# 1.A.3.d ii - National Navigation

## Short description

Under category *1.A.3.d ii - National Navigation* emissions from national navigation (both inland and maritime) are reported.

| Category Code | Method | | | | | AD | | | | | EF | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.3.d ii | T1, T2, T3 | | | | | NS, M | | | | | CS, D, M | | | | |
| | **$NO_x$** | **NMVOC** | **$SO_2$** | **$NH_3$** | **$PM_{2.5}$** | **$PM_{10}$** | **TSP** | **BC** | **CO** | **PB** | **Cd** | **Hg** | **Diox** | **PAH** | **HCB** |
| Key Category: | L/- | -/- | -/- | -/- | L/T | -/T | -/- | -/- | -/- | -/- | -/- | -/- | -/- | -/- | -/- |

**T** = key source by Trend **L** = key source by Level

| Methods | |
|---|---|
| **D** | Default |
| **T1** | Tier 1 / Simple Methodology * |
| **T2** | Tier 2* |
| **T3** | Tier 3 / Detailed Methodology * |
| **C** | CORINAIR |
| **CS** | Country Specific |
| **M** | Model |
| * as described in the EMEP/EEA Emission Inventory Guidebook - 2019, in the group specific chapters. | |

| AD - Data Source for Activity Data | |
|---|---|
| **NS** | National Statistics |
| **RS** | Regional Statistics |
| **IS** | International Statistics |
| **PS** | Plant Specific data |
| **As** | Associations, business organisations |
| **Q** | specific Questionnaires (or surveys) |
| **M** | Model / Modelled |
| **C** | Confidential |

| EF - Emission Factors | |
|---|---|
| **D** | Default (EMEP Guidebook) |
| **C** | Confidential |
| **CS** | Country Specific |
| **PS** | Plant Specific data |
| **M** | Model / Modelled |

## Methodology

### Activity data

As described for the over-all sector 1.A.3.d and all other navigational activities in the superordinate chapter, specific fuel consumption data for NFR 1.A.3.d ii is included in the primary fuel deliveries data provided in NEB lines 6 ('International Maritime Bunkers') and 64 ('Coastal and Inland Navigation') [1)].

Here, the annual fuel consumption for domestic *maritime* navigation are modelled within [2)] based on AIS data and deduced from NEB lines 6 and 64 respectively, depending on whether or not a certain ship is registered by the International Maritime Organization (IMO). Here, fuels consumed by large, IMO-registered and sea-going ships and vessels are included in NEB line 6 whereas fuels consumed by smaller ships without IMO-registration are included in NEB line 64. After these deductions, the amounts of fuels remaining in NEB 64 are allocated to domestic *inland* navigation.

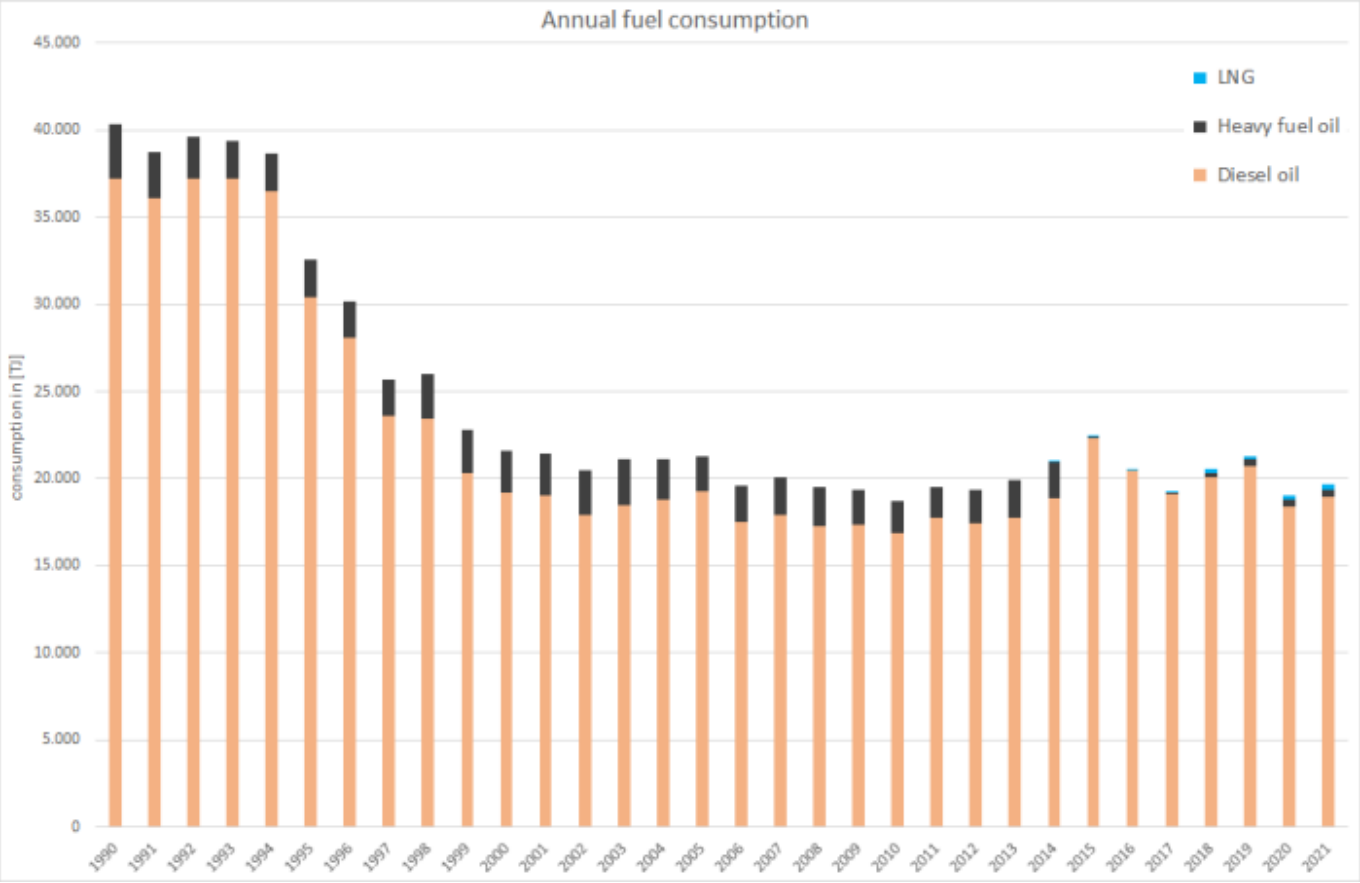
The small amounts of LNG used almost entirely in ferries are not yet included in the NEB but are estimated directly in the BSH model.

Table 1: Annual over-all fuel consumption for domestic navigation, in terajoule

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Diesel Oil** | 37,199 | 30,389 | 19,231 | 19,250 | 16,872 | 17,719 | 17,411 | 17,768 | 18,878 | 22,301 | 20,466 | 19,110 | 20,064 | 20,756 | 18,416 | 18,955 |
| **Heavy fuel oil** | 3,103 | 2,186 | 2,382 | 2,054 | 1,810 | 1,790 | 1,932 | 2,134 | 2,057 | 108 | 37,0 | 81,1 | 262 | 394 | 368 | 392 |
| **LNG** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 22 | 64 | 59 | 197 | 153 | 276 | 293 |
| **Σ 1.A.3.d ii** | **40,303** | **32,575** | **21,613** | **21,304** | **18,682** | **19,509** | **19,343** | **19,902** | **20,952** | **22,431** | **20,567** | **19,250** | **20,524** | **21,303** | **19,060** | **19,640** |

Table 2: Specific fuel consumption data for domestic maritime and inland navigation, in terajoule

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **NATIONAL MARITIME NAVIGATION** | | | | | | | | | | | | | | | | |
| **Diesel Oil** | 9,484 | 6,828 | 7,367 | 6,399 | 5,690 | 5,669 | 6,089 | 6,133 | 6,766 | 8,980 | 9,335 | 8,960 | 9,445 | 9,497 | 8,339 | 8,475 |
| **Heavy fuel oil** | 3,103 | 2,186 | 2,382 | 2,054 | 1,810 | 1,790 | 1,932 | 2,134 | 2,057 | 108,0 | 37,0 | 81,1 | 262 | 394 | 368 | 392 |
| **LNG** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 22 | 64 | 59 | 197 | 153 | 276 | 293 |
| **NATIONAL INLAND NAVIGATION** | | | | | | | | | | | | | | | | |
| **Diesel Oil** | 27,716 | 23,562 | 11,864 | 12,851 | 11,182 | 12,050 | 11,322 | 11,635 | 12,112 | 13,321 | 11,131 | 10,150 | 10,619 | 11,259 | 10,076 | 10,481 |
| **Σ 1.A.3.d ii** | **40,303** | **32,575** | **21,613** | **21,304** | **18,682** | **19,509** | **19,343** | **19,902** | **20,952** | **22,431** | **20,567** | **19,250** | **20,524** | **21,303** | **19,060** | **19,640** |




## Emission factors

The emission factors applied for **national maritime navigation** are derived from different sources and therefore are of very different quality.

For the main pollutants, country-specific implied values are used, that are based on tier3 EF included in the BSH model [3)] which mainly relate on values from the EMEP/EEA guidebook 2019 [4)]. These modelled IEFs take into account the ship specific

information derived from AIS data as well as the mix of fuel-qualities applied depending on the type of ship and the current state of activity.

Here, for **sulphur dioxide** and **particulate matter**, annual values are available representing the impact of fuel sulphur legislation. In addition, regarding $_2$, the increasing operation of so-called scrubbers in order to fullfil emission limits especially within SECA areas is reflected for heavy fuel oil.

Table 3: Country-specific emission factors applied for fuels used in domestic maritime navigation, in [kg/TJ]

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DIESEL OIL** | | | | | | | | | | | | | | | | |
| **$NH_3$** | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| **NMVOC** | 48.5 | 48.4 | 48.4 | 48.4 | 48.4 | 48.4 | 48.4 | 47.7 | 44.9 | 44.4 | 43.9 | 44.2 | 43.8 | 44.0 | 44.0 | 42.1 |
| **$NO_x$** | 1,101 | 1,101 | 1,101 | 1,101 | 1,101 | 1,101 | 1,119 | 1,126 | 1,155 | 1,184 | 1,183 | 1,189 | 1,200 | 1,199 | 1,169 | 1,194 |
| **$SO_2$** | 466 | 419 | 233 | 186 | 69.8 | 65.2 | 54.8 | 52.9 | 51.1 | 37.2 | 37.2 | 37.2 | 37.2 | 37.2 | 37.2 | 37.2 |
| **BC[1]** | 110 | 99.1 | 55.0 | 44.0 | 16.5 | 15.5 | 15.4 | 15.3 | 15.3 | 17.4 | 17.7 | 17.7 | 17.3 | 17.5 | 16.8 | 16.9 |
| **$PM_{2.5}$** | 354 | 320 | 177 | 142 | 53.3 | 49.9 | 49.8 | 49.3 | 49.4 | 56.2 | 57.1 | 57.1 | 55.9 | 56.5 | 54.2 | 54.6 |
| **$PM_{10}$** | 378 | 342 | 190 | 152 | 57.1 | 53.4 | 53.3 | 52.7 | 52.9 | 60.1 | 61.1 | 61.1 | 59.8 | 60.4 | 58.0 | 58.5 |
| **TSP[2]** | 378 | 342 | 190 | 152 | 57.1 | 53.4 | 53.3 | 52.7 | 52.9 | 60.1 | 61.1 | 61.1 | 59.8 | 60.4 | 58.0 | 58.5 |
| **CO** | 128 | 128 | 128 | 128 | 128 | 129 | 128 | 128 | 130 | 140 | 142 | 141 | 139 | 140 | 138 | 140 |
| **HEAVY FUEL OIL** | | | | | | | | | | | | | | | | |
| **$NH_3$** | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| **NMVOC** | 43.0 | 42.8 | 42.9 | 42.9 | 42.8 | 42.7 | 42.8 | 41.6 | 42.3 | 26.1 | 30.2 | 33.7 | 32.5 | 32.7 | 37.4 | 37.5 |
| **$NO_x$** | 1,368 | 1,368 | 1,368 | 1,368 | 1,368 | 1,367 | 1,367 | 1,384 | 1,433 | 1,487 | 1,440 | 1,479 | 1,480 | 1,507 | 1,509 | 1,526 |
| **$SO_x$** | 1,319 | 1,332 | 1,323 | 1,336 | 496 | 496 | 496 | 495 | 506 | 48.6 | 49.2 | 48.1 | 45.9 | 46.5 | 48.1 | 47.0 |
| **BC[1]** | 70.8 | 71.2 | 70.8 | 71.6 | 26.5 | 26.5 | 26.5 | 25.6 | 25.6 | 14.2 | 18.0 | 20.1 | 19.1 | 18.9 | 21.4 | 21.3 |
| **$PM_{2.5}$** | 590 | 594 | 590 | 596 | 221 | 221 | 221 | 213 | 213 | 118 | 150 | 168 | 159 | 158 | 179 | 178 |
| **$PM_{10}$** | 649 | 653 | 649 | 656 | 243 | 243 | 243 | 234 | 235 | 130 | 165 | 184 | 175 | 173 | 197 | 195 |
| **TSP[2]** | 649 | 653 | 649 | 656 | 243 | 243 | 243 | 234 | 235 | 130 | 165 | 184 | 175 | 173 | 197 | 195 |
| **CO** | 179 | 179 | 179 | 179 | 179 | 179 | 179 | 175 | 173 | 144 | 162 | 157 | 156 | 150 | 151 | 147 |

[1] estimated from f-BCs as provided in [5)]: f-BC (HFO) = 0.12, f-BC (MDO/MGO) = 0.31 as provided in [6)], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2
[2] ratio of $PM_{2.5}$ : $PM_{10}$ : TSP derived from the tier1 default EF as provided in [7)], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2

For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For main pollutants and particulate matter from **national inland navigation**, modelled emission factors are available from TREMOD (Knörr et al. (2022a)) [8)]. Here, for *$SO_2$*, and *PM*, annual values reflect the impact of fuel-sulphur legislation.

Table 4: Country-specific emission factors for diesel fuels used in domestic inland navigation, in [kg/TJ]

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$NH_3$** | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| **NMVOC** | 96.4 | 87.9 | 77.7 | 72.3 | 67.1 | 66.0 | 64.7 | 63.7 | 62.7 | 61.5 | 60.6 | 59.7 | 58.7 | 58.0 | 57.1 | 56.4 |
| **$NO_x$** | 1,327 | 1,331 | 1,336 | 1,289 | 1,234 | 1,225 | 1,212 | 1,201 | 1,190 | 1,177 | 1,166 | 1,154 | 1,143 | 1,134 | 1,123 | 1,114 |
| **$SO_x$** | 85.2 | 60.5 | 60.5 | 60.5 | 60.5 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |
| **BC[1]** | 17.5 | 16.0 | 14.1 | 11.8 | 9.29 | 9.09 | 8.84 | 8.63 | 8.45 | 8.24 | 8.08 | 7.91 | 7.74 | 7.62 | 7.47 | 7.35 |
| **PM[2]** | 56.5 | 51.7 | 45.6 | 38.1 | 30.0 | 29.3 | 28.5 | 27.8 | 27.3 | 26.6 | 26.1 | 25.5 | 25.0 | 24.6 | 24.1 | 23.7 |
| **CO** | 417 | 387 | 337 | 299 | 259 | 254 | 248 | 242 | 237 | 232 | 227 | 223 | 218 | 215 | 210 | 207 |

[1] calculated from f-BC as provided in [9)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii, Table 3-2: f-BC (MDO/MGO) = 0.31
[2] EF($PM_{2.5}$) also applied for $PM_{10}$ and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [1)]

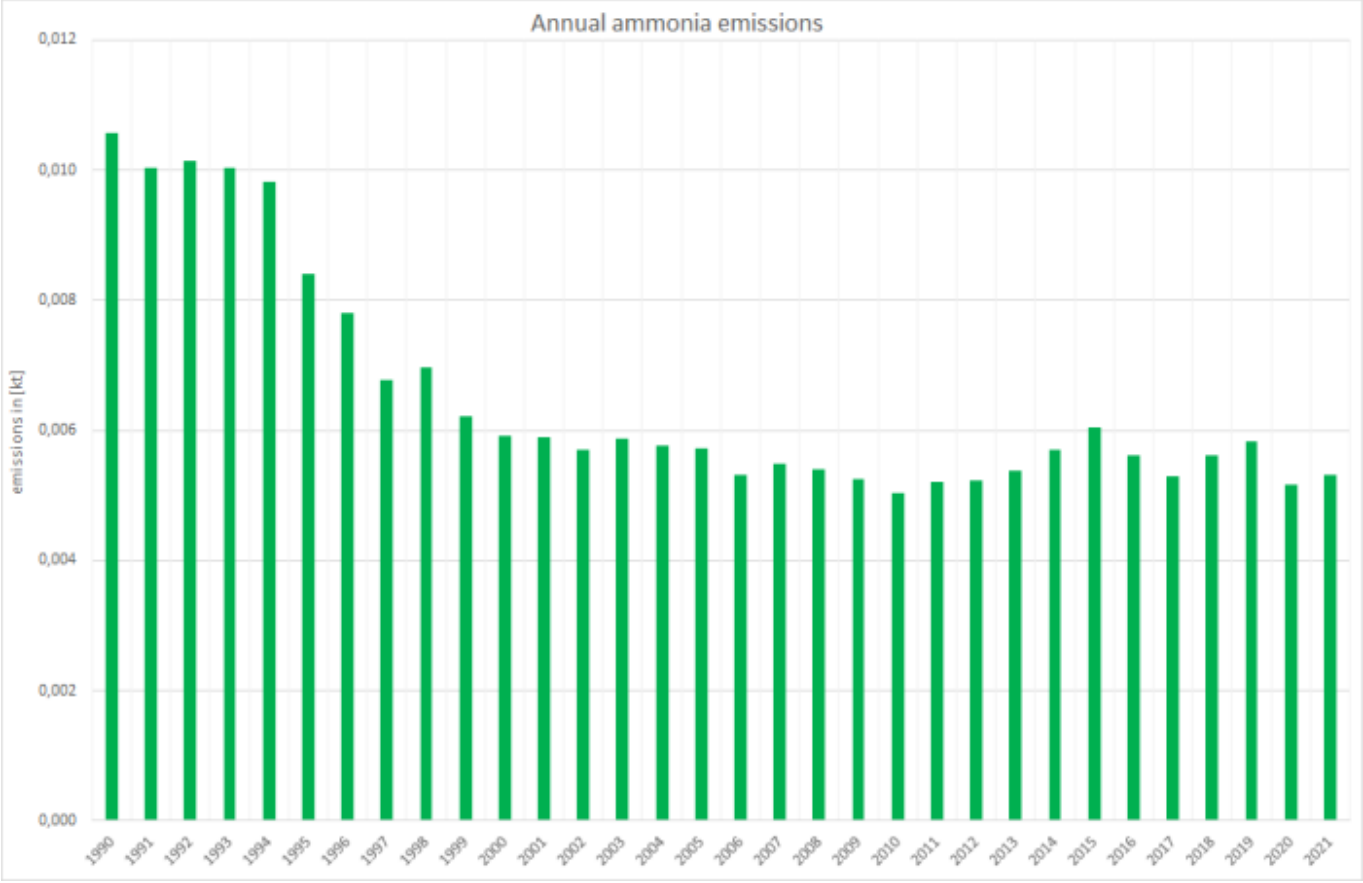
For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

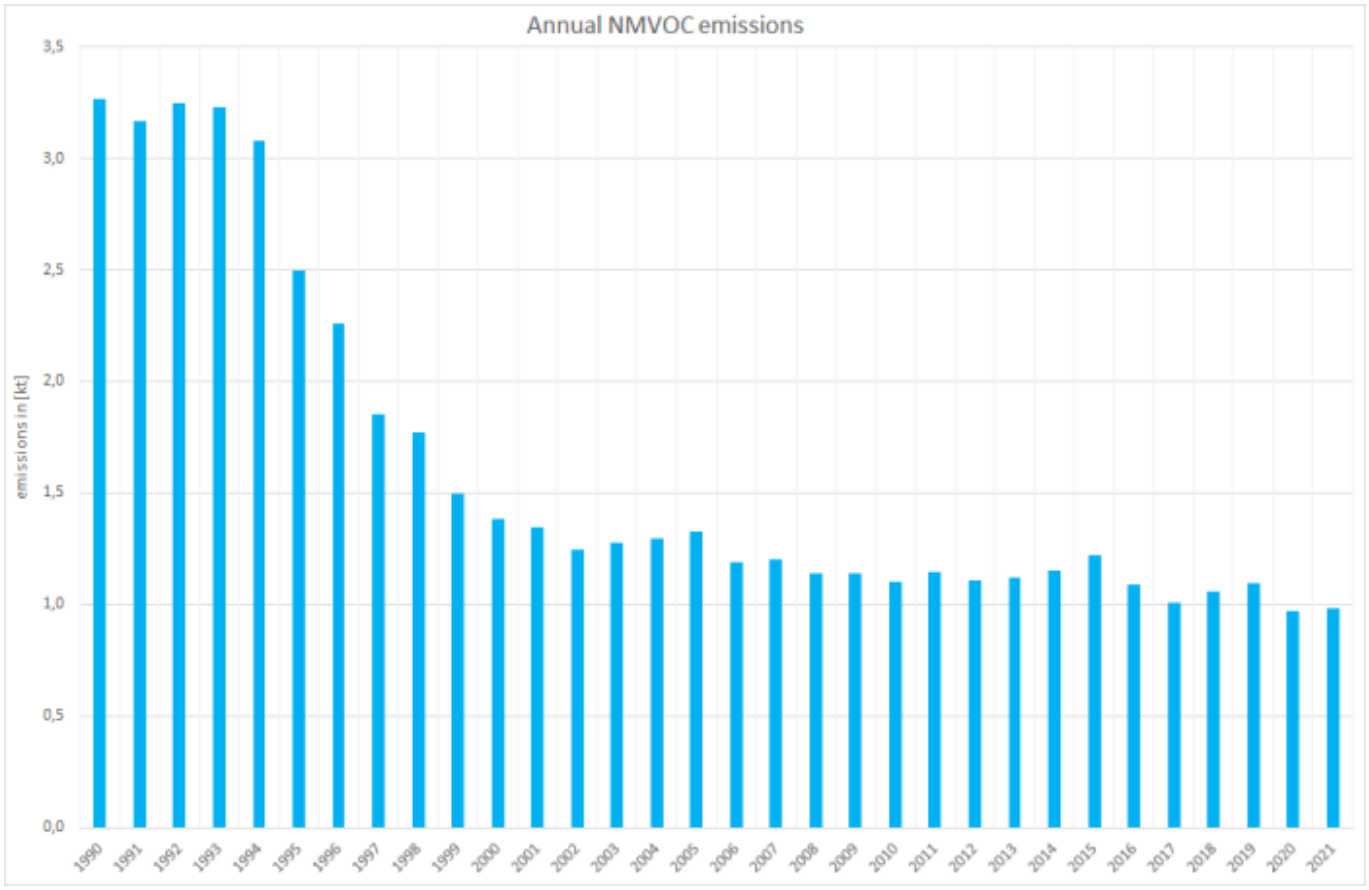
## Discussion of emission trends

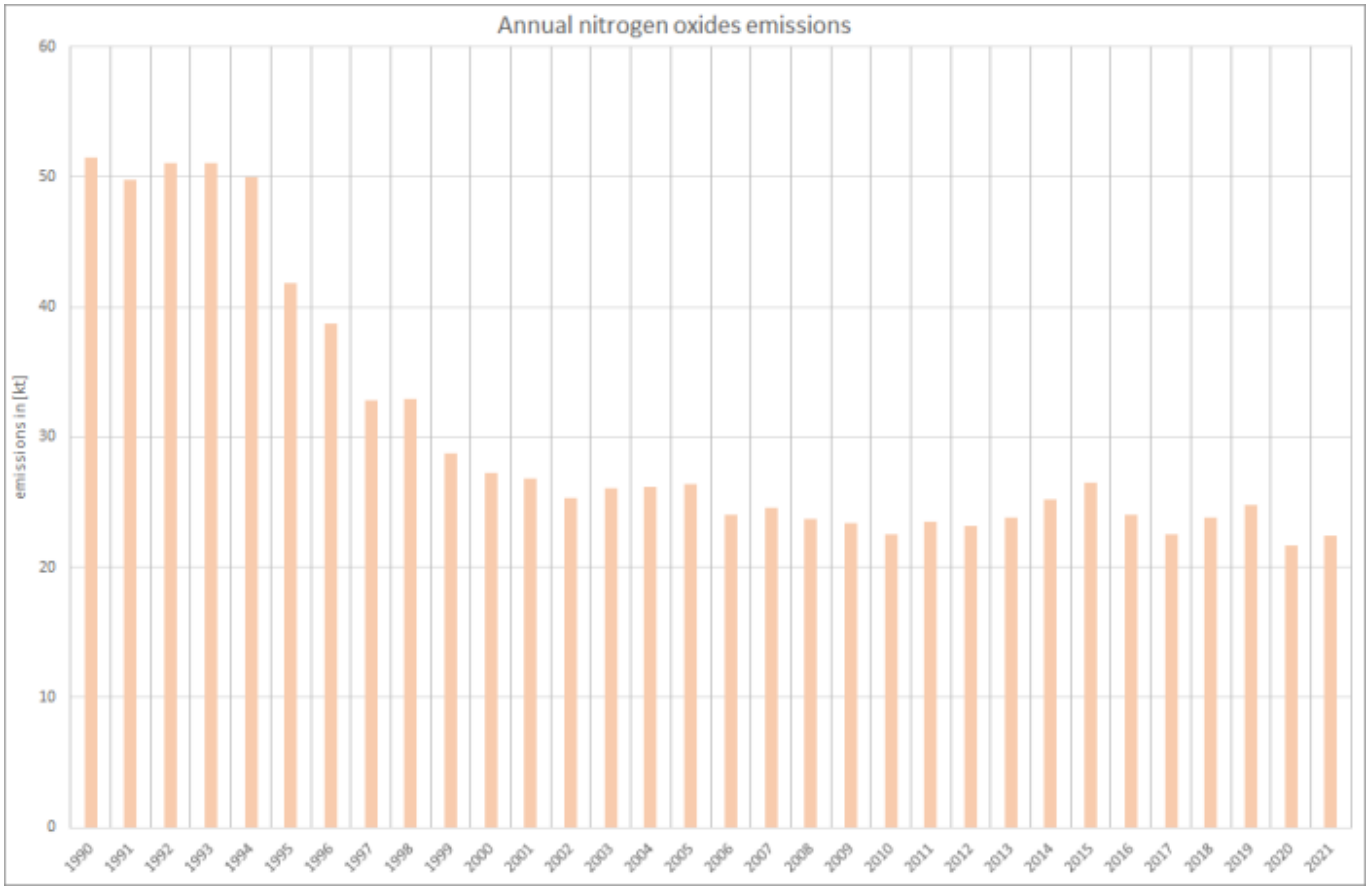
Table 5: Outcome of Key Category Analysis

| for: | **$PM_{10}$** | **$PM_{2.5}$** |
|---|---|---|
| by: | L/T | L/T |

For **ammonia**, **NMVOC**, and **nitrogen oxides** as well as **carbon monoxide**, emission trends more or less represent the trend in over-all fuel consumption.

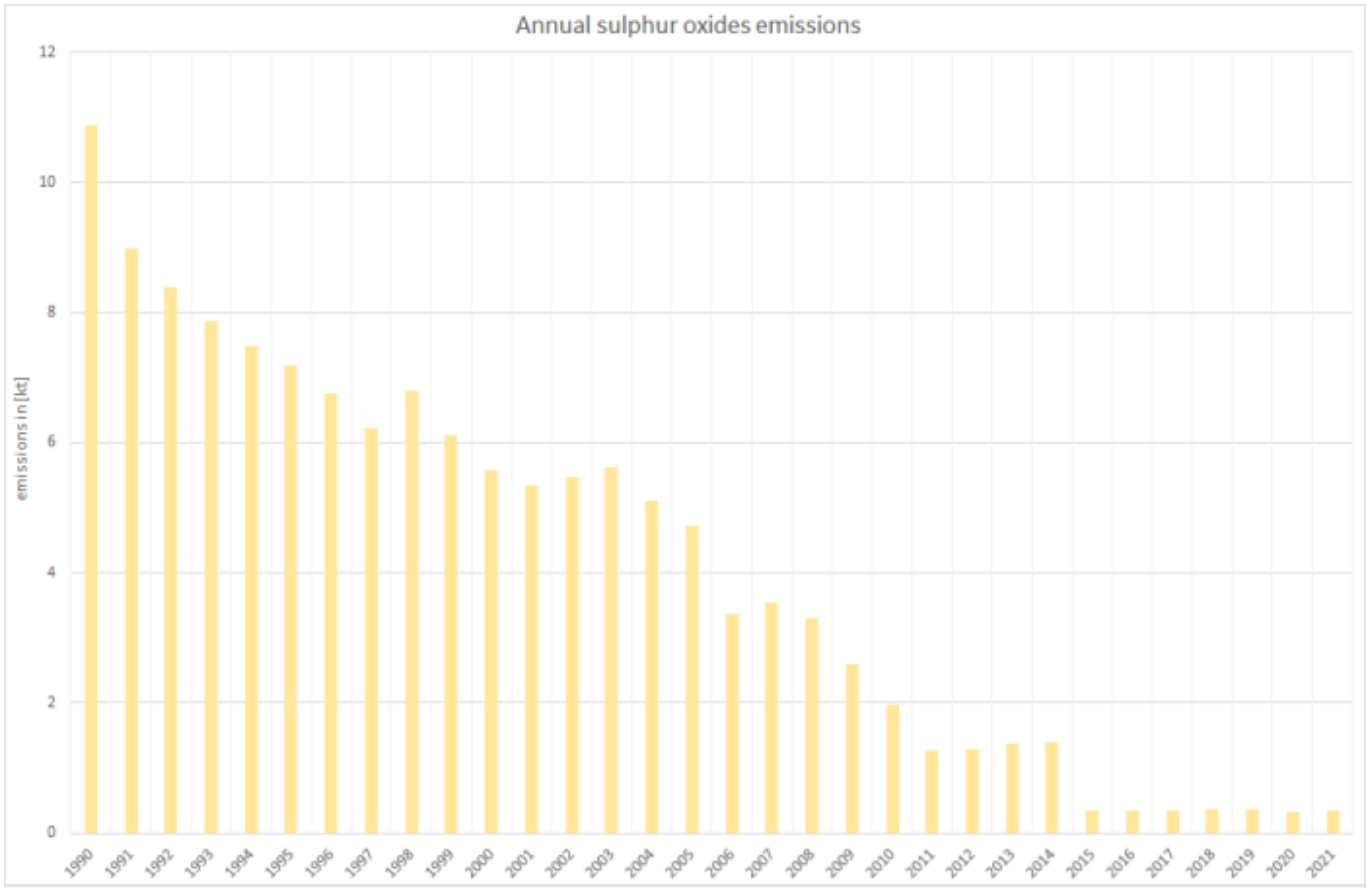


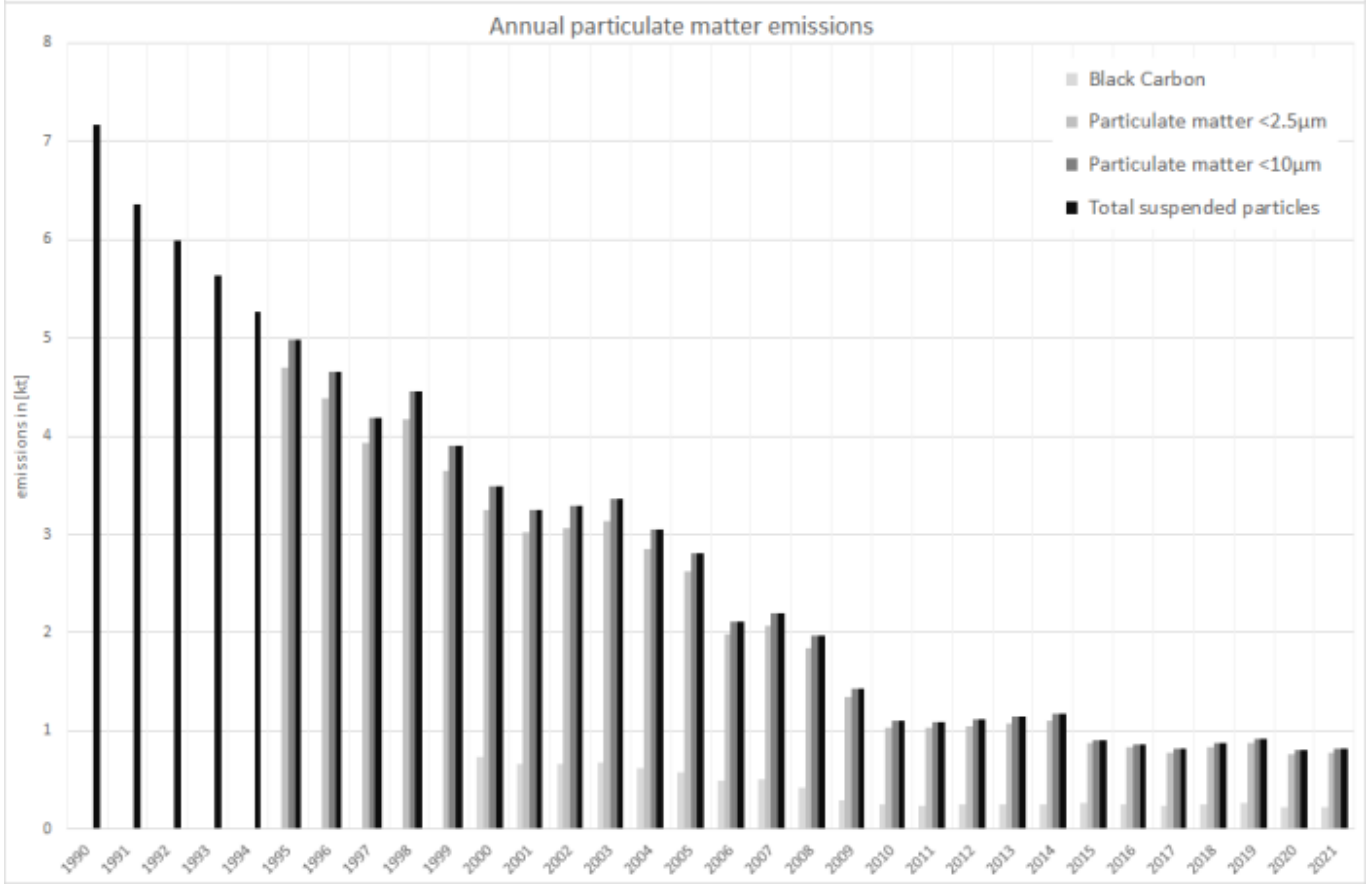



Nonetheless, for these pollutants, annual emission factors from BSH [10)] and TREMOD [11)] have been applied for national *maritime* and *inland* navigation, respectively, reflecting the technical development of the German inland navigation fleet.

Here, the trends in **sulphur dioxide** and **particulate matter** emissions reflect the impact of ongoing fuel-sulphur legislation especially in maritime navigation.




## Recalculations

Rëstimated emission estimates result solely from revised **activity data** result from the revision of the National Energy Balance 2020.

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| **Diesel oil** | | | | | | |
| Submission 2023 | 22.301 | 20.466 | 19.110 | 20.064 | 20.756 | 18.416 |
| Submission 2022 | 22.301 | 20.466 | 19.110 | 20.064 | 20.756 | 18.417 |
| absolute change | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,29 |
| relative change | 0,00% | 0,0% | 0,0% | 0,0% | 0,00% | 0,0% |
| **Heavy fuel oil** | | | | | | |
| Submission 2023 | 108 | 37,0 | 81,1 | 262 | 394 | 368 |
| Submission 2022 | 108,0 | 37,02 | 81,10 | 262 | 394 | 368 |
| absolute change | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| relative change | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| **LNG** | | | | | | |
| Submission 2023 | 22 | 64 | 59 | 197 | 153 | 276 |
| Submission 2022 | 0 | 0 | 0 | 0 | 0 | 0 |
| absolute change | 22,0 | 64,4 | 58,8 | 197 | 153 | 276 |
| **Over-all fuel consumption** | | | | | | |
| Submission 2023 | 22.431 | 20.567 | 19.250 | 20.524 | 21.303 | 19.060 |
| Submission 2022 | 22.409 | 20.503 | 19.191 | 20.326 | 21.150 | 18.785 |
| absolute change | 22,0 | 64,4 | 58,8 | 197 | 153 | 274 |
| relative change | 0,1% | 0,3% | 0,3% | 1,0% | 0,72% | 1,46% |

Table 6: Revised over-all fuel consumption data for national navigation, in terajoules

| | Diesel oil | Heavy Fuel Oil | LNG | Over-all fuel consumption |
|---|---|---|---|---|
| **current submission** | 18.416 | 368 | 276 | 18.784 |
| **previous submission** | 18.417 | 368 | NE | 18.785 |
| **absolute change** | -1,29 | 0,00 | 276 | -1,29 |
| **relative change** | -0,01% | 0,00% | | -0,01% |

Furthermore, the use of LNG is reported for the first time, starting in 2015:

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| **current submission** | 22.0 | 64.4 | 58.8 | 197 | 153 | 276 |
| **previous submission** | NE | NE | NE | NE | NE | NE |
| **absolute change** | 22.0 | 64.4 | 58.8 | 197 | 153 | 276 |

In cotrast, all country-specific **emission factors** remain unaltered.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

## Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by Knörr et al. (2009) [12)].

## Planned improvements

Besides the **routine revisions of the models** used for maritime and inland navigation, no specific improvements are scheduled.

[1)] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2019.html, (Aufruf: 23.11.2021), Köln & Berlin, 2022

[3), 10)] Deichnik (2021): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH - Federal Maritime and Hydrographic Agency); Hamburg, 2022.

[4), 5), 6), 7), 9)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

[8), 11)] Knörr et al. (2021a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

[12)] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

1)

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.