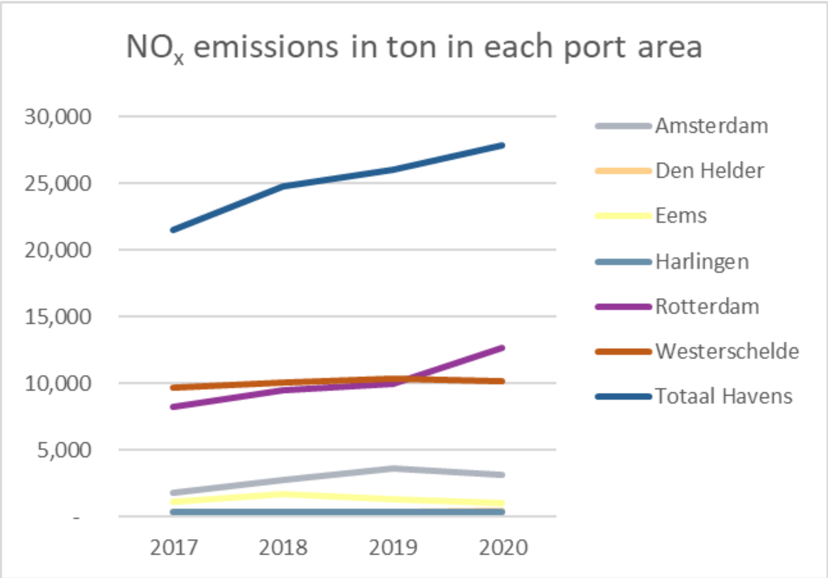

Figure 6-2 **NO_x emissions in ton in each port area for 2017-2020, excluding fishing vessels.**

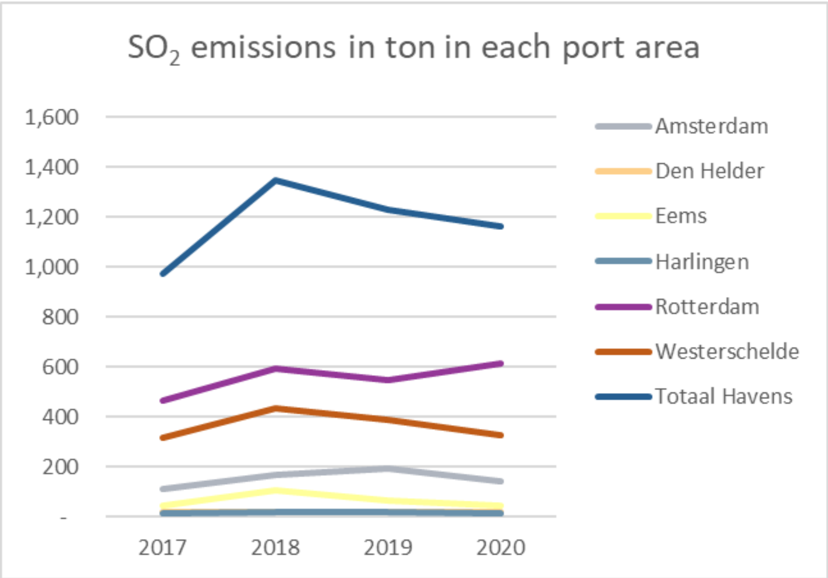

Figure 6-3 **SO_2 emissions in ton in each port area for 2017-2020, excluding fishing vessels.**

Table 6-1 Total emissions in ton in each port area for 2020, excluding fishing vessels (EMS-type 11).

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	13	65	1	19	12	5	115
	Total	13	65	1	19	12	5	115
1237 VOC	Berthed	66	371	116	14	13	6	586
	Sailing	278	178	30	25	5	8	524
	Total	344	549	146	39	18	14	1109
4001 SO_2	Berthed	77	472	119	19	16	6	709
	Sailing	252	143	22	25	5	7	454
	Total	329	615	141	44	21	13	1163
4013 NO_x	Berthed	1639	8302	2473	373	340	144	13271
	Sailing	8581	4346	646	690	132	190	14584
	Total	10220	12648	3118	1063	471	334	27855
4031 CO	Berthed	106	652	199	23	19	8	1008
	Sailing	509	344	55	47	13	13	981
	Total	615	996	254	70	32	21	1988
4032 CO_2	Berthed	135573	893356	284041	28639	22477	9159	1373246
	Sailing	365066	210819	31448	36638	8383	10077	662432
	Total	500639	1104176	315489	65277	30861	19236	2035678
6601 Aerosols MDO	Berthed	32	190	56	7	5	3	292
	Sailing	40	34	7	7	2	4	93
	Total	72	224	63	13	7	7	385
6602 Aerosols HFO	Berthed	1	1	1	1	1	0	5
	Sailing	180	100	12	17	3	1	312
	Total	181	101	13	17	4	1	317

Table 6-2 Emissions in each port area for 2020 as percentage of the emissions in 2019, excluding fishing vessels (EMS-type 11). The percentages in grey are based on very low absolute numbers, and not very reliable.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	104%	91%	83%	100%	23%		
	Total	104%	91%	83%	100%	23%		
1237 VOC	Berthed	107%	145%	93%	78%	174%	133%	124%
	Sailing	95%	94%	69%	84%	126%	73%	92%
	Total	97%	123%	87%	82%	157%	90%	106%
4001 SO_2	Berthed	92%	127%	75%	67%	139%	122%	107%
	Sailing	82%	82%	60%	72%	97%	57%	80%
	Total	84%	112%	72%	70%	125%	76%	94%
4013 NO_x	Berthed	110%	152%	90%	79%	174%	132%	126%
	Sailing	97%	96%	71%	83%	103%	68%	94%
	Total	98%	126%	85%	81%	146%	86%	107%
4031 CO	Berthed	105%	144%	93%	79%	164%	141%	124%
	Sailing	95%	93%	67%	88%	65%	86%	91%
	Total	97%	121%	86%	85%	101%	101%	105%
4032 CO_2	Berthed	103%	140%	95%	80%	164%	143%	122%
	Sailing	97%	96%	71%	86%	79%	69%	94%
	Total	99%	129%	92%	83%	127%	91%	111%
6601 Aerosols MDO	Berthed	106%	144%	91%	80%	159%	131%	123%
	Sailing	97%	96%	73%	82%	119%	98%	93%
	Total	101%	134%	89%	81%	145%	110%	114%
6602 Aerosols HFO	Berthed	331%	396%	75%	70%	192%	882%	147%
	Sailing	95%	94%	64%	85%	95%	22%	92%
	Total	96%	95%	64%	85%	115%	22%	92%

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 2020 are summarised in Table 6-3. This table also contains a comparison with 2019.

The substances show an overall increase for not moving vessels and a decrease for moving vessels. The substance CO_2 has the largest contribution to the total emissions in ton (97%). For NCS combined with the 12-miles zone there is a total decrease of CO_2 emission by 2%, the result of a 19% increase for ships at anchor and a 4% decrease for sailing ships. For the Netherlands sea area the average number of ships increased by 4%.

Figure 6-4 shows CO_2, NO_x and SO_2 emissions in ton in the Netherlands sea area from 2017 up to and including 2020. The total emissions in ton contains not moving and moving ships excluding fishing vessels. Like CO_2 , also NO_x and SO_2 emissions decreased since the previous registration.

Table 6-3 Emissions of ships in ton in the Netherlands sea area for 2020 compared with 2019, excluding fishing vessels (EMS-type 11). The percentages in grey are based on very low absolute numbers, and not very reliable.

No	Substance	Emission in ton in 2020			Emission in 2020 as percentage of 2019		
		Not moving	Moving	Total	Not moving	Moving	Total
1011	Methane		1023	1023		142%	142%
1237	VOC	138	2188	2325	117%	95%	96%
4001	SO_2	179	2175	2353	101%	81%	82%
4013	NO_x	4098	75236	79334	118%	96%	97%
4031	CO	224	4173	4397	119%	98%	99%
4032	CO_2	257780	3224241	3482021	119%	96%	98%
6601	Aerosols MDO	102	261	363	116%	98%	102%
6602	Aerosols HFO	5	1673	1678	126%	92%	92%
Average number of ships present in the area		125	168	293	110%	100%	104%

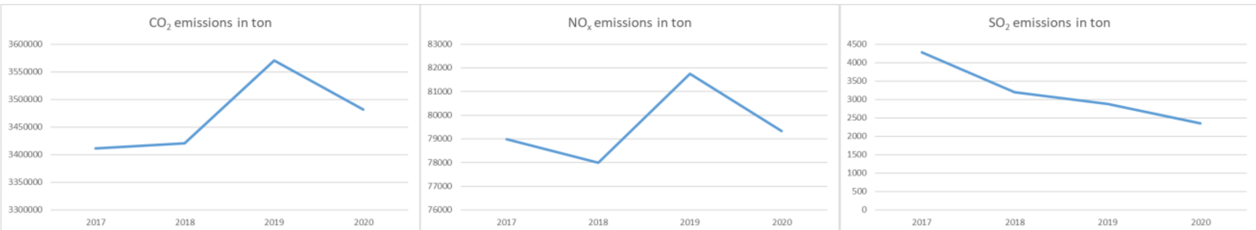

Figure 6-4 CO_2, NO_x and SO_2 emissions in ton in the Netherlands sea area for 2017-2020, excluding fishing vessels.

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 2019 and 2020 and the third one shows the *relative* change in emission between 2019 and 2020. 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 2019 and 2020 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.

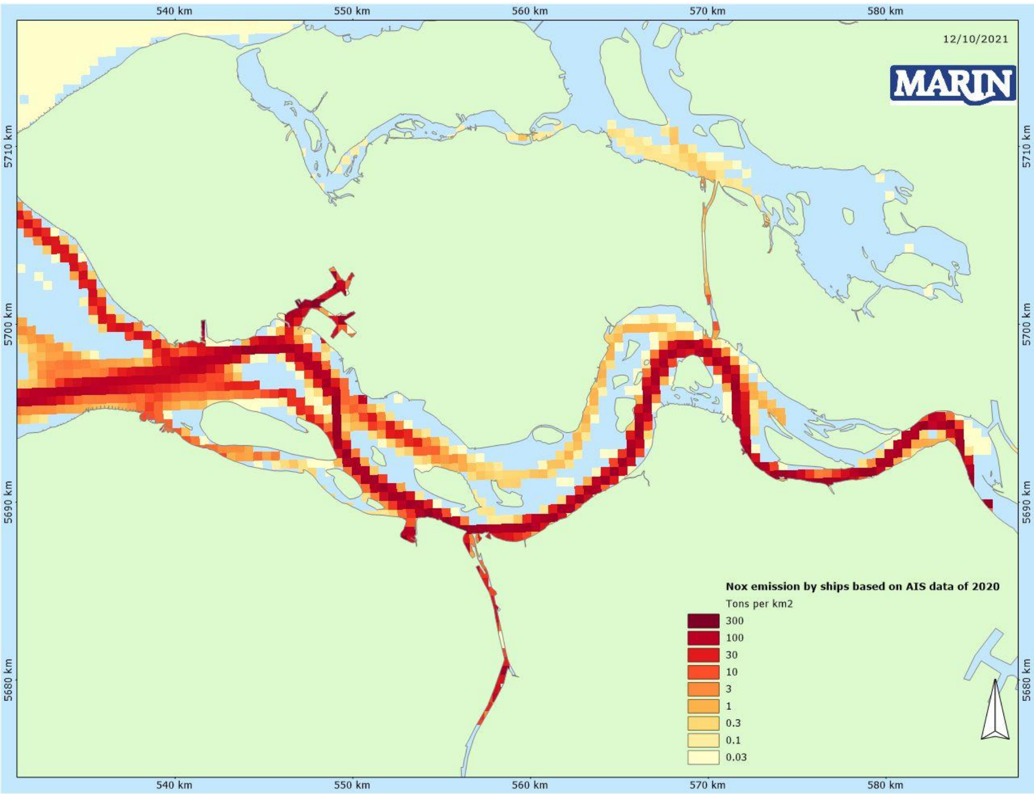

Figure 6-5 **NO_x emission in 2020 in the Dutch part of the Western Scheldt by ships with AIS.**

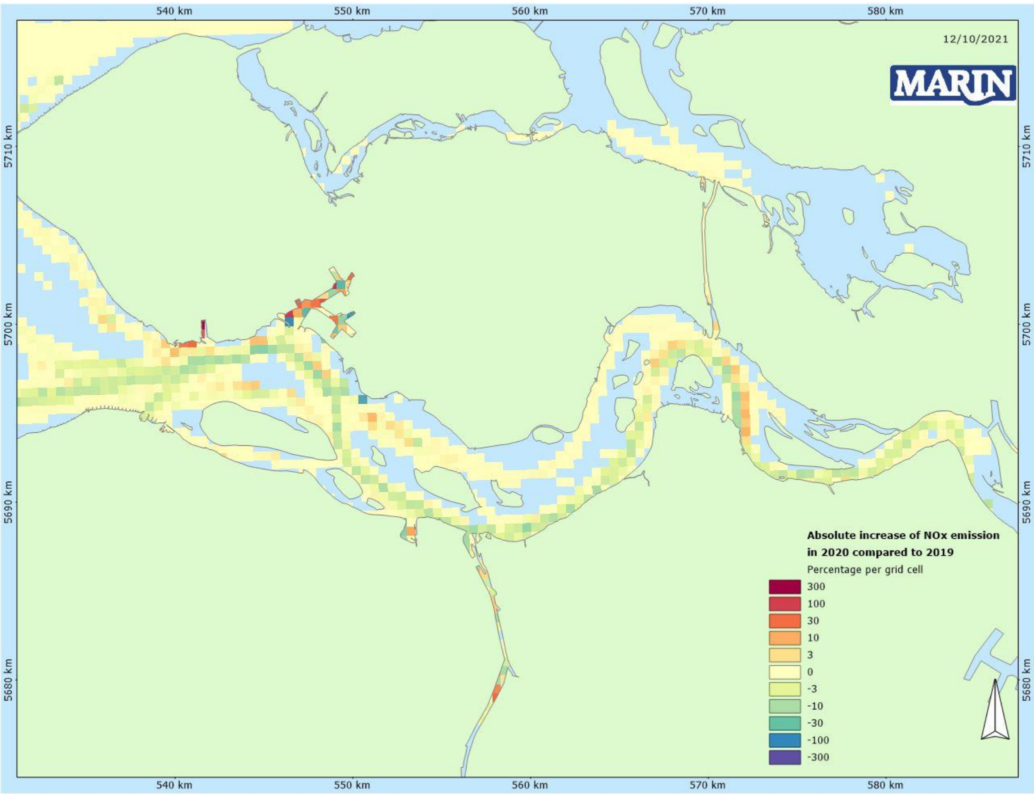

Figure 6-6 **Absolute change in NO_x emission from 2019 to 2020 in the Dutch part of the Western Scheldt by ships with AIS.**

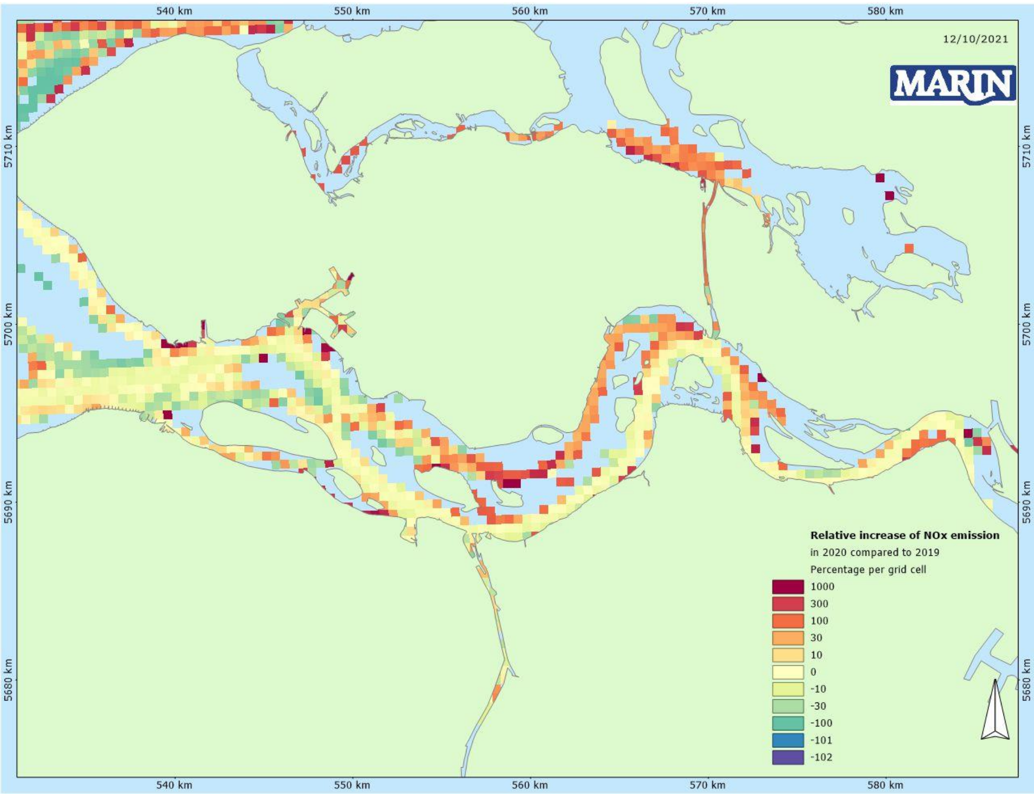

Figure 6-7 **Relative change in NO_x emission from 2019 to 2020 in the Dutch part of the Western Scheldt by ships with AIS.**

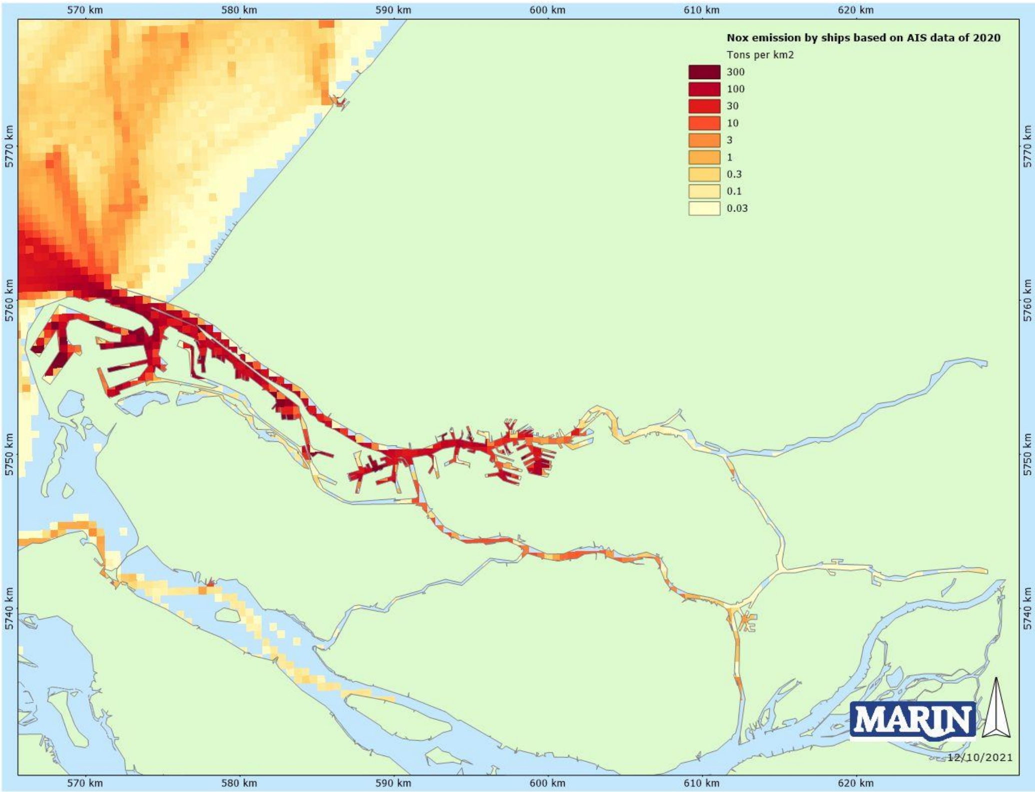

Figure 6-8 **NO_x emission in 2020 in the port area of Rotterdam by ships with AIS.**

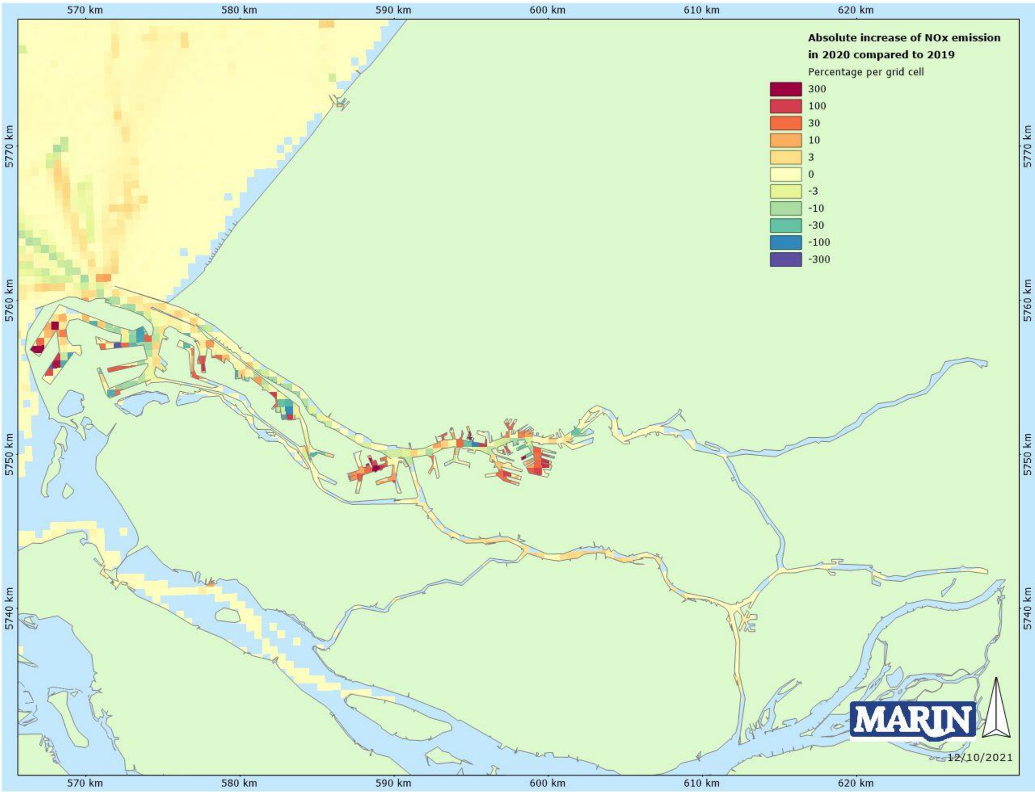

Figure 6-9 **Absolute change in NO_x emission from 2019 to 2020 in the port area of Rotterdam by ships with AIS.**

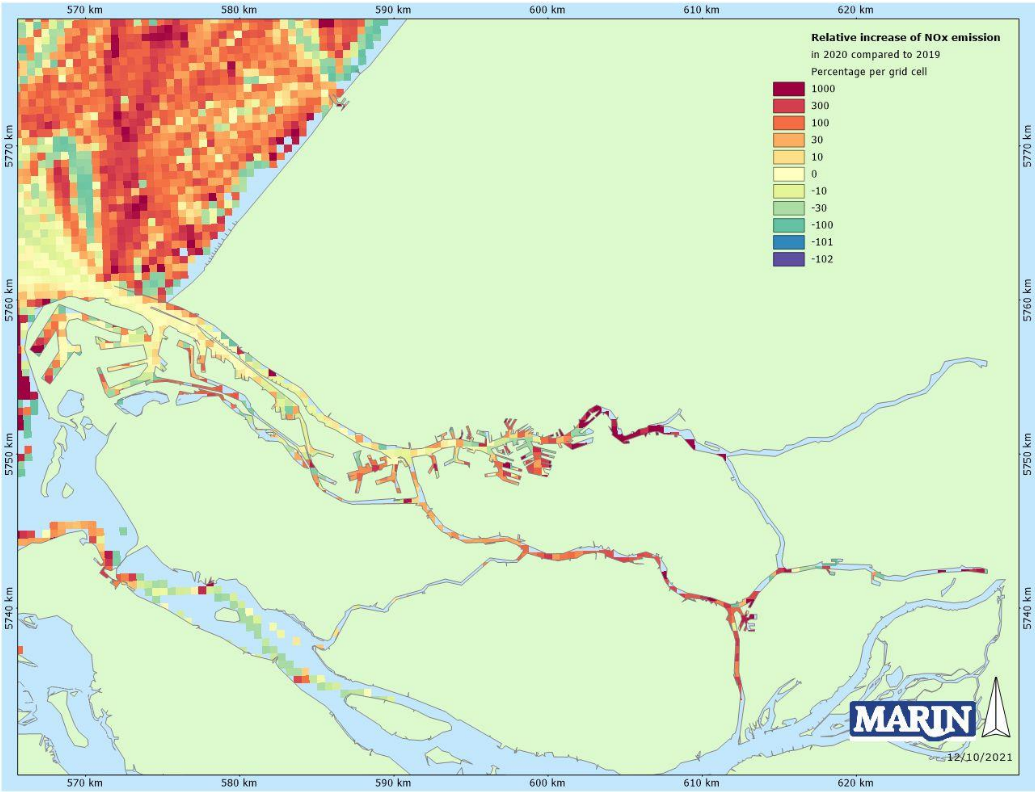

Figure 6-10 **Relative change in NO_x emission from 2019 to 2020 in the port area of Rotterdam by ships with AIS.**

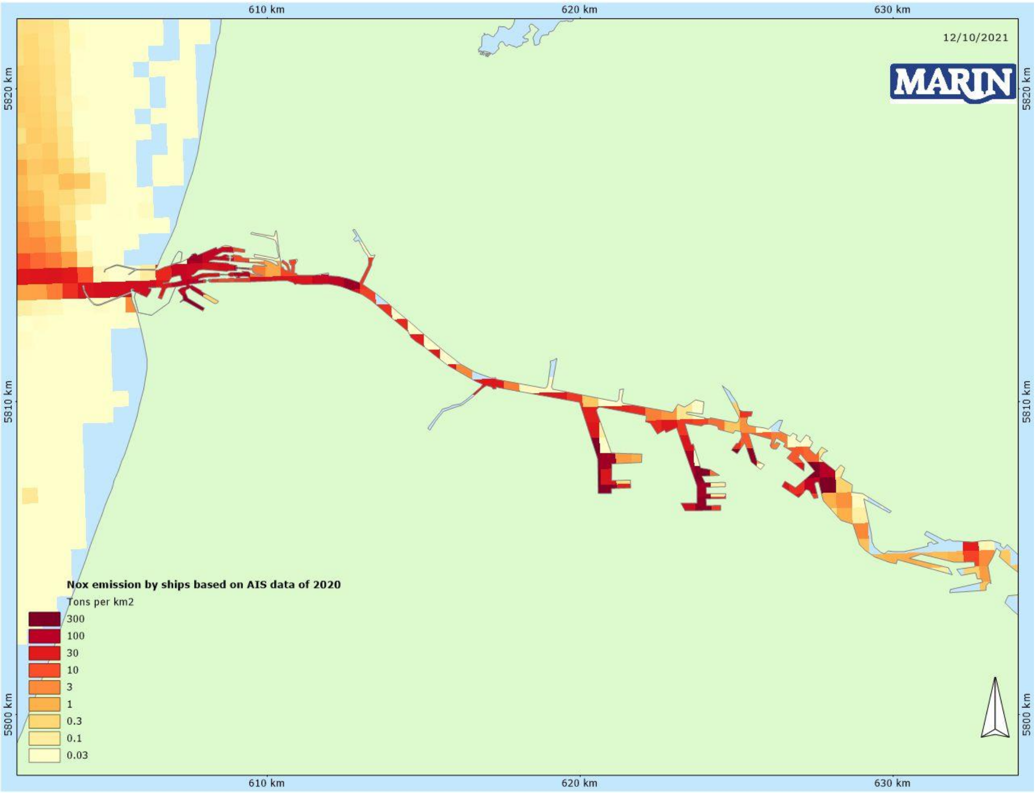

Figure 6-11 NO$_x$ emission in 2020 in the port area of Amsterdam by ships with AIS.

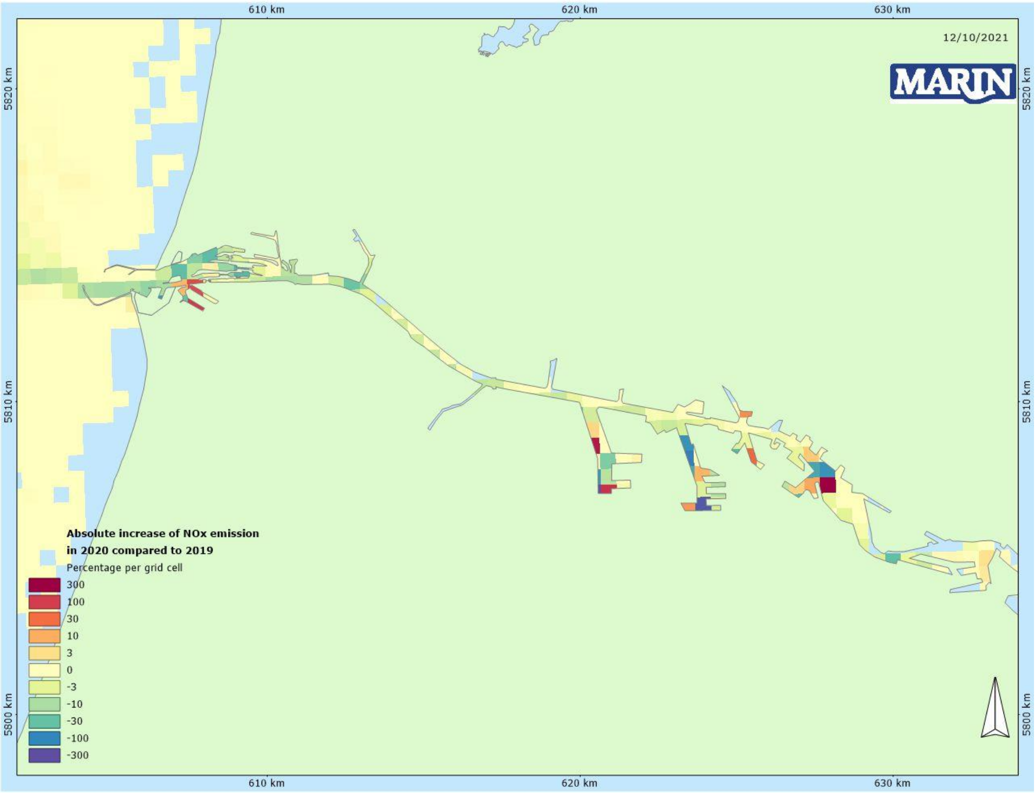

Figure 6-12 Absolute change in NO$_x$ emission from 2019 to 2020 in the port area of Amsterdam by ships with AIS.

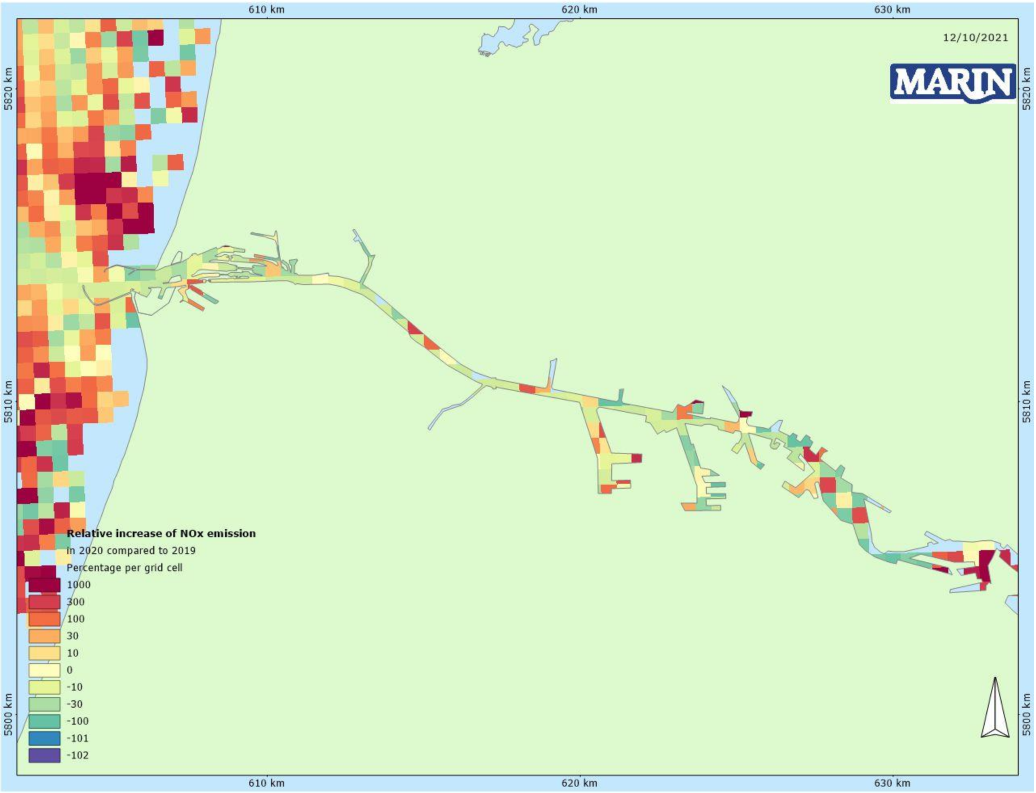

Figure 6-13 **Relative change in NO_x emission from 2019 to 2020 in the port area of Amsterdam by ships with AIS.**

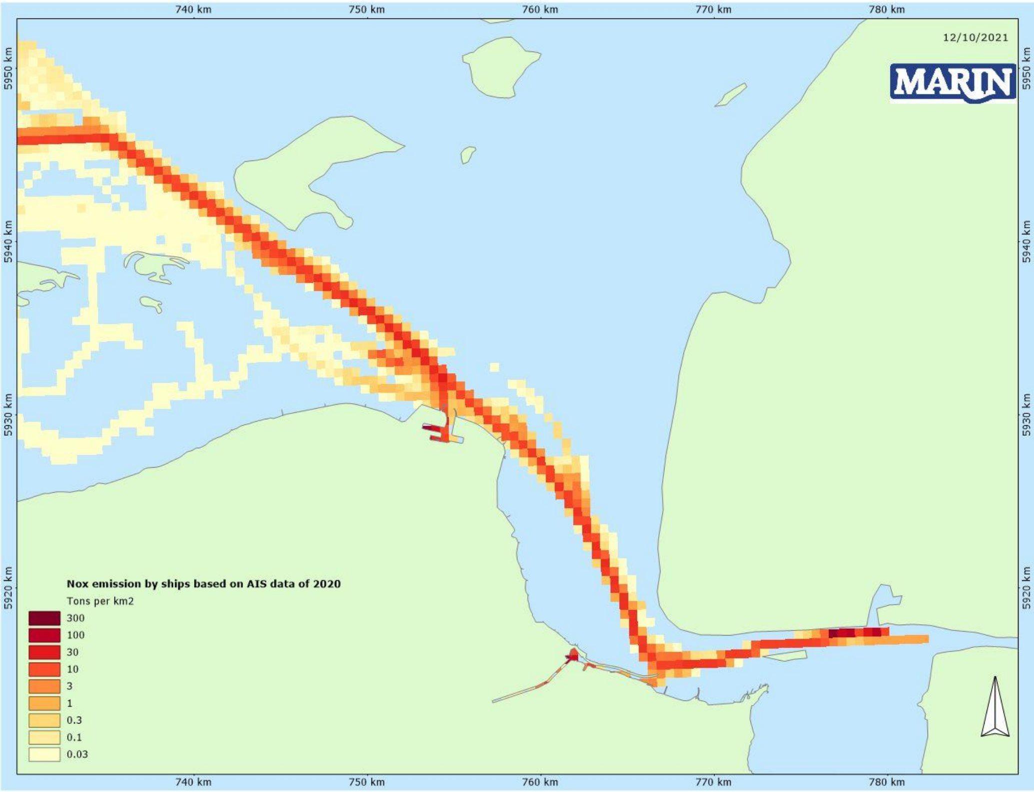

Figure 6-14 **NO_x emission in 2020 in the Ems area by ships with AIS.**

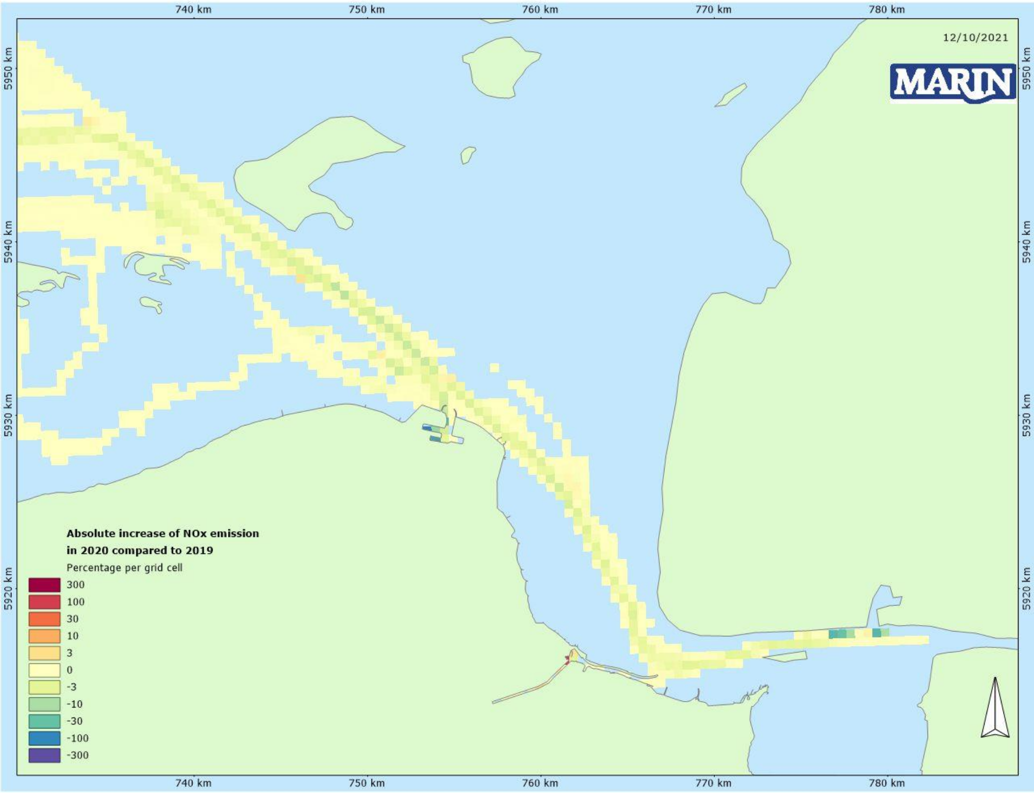

Figure 6-15 **Absolute change in NO_x emission from 2019 to 2020 in the Ems area by ships with AIS.**

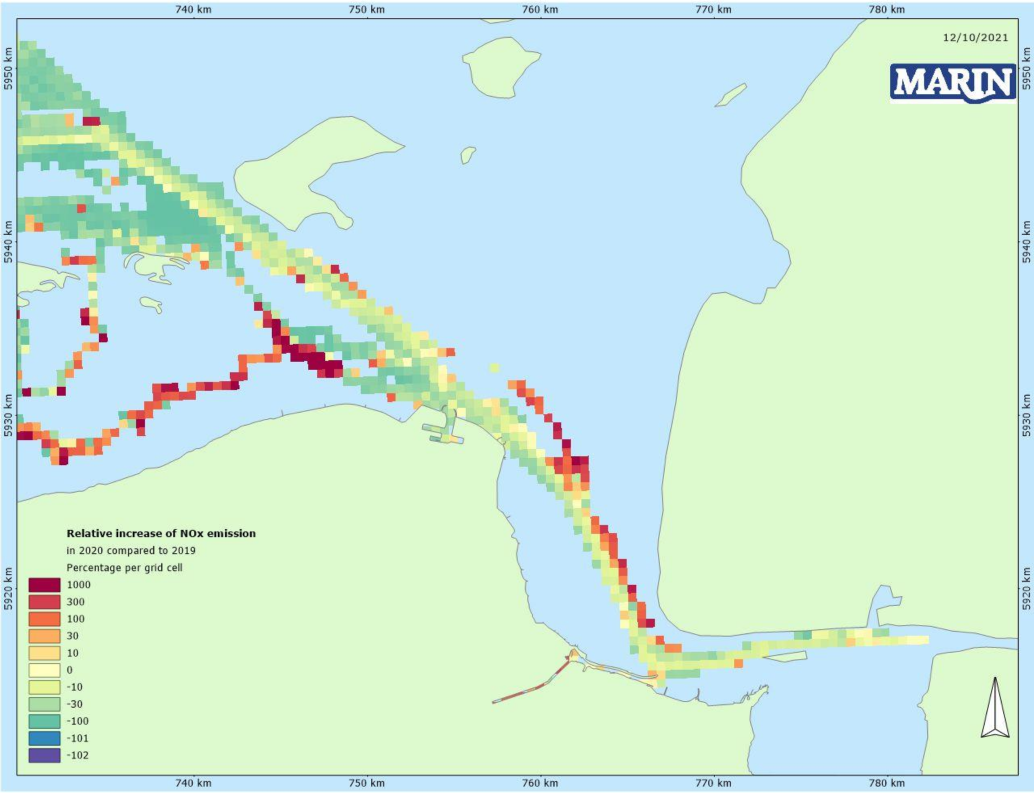

Figure 6-16 **Relative change in NO_x emission from 2019 to 2020 in the Ems area by ships with AIS.**

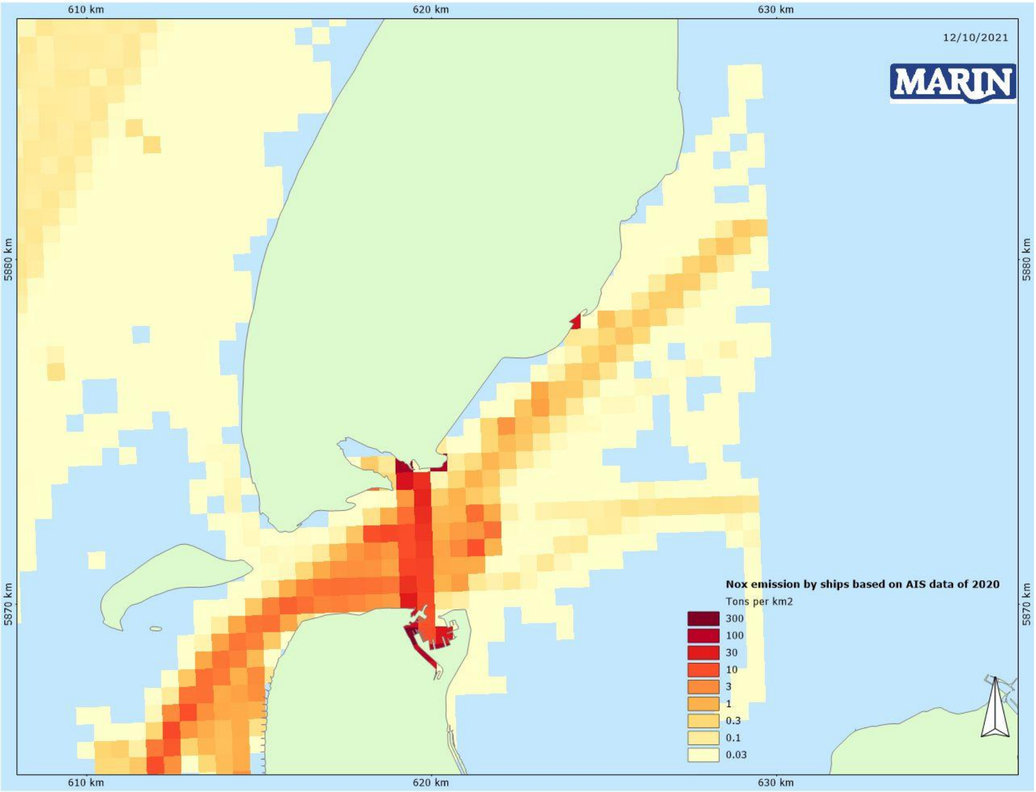

Figure 6-17 **NO_x emission in 2020 in the port area of Den Helder by ships with AIS.**

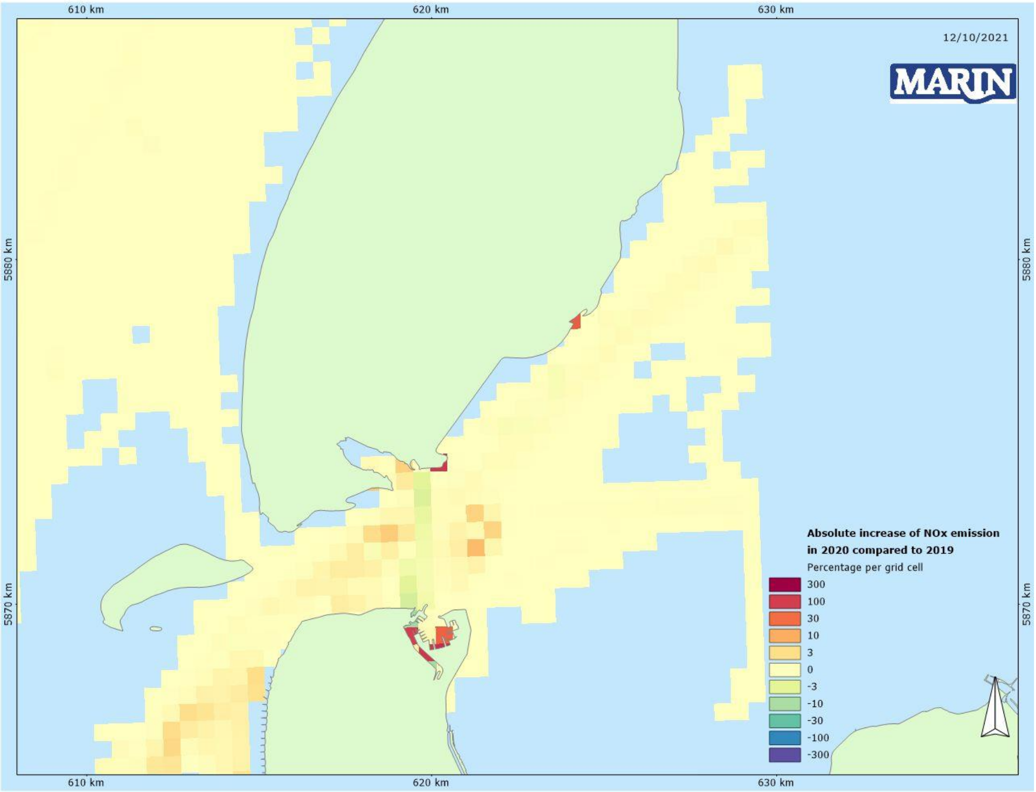

Figure 6-18 **Absolute change in NO_x emission from 2019 to 2020 in the port area of Den Helder by ships with AIS.**

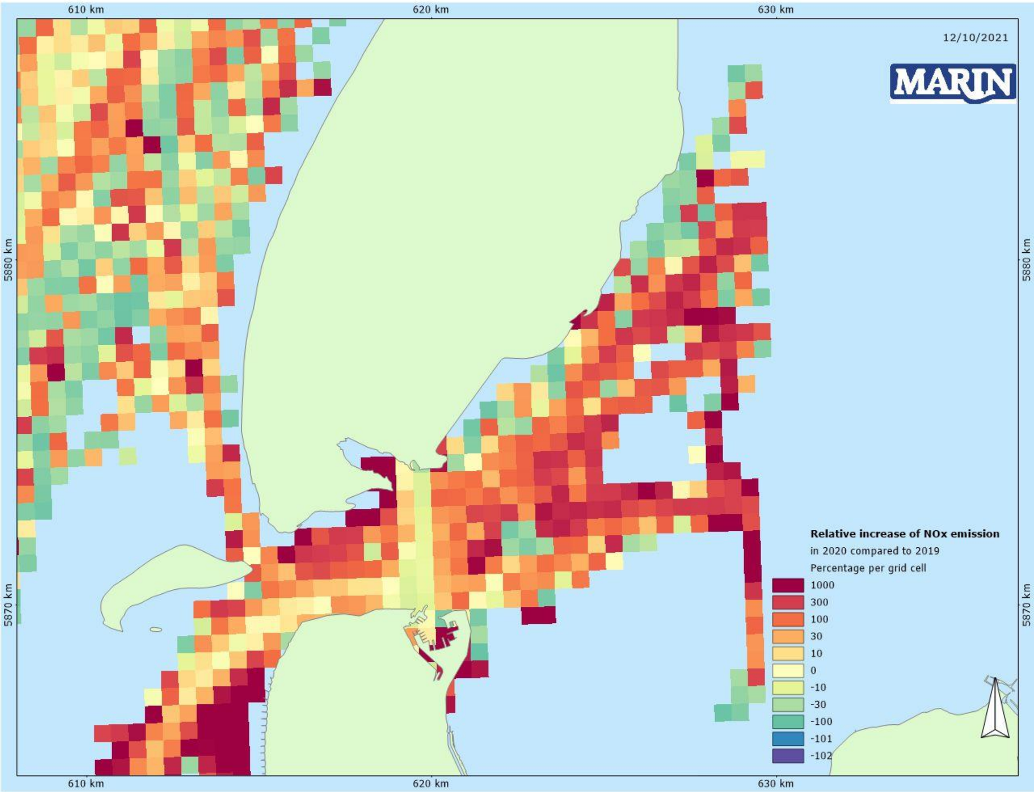

Figure 6-19 Relative change in NO_x emission from 2019 to 2020 in the port area of Den Helder by ships with AIS.

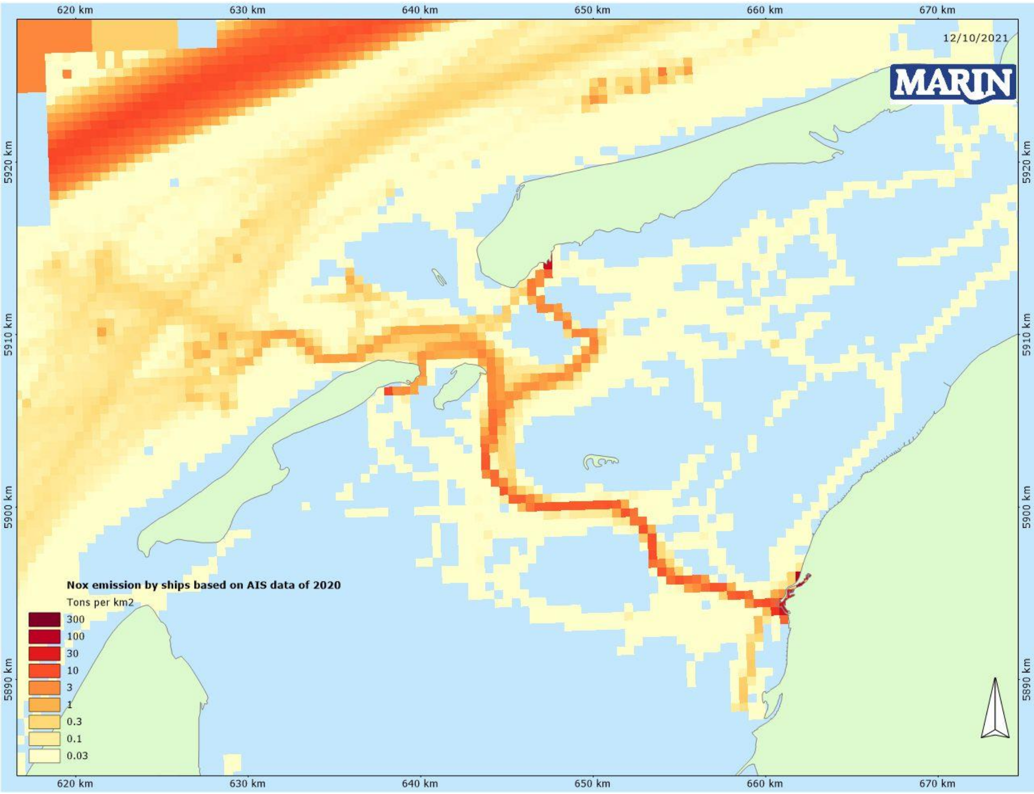

Figure 6-20 NO_x emission in 2020 in the port area of Harlingen by ships with AIS.

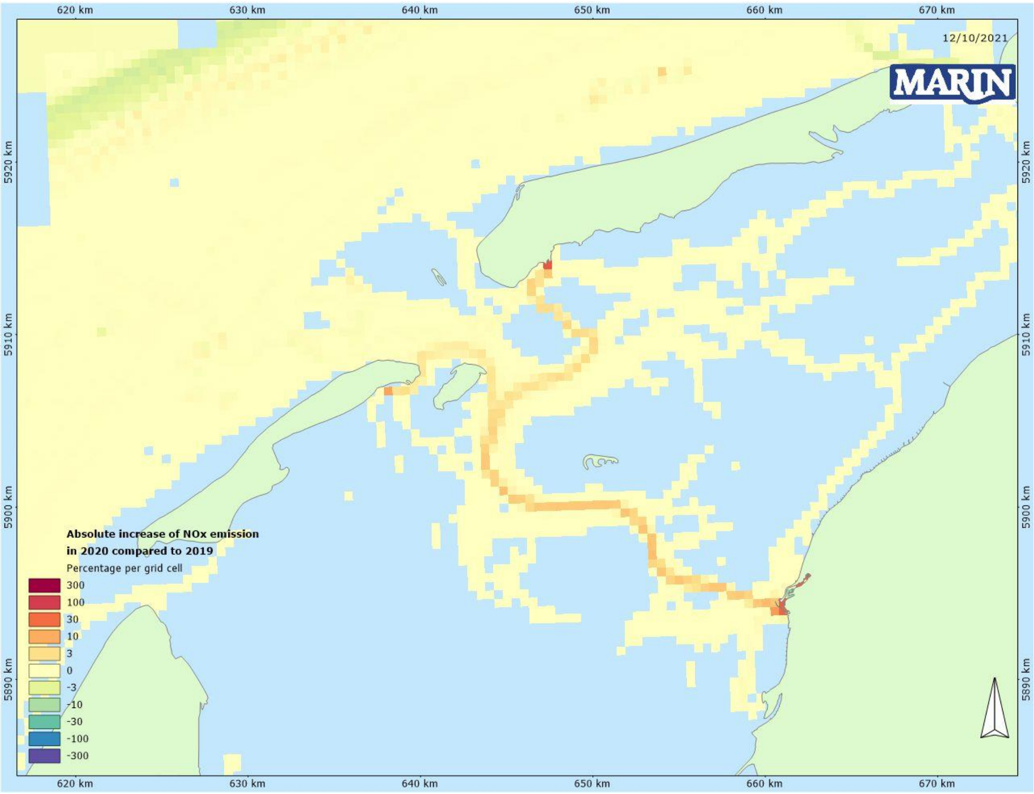

Figure 6-21 **Absolute change in NO_x emission from 2019 to 2020 in the port area of Harlingen by ships with AIS.**

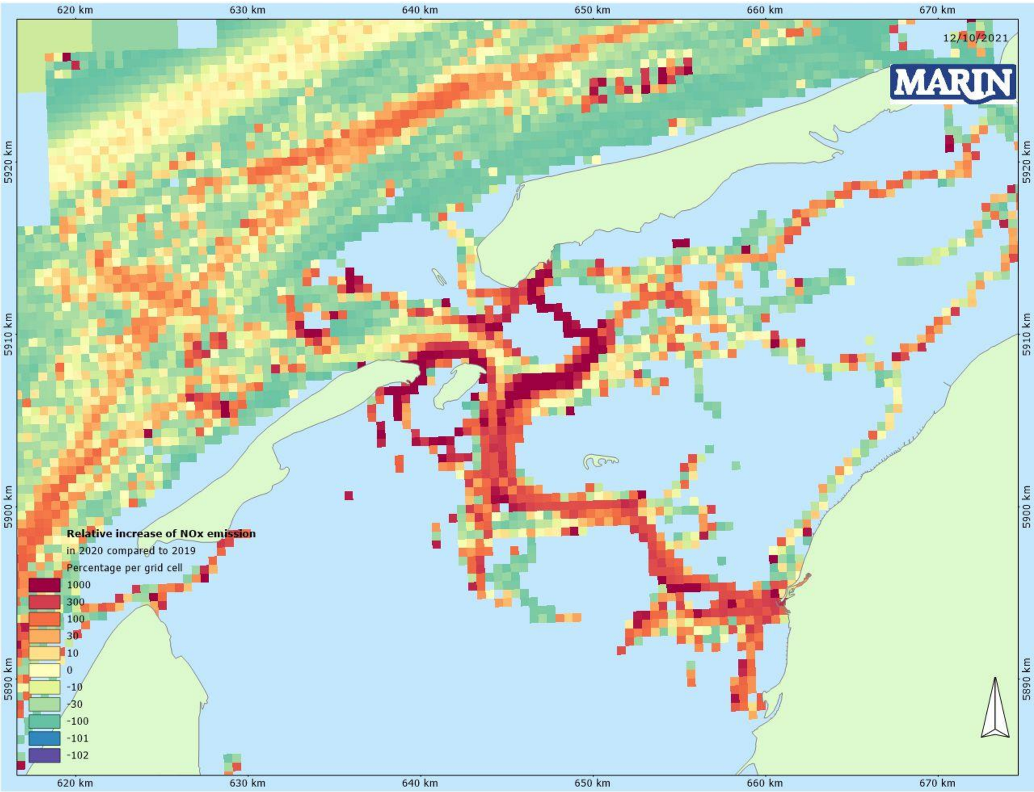

Figure 6-22 **Relative change in NO_x emission from 2019 to 2020 in the port area of Harlingen by ships with AIS.**

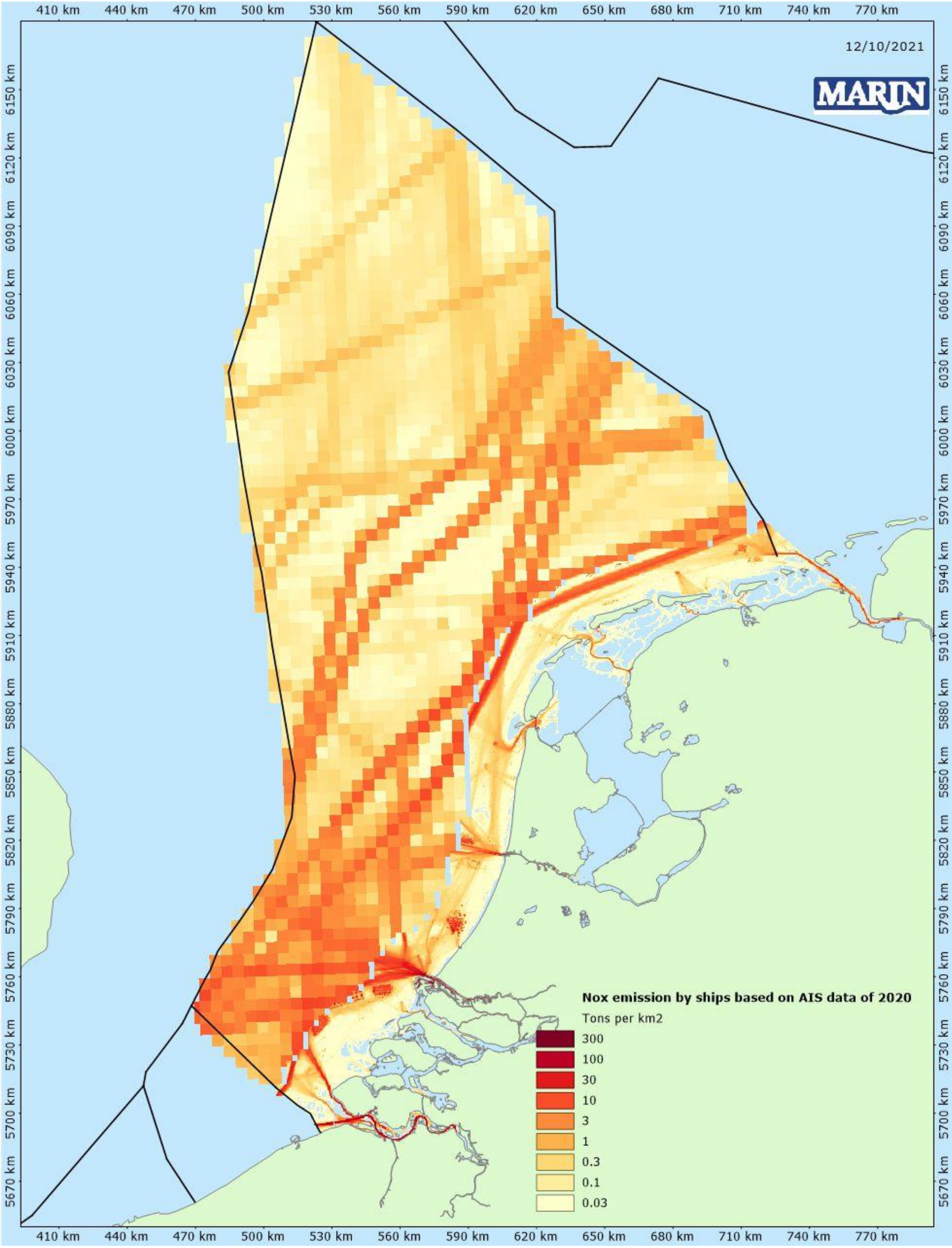

Figure 6-23 NO_x emission in 2020 in the NCS, the 12-mile zone and the Dutch port areas by ships with AIS.

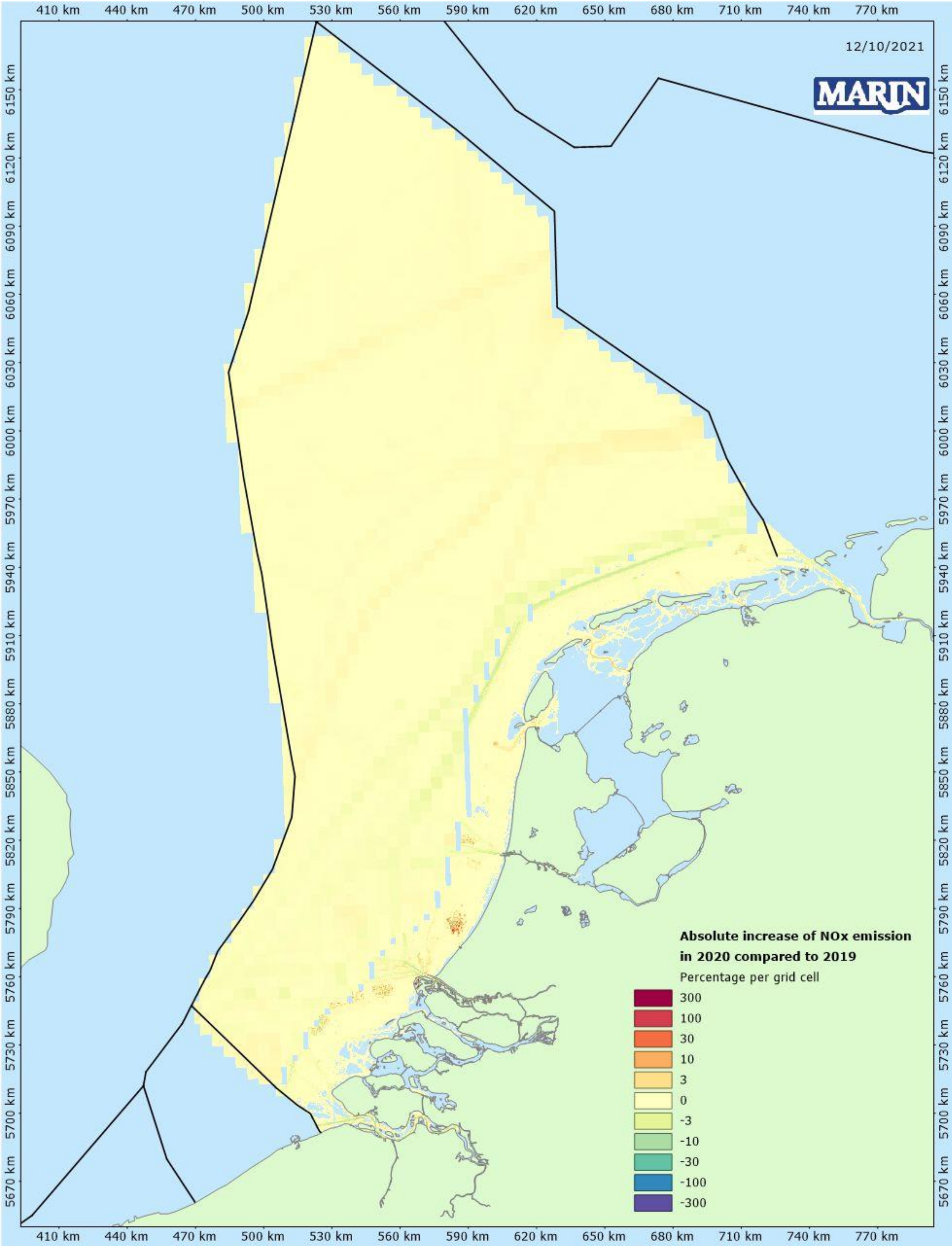

Figure 6-24 **Absolute change in NO_x emission from 2019 to 2020 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.**

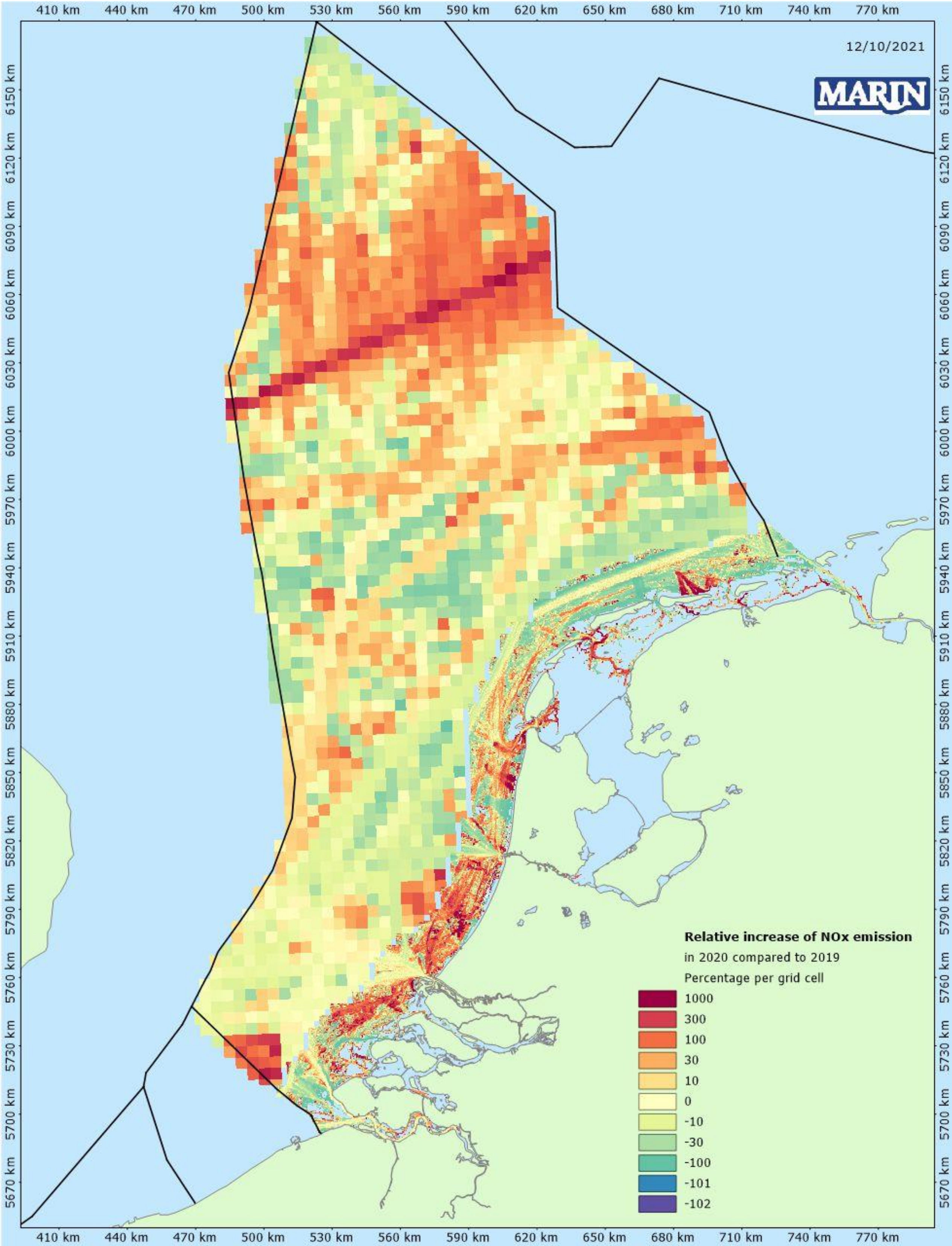

Figure 6-25 **Relative change in NO_x emission from 2019 to 2020 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.**

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 2020 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 2019. 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 2019. Figure 7-1 up to and including 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, Amsterdam and the WesternScheldt.

Compared to the previous year there is a clear increase of CO_2 emissions in the port of Rotterdam, for berthed and sailing ships together 23%. Except for the port of Den Helder, the total emissions of fishing vessels has increased compared to 2019. For all ports together, there is an increase of CO_2 emissions by 14 percent.

For the NCP and the 12-miles zone, the CO_2 emissions by fishing vessels increased by 37 percent, mainly caused by an increase of not moving ships by 75%. The increase of CO2 emissions by not moving ships may be related to the restrictive COVID-19 measures for fishing vessels, which prevented them from being operational.

Table 7-1 Total emissions in ton in each port area for 2020, fishing vessels including trawlers.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	5	3	6	1	2	7	0	24
	Sailing	2	0	1	1	1	5	2	11
	Total	6	3	7	1	4	12	2	35
4001 SO_2	Berthed	5	3	6	1	2	7	0	25
	Sailing	1	0	1	1	2	5	1	11
	Total	6	3	7	1	4	12	2	36
4013 NO_x	Berthed	113	68	152	13	55	163	8	573
	Sailing	32	5	23	17	35	115	31	258
	Total	145	73	175	30	91	279	39	831
4031 CO	Berthed	6	3	7	1	3	8	0	29
	Sailing	2	0	1	1	2	6	2	14
	Total	8	4	9	2	5	14	2	43
4032 CO_2	Berthed	7,677	4,905	9,422	949	3,914	11,617	533	39,017
	Sailing	2,036	322	1,424	1,205	2,392	8,101	2,219	17,698
	Total	9,713	5,227	10,845	2,154	6,306	19,718	2,752	56,715
6598 Aerosols MDO/HFO	Berthed	4	2	2	0	2	6	0	16
	Sailing	1	0	0	1	1	4	1	8
	Total	4	2	3	1	3	9	1	24

Table 7-2 **Emissions in each port area for 2020 as percentage of the emissions in 2019, fishing vessels including trawlers. The percentages in grey are based on very low absolute numbers, and not very reliable.**

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	119%	125%	112%	129%	90%	118%	174%	115%
	Sailing	137%	141%	114%	109%	132%	104%	114%	114%
	Total	123%	126%	112%	117%	103%	112%	124%	115%
4001 SO_2	Berthed	117%	121%	109%	128%	88%	115%	152%	112%
	Sailing	127%	139%	116%	106%	124%	102%	114%	111%
	Total	119%	122%	110%	115%	99%	109%	120%	112%
4013 NO_x	Berthed	119%	122%	113%	129%	89%	115%	158%	114%
	Sailing	131%	142%	121%	107%	130%	101%	115%	112%
	Total	121%	123%	114%	115%	101%	109%	121%	113%
4031 CO	Berthed	119%	126%	117%	128%	90%	118%	169%	116%
	Sailing	141%	147%	121%	108%	136%	107%	115%	117%
	Total	124%	127%	117%	116%	104%	113%	123%	116%
4032 CO_2	Berthed	120%	122%	120%	129%	88%	115%	151%	115%
	Sailing	128%	141%	126%	107%	123%	105%	114%	113%
	Total	121%	123%	120%	115%	99%	111%	120%	114%
6598 Aerosols MDO/HFO	Berthed	118%	119%	123%	130%	91%	118%	153%	115%
	Sailing	114%	129%	117%	107%	110%	109%	111%	110%
	Total	117%	119%	122%	115%	97%	114%	118%	114%

Table 7-3 Total emissions in ton in the 12 mile zone and the NCP for 2020, fishing vessels including trawlers.

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	4	1	5
	Sailing	23	64	87
	Total	27	65	92
4001 SO_2	Berthed	4	1	5
	Sailing	23	66	89
	Total	27	66	93
4013 NO_x	Berthed	108	15	123
	Sailing	519	1,531	2,051
	Total	627	1,547	2,174
4031 CO	Berthed	5	1	6
	Sailing	28	80	108
	Total	33	81	114
4032 CO_2	Berthed	6,346	997	7,343
	Sailing	36,079	102,305	138,384
	Total	42,426	103,302	145,727
6598 Aerosols MDO/HFO	Berthed	1	0	1
	Sailing	16	42	58
	Total	17	43	59

Table 7-4 Emissions in 12 miles and NCP for 2020 as percentage of the emissions in 2019, fishing vessels including trawlers. The percentages in grey are based on very low absolute numbers, and not very reliable.

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	162%	150%	160%
	Sailing	120%	138%	133%
	Total	125%	139%	134%
4001 SO_2	Berthed	166%	148%	163%
	Sailing	118%	138%	132%
	Total	124%	138%	134%
4013 NO_x	Berthed	176%	154%	173%
	Sailing	119%	140%	134%
	Total	126%	140%	136%
4031 CO	Berthed	177%	157%	174%
	Sailing	122%	143%	137%
	Total	128%	143%	139%
4032 CO_2	Berthed	180%	149%	175%
	Sailing	120%	142%	135%
	Total	126%	142%	137%
6598 Aerosols MDO/HFO	Berthed	98%	115%	102%
	Sailing	118%	136%	130%
	Total	117%	135%	130%

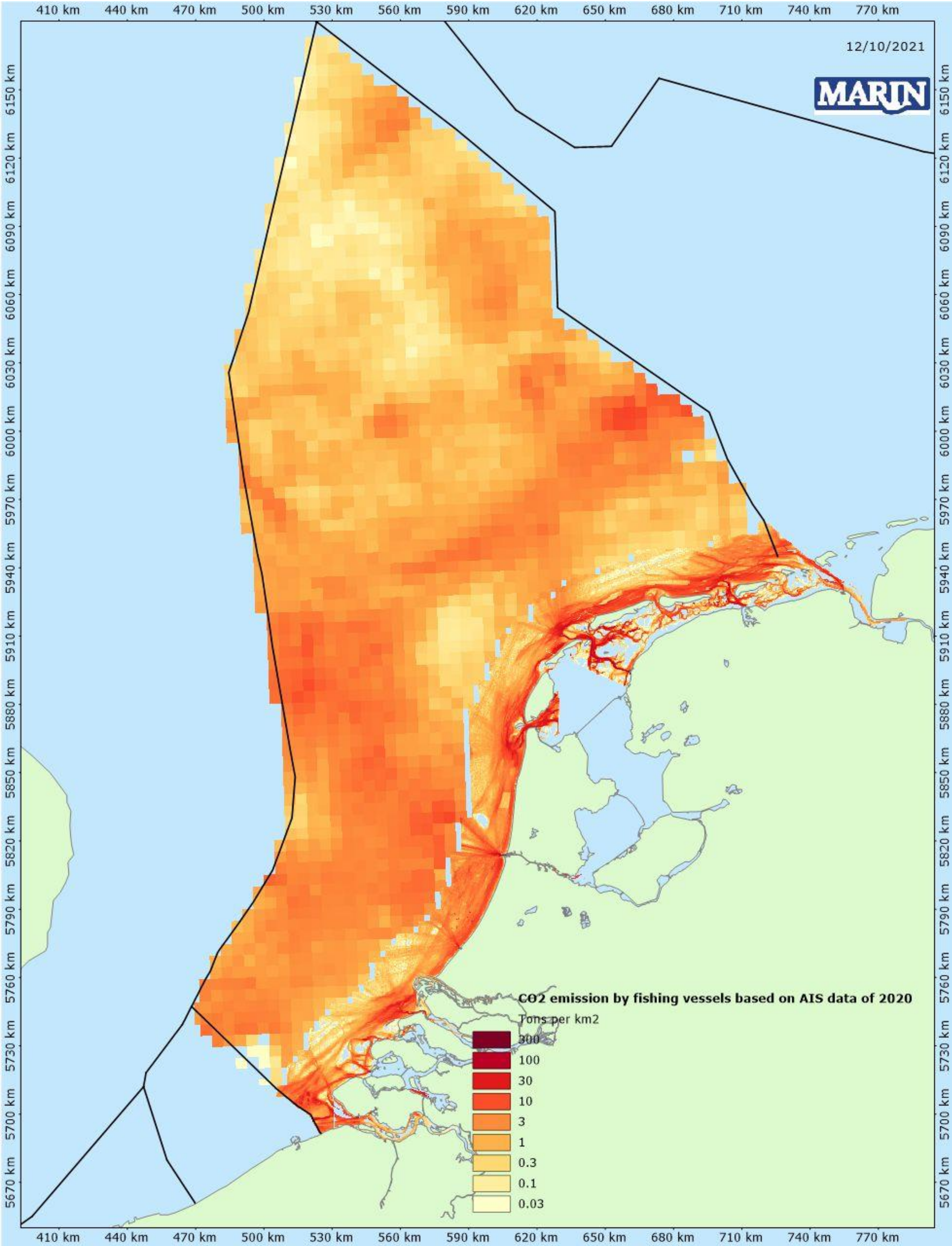

Figure 7-1 **CO_2 emission observed in the NCS, fishing vessels including trawlers, based on AIS-data of 2020**

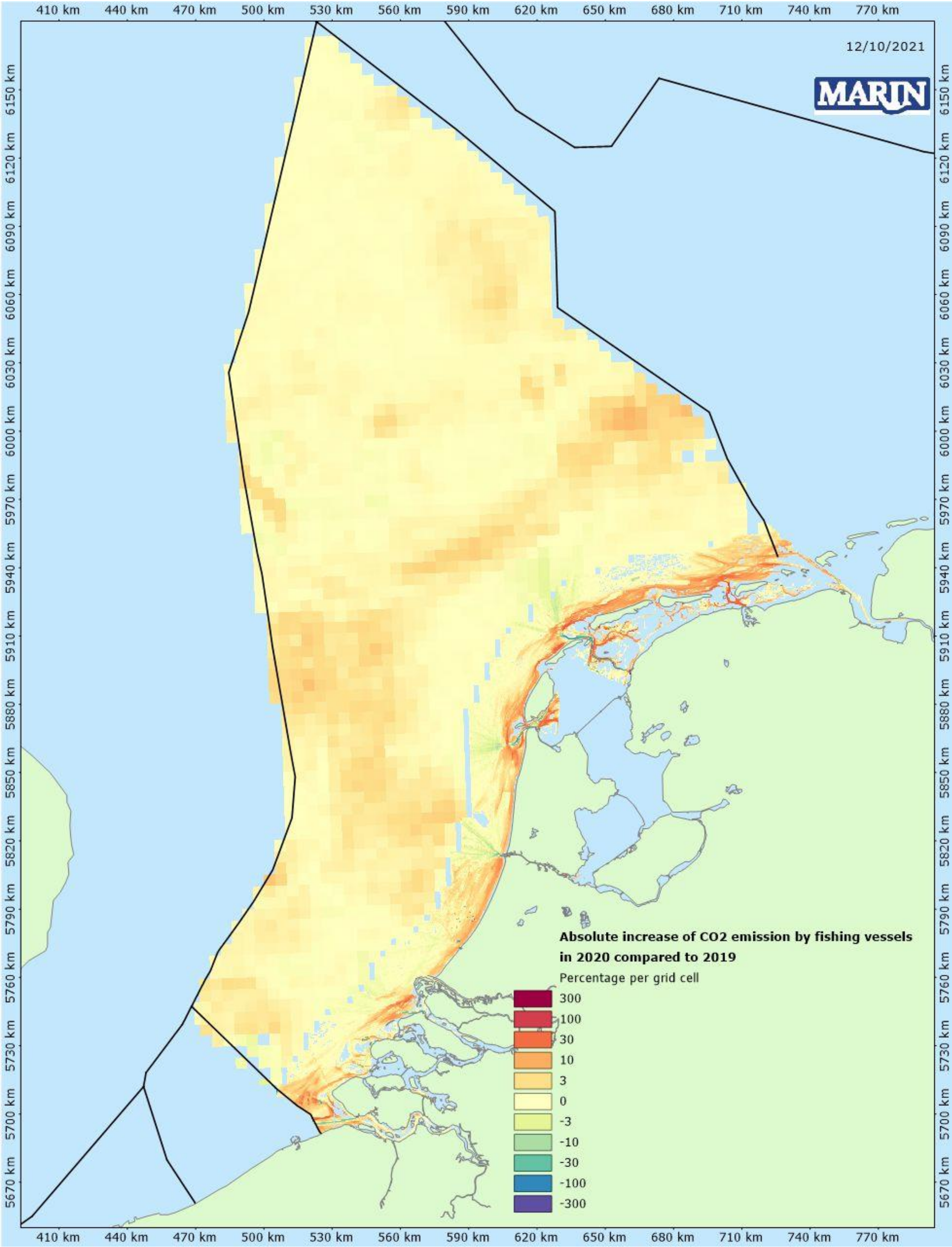

Figure 7-2 **Absolute change in CO2 emission from 2019 to 2020 observed in the NCS, fishing vessels including trawlers.**

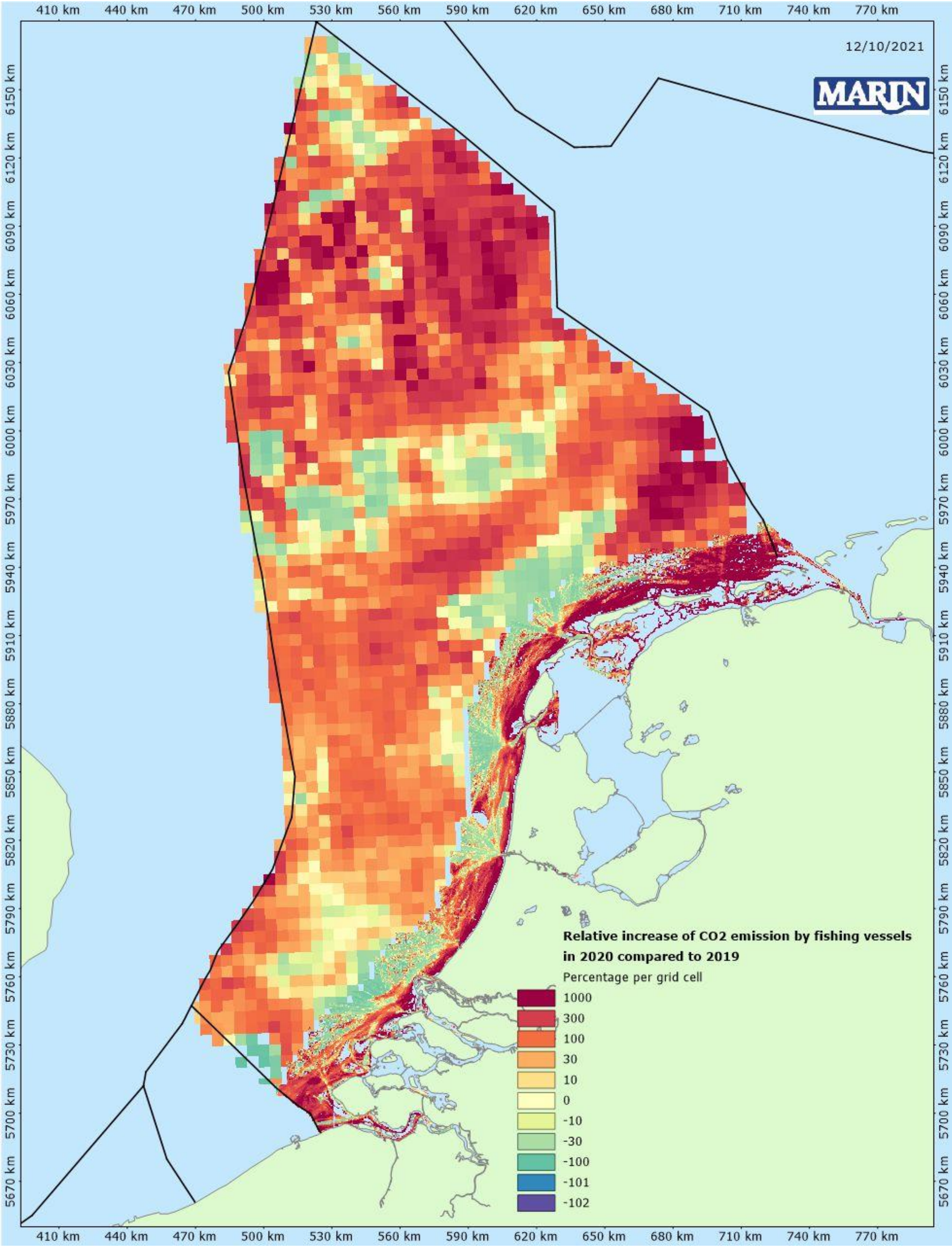

Figure 7-3 **Relative change in CO2 emission from 2019 to 2020 observed in the NCS, fishing vessels including trawlers.**

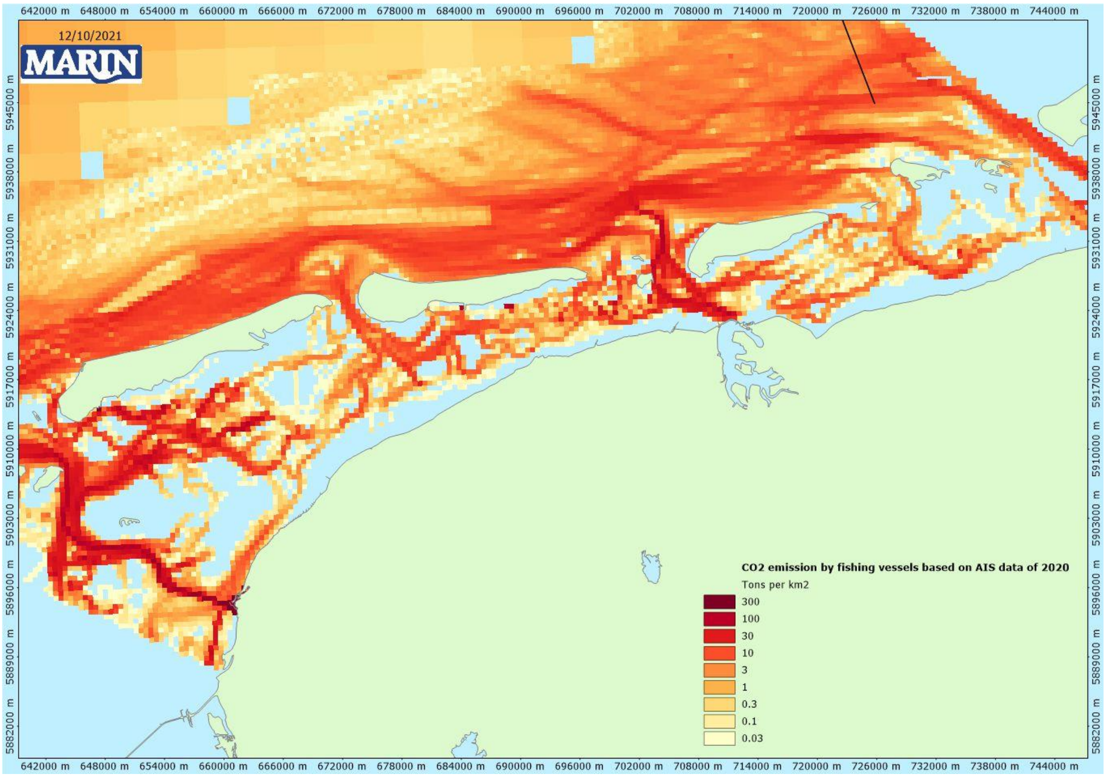

Figure 7-4 **CO_2 emission observed in the Dutch Wadden Sea, fishing vessels including trawlers, based on AIS-data of 2020**

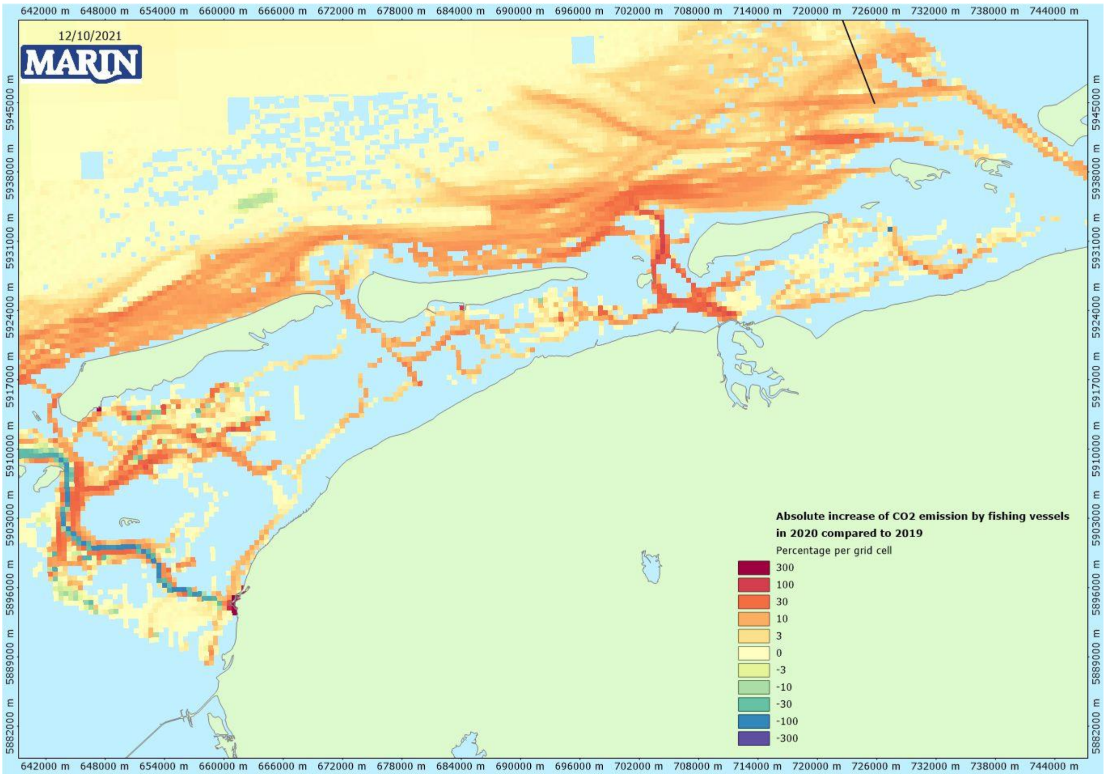

Figure 7-5 **Absolute change in CO2 emission from 2019 to 2020 in the Dutch Wadden Sea, fishing vessels including trawlers.**

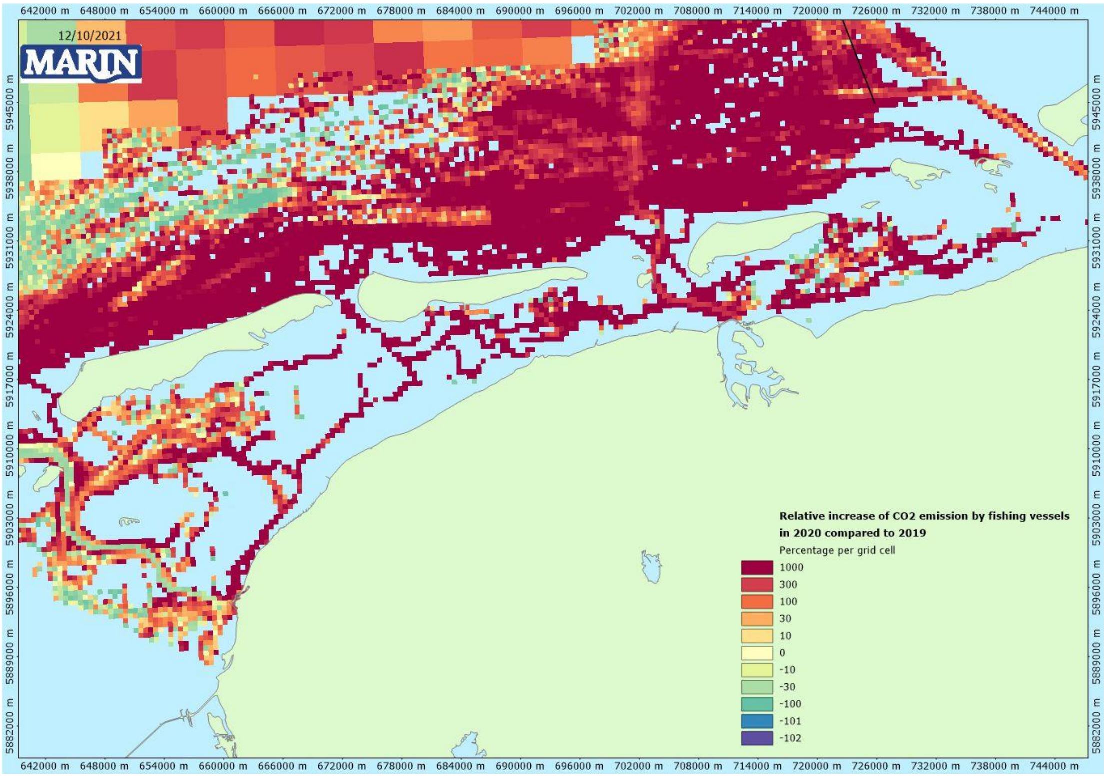

Figure 7-6 **Relative change in CO_2 emission from 2019 to 2020 in the Dutch Wadden Sea, fishing vessels including trawlers.**

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 about 28 minutes for 2020. The AIS-data is practically complete, so there is no need to compensate for this.

- **Activity data**
  Compared to 2019 there is a clear increase of berthed hours in the Dutch port areas except for the port of Ems. Moving activities (gross tonnage time’s nautical miles) decreased except for the port of Den Helder. This can also be seen in the average number of ships per day. For the NCS combined with 12-miles the average berthed GT hours increased with 14% and the total GT.nm for moving vessels decreased with 4.0%.

- **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 11%. Ships at berth have a total increase of CO_2 by 22% ,and the emission of sailing ships decreased by 6%. The increase in CO_2 emissions for ships at berth is mainly caused by not moving / anchored ships in the port of Rotterdam since this port has a significant influence in an absolute sense. For all ports together NO_x emissions increased and SO_2 emissions decreased compared to 2019.

  For NCS combined with the 12-miles zone there is a total decrease of CO_2 by 2%, a result of 19% increase for ships at anchor and 4% decrease for sailing ships. NO_x and SO_2 emissions also decreased since the previous registration in 2019. For the Netherlands sea area the average number of ships increased by 4%.

- **Emission results fishery**
  The absolute contribution of CO_2 emissions by fishing vessels is largest in Harlingen, Amsterdam and the WesternScheldt. Compared to the previous year there is a clear increase of CO_2 emissions in the port of Rotterdam, for berthed and sailing ships together 23%. Except for the port of Den Helder, the total emissions of fishing vessels has increased compared to 2019. For all ports together, there is an increase of CO_2 emissions by 14 percent.

  For NCS combined with the 12-miles zone, the CO_2 emissions by fishing vessels increased by 37 percent, mainly caused by an increase of not moving ships by 75%.

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APPENDIX A: EMISSION FACTORS

Written by Jan Hulskotte 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 language report [5] is available, which covers the emission calculations in accordance with the EMS protocols. 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 A1.2.

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-3/Table A-10)
CEF Correction factors of basic engine emission factors (Table A-12/Table A-14))
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)

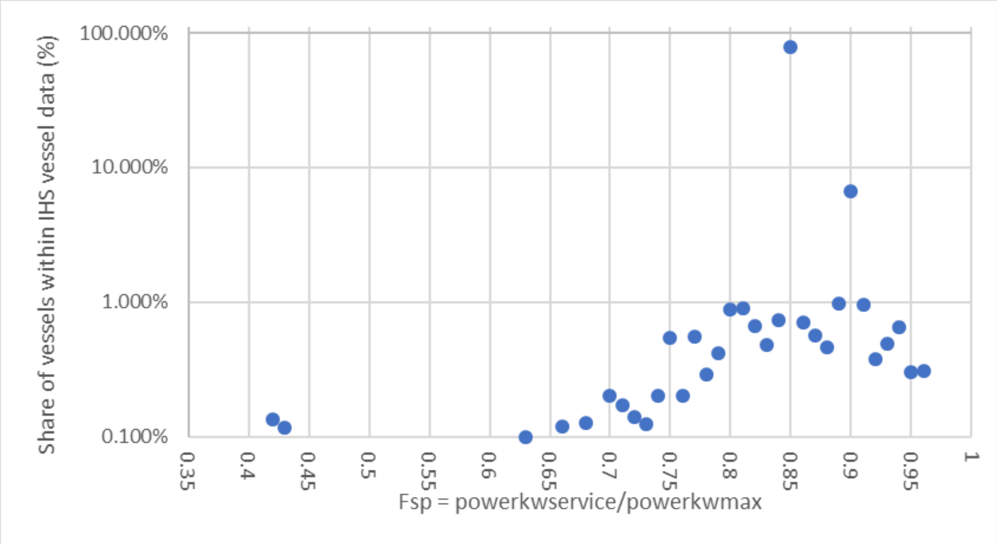

Figure A- 1 Statistics of the Sea-margin

Figure A-1 shows that of the majority of this 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. I a 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.

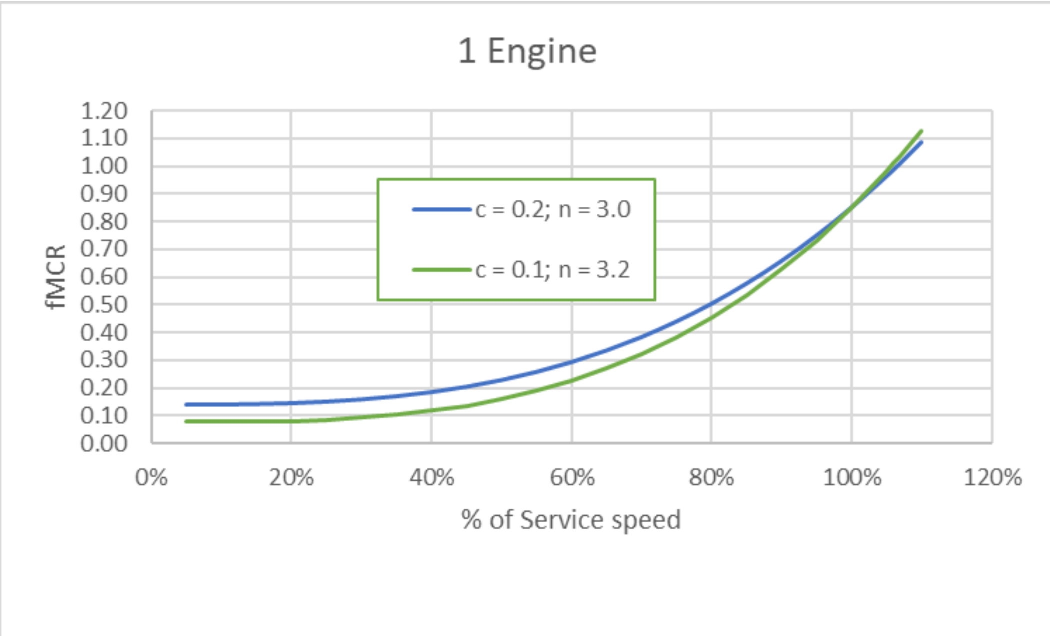

Figure A- 2 The relationship between service speed and fMCR at ships with one single propulsion engine used in emission calculations

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 will 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 consumptions 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-3 to A-6.

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.

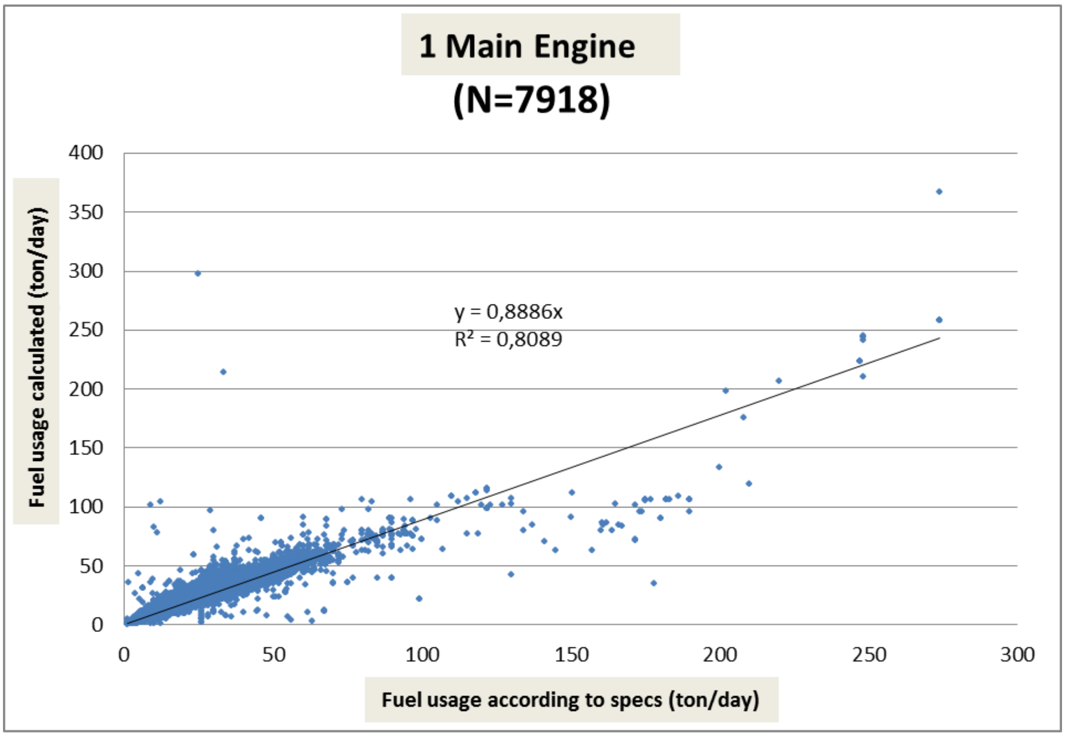

Figure A- 3 Calculated daily fuel usage of one-engine ships compared with specifications

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.

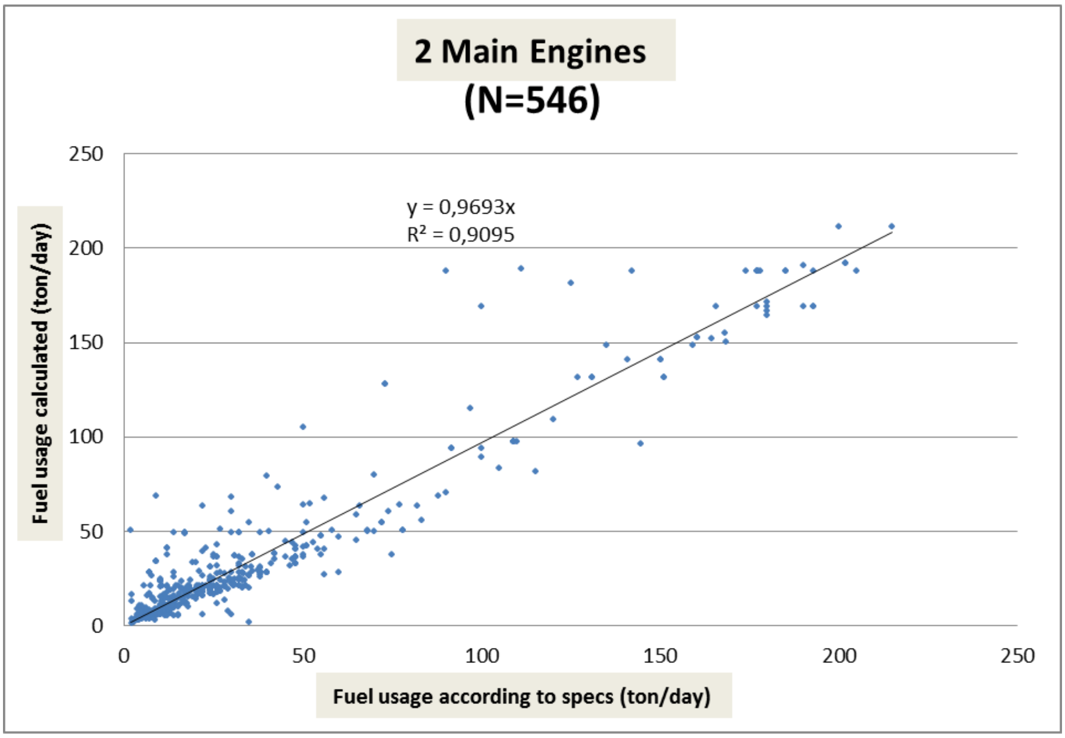

Figure A- 4 Calculated daily fuel usage of two engine ships compared with specifications

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-4 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.

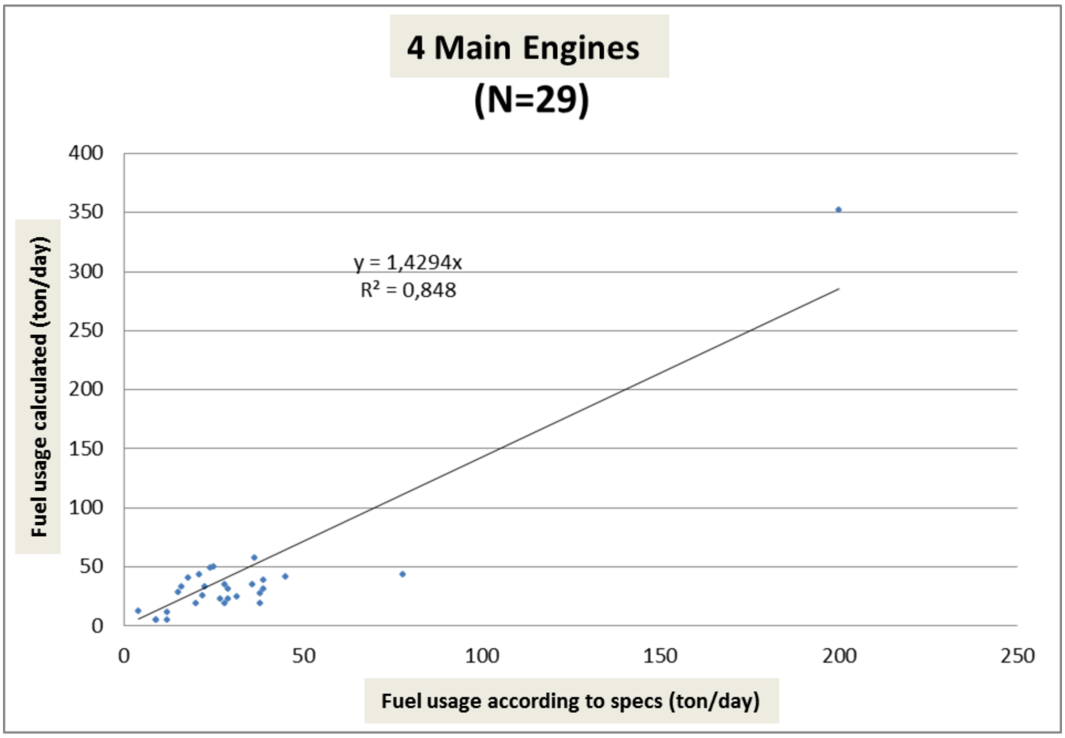

Figure A- 5 Calculated daily fuel usage of four engine ships compared with specifications

It can be argued that energy consumption of four engine 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 engine 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-3/Table A-10)
CEF Correction factors of basic engine emission factors (Table A12/Table A-14)
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 very little 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-3 to Table A-10 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 SO2 and CO2 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	1.52
Baltic sea	2	3.8	3.46	3.1	2.13	0.59	0.59
Calculated average S% North sea regions	0.15	0.15	0.17	0.15	0.13	0.114	0.114

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 0.13% for all areas. It can be concluded that compliance of sulphur legislation is very high 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 0.13% of HFO and MDO was assumed in all areas in 2019 (see table A-3). According to [12] the contribution of PM from sulphur was calculated as 8% of SO2 (calculated from S%): 0.08 * 0.13 * 20 = 0.208 g/kg fuel. For instance having a SFOC value of 210 g/kWh results in PM from sulphur alone in 210/1000 * 0.208 = 0.044 g/kWh. The PM emission factors in the tables below (table A3 – A10) 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[1]	PM-HFO Other[2]	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	~rpm[3]	0,34	0,34	0.50	0.50	0.3	0.5	533	168
2011 – 2018		0,23	0,23	0.50	0.50	0.3	0.5	524	165

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[1]	0,24	0,24	0.50	0.50	0.3	0.5	533	168
2011 – 2018		0,23	0,23	0.50	0.50	0.3	0.5	523	165

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

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[1] 9[2]	0,54	0,54	0.55	0.55	0.3	0.5	581	183
2011 - 2018	~rpm 7[2]	0,54	0,54	0.54	0.54	0.3	0.5	571	180

[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[1] 9[2]	0,24	0,24	0.55	0.55	0.3	0.5	581	183
2011 - 2018	~rpm[1] 7[2]	0,24	0,24	0.54	0.54	0.3	0.5	571	180

[2] applied on auxiliary engines only

Emission factors of CO were reduced by a factor of 4 according to [16]. Emission factors of PM and SO2 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 – 2018 (Tier II)	< 130 RPM	14.4	0.93 x 17.0
	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

The reduction factors for Tier I engines (0.87) and Tier II engines (0.93) 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

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

The methane (CH4) 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-11 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-11. 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 auxiliary engines are also presented in the same table A-12.

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-12 to Table A-14. 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			
10	1.2	1.21	1.34	1,74	1.63	4.46	5.22
15	1.15	1.18	1.17	1,52	1.32	2.74	3.51
20	1.1	1.15	1.1	1,36	1.19	2.02	2.66
25	1.07	1.13	1.06	1,3	1.12	1.65	2.14
30	1.06	1.11	1.04	1,32	1.08	1.42	1.8
35	1.05	1.09	1.03	1,34	1.05	1.27	1.56
40	1.045	1.07	1.02	1,34	1.03	1.16	1.38
45	1.035	1.05	1.01	1,32	1.01	1.09	1.23
50	1.03	1.04	1.00	1,3	1.01	1.03	1.12
55	1.025	1.03	1.00	1,27	1.00	1.00	1.06
60	1.015	1.02	0.99	1,23	1.00	0.98	1.00
65	1.01	1.01	0.99	1,13	0.99	0.95	0.94
70	1.00	1.01	0.98	1,01	0.99	0.92	0.88
75	1.00	1.00	0.98	0,95	0.98	0.89	0.82
80	1.01	1.00	0.97	0,95	0.98	0.87	0.76
85	1.02	1.00	0.97	0,95	0.97	0.84	0.7
90	1.03	1.01	0.97	0,95	0.97	0.85	0.7
95	1.04	1.02	0.97	0,95	0.97	0.86	0.7
100	1.05	1.02	0.97	0,95	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.

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 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- 16).

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-17 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 (%)

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-18 to Table A- 21, 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 – 2016	43	0.8	1.6	2,75

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 A1.2) 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	SO2	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
2015-2018	0.2	7	0.3	0.2	0.39	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 combined European fishing registers or the FIGIS-database managed by FAO.
As fuel, marine diesel with a sulphur content of 0.1% was assumed.

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