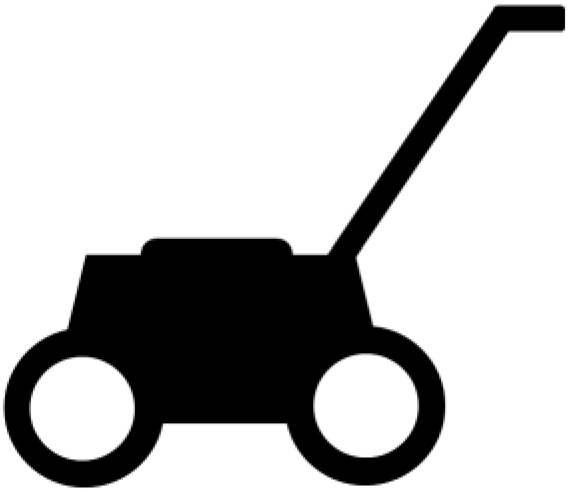
1.A.4.b ii - Residential: Household and Gardening: Mobile

Short description

Under sub-category *1.A.4.b ii - Residential: Mobile Sources in Households and Gardening* fuel combustion activities and resulting emissions from combustion engine driven devices such as motor saws and lawn mowers are being reported.



Method	AD	EF	Key Category Analysis
T1, T2	NS, M	CS, M, D	**L/T**: CO

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Methodology

Activity data

Activity data are taken from annual fuel delieveries data provided in line 66: 'Households' of the National Energy Balances (NEB) for Germany (AGEB, 2020) [1].

Table 1: Sources for consumption data in 1.A.4.b ii

Relevant years	Data Source
through 1994	**AGEB** - National Energy Balance, line 79: Households
since 1995	**AGEB** - National Energy Balance, line 66: Households

Here, given the rare statistics on sold machinery, these activity data is of limited quality only (no annual but cascaded trend).

As the NEB only provides primary activity data for *total biomass* used in 'households', but does not distinguish into specific biofuels, consumption data for bioethanol used in NFR 1.A.4.b ii are calculated by applying Germany's official annual shares of biogasoline blended to fossil gasoline.

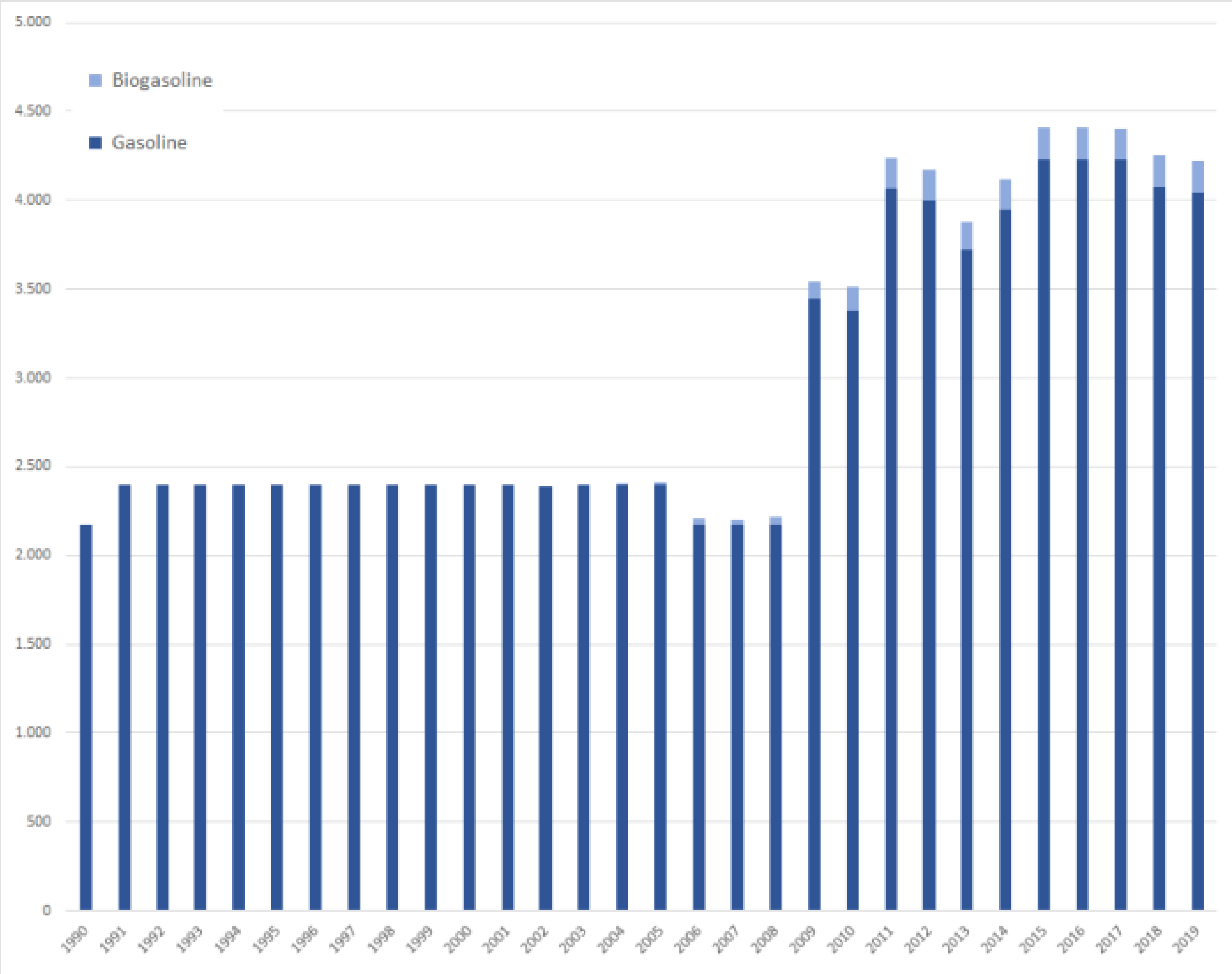
Please note: *Data on gasoline used in households* as provided in the National Energy Balances represents *a "residual item"* following the allocation of the majority of this fuel to road and military vehicles. Here, fuel sales to road vehicles might also include gasoline acquired on filling stations but used for household equipment.

Due to these reasons, activity data for gasoline consumption in households machinery and, hence, several emission estimates *show no realistic trend but a stepwise development* with significant jumps.

Table 2: Annual over-all fuel deliveries to residential mobile sources, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	2,177	2,395	2,395	2,395	3,379	4,069	3,995	3,720	3,946	4,228	4,228	4,228	4,228	4,228	4,055
Biogasoline	0	0	0	16	131	167	177	159	172	183	184	178	190	182	183
Σ 1.A.4.b ii	**2,177**	**2,395**	**2,395**	**2,411**	**3,510**	**4,236**	**4,172**	**3,879**	**4,118**	**4,411**	**4,412**	**4,406**	**4,418**	**4,410**	**4,238**

source: AGEB, 2020 [2] and TREMOD MM [3]



These primary activity data can be distributed onto 2- and 4-stroke engines used in households via annual shares from Knörr et al. (2020b) [4].

Table 3: Annual shares of 2- and 4-stroke engines

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2-Stroke Machinery	25,0%	43,7%	58,4%	61,8%	66,0%	66,4%	67,0%	67,3%	67,3%	67,3%	67,3%	67,3%	67,3%	67,2%	67,2%
4-Stroke Machinery	63,7%	44,2%	29,5%	27,0%	23,3%	22,7%	21,6%	20,8%	20,5%	20,3%	20,0%	19,8%	19,6%	19,5%	19,4%
2-Stroke Boats	10,1%	10,3%	8,80%	5,61%	2,16%	2,19%	2,23%	2,28%	2,31%	2,34%	2,37%	2,39%	2,40%	2,41%	2,43%
4-Stroke Boats	1,2%	1,8%	3,3%	5,6%	8,5%	8,8%	9,2%	9,5%	9,8%	10,1%	10,3%	10,5%	10,7%	10,9%	11,0%
	100%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

source: TREMOD MM [5]

Table 4: Resulting estimates for fuel consumption in 2- and 4-stroke engines, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

2-stroke machinery															
Gasoline	1,387	1,058	705	646	787	922	861	775	810	857	847	838	830	824	786
Biogasoline	0.00	0.00	0.00	4.44	30.4	37.8	38.2	33.2	35.2	37.2	36.8	35.3	37.3	35.5	35.4
4-stroke machinery															
Gasoline	545	1,046	1,400	1,480	2,231	2,700	2,677	2,505	2,656	2,844	2,844	2,844	2,843	2,842	2,724
Biogasoline	0.00	0.00	0.00	10.2	86.2	111	119	107	116	123	124	120	128	123	123
2-stroke boats															
Gasoline	220	248	211	134	73,1	88,9	89,2	84,7	91,2	99,1	100	101	102	102	98.5
Biogasoline	0.00	0.00	0.00	0.92	2.82	3.64	3.95	3.63	3.97	4.30	4.35	4.25	4.57	4.40	4.43
4-stroke boats															
Gasoline	25,6	43,0	79,2	134	287	358	367	355	388	428	437	446	453	460	447
Biogasoline	0.00	0.00	0.00	0.92	11.1	14.7	16.3	15.2	16.9	18.5	19.0	18.8	20.4	19.8	20.1
Σ 1.A.4.b ii	**2,177**	**2,395**	**2,395**	**2,411**	**3,510**	**4,236**	**4,172**	**3,879**	**4,118**	**4,411**	**4,412**	**4,406**	**4,418**	**4,410**	**4,238**

Emission factors

The emission factors used here are of rather different quality: For all **main pollutants**, **carbon monoxide** and **particulate matter**, annually changing values computed within TREMOD-MM (Knörr et al. (2020b)) [6)] are used, representing the development of mitigation technologies and the effect of fuel-quality legislation.

Here, as no such specific EF are available for biofuels, the values used for gasoline are applied to bioethanol, too.

For lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions are are calculated from 1990 to 1997 based upon contry-specific emission factors from [7)].)

Table 4: Annual country-specific emission factors from TREMOD MM[1], in kg/TJ

	1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
4-stroke machinery																			
NH_3	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
NMVOC[2]	475	1.289	1.604	1.651	1.656	1.656	1.656	1.651	1.647	1.646	1.645	1.643	1.641	1.638	1.635	1.632	1.628	1.624	1.620
NMVOC[3]	727	819	809	783	779	776	775	774	774	771	769	767	765	763	762	761	760	765	750
NO_x	51,0	85,3	103	108	111	113	116	119	122	124	126	129	131	132	133	134	135	133	127
SO_x	10,1	8,27	3,22	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37
BC[5]	0,31	0,27	0,24	0,23	0,23	0,23	0,24	0,24	0,24	0,25	0,25	0,25	0,26	0,26	0,26	0,26	0,26	0,26	0,26
PM[4]	6,29	5,46	4,85	4,62	4,65	4,69	4,75	4,81	4,87	4,94	5,00	5,06	5,11	5,15	5,19	5,22	5,24	5,25	5,25
CO	39.998	32.154	28.346	27.161	27.218	27.357	27.538	27.762	27.992	28.278	28.555	28.813	29.047	29.249	29.418	29.548	29.647	29.614	29.258
2-stroke machinery																			
NH_3	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,08	0,08	0,08	0,09	0,09	0,09	0,09	0,09	0,09	0,09
NMVOC[2]	6.126	5.914	5.879	5.816	5.827	5.820	5.830	5.860	5.835	5.372	4.327	3.635	3.473	3.315	3.164	3.024	2.900	2.796	2.718
NMVOC[3]	1.387	1.129	510	392	370	342	312	279	280	288	305	317	321	325	328	331	334	335	337
NO_x	19,84	25,71	36,34	53,39	59,95	61,51	62,50	62,92	63,80	61,92	57,10	54,98	55,93	56,79	57,55	58,19	58,72	59,25	59,81
SO_x	10,10	8,27	3,22	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37
BC[5]	6,91	6,14	5,13	4,93	4,90	4,85	4,81	4,79	4,79	4,93	5,22	5,41	5,49	5,55	5,61	5,67	5,71	5,75	5,77
PM[4]	138	123	103	98,7	98,0	97,0	96,2	95,8	95,7	98,6	104	108	110	111	112	113	114	115	115
CO	20.270	18.743	16.255	15.483	15.271	15.090	14.904	14.713	14.699	15.068	15.891	16.438	16.618	16.797	16.967	17.125	17.266	17.385	17.481
2- and 4-stroke machinery																			
TSP[6]	2,35	0,82																	
Pb	1,47	0,52																	

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] from fuel combustion
[3] from gasoline evaporation
[4] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[5] estimated via a f-BCs as provided in [8)], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1 emission factors for off-road machinery
[6] from leaded gasoline (until 1997)

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. [9)]

For lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions are are calculated from 1990 to 1997 based upon contry-specific emission factors from [10].

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

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

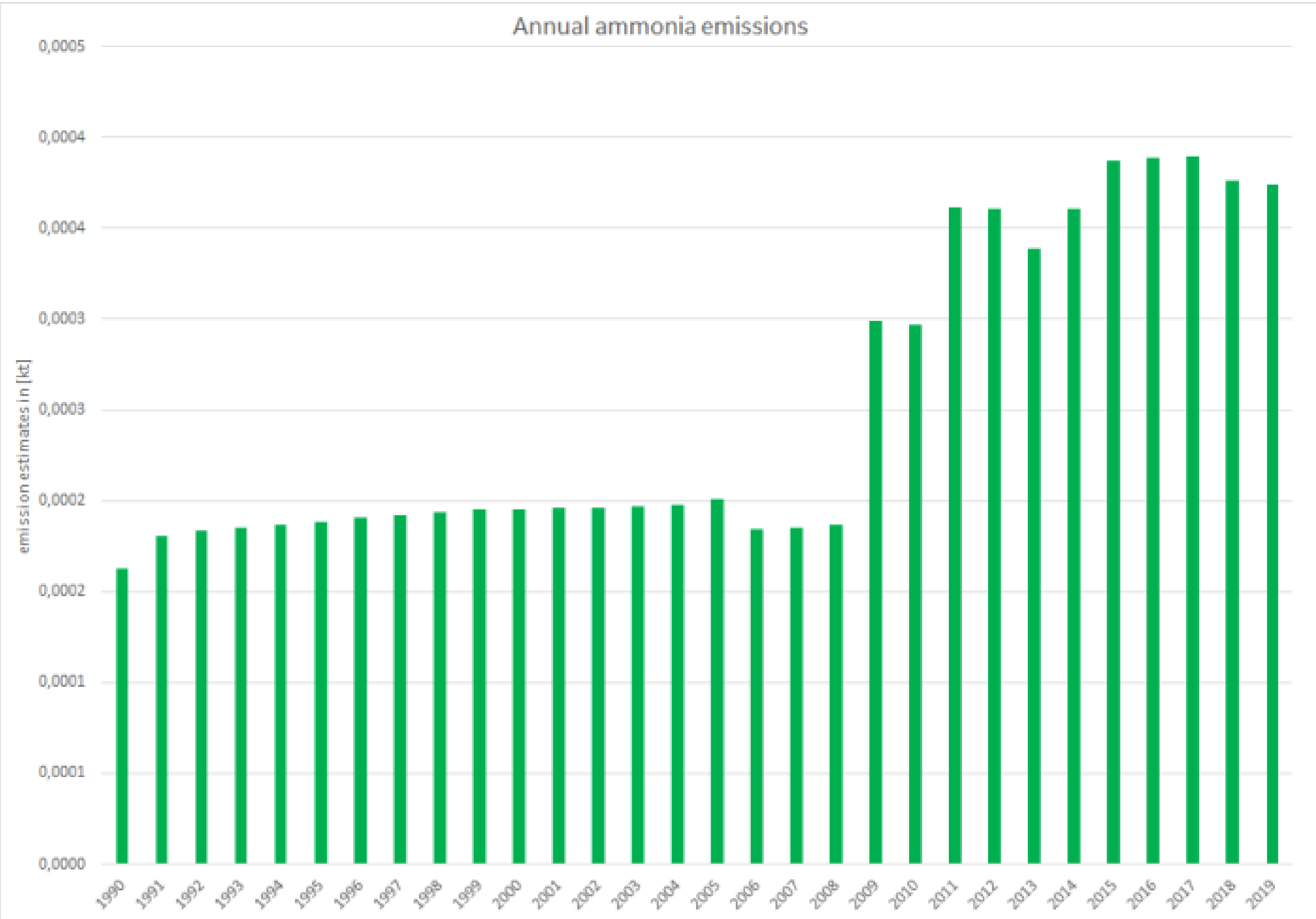
Table: Outcome of Key Category Analysis

for:	**CO**
by:	Level & Trend

Given the limited quality of gasoline-deliveries data from NEB line 66, the following emission trends are of limited significance only.

Unregulated pollutants (Ammonia, HMs, POPs, ...)

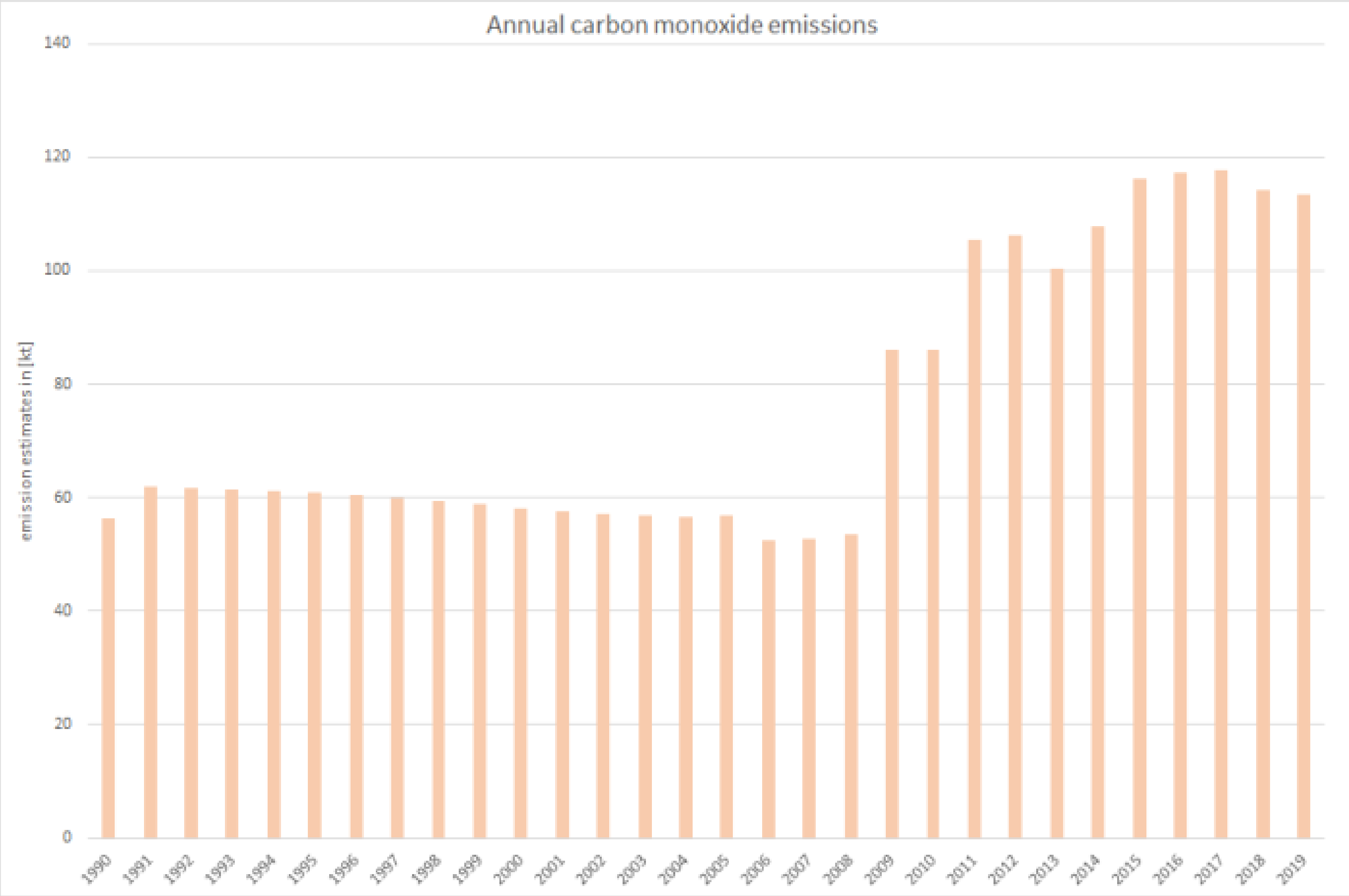
For all unregulated pollutants, emission trends directly follow the trend in fuel consumption.

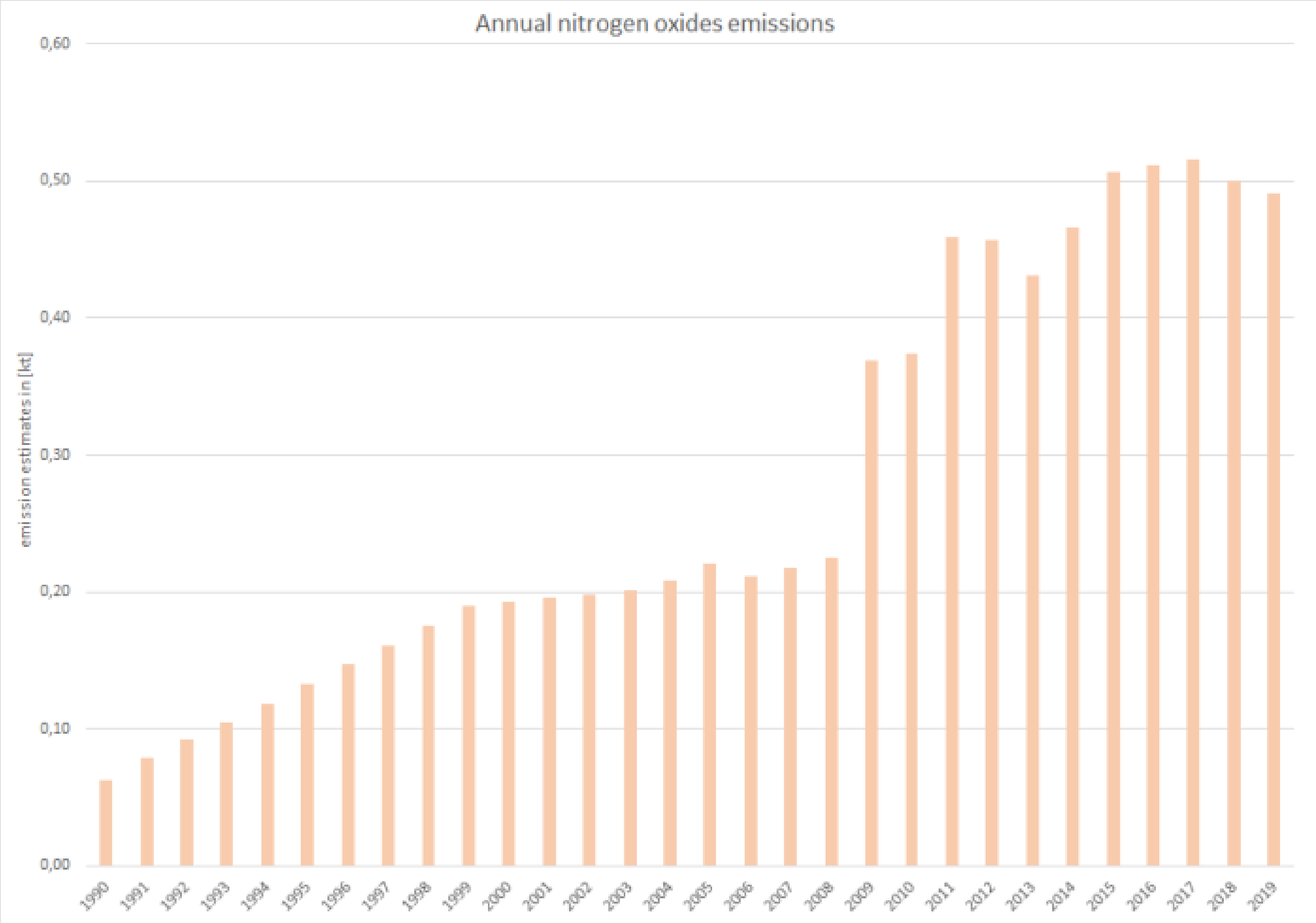


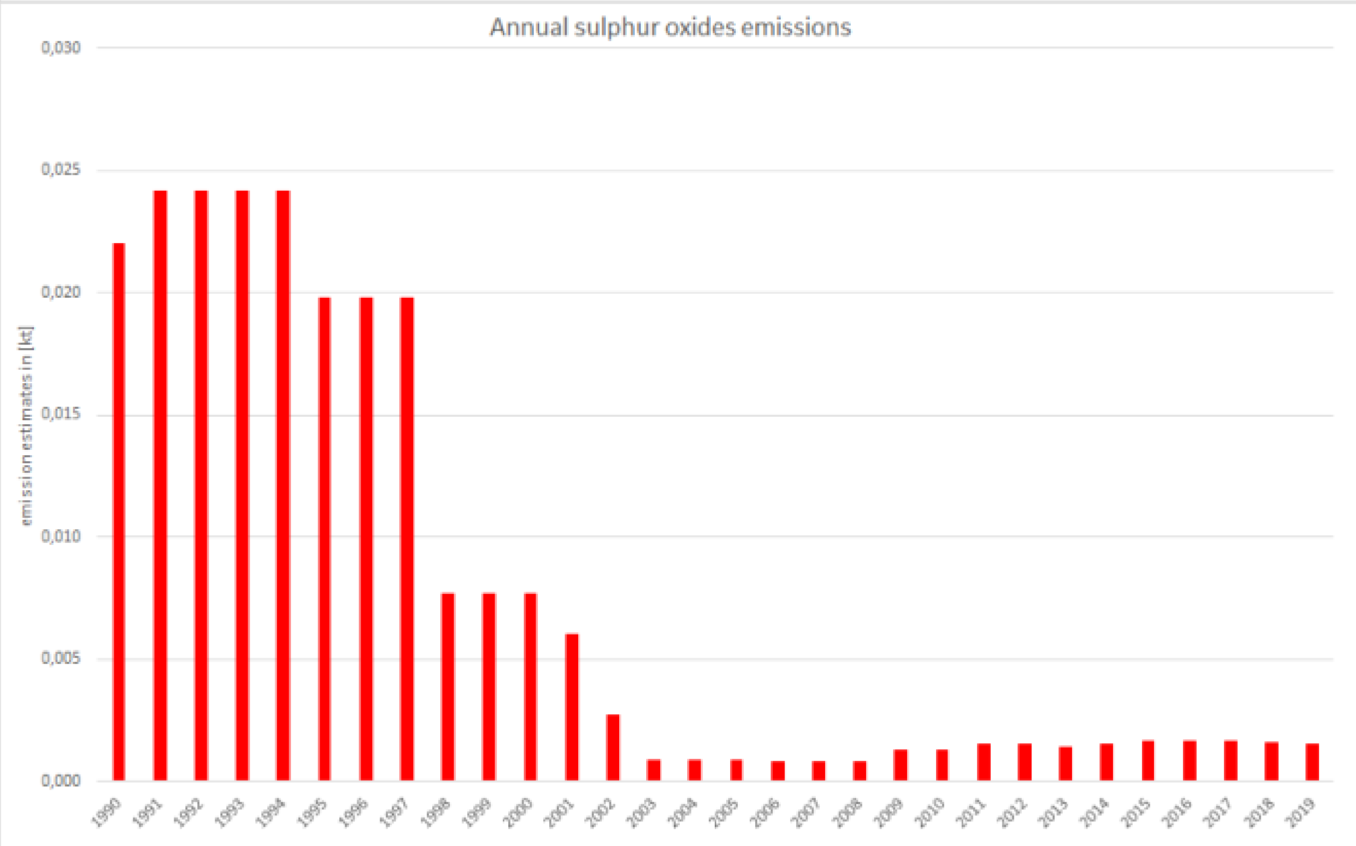
Here, as the emission factors for heavy metals (and POPs) are derived from tier1 default values, the emission's trend is stronlgy influenced by the share of 2-stroke gasoline fuel (containing lube oil with presumably higher HM content) consumed.

Regulated pollutants

For all regulated pollutants, emission trends follow not only the trend in fuel consumption but also reflect the impact of fuel-quality and exhaust-emission legislation. However, especially for CO and NOx, trends are strongly influenced by the changes in annual fuel deliveries as provided in NEB line 66.







Particulate matter

Over-all PM emissions are by far dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption between 2000 and 2005. Nonetheless, the decrease of the over-all emission trend was and still is amplified by the expanding use of particle filters especially to eliminate soot emissions.

Additional contributors such as the impact of TSP emissions from the use of leaded gasoline (until 1997) have no significant effect onto over-all emission estimates.

Here, as the EF(BC) are estimated via fractions provided in [11], black carbon emissions follow the corresponding emissions of $PM_{2.5}$.

Recalculations

Primary activity data fro NEB line 66 remains unrevised. However, the percental shares of 2- and 4-stroke engines have been revised according to TREMOD MM.

Table 5: Revised annual shares of 2- and 4-stroke engines

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2-stroke machinery														
Submission 2022	0,25	0,44	0,58	0,62	0,66	0,66	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67
Submission 2021	0,28	0,50	0,66	0,70	0,74	0,75	0,76	0,76	0,77	0,77	0,77	0,77	0,77	0,78
absolute change	-0,03	-0,06	-0,08	-0,08	-0,08	-0,08	-0,09	-0,09	-0,09	-0,10	-0,10	-0,10	-0,10	-0,10
relative change	-11,3%	-12,1%	-12,1%	-11,2%	-10,7%	-11,0%	-11,4%	-11,8%	-12,2%	-12,5%	-12,7%	-12,9%	-13,1%	-13,3%
4-stroke machinery														
Submission 2022	0,64	0,44	0,29	0,27	0,23	0,23	0,22	0,21	0,21	0,20	0,20	0,20	0,20	0,19
Submission 2021	0,72	0,50	0,34	0,30	0,26	0,25	0,24	0,24	0,23	0,23	0,23	0,23	0,23	0,22
absolute change	-0,08	-0,06	-0,04	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03
relative change	-11,3%	-12,1%	-12,1%	-11,2%	-10,7%	-11,0%	-11,4%	-11,8%	-12,2%	-12,5%	-12,7%	-12,9%	-13,1%	-13,3%
2-stroke boats														
Submission 2022	0,01	0,02	0,03	0,06	0,09	0,09	0,09	0,10	0,10	0,10	0,10	0,11	0,11	0,11
Submission 2021	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4-stroke boats														
Submission 2022	0,10	0,10	0,09	0,06	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Submission 2021	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 5: Resulting revised annual fuel consumptions of 2- and 4-stroke engines

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2-stroke machinery														
Submission 2022	1.563	1.204	803	733	915	1.078	1.015	917	963	1.021	1.012	1.003	961	
Submission 2021	1.563	1.204	803	754	955	1.128	1.065	962	1.010	1.072	1.062	1.053	1.009	
absolute change	0,00	0,00	0,00	-21,2	-40,0	-50,1	-49,1	-45,3	-47,7	-50,6	-49,9	-50,1	-48,1	
relative change	0,00%	0,00%	0,00%	-2,81%	-4,19%	-4,44%	-4,62%	-4,70%	-4,73%	-4,72%	-4,70%	-4,76%	-4,77%	
4-stroke machinery														
Submission 2022	614	1.191	1.592	1.679	2.594	3.158	3.157	2.963	3.155	3.390	3.399	3.404	3.292	
Submission 2021	614	1.191	1.592	1.658	2.554	3.108	3.108	2.917	3.107	3.340	3.349	3.354	3.244	
absolute change	0,00	0,00	0,00	21,20	40,03	50,09	49,13	45,26	47,74	50,63	49,89	50,11	48,11	

relative change	0,00%	0,00%	0,00%	1,28%	1,57%	1,61%	1,58%	1,55%	1,54%	1,52%	1,49%	1,49%	1,48%	
2-stroke boats														
Submission 2022														
Submission 2021														
absolute change														
4-stroke boats														
Submission 2022														
Submission 2021														
absolute change														

For pollutant-specific information on recalculated emission estimates for Base Year and 2018, 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 (Knörr et al. (2009))[12]: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland”.

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

Besides a **routine revision** of the **TREMOD MM** model, no specific improvements are planned.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [13] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained in biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel and bioethanol.

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[1], [2] AGEB, 2020: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2018.html, (Aufruf: 29.11.2020), Köln & Berlin, 2020

[3], [4], [5], [6], [7] Knörr et al. (2020b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2020, Heidelberg, 2020.

[8], [10], [11] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

[9] 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.

[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.

[13] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen

Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer