

Heavy lift vessels at berth

AERIUS emission factors Sif

TNO 2026 R16918 – 15 June 2026

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Copy number	2026-STL-RAP-100357727
Number of pages	16 (excl. front and back cover)
Number of appendices	0
Project name	Emissiegetallen AERIUS 2026
Project number	060.67566/01.02

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Summary

Heavy lift and transport vessels of different sizes frequently visit the premises of Sif Netherlands B.V. in the Port of Rotterdam. The environmental impact of the berthed vessels, in particular the emission of NO_x , is subject to permits. A reliable and accurate quantification of the actual emissions is therefore crucial from both the environmental and the business perspective. The default emission factors used by AERIUS, the tool that is used to estimate the NO_x emissions and distribution for the granting of permits, are based on the NO_x mass that is emitted according to the Dutch Pollutant Release and Transfer Register (PRTR). To that end, vessels are grouped into several size bins based on gross tonnage and the average emissions are used to define emission factors for these bins. Since the emissions of vessels strongly differ depending on, e.g., age and Tier-level, the emission factors of the size bins can be very different from the ones of individual vessels. The goal of the study described in this report was to determine more representative NO_x emission factors by applying the method of the Pollutant Release and Transfer Register to individual ships. The main deliverable is a table that provides adapted NO_x emission factors in kg/h that can be used as input for AERIUS. This document is based on an earlier report [1] and has been adapted for public publication.

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Abbreviations

$EF_{NO_x}^{[kg/h]}$	NO _x emissions in kg/h
$FC^{[kg/1000\ GT\cdot h]}$	Fuel Consumption at berth in kg/1000 GT·h
$FC^{[kg/h]}$	Fuel Consumption at berth in kg/h
FC	Fuel Consumption
GHG	GreenHouse Gas
PRTR	(Dutch) Pollutant Release and Transfer Register
SCR	Selective Catalytic Reduction (also used to refer to a catalytic converter applying this principle)
WFR	World Fleet Register

1 Introduction

The operation of combustion engines on board seagoing vessels in ports poses a relevant source of pollutant and greenhouse gas emissions. Several models for the estimation of the fuel consumption at berth have been developed. The work on the model used in the course of the Dutch Pollutant Release and Transfer Register (PRTR) was started in the early 2000s [2, 3, 4] and has been continuously improved since then. The development of formulae for fuel consumption at berth is described in [5]. The latest version of the model is described in Appendix A of [6]. It also forms the basis for the emission factors of AERIUS® [7], the software that is used to support the granting of permits under applicable environmental laws. Detailed information on the emission factors used by AERIUS can be found in [8, 9, 10]. Another relevant model is the one used by the International Maritime Organization in its Fourth Greenhouse Gas Study of 2020 [11]. Further research on emissions of seafaring vessels at berth can be found in [12, 13, 14, 15, 16, 17, 18, 19].

However, just like any model these models involve uncertainties. This is particularly true for heavy-lift and crane vessels for which operation profiles are diverse and data is scarce. In the PRTR, these vessels are categorised as "Tug/Supply" or "Other"¹. In AERIUS, there is no dedicated group for heavy lift vessels but the results of the ship types "Tug/Supply", "Miscellaneous", and "Non Merchant" are condensed into the main category "Hoofdgroep 6: Sleepboten, werkschepen en overige" [8, Tabel 1]. The NO_x emission factors² at berth for the size bins of this group are given in Table 1.1 below. Due to the varied nature and operations of the vessels in this group, the AERIUS emissions factors are likely not representative for the actual emissions of heavy lift vessels at berth.

Table 1.1: AERIUS emission factors for "Sleepboten, werkschepen en overige" in 2025 [20]

Category [-]	Size bin	GT range [-]	NO _x emission factor [kg/h]
SW100	1	100 – 1599	0.256
SW1600	2	1600 – 2999	1.235
SW3000	3	3000 – 4999	1.993
SW5000	4	5000 – 9999	3.323
SW10000	5	10000 – 29999	9.533
SW30000	6	30000 – 59000	20.284
SW60000	7	60000 – 99999	34.028
SW100000	8	≥ 100000	187.434

Sif Netherlands B.V. (hereinafter referred to as Sif) has commissioned TNO to investigate the actual NO_x emissions of heavy lift vessels that frequently visit its premises in the Port of Rotterdam. The goal of the study is to obtain a better understanding of the environmental impact of the vessels during their stay at berth and to compare it to the emission factors which the AERIUS calculation is based on. An overview of the vessels which are expected to dock at Sif is given in Table 1.2 below. In total, there are twenty-one vessels ranging from size bins 5 to

¹The category of the vessels listed in Table 1.2 has been verified by the TNO-colleagues involved in the Emission Inventory.

²The values in the table have been rounded to three decimal places. For any calculations the untruncated numbers were used.

8. The largest vessel has a gross tonnage of 187,987. The oldest was built in 1985, while some are still being built. IMO Tier-levels range from 0 to III. The ship type refers to the category used in the model of the Emission Inventory. The ship type is derived from the type code of the vessels as stated in the Lloyds database. The main difference between the two types "Tug/supply" and "Other" is the default value of fuel consumption at berth.

Table 1.2: Data of vessels visiting Sif

#	Vessel ID	GT	GT bin	Built	IMO NO _x Tier	Ship type
1	Vessel A	19848	5	2014	II	Tug/supply
2	Vessel B	10510	5	2018	II	Other
3	Vessel C	47617	6	2024	III	Other
4	Vessel D	15027	5	2008	I	Other
5	Vessel E	49091	6	2017	II	Other
6	Vessel F	49091	6	2019	II	Other
7	Vessel G	22313	5	2012	I	Tug/supply
8	Vessel H	58167	6	2023	III	Other
9	Vessel I	19533	5	2011	I	Other
10	Vessel J	14310	5	2003	I	Tug/supply
11	Vessel K	58203	6	2019	III	Other
12	Vessel L	117812	8	1987	0	Other
13	Vessel M	17854	5	2012	II	Tug/supply
14	Vessel N	67071	7	2023	III	Other
15	Vessel O	47426	6	2010	II	Tug/supply
16	Vessel P	187987	8	2019	III	Other
17	Vessel Q	136709	8	1985	0	Other
18	Vessel R	24586	5	2012	II	Other
19	Vessel S	34100	6	2025	III	Other
20	Vessel T	34100	6	2026	III	Other
21	Vessel U	34100	6	2027	III	Other

2 Methods

As already mentioned, the AERIUS [20] NO_x emission factors in kg/h are calculated from the PRTR based on the cumulated NO_x emission of the vessels of a size bin and their cumulated hours at berth. For the purpose of this study, the NO_x emission factors in kg/h according to the PRTR of the individual ships are calculated. They are obtained as the product of hourly fuel consumption at berth $FC^{[kg/h]}$, a correction factor based on year of build $f_{corr}^{[-]}$ ³, and a NO_x emission factor in g per kg of fuel $EF_{NO_x}^{[g/kg \text{ fuel}]}$:

$$EF_{NO_x}^{[kg/h]} = \underbrace{FC^{[kg/1000 \text{ GT} \cdot h]} \cdot \frac{GT}{1000}}_{=FC^{[kg/h]}} \cdot f_{corr}^{[-]} \cdot EF_{NO_x}^{[g/kg \text{ fuel}]} \quad (2.1)$$

The factor $FC^{[kg/1000 \text{ GT} \cdot h]}$ can be obtained from [6, Table A-17]. Together with the vessels' gross tonnage (1.2), $FC^{[kg/h]}$ can be calculated. The correction factors are stated in Table 2.1, and the NO_x emissions per fuel mass is given in [6, Table A-20].

Table 2.1: Correction factors for fuel consumption based on year of build

#	Year of Build	Tier-level	Correction factor
1	1900 - 1974	pre-Tier I	1.1842
2	1975 - 1979	pre-Tier I	1.1316
3	1980 - 1984	pre-Tier I	1.0789
4	1985 - 1989	pre-Tier I	1.0263
5	1990 - 1994	pre-Tier I	1.0000
6	1995 - 1999	pre-Tier I	0.9737
7	2000 - 2010	Tier I	0.9632
8	2011 - 2022	Tier II	0.9474
9	≥ 2023	Tier III	0.8631

The emission factors have to be multiplied by the time at berth to obtain the total emitted mass of NO_x. This method does not distinguish between the hours of a port call, i.e., the NO_x emission are assumed to be constant over the whole duration of a port call. In mathematical terms, there is only a gain but no offset of the modelled emissions. That means that it is assumed that there is no amount of NO_x that will be emitted independently of the duration of the port call. This could, for example, be the emissions related to loading/unloading operation that is done only once during the port call and which are therefore independent of the total time at berth. Discussing the pros and cons of the model assumptions was beyond the scope of the study at hand. The approach throughout the analysis was to derive emissions factors for the release of NO_x by ships at berth in kg/h that can be directly compared to the numbers used in AERIUS. The scope was limited to the Sif premises and the fleet that is expected to come there for loading/unloading.

³This factor has not been taken into account in [1].

3 Results

This section contains the results of the calculations which have been described in the previous section. The determined NO_x emission factors for the fleet expected at the premises of Sif are summarized in column **NO_x [kg/h] (TNO)** of Table 3.1. For each of the twenty-one vessels, ID, Tier-level, relevant AERIUS emission, and the determined emission factor are given.

Table 3.1: Derived NO_x emission factors of vessels visiting SIF

#	Vessel ID	IMO Tier	NO _x [kg/h] (AERIUS) 2025	NO _x [kg/h] (TNO)
1	Vessel A	II	9.533	12.614
2	Vessel B	II	9.533	3.939
3	Vessel C	III	20.284	4.844
4	Vessel D	I	9.533	6.658
5	Vessel E	II	20.284	18.399
6	Vessel F	II	20.284	18.399
7	Vessel G	I	9.533	14.180
8	Vessel H	III	20.284	5.917
9	Vessel I	I	9.533	7.321
10	Vessel J	I	9.533	10.751
11	Vessel K	III	20.284	6.499
12	Vessel L	0	187.434	91.215
13	Vessel M	II	9.533	11.347
14	Vessel N	III	34.028	6.822
15	Vessel O	II	20.284	35.631
16	Vessel P	III	187.434	20.989
17	Vessel Q	0	187.434	105.846
18	Vessel R	II	9.533	9.215
19	Vessel S	III	20.284	3.469
20	Vessel T	III	20.284	3.469
21	Vessel U	III	20.284	3.469

For sixteen vessels, the study yielded lower or equal emission factors than the ones used by AERIUS. The results of Table 3.1 for the two ship types "Tug/supply" and "Other" are illustrated in Figures 3.1 and 3.2, respectively. In both figures, NO_x emissions in kg/h are plotted versus the gross tonnage. The AERIUS emission factors are depicted as blue line. The relevant size bins for this study are labelled. Furthermore, the emission factors for the different Tier levels as a function of GT as obtained by using the PRTR method are plotted. The dots refer to the results of the individual vessels listed in Table 3.1, their colors correspond to the applicable Tier level. Violet dots represent pre-Tier ships.

Referring to the ship type "Tug/supply" in Figure 3.1, it becomes clear that the individual emission factors for Tier III vessels of any size are lower than the fleet average represented in AERIUS. For Tier I and Tier II, the individual NO_x emission factors are higher than the AERIUS

emission factor, except for narrow GT-ranges at the low end and the whole of size bin 8.

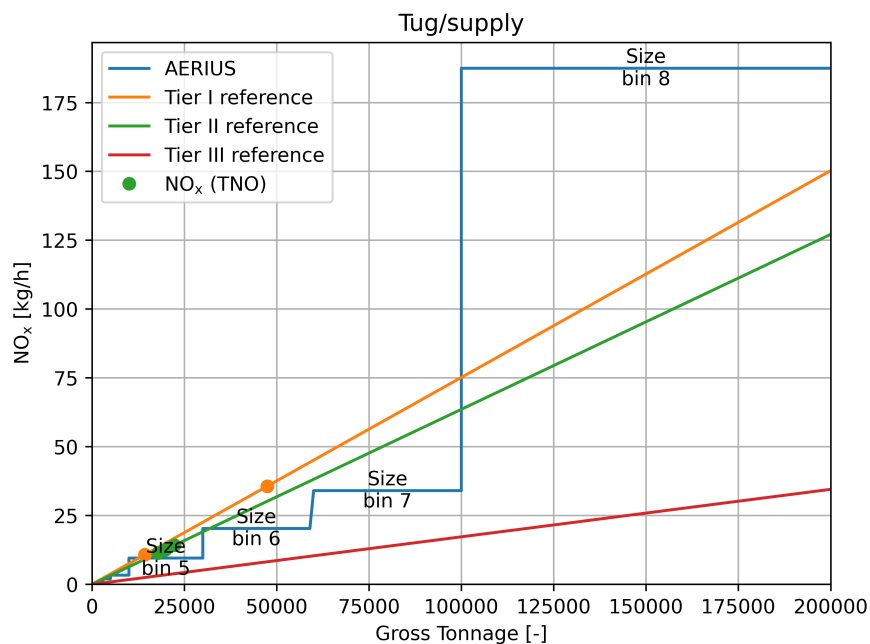


Figure 3.1: Illustration of NO_x (TNO) and AERIUS emission factors for ship type "Tug/supply"

The situation for the ship type "Other" plotted in Figure 3.2 is similar. However, due to the lower default fuel consumption of this category, the individual ships have lower NO_x emission factors for "Other" compared to "Tug/supply". As a consequence, all sizes of Tier III ships but also wide GT-ranges of Tier I and Tier II yield lower hourly emissions of NO_x than AERIUS. Also the two large pre-Tier vessels included in the study – vessels L and Q – which are depicted as violet dots show lower emissions compared to the default values for size bin 8.

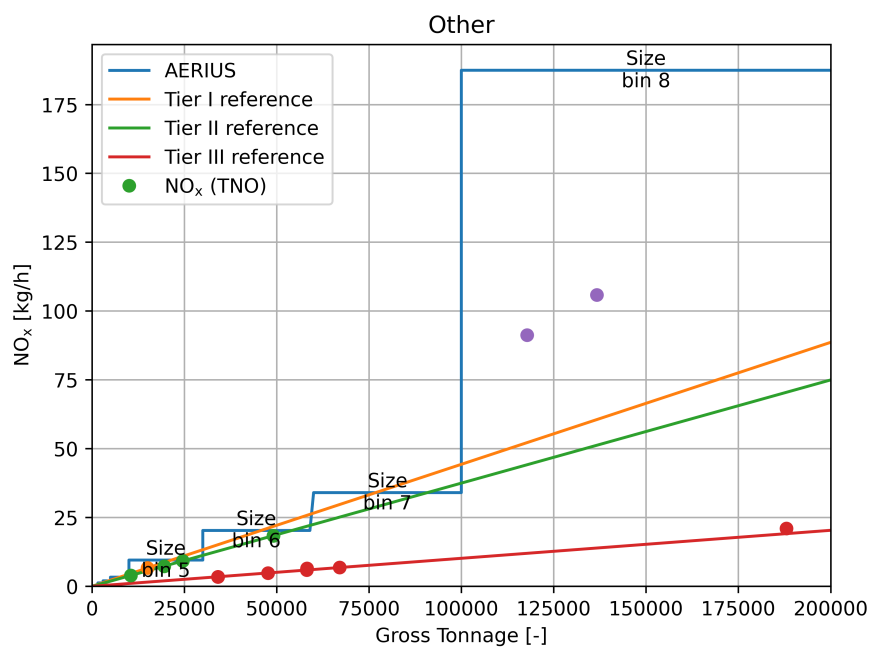


Figure 3.2: Illustration of NO_x (TNO) and AERIUS emission factors for ship type "Other"

4 Conclusion

The goal of the study at hand was to determine NO_x emission factors in kg/h which better represent the fleet that frequently visits the premises of Sif in the Port of Rotterdam than the default emission factors used in AERIUS. Based on ship type, gross tonnage, and year of build, emission factors were determined for twenty-one vessels. The results illustrated in Figures 3.1 and 3.2 point out the effect the different Tier-levels have on the modelled NO_x emission factors. Tier III yields particularly low values compared to AERIUS.

For the majority of the vessels, the determined factors are lower than the values used in AERIUS. There are three possible causes for differences between the derived numbers and AERIUS:

1. The gross tonnage differs from the average of the fleet grouped into a size bin.
2. The year of build differs from the average of the fleet grouped into a size bin.
3. The vessel's NO_x emission factor per fuel mass is different to the the average of the fleet bin which the AERIUS factor is based on.

Of course, more than one might apply for a given vessel. The effects can either act in the same direction (towards lower or higher NO_x emissions) or (partially) cancel out. The numbers provided in Table 3.1 are intended to be used as input for AERIUS calculations. The estimated hours at berth per ship will yield the expected emissions of vessels berthed at Sif.

The AERIUS emission factors and the derived ones listed in the rightmost column of Table 3.1 were obtained by using the same approach. The only difference is that for the latter individual vessels instead of the fleet in a size bin were considered. Furthermore, the vessels used for transport and installation of components of offshore wind turbines are rather special and the "Hoofdgroep 6: Sleepboten, werkschepen en overige" is rather diverse. This is an additional source of uncertainty when using the AERIUS-factors. Finally, considering individual vessels rather than the average of a size bin allows for the inclusion of the positive effects of higher environmental standards like, for example, Tier III.

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Signature

TNO › Mobility & Built Environment › Den Haag › 15 June 2026

ValidSigned door Fieke Beemster
op 21-07-2026

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