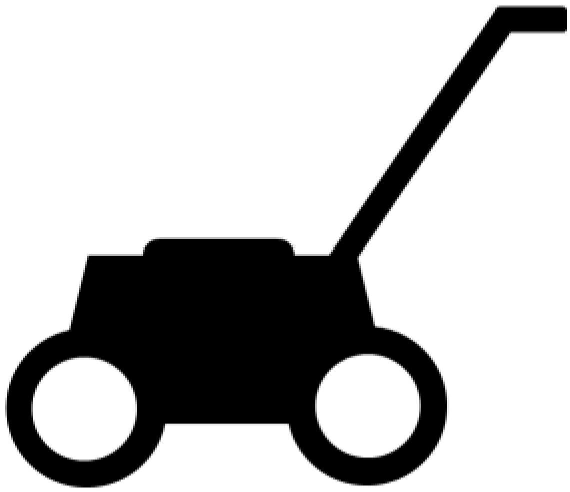
1.A.4.b ii - Residential: Household and Gardening: Mobile

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	NS, M	CS, 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, 2019) [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**
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	4.070	4.046
Biogasoline	0	0	0	16	131	167	177	159	172	183	184	178	183	175
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**	**4.253**	**4.221**

source: AGEB, 2019 [2)] and TREMOD MM [3)]

gallery size="medium" : 1A4bii_AD.png : 1A4bii_AD_bio.png gallery

These primary activity data can be distributed onto 2- and 4-stroke engines used in households via annual shares from Knörr et al. (2019b) [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**
2-Stroke	28,2 %	49,7 %	66,5 %	69,6 %	73,9 %	74,5 %	75,7 %	76,4 %	76,6 %	76,8 %	77,1 %	77,2 %	77,4 %	77,5 %
4-Stroke	71,8 %	50,3 %	33,5 %	30,4 %	26,1 %	25,5 %	24,3 %	23,6 %	23,4 %	23,2 %	22,9 %	22,8 %	22,6 %	22,5 %

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**
2-stroke engines														
Gasoline	614	1.191	1.592	1.667	2.498	3.033	3.023	2.841	3.023	3.249	3.258	3.266	3.150	3.137
Biogasoline	0	0	0	11	97	124	134	122	131	141	142	138	142	135
4-stroke engines														
Gasoline	1.563	1.204	803	728	881	1.036	972	879	923	979	970	962	920	909
Biogasoline	0	0	0	5	34	42	43	38	40	42	42	41	41	39
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**	**4.253**	**4.221**

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. (2019b)) [6)] are used, representing the development of mitigation technologies and th 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	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
4-stroke machinery														
NH_3	0.089	0.092	0.093	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	
NMVOC[2]	77.8	74.8	82.3	101	106	106	106	106	106	106	106	106	106	
NMVOC[3]	77.8	74.8	82.3	101	106	106	106	106	106	106	106	106	106	
NO_x	54.0	68.3	75.9	76.8	76.9	76.9	77.0	77.0	77.0	77.0	77.0	77.0	77.0	
SO_x	10.1	8.3	3.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
BC[5]	0.302	0.271	0.241	0.236	0.236	0.236	0.236	0.236	0.235	0.235	0.235	0.235	0.235	
PM[4]	6.03	5.43	4.83	4.72	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	
CO	38,459	35,290	32,423	32,108	34,681	35,250	35,791	36,289	36,661	36,840	36,918	36,973	37,010	
2-stroke machinery														
NH_3	0.161	0.164	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
NMVOC[2]	185	157	134	90	59	55	52	48	44	41	38	35	32	
NMVOC[3]	185	157	134	90	59	55	52	48	44	41	38	35	32	
NO_x	1,047	1,012	970	757	523	484	449	417	386	357	325	292	263	
SO_x	79.6	60.5	14.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
BC[5]	78.5	64.1	51.1	36.4	27.6	26.5	25.3	23.8	22.1	20.5	18.8	17.2	15.7	
PM[4]	149	121	94	60	39	36	34	32	29	27	25	22	20	
CO	585	579	552	421	324	313	304	296	289	283	278	272	267	
2- and 4-stroke machinery														
TSP[6]	0.161	0.164	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Pb	185	157	134	90	59	55	52	48	44	41	38	35	32	

[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. [1]

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 [9].

> **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].

[!– Table 6: Tier1 emission factors for heavy-metal and POP exhaust emissions from fuel combustion and engine wear

=	= **Pb**	= **Cd**	= **Hg**	= **As**	= **Cr**	= **Cu**	= **Ni**	= **Se**	= **Zn**	= **B[a]P**	= **B[b]F**	= **B[k]F**	= **I[...]p**	= **PAH 1-4**	= **PCDD/F**			
=									= [g/TJ]					= [mg/TJ]	= [µg/TJ]			
~ Gasoline fuels - 4-stroke	> 0.037	> 0.005	> 0.200	> 0.007	> 0.145	> 0.103	> 0.053	> 0.005	> 0.758	> 919	> 919	> 90	> 204	> 2.062	**3**		> 2.76	**4**
~ Gasoline fuels - 2-stroke	> 0.051	> 2.10	> 0.196	> 0.007	> 8.96	> 357	> 14.7	> 2.09	> 208	> 919	> 919	> 90	> 204	> 2.131	**3**		> 57.50	**4**
1																		
2																		
3																		
4																		

In contrast, without country-specific information, regarding all heavy metals and POPs, tier1 values are applied. Here, EF for exhaust HMs and PAHs have been derived from the July 2017 version of the EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP/EEA, 2016) [10] for road vehicles (chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv Passenger cars, light commercial trucks, heavy-duty vehicles including buses and motor cycles; page: 92 ff). Regarding heavy metals, separate tier1 default EFs are provided there in tables 3.77 and 3.78 for emissions from fuel combustion and engine wear as well as lubricant co-incineration. Heavy-metal emissions from lubricants (as far as not used in 2-stroke mix) are reported under NFR 2.G as emissions from product use. *(Note: Until submission 2017, the EMEP/EEA default EFs provided for NRMM were used in the German inventory. As these EFs do not differentiate between fuel combustion and lubricant co-incineration, the inventory compiler decided to apply the more specific EFs from road transport to NRMM in 1.A.2.g vii, 1.A.4.a ii, b ii and c ii and 1.A.5.b, too.)*

The tier1 EF apllied for **PCDD/F** has been derived from a study carried out by (Rentz et al., 2008) [11] for the German Federal Environment Agency. For **HCB** and **PCBs**, no emission factors are available at the moment.

–]

Discussion of emission trends

> **NFR 1.A.4.b ii** is no key source.
>
> Given the limited quality of gasoline-deliveries data from NEB line 66, the following emission trends are of limited significance only.

++ Unregulated pollutants (NH,,3,,, HMs, POPs, ...)

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

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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.

gallery size="medium" : 1A4bii_EM_Cd.PNG gallery

++ Regulated pollutants

+++ Nitrogen oxides (NO,,x,,), Sulphur dioxide (SO,,2,,)

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.

gallery size="medium" : 1A4bii_EM_NOx.PNG : 1A4bii_EM_SOx.PNG gallery

+++ Particulate matter (BC, PM,,2.5,,, PM,,10,,, and TSP)

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 [12)], black carbon emissions follow the corresponding emissions of PM,,2.5,,.

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Recalculations

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

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018
2-stroke machinery													
Submission 2021	0,070	0,067	0,070	0,072	0,065	0,064	0,062	0,060	0,058	0,057	0,058	0,058	0,057
Submission 2020	0,069	0,066	0,066	0,071	0,070	0,070	0,069	0,068	0,068	0,068	0,068	0,068	0,068
absolute change	0,001	0,001	0,003	0,000	-0,005	-0,006	-0,007	-0,009	-0,010	-0,011	-0,010	-0,010	-0,011
relative change	0,94%	1,48%	5,23%	0,54%	-7,09%	-8,62%	-10,2%	-13,0%	-14,2%	-15,6%	-14,1%	-14,8%	-15,9%
4-stroke machinery													
Submission 2021	0,070	0,067	0,070	0,072	0,065	0,064	0,062	0,060	0,058	0,057	0,058	0,058	0,057
Submission 2020	0,069	0,066	0,066	0,071	0,070	0,070	0,069	0,068	0,068	0,068	0,068	0,068	0,068
absolute change	0,001	0,001	0,003	0,000	-0,005	-0,006	-0,007	-0,009	-0,010	-0,011	-0,010	-0,010	-0,011

relative change	0,94%	1,48%	5,23%	0,54%	-7,09%	-8,62%	-10,2%	-13,0%	-14,2%	-15,6%	-14,1%	-14,8%	-15,9%

As all **emission factors** remain unchanged, recalculations occur only for 2017, resulting from the application of **activity data** from the now finalised National Energy Balance 2017.

Table 7: Revised total inland fuel deliveries 2017 for household-related consumption, in terajoules

=			= **gasoline**			= **biogasoline**
=	= **total**	= **2-stroke**	= **4-stroke**	= **total**	= **2-stroke**	= **4-stroke**
~ Submission 2020	> 4,228	> 1.010	> 3,218	> 178	> 42.6	> 135.7
~ Submission 2019	> 4,228	> 1.010	> 3,218	> 180	> 43.0	> 137.0
~ absolute change	> 0	> 0	> 0	> -2	> -0.4	> -1.3
~ relative change	> 0.00%	> 0.00%	> 0.00%	> -0.96%	> -0.98%	> -0.96%

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)) [13)]: “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 at the moment.

FAQs

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

The EF provided in [14)] 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.

bibliography : 1 : AGEB, 2019: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2017.html, (Aufruf: 29.10.2019), Köln & Berlin, 2019. : 2 : Knörr et al. (2019b): 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) 2019, Heidelberg, 2019. : 3 : EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019. : 4 : 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 : 5 : 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. bibliography

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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.