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)].

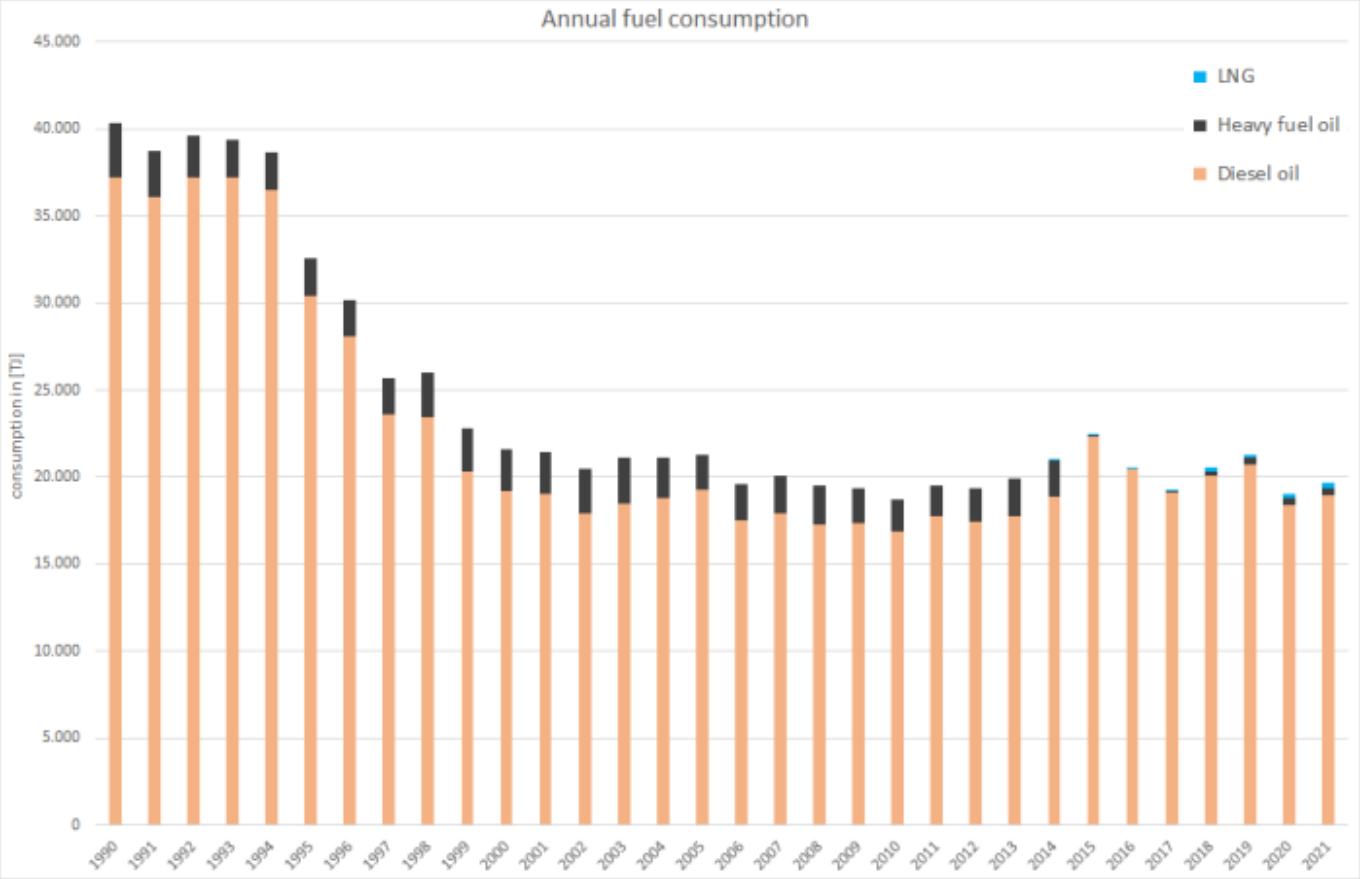
Here, the annual fuel consumption for domestic *maritime* navigation are modelled within [2)] based on AIS data and deduced from NEB lines 6 and 64 respectively, depending on whether or not a certain ship is registered by the International Maritime Organization (IMO). Here, fuels consumed by large, IMO-registered 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.

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

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Diesel Oil	37,199	30,389	19,231	19,250	17,553	17,930	17,268	17,365	16,872	17,719	17,411	17,768	18,878	22,301	20,466	19,110	20,064	20,756	18,417
Heavy fuel oil	3,103	2,186	2,382	2,054	2,025	2,160	2,278	1,988	1,810	1,790	1,932	2,134	2,057	108	37.0	81.1	262	394	368
Σ 1.A.3.d ii	**40,303**	**32,575**	**21,613**	**21,304**	**19,579**	**20,090**	**19,546**	**19,353**	**18,682**	**19,509**	**19,343**	**19,902**	**20,935**	**22,409**	**20,503**	**19,191**	**20,326**	**21,150**	**21,150**

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

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
NATIONAL MARITIME NAVIGATION																			
Diesel Oil	9,484	6,828	7,367	6,399	6,360	6,763	7,101	6,254	5,690	5,669	6,089	6,133	6,766	8,980	9,335	8,960	9,445	9,497	8,339
Heavy fuel oil	3,103	2,186	2,382	2,054	2,025	2,160	2,278	1,988	1,810	1,790	1,932	2,134	2,057	108,0	37,0	81,1	262	394	368
NATIONAL INLAND NAVIGATION																			
Diesel Oil	27,716	23,562	11,864	12,851	11,193	11,167	10,167	11,111	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,078
Σ 1.A.3.d ii	**40,303**	**32,575**	**21,613**	**21,304**	**19,579**	**20,090**	**19,546**	**19,353**	**18,682**	**19,509**	**19,343**	**19,902**	**20,935**	**22,409**	**20,503**	**19,191**	**20,326**	**21,150**	**18,785**



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	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	0,32	0,32	0,32
NMVOC	48,5	48,4	48,4	48,4	48,4	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
NO_x	1.101	1.101	1.101	1.101	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
SO_2	466	419	233	186	186	186	140	69,8	69,8	65,2	54,8	52,9	51,1	37,2	37,2	37,2	37,2	37,2	37,2
BC[1]	110	99,1	55,0	44,0	44,1	44,1	33,0	16,5	16,5	15,5	15,4	15,3	15,3	17,4	17,7	17,7	17,3	17,5	16,8
$PM_{2.5}$	354	320	177	142	142	142	106	53,3	53,3	49,9	49,8	49,3	49,4	56,2	57,1	57,1	55,9	56,5	54,2
PM_{10}	378	342	190	152	152	152	114	57,1	57,1	53,4	53,3	52,7	52,9	60,1	61,1	61,1	59,8	60,4	58,0
TSP[2]	378	342	190	152	152	152	114	57,1	57,1	53,4	53,3	52,7	52,9	60,1	61,1	61,1	59,8	60,4	58,0
CO	128	128	128	128	128	128	128	128	128	129	128	128	130	140	142	141	139	140	138
HEAVY FUEL OIL																			
NH_3	0,33	0,33	0,33	0,33	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
NMVOC	43,0	42,8	42,9	42,9	42,8	42,8	42,9	42,8	42,8	42,7	42,8	41,6	42,3	26,1	30,2	33,7	32,5	32,7	37,4
NO_x	1.368	1.368	1.368	1.368	1.368	1.368	1.368	1.367	1.368	1.367	1.367	1.384	1.433	1.487	1.440	1.479	1.480	1.507	1.509
SO_x	1.319	1.332	1.323	1.336	744	742	742	744	496	496	496	495	506	48,6	49,2	48,1	45,9	46,5	48,1
BC[1]	70,8	71,2	70,8	71,6	39,8	39,7	39,7	39,7	26,5	26,5	26,5	25,6	25,6	14,2	18,0	20,1	19,1	18,9	21,4
$PM_{2.5}$	590	594	590	596	331	331	331	331	221	221	221	213	213	118	150	168	159	158	179
PM_{10}	649	653	649	656	365	364	364	364	243	243	243	234	235	130	165	184	175	173	197
TSP[2]	649	653	649	656	365	364	364	364	243	243	243	234	235	130	165	184	175	173	197
CO	179	179	179	179	179	179	179	179	179	179	179	175	173	144	162	157	156	150	151

[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. (2021a)) [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	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	0.23	0.23	0.23
NMVOC	96.4	87.9	77.7	72.3	71.1	70.0	68.9	67.8	67.1	66.0	64.7	63.7	62.7	61.5	60.6	59.7	58.7	58.0	57.1
NO_x	1,327	1,331	1,336	1,289	1,278	1,267	1,256	1,244	1,234	1,225	1,212	1,201	1,190	1,177	1,166	1,154	1,143	1,134	1,123
SO_x	85.2	60.5	60.5	60.5	60.5	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
BC[1]	17.5	16.0	14.1	11.8	11.3	10.8	10.3	9.72	9.29	9.09	8.84	8.63	8.45	8.24	8.08	7.91	7.74	7.62	7.47
PM[2]	56.5	51.7	45.6	38.1	36.5	34.8	33.1	31.4	30.0	29.3	28.5	27.8	27.3	26.6	26.1	25.5	25.0	24.6	24.1
CO	417	387	337	299	290	282	274	265	259	254	248	242	237	232	227	223	218	215	210

[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)]

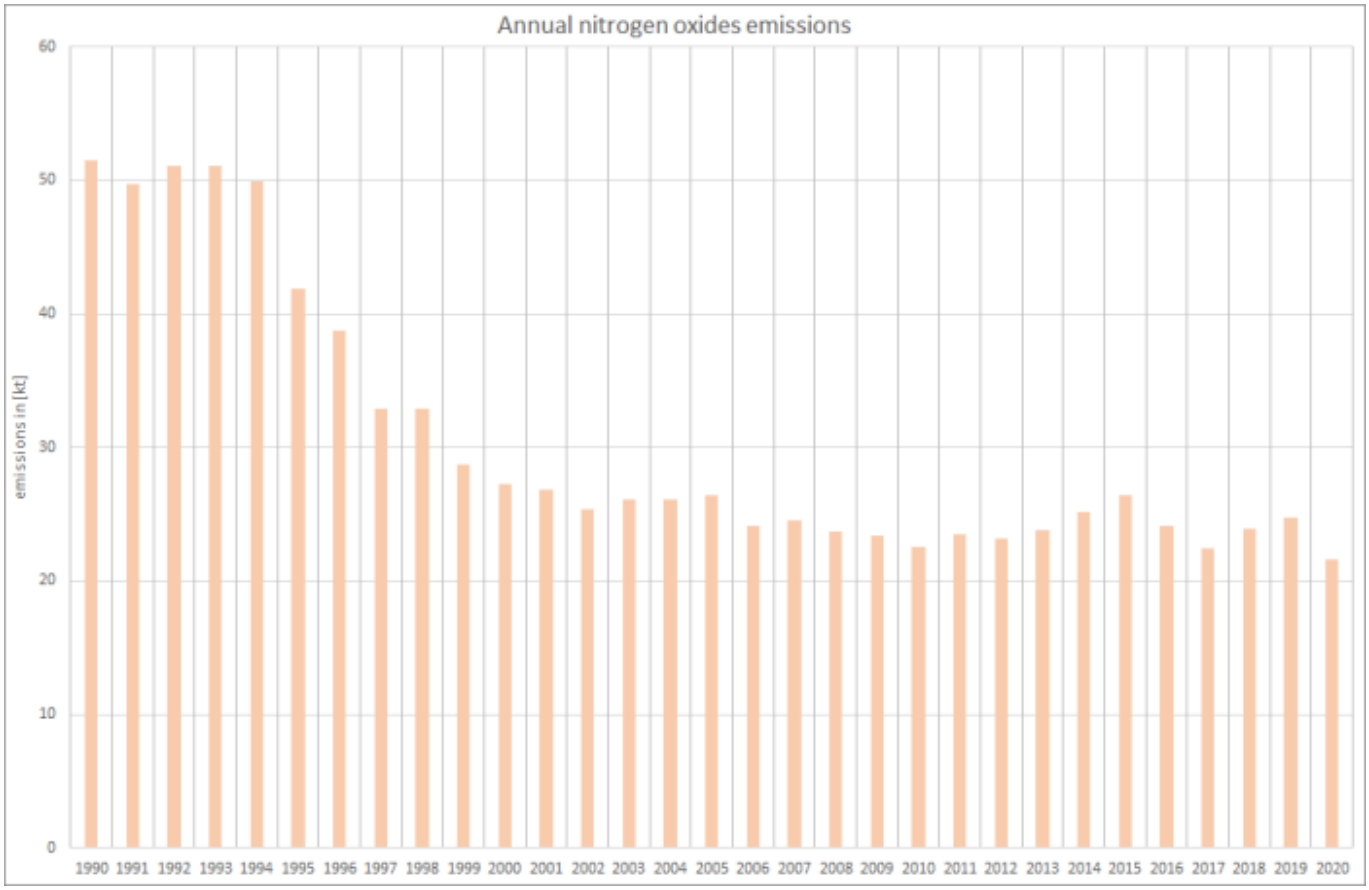
For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Discussion of emission trends

Table: Outcome of Key Category Analysis

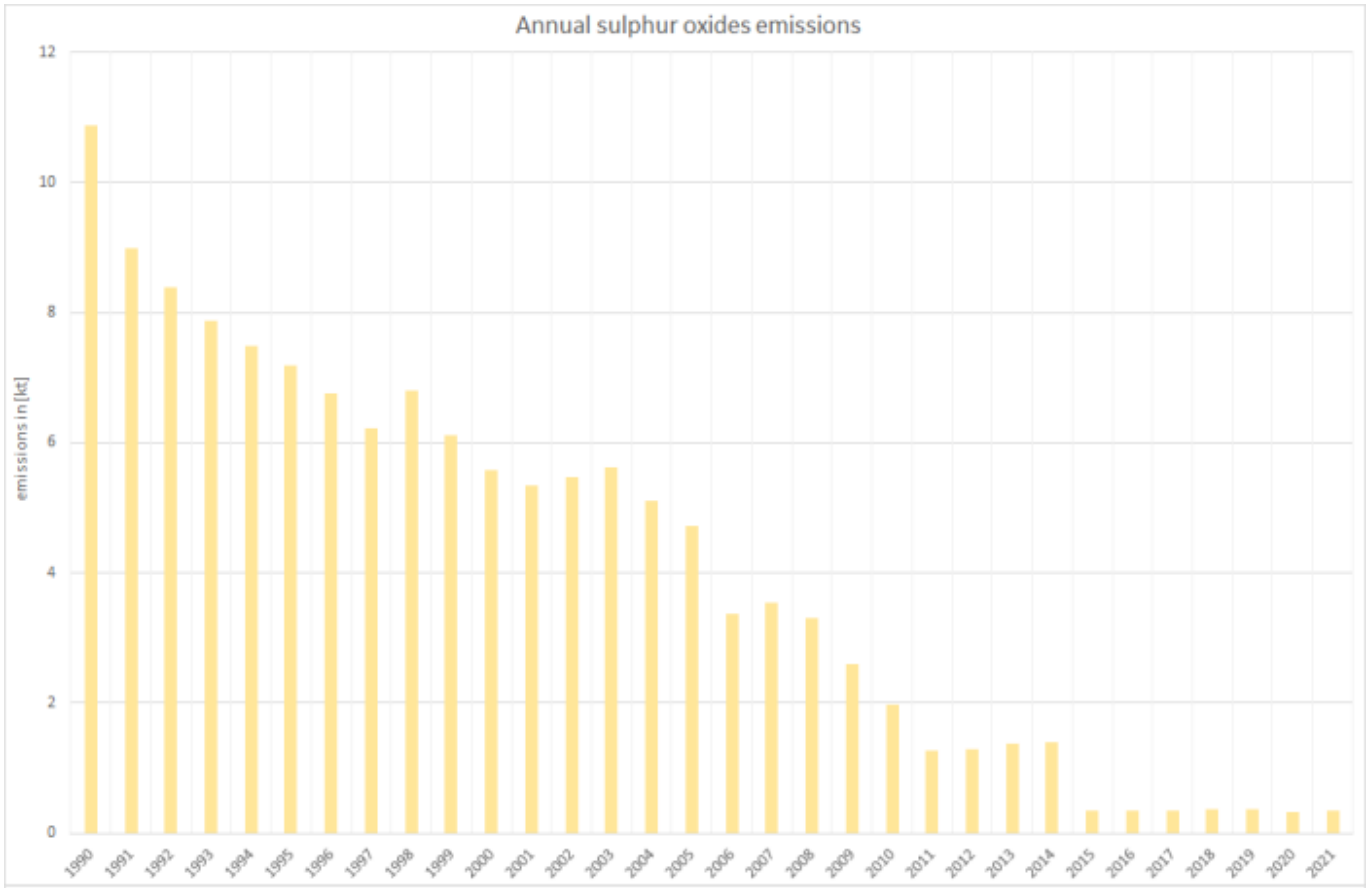
for:	**PM_{10}**	**$PM_{2.5}$**
by:	L/T	L/T

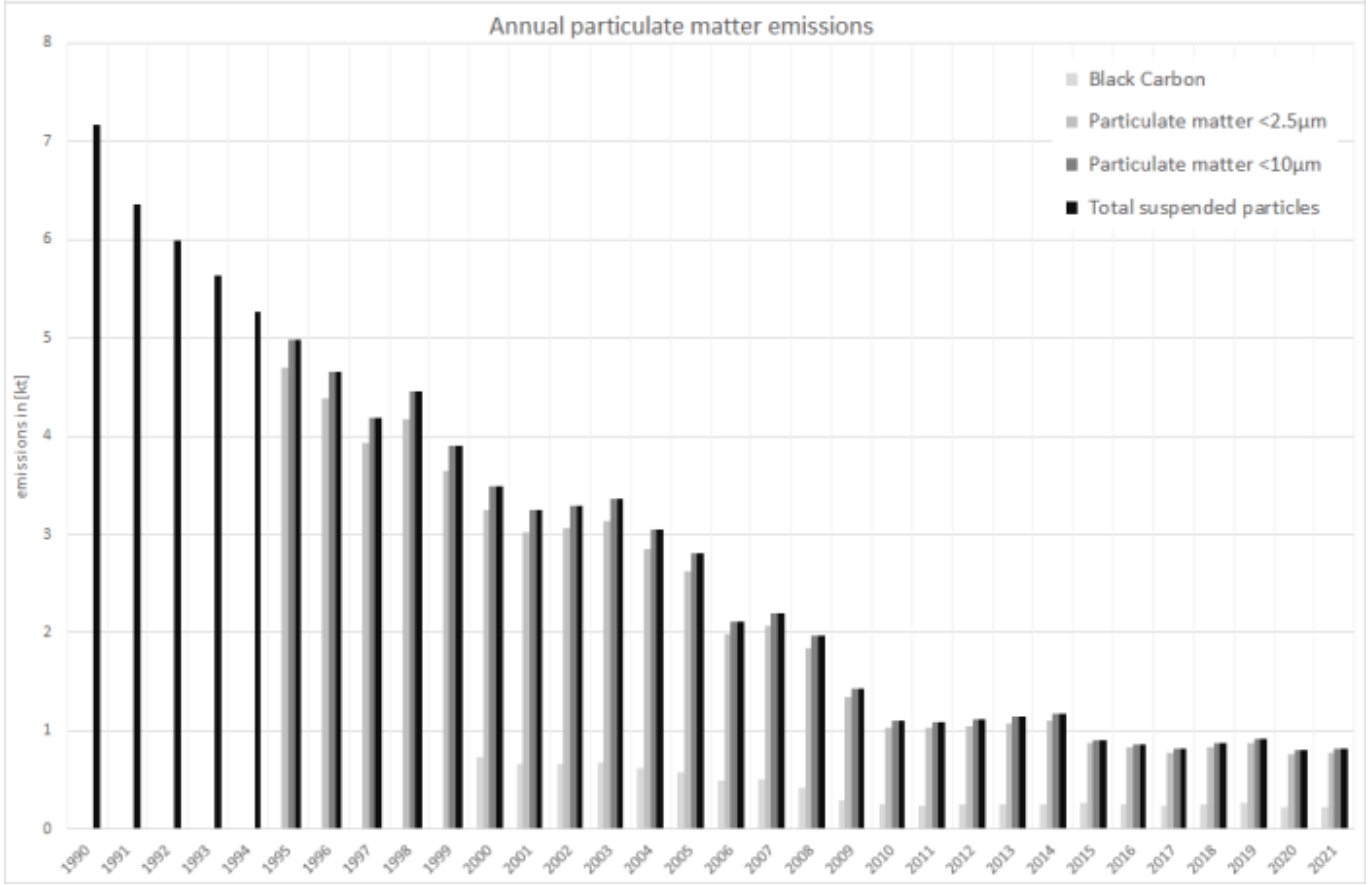
For **ammonia**, **NMVOC**, and **nitrogen oxides** as well as **carbon monoxide**, emission trends more or less represent the trend in over-all fuel consumption.



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

Major changes in **activity data** result from the revision of the National Energy Balance 2019. Furthermore, as no biodiesel is blended to marine diesel oil for technical reasons, no more biodiesel is reported for nautical activities. This correction results

in additional recalculations for all years as of 2004.

Table 5: Revised fuel consumption data for national maritime navigation, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
DIESEL OIL																		
current submission	9.484	6.828	7.367	6.399	6.360	6.763	7.101	6.254	5.690	5.669	6.089	6.133	6.766	8.980	9.335	8.960	9.445	9.497
previous submission	15.940	11.258	11.860	9.962	9.845	10.395	10.834	9.486	8.685	8.489	9.046	9.047	9.965	13.359	16.295	15.221	16.336	13.961
absolute change	-6.456	-4.430	-4.492	-3.563	-3.484	-3.632	-3.733	-3.232	-2.996	-2.820	-2.957	-2.913	-3.199	-4.379	-6.960	-6.261	-6.891	-4.464
relative change	-40,5%	-39,4%	-37,9%	-35,8%	-35,4%	-34,9%	-34,5%	-34,1%	-34,5%	-33,2%	-32,7%	-32,2%	-32,1%	-32,8%	-42,7%	-41,1%	-42,2%	-32,0%
HEAVY FUEL OIL																		
current submission	3.103	2.186	2.382	2.054	2.025	2.160	2.278	1.988	1.810	1.790	1.932	2.134	2.057	108	37,0	81,1	262	394
previous submission	11.723	8.041	8.577	7.172	7.004	7.425	7.797	6.733	6.114	5.961	6.410	6.376	6.046	50,0	7,05	7,01	190	358
absolute change	-8.619	-5.855	-6.195	-5.118	-4.979	-5.265	-5.519	-4.745	-4.304	-4.171	-4.478	-4.242	-3.989	57,9	30,0	74,1	71,7	35,9
relative change	-73,5%	-72,8%	-72,2%	-71,4%	-71,1%	-70,9%	-70,8%	-70,5%	-70,4%	-70,0%	-69,9%	-66,5%	-66,0%	116%	425%	1057%	37,7%	10,0%

Table 5: Revised fuel consumption data for national inland navigation, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
current submission	27.716	23.562	11.864	12.851	11.193	11.167	10.167	11.111	11.182	12.050	11.322	11.635	12.112	13.321	11.131	10.150	10.619	11.259
previous submission	20.664	18.597	6.788	8.634	7.050	6.836	5.683	7.129	7.497	8.466	7.556	7.777	8.567	9.422	7.873	7.179	7.511	7.595
absolute change	7.052	4.965	5.076	4.217	4.143	4.330	4.484	3.981	3.685	3.584	3.766	3.858	3.545	3.899	3.258	2.971	3.108	3.664
relative change	34,1%	26,7%	74,8%	48,8%	58,8%	63,3%	78,9%	55,8%	49,1%	42,3%	49,8%	49,6%	41,4%	41,4%	41,4%	41,4%	41,4%	48,2%

Furthermore, most of the country-specific **emission factors** applied for both **national maritime navigation** and **domestic inland navigation** have been revised within the BSH model and TREMOD, respectively.

For more information on recalculated emission estimates for Base Year and 2019, please see the pollutant-specific 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, 2021: 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, 2021

[2), 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, 2021.
[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, 2021.
[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.