1.A.4.c ii - Agriculture/Forestry/Fishing: Off-Road Vehicles and Other Machinery

Short description

Under sub-category *1.A.4.c ii - Agriculture/Forestry/Fishing: Off-road Vehicles and other Machinery* fuel combustion activities and resulting emissions from off-road vehicles and machinery used in agriculture and forestry are reported seperately.

NFR Code	Source category	Method	AD	EF	Key Category Analysis
1.A.4.c ii	Agriculture/Forestry/Fishing: Off-Road Vehicles and Other Machinery	T1, T2	NS, M	CS, D, M	**L & T**: BC, $PM_{2.5}$, PM_{10} / **L**: NO_x,
including mobile sources sub-categories					
1.A.4.c ii (a)	Off-road Vehicles and Other Machinery: Agriculture	T1, T2	NS, M	CS, D, M	-
1.A.4.c ii (b)	Off-road Vehicles and Other Machinery: Forestry	T1, T2	NS, M	CS, D, M	-

Methodology

Activity data

Sector-specific consumption data is included in the primary fuel-delivery data are available from NEB line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1].

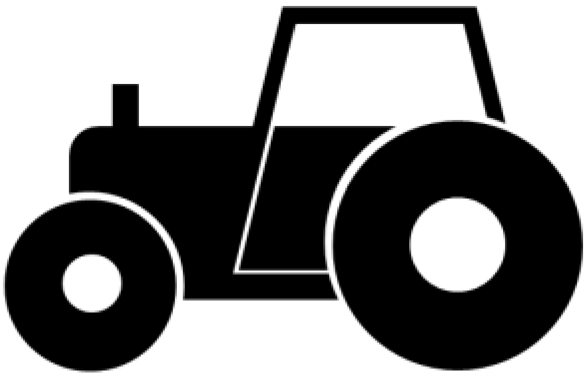


Table 1: Sources for primary fuel-delivery data

through 1994	**AGEB** - National Energy Balance, line 79: 'Haushalte und Kleinverbraucher insgesamt'
as of 1995	**AGEB** - National Energy Balance, line 67: 'Gewerbe, Handel, Dienstleistungen u. übrige Verbraucher'

Following the deduction of energy inputs for military vehicles as provided in (BAFA, 2022) [2], the remaining amounts of gasoline and diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and commercial/institutional used off-road vehicles (1.A.4.a ii) as well as agriculture and forestry (NFR 1.A.4.c ii) based upon annual shares derived from TREMOD MM (Knörr et al. (2022b)) [3] (cf. superordinate chapter).

To provide more specific information on mobile sources in agriculture and forestry, the inventory compiler further devides NFR sector 1.A.4.c ii into **1.A.4.c ii (i) - NRMM in agriculture** in and **1.A.4.c ii (ii) - NRMM in forestry**.

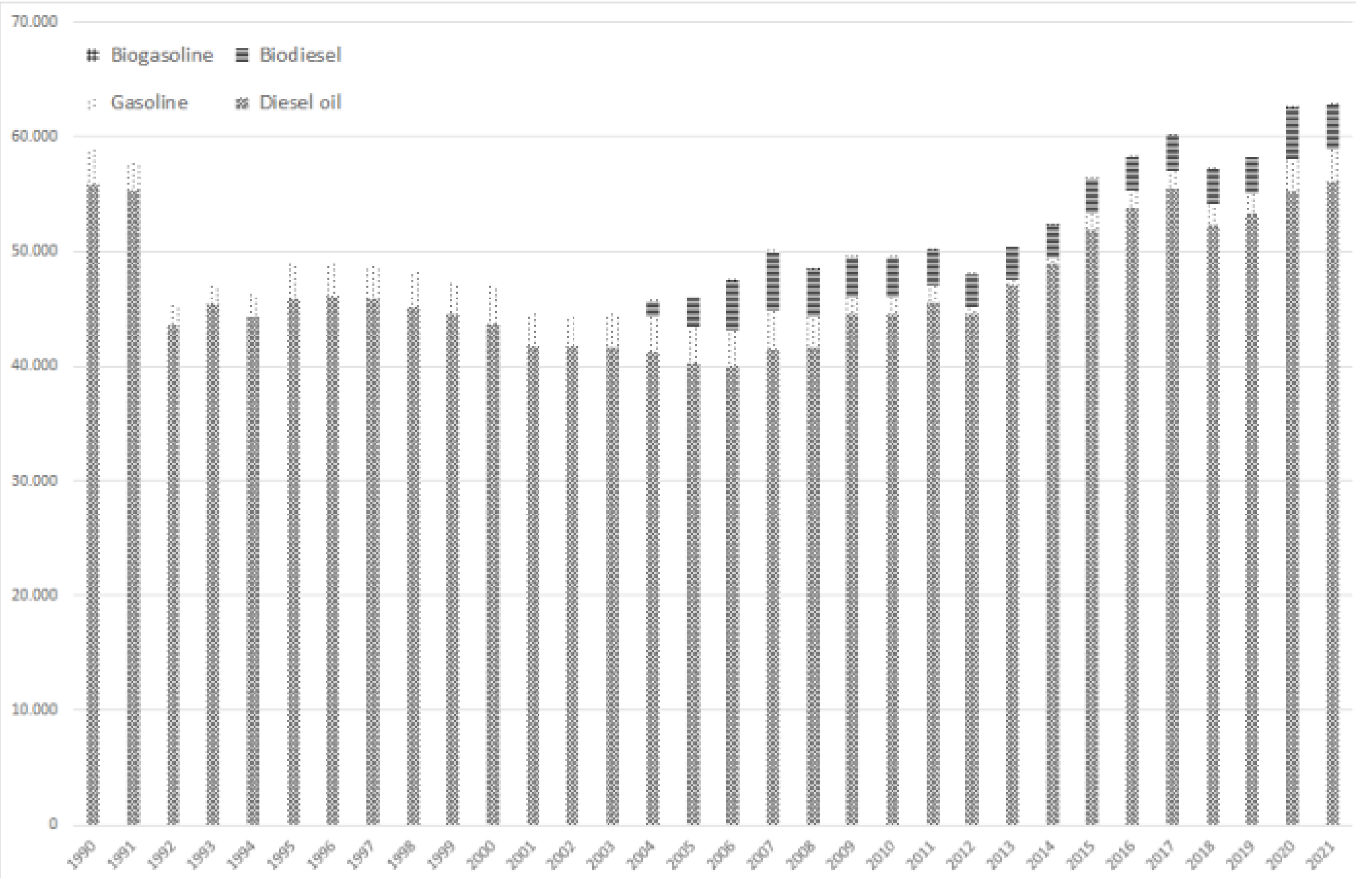
Table 2: Annual percentual contribution of NFR 1.A.4.c ii to the primary fuel delivery data provided in NEB line 67

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
DIESEL FUELS													
1.A.4.c ii (i)	61.5%	76.4%	78.5%	79.6%	71.9%	66.2%	65.2%	64.7%	66.9%	65.5%	65.1%	65.3%	68.8%
1.A.4.c ii (ii)	1.95%	0.63%	0.87%	1.13%	1.55%	1.85%	1.80%	1.87%	2.10%	2.34%	2.74%	2.82%	2.49%
GASOLINE FUELS[1]													
1.A.4.c ii (ii)	68.5%	40.3%	44.9%	41.4%	35.5%	33.3%	31.6%	31.9%	35.8%	36.8%	40.3%	40.8%	40.4%

source: own estimations based on Knörr et al. (2022b) [4] [1] no gasoline used in agriculatural vehicles and mobile machinery

Table 3: Annual mobile fuel consumption in agriculture and forestry, in terajoules

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Diesel oil	71,042	75,327	75,451	66,242	65,143	70,282	70,480	70,888	71,227	71,802	70,812	72,382	73,091
Biodiesel	6,186	6,009	6,648	6,058	7,201	5,943	5,449	5,373	6,083	6,444	7,035	7,268	7,132
Gasoline				4,405	5,095	3,904	3,820	3,864	4,019	4,073	5,792	5,076	5,079
Biogasoline				42.0	122	241	222	217	263	266	315	342	331
Σ 1.A.4.c ii	**77,228**	**81,336**	**82,100**	**76,747**	**77,561**	**80,370**	**79,972**	**80,343**	**81,592**	**82,585**	**83,955**	**85,068**	**85,632**



Emission factors

The emission factors applied here are of rather different quality:

Basically, for all **main pollutants**, **carbon monoxide** and **particulate matter**, annual IEF modelled within TREMOD MM are used, representing the sector's vehicle-fleet composition, the development of mitigation technologies and the effect of fuel-quality legislation.

For Information on the country-specific implied emission factors applied to mobile machinery in agriculture and forestry, please refer to the respective sub-chapters linked above.

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

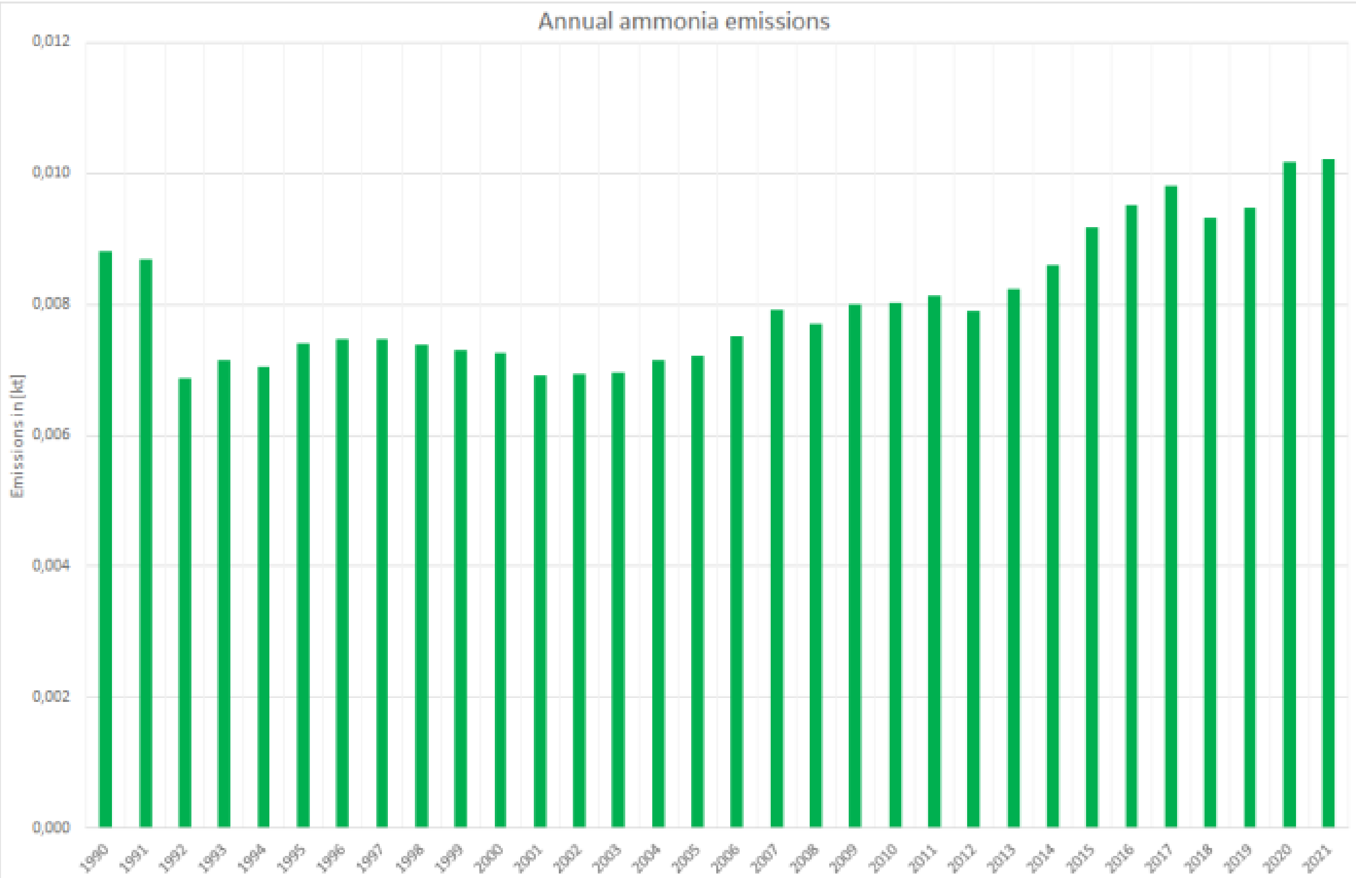
Table: Outcome of Key Catgegory Analysis

for:	NO_x	$PM_{2.5}$	PM_{10}	BC
by:	Level	L	L	Level & Trend

> **NFR 1.A.4.c ii** is key source for emissions of NO_x, **BC**, $PM_{2.5}$ and PM_{10}.

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

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



Here, exemplary for cadmium, the extreme steps in emission estimates result from two effects:

(i) the annual amounts of gasoline fuels allocated to NFR 1.A.4.c ii depend on the amounts delivered to the military also covered in NEB line 67. (see superordinate chapter for further information). This approach results in strong declines in gasoline consumption after 2007 and 2011 followed by an increase after 2014. In addition, in contrast to the main pollutants, all heavy-metal and POP emissions are calculated based on default EF from [5].

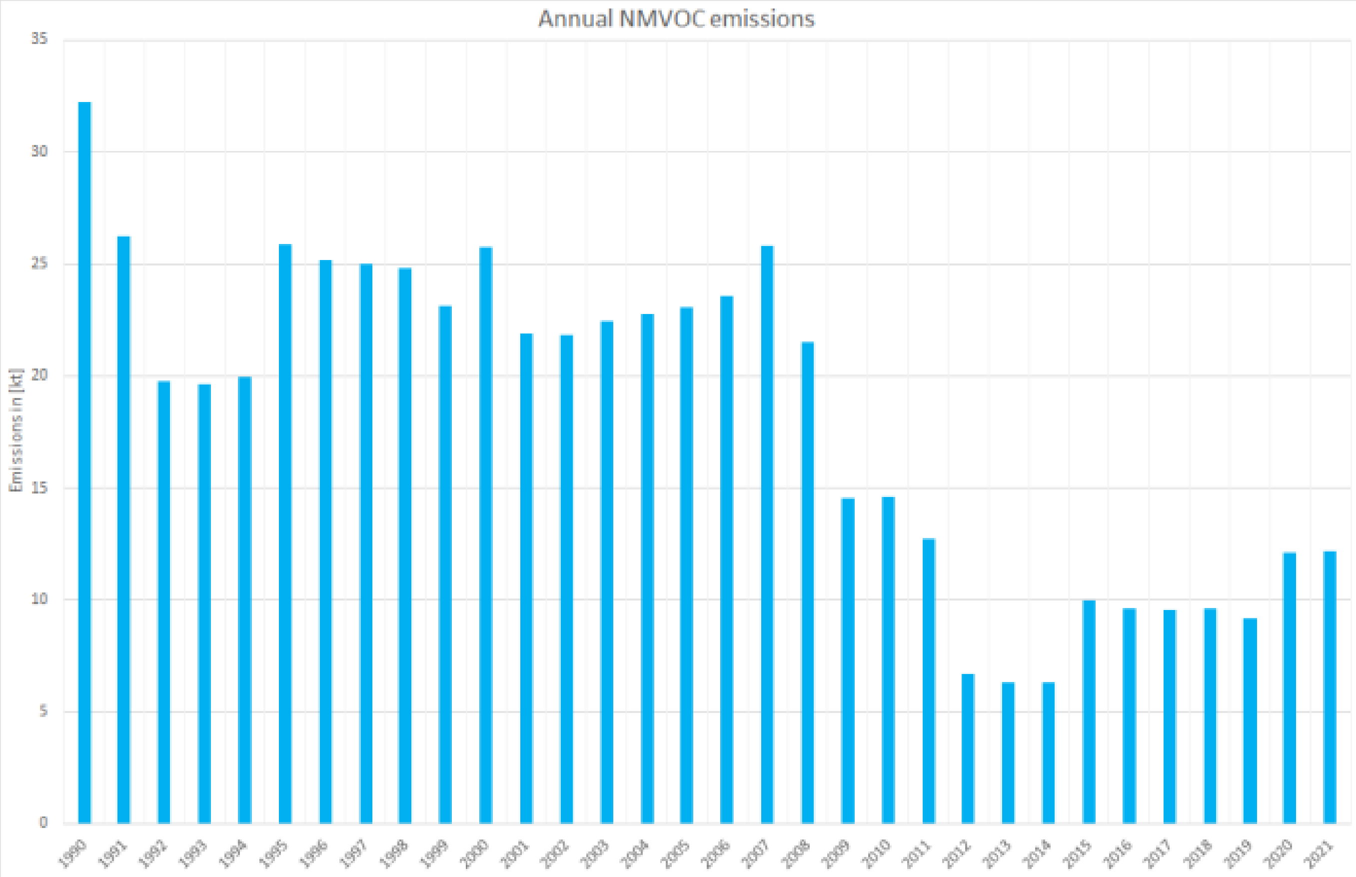


Table 4: Development of gasoline consumption in NFR 1.A.4.c ii, in terajoules

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	1.543	1.404	392	383	412	1.660	1.575	1.588	1.741	1.739		
Biogasoline	60	58	17	16	18	72	68	67	78	75		

(ii) All gasoline fuels allocated to NFR 1.A.4.c ii are used in 2-stroke-engines in forestry equipment. As the 2-stroke fuel also includes lubricant oil, the fuel's heavy metal content is significantly higher than that of 4-stroke gasoline (or diesel fuels). (see Appendix 2.3 for more information on the reporting of HM emissions.)

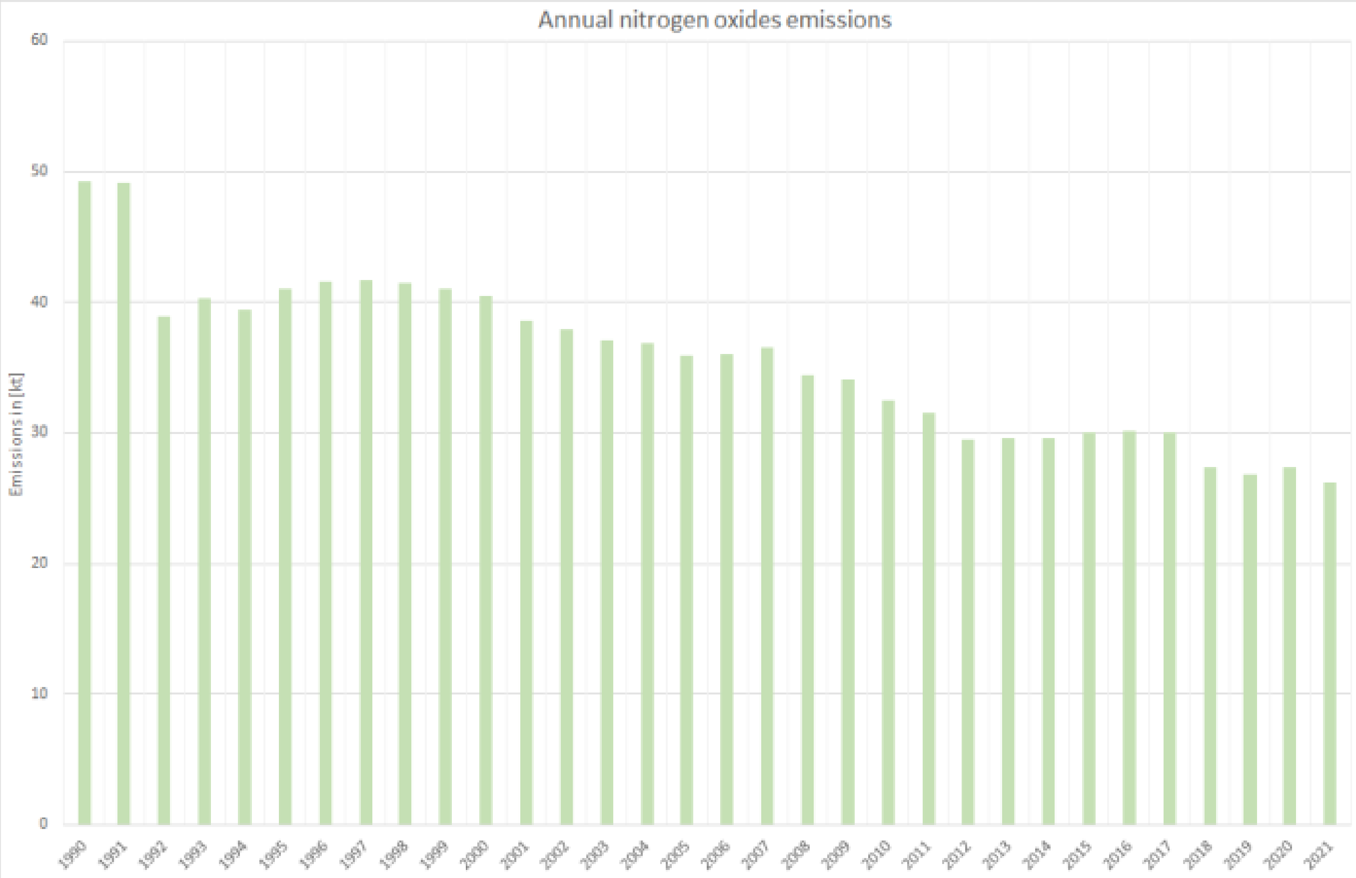
Table 5: Tier1 default emission factors applied to NRMM, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483
Gasoline fuels - 4-stroke	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758
Gasoline fuels - 2-stroke[2]	0.051	2.10	0.196	0.007	8.96	357	14.7	2.09	208
LPG (1.A.4.a ii only)	NE								

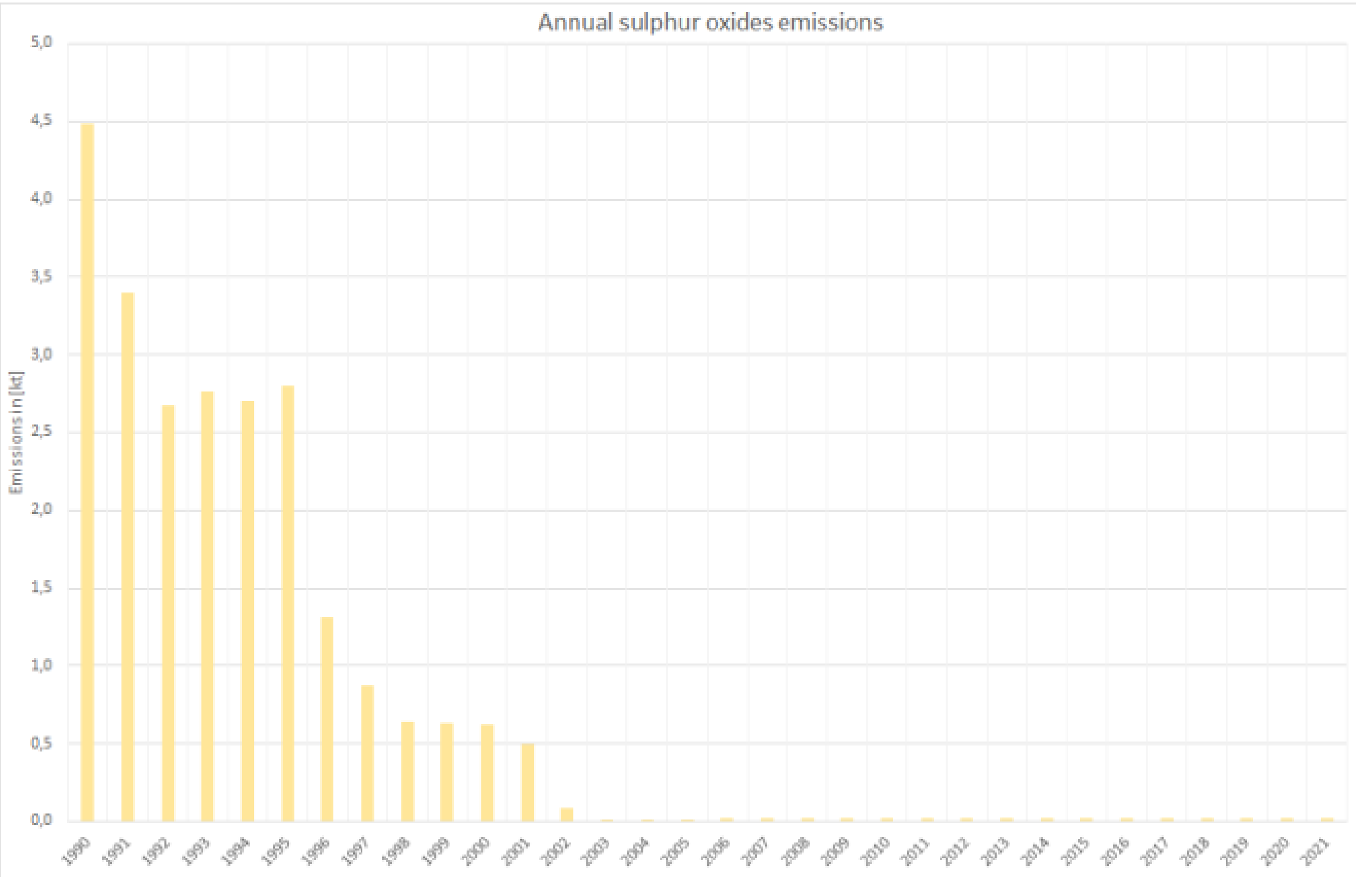
[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel [2] including the HM of 1:50 lube oil mixed to the gasoline Hence, emission estimates reported for cadmium are significantly higher for years with higher gasoline use (in 2-stroke enignes).

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.



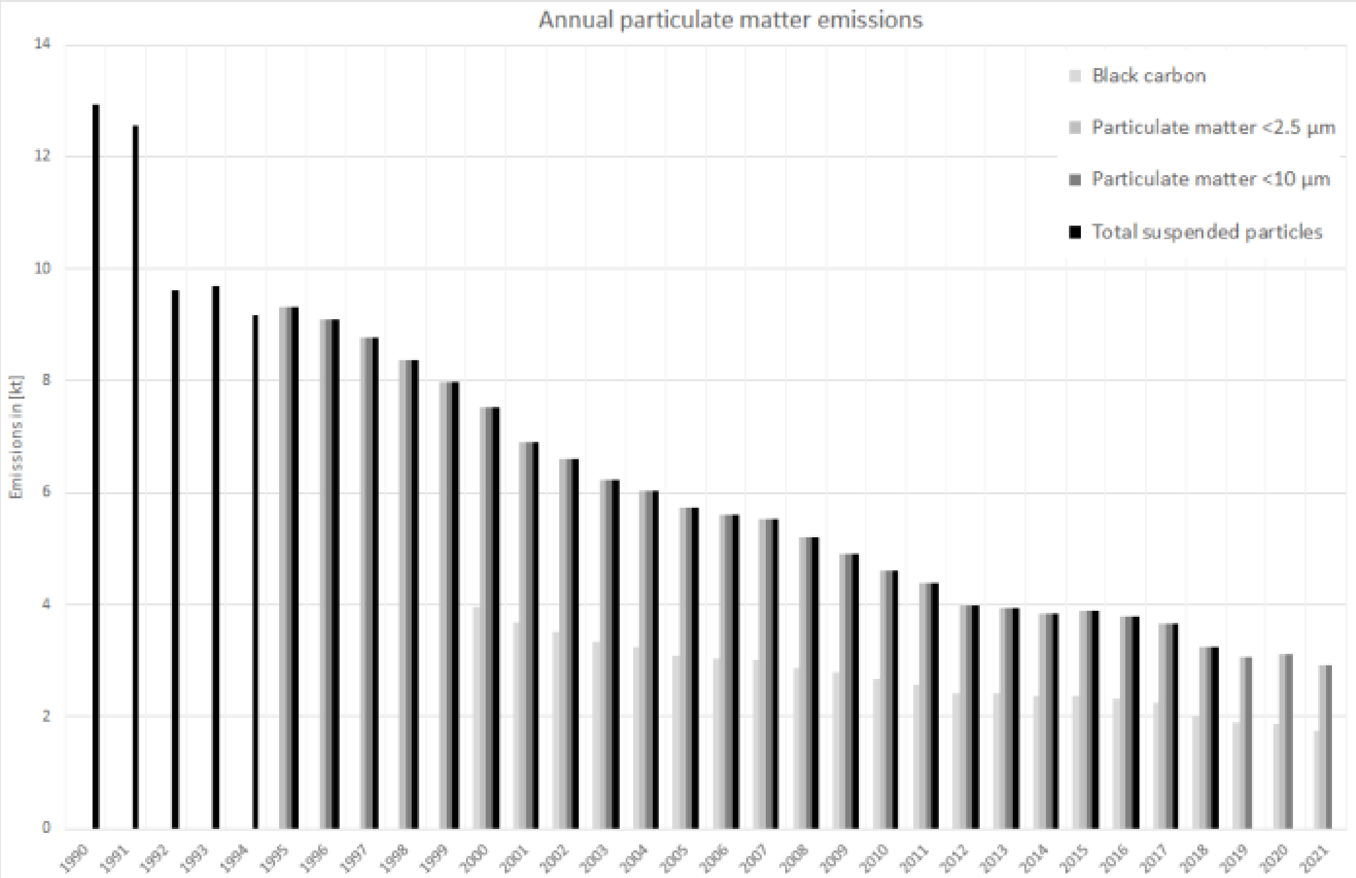
Here, emissions of sulphur oxides follow the step-by-step reduction of sulphur contents in liquid fuels, resulting in a reduction of over 99% since 1990:



Particulate matter & Black carbon

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.



Recalculations

Compared to previous submissions, **activity data** has been recalculated for all years. Here, as fuel consumpion in agricultural vehicles was underestimated in former years*, the methodolgy for deriving the respective consumption data was revised in a way that now the estimates show a very good correlation to the annual amounts of agricultural diesel as recorded in official tax statistics.

As the consumption data for agricultural vehicles is estimated as part of the over-all amounts provided in row 67 of the National Energy Balance via percental shares, these shares have been revised as follows:

Table 6: Revision of annual percental shares of fuels consumed in both agriculture and forestry

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS: AGRICULTURE												
current submission	0.615	0.764	0.785	0.796	0.719	0.662	0.652	0.647	0.669	0.655	0.651	0.653
previous submission	0.475	0.456	0.438	0.462	0.474	0.482	0.484	0.485	0.484	0.484	0.482	0.486
absolute change	0.140	0.308	0.347	0.334	0.244	0.180	0.168	0.162	0.186	0.172	0.169	0.167
relative change	29.5%	67.7%	79.2%	72.4%	51.6%	37.2%	34.7%	33.5%	38.4%	35.5%	35.0%	34.4%
DIESEL FUELS: FORESTRY												
current submission	0.019	0.006	0.009	0.011	0.016	0.019	0.018	0.019	0.021	0.023	0.027	0.028
previous submission	0.024	0.014	0.022	0.029	0.029	0.029	0.027	0.028	0.033	0.035	0.042	0.043
absolute change	-0.005	-0.007	-0.013	-0.018	-0.014	-0.010	-0.009	-0.009	-0.012	-0.012	-0.014	-0.014

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
relative change	-19.0%	-53.4%	-59.4%	-60.9%	-46.8%	-35.9%	-33.9%	-32.9%	-37.2%	-33.9%	-33.9%	-33.8%

Resutling from the revised annual shares, **activity data** have been re-calculated accordingly:

Table 7: Revision of annual activity data, in terajoules

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS												
current submission	71,042	75,327	75,451	70,647	70,238	74,186	74,300	74,753	75,246	75,875	76,604	77,458
previous submission	55,882	45,884	43,681	42,831	47,968	54,608	56,683	58,484	55,381	56,282	59,872	60,041
absolute change	15,161	29,443	31,771	27,817	22,270	19,578	17,618	16,269	19,865	19,593	16,732	17,417
relative change	27.1%	64.2%	72.7%	64.9%	46.4%	35.9%	31.1%	27.8%	35.9%	34.8%	27.9%	29.0%
GASOLINE FUELS												
current submission	6,186	6,009	6,648	6,100	7,322	6,184	5,671	5,591	6,346	6,710	7,351	7,610
previous submission	3,093	3,005	3,324	3,050	1,628	1,751	1,660	1,668	1,875	1,781	2,802	2,892
absolute change	3,093	3,005	3,324	3,050	5,694	4,433	4,012	3,923	4,471	4,929	4,549	4,718
relative change	100%	100%	100%	100%	350%	253%	242%	235%	238%	277%	162%	163%
OVER-ALL FUEL CONSUMPTION												
current submission	77,228	81,336	82,100	76,747	77,561	80,370	79,972	80,343	81,592	82,585	83,955	85,068
previous submission	58,974	48,888	47,005	45,880	49,597	56,359	58,342	60,152	57,256	58,062	62,674	62,933
absolute change	18,254	32,448	35,095	30,867	27,964	24,011	21,629	20,192	24,336	24,523	21,281	22,135
relative change	31.0%	66.4%	74.7%	67.3%	56.4%	42.6%	37.1%	33.6%	42.5%	42.2%	34.0%	35.2%

In contrast, all **emission factors** remain unrevised compared to last year's susbmission.

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)) [6].

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 TREMOD MM**, 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 [7] 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 the 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.

[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022
[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.
[3], [4] Knörr et al. (2022b): 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) 2022, Heidelberg, 2022.
[5], [7] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[6] 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.