

1.A.3.b i - Road transport: Passenger cars

Short description

In sub-category *1.A.3.b i - Road transport: Passenger cars* emissions from fuel combustion in passenger cars (PCs) are reported.

Method	AD	EF	Key Category Analysis
T1, T3	NS, M	CS, M, D	L & T: NO _x , NMVOC, CO, PM _{2.5} , & PM ₁₀ , BC, Pb / L PCDD/F

Methodology

Detailed information on the methods applied is provided in the [superordinate chapter](#).

Activity data

Specific consumption data for passenger cars is generated within TREMOD ¹⁾.

The following table gives an overview of annual amounts of the fuels consumed by passenger cars in Germany.

Table 1: Annual passenger car fuel consumption, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Diesel oil	253,892	305,128	324,929	440,663	492,791	518,198	518,957	556,096	589,674	593,962	621,938	641,476	610,293	
Gasoline	1,275,916	1,260,078	1,196,370	958,621	765,478	762,566	718,328	717,580	720,676	684,853	684,954	694,769	668,337	
LPG	138	138	94	2,357	21,823	23,613	23,532	23,077	21,464	18,963	16,799	15,377	13,570	
CNG	0	0	0	1,608	5,361	5,505	5,151	4,389	4,519	4,492	3,603	3,257	3,980	
Biodiesel	0	476	3,600	29,343	37,500	35,842	36,337	32,710	35,928	32,198	32,732	34,022	35,226	
Biogasoline	0	0	0	6,585	29,575	31,257	31,833	30,760	31,340	29,703	29,752	29,291	30,051	
Biogas	0	0	0	0	0	0	736	868	1,139	757	847	1,013	930	
Σ 1.A.3.b i	1,529,946	1,565,820	1,524,993	1,439,177	1,352,529	1,376,981	1,334,873	1,365,479	1,404,740	1,364,927	1,390,625	1,419,204	1,362,386	

Here, the following charts underline the ongoing shift from gasoline to diesel-powered passenger cars, that started around 1999/2000.

[gallery size="medium"](#) : 1A3bi_AD.png : 1A3bi_AD_Gasoline.png : 1A3bi_AD_Diesel.png : 1A3bi_AD_bio.png : 1A3bi_AD_Other.png [gallery](#)



For information on mileage, please refer to sub-chapters on emissions from [tyre & brake wear and road abrasion](#).

Emission factors

The majority of emission factors for exhaust emissions from road transport are taken from the

'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) ²⁾ where they are provided on a tier3 level mostly and processed within the TREMOD software used by the party ³⁾.

However, it is not possible to present these highly specific tier3 values in a comprehensible way here.

[!- Table 2: selected annual fuel-specific IEF for passenger cars, in kg/T]

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline fuels¹																		
NH₃	0.66	12.6	23.1	21.3	21.3	20.8	20.0	18.9	17.8	17.1	16.5	15.8	15.3	15.0	15.0	14.9		
NM VOC²	731	281	151	106	99.4	94.8	86.5	82.1	78.4	76.0	74.1	72.4	71.3	70.5	70.1	69.5		
NO_x	616	342	217	142	130	119	99.2	87.8	77.6	70.7	64.6	59.3	55.1	51.8	49.1	46.5		
SO₂	11.8	8.36	3.25	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		
CO	4,698	2,340	1,397	1,013	948	911	844	802	763	741	720	700	687	678	677	673		
BC⁵	0.07	0.30	0.44	0.36	0.35	0.34	0.31	0.28	0.25	0.24	0.22	0.20	0.19	0.18	0.18	0.17		
PM³	3.67	2.75	2.48	1.87	1.82	1.74	1.60	1.49	1.37	1.31	1.24	1.18	1.14	1.10	1.09	1.07		
TSP⁴	5.58	3.03	2.48	1.87	1.82	1.74	1.60	1.49	1.37	1.31	1.24	1.18	1.14	1.10	1.09	1.07		
Diesel fuels¹																		
NH₃	0.36	0.37	0.39	0.41	0.40	0.41	0.41	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.44	0.44		
NM VOC	45.5	36.8	29.1	18.6	16.5	15.0	13.5	12.5	11.7	11.0	10.4	9.93	9.64	9.62	9.85	10.1		
NO_x	273	274	304	308	302	298	294	293	298	309	320	329	334	332	324	313		
SO₂	80.8	60.5	14.0	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		
CO	250	205	152	87.9	78.8	71.5	64.3	59.8	56.3	53.1	50.4	48.3	46.7	45.6	44.6	44.0		
BC⁵	29.6	30.4	28.8	18.3	15.5	13.3	11.2	9.53	8.29	7.19	6.07	5.13	4.35	3.72	3.22	2.80		
PM³	48.8	46.1	39.5	23.2	19.6	16.8	14.1	12.1	10.5	9.20	7.86	6.74	5.82	5.09	4.49	4.00		
Liquefied Petroleum Gas - LPG																		
NH₃	0.84	6.92	37.3	32.6	28.6	26.7	23.5	22.1	21.6	21.3	20.9	20.5	20.2	19.9	19.8	19.6		
NM VOC	329	283	49.6	9.73	8.63	8.22	7.50	7.24	7.17	7.10	6.97	6.88	6.82	6.78	6.77	6.75		
NO_x	1,047	906	200	66.1	58.7	56.5	52.6	50.9	49.9	49.3	48.1	46.7	45.6	44.8	44.0	43.2		
SO₂	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41		
CO	2,043	1,812	662	509	452	458	456	456	453	455	452	449	448	447	452	453		
BC⁵	0.24	0.33	0.75	0.56	0.47	0.43	0.36	0.33	0.32	0.31	0.30	0.29	0.29	0.28	0.28	0.28		
PM³	0.97	1.31	3.01	2.41	2.05	1.90	1.64	1.53	1.48	1.47	1.43	1.40	1.38	1.37	1.37	1.36		
Compressed Natural Gas (CNG) & Biogas⁶																		
NH₃				10.6	10.6	10.7	10.7	10.7	10.7	10.8	10.8	10.8	11.0	11.1	11.4	11.6		
NM VOC				0.48	0.48	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.50	0.51	0.52	0.52		
NO_x				40.6	40.6	40.6	40.4	40.3	39.6	37.6	35.1	33.3	31.7	30.3	29.3	28.2		
SO₂				0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15		
CO				258	258	262	261	261	259	258	255	252	251	252	255	257		
BC⁵				0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11		
PM³				0.67	0.67	0.67	0.67	0.67	0.67	0.68	0.69	0.70	0.71	0.72	0.74	0.75		

¹ due to lack of better information: similar EF are applied for fossil and biofuels

² not including NM VOC from gasoline evaporation!

³ EF(PM_{2.5}) also applied for PM₁₀ and TSP (assumption: > 99% of TSP consists of PM_{2.5})

⁴ 1990-1997: including additional TSP from combustion of leaded gasoline

⁵ EF(BC) estimated via f(BC)

⁶ due to lack of better information: similar EF are applied for CNG and biogas -]



With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely



included at least partly. ¹⁾

For heavy-metal (other than lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from (EMEP/EEA, 2019) ⁴⁾ have been applied. Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008) ⁵⁾ is used.

Table 3: tier1 emission factors

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[1,2,3-c,d]p	PAH 1-4	PCDD/F
	[g/TJ]									[mg/TJ]					[µg/km]
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419	498	521	275	493	1.788	
Biodiesel ¹⁾	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483	575	601	317	569	2.062	
Gasoline fuels	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758	96	140	69	158	464	
CNG²⁾ & biogas³⁾	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
LPG⁴⁾	NE	NE	NE	NE	NE	NE	NE	NE	NE	4.35	0.00	4.35	4.35	13.0	
all fuels															0.000006

¹⁾ values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

²⁾ no specific default available from ⁶⁾; value derived from CNG powered busses

³⁾ no specific default available from ⁷⁾; values available for CNG also applied for biogas

⁴⁾ no specific default available from ⁸⁾; value derived from LPG powered passenger cars

Discussion of emission trends

NFR 1.A.3.b i is key category for **NH₃**, **NO_x**, **NM VOC**, **CO**, **PM_{2.5}**, and **PM₁₀**.

++ Non-methane volatile organic compounds (NM VOC), nitrogen oxides (NO_x), and carbon monoxide (CO)

Since 1990, exhaust emissions of **nitrogen oxides**, **NM VOC**, and **carbon monoxide** have decreased sharply due to catalytic-converter use and engine improvements resulting from ongoing tightening of emissions laws and improved fuel quality.

[gallery size="medium"](#) : 1A3bi_EM_NOx.PNG : 1A3bi_EM_NM VOC.PNG : 1A3bi_EM_CO.PNG [gallery](#)

++ Ammonia (NH₃) and sulphur dioxide (SO₂)

As for the entire road transport sector, the trends for **sulphur dioxide** (SO₂) and **ammonia** (NH₃) exhaust emissions from passenger cars show characteristics very different from those shown above: Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of SO₂ emissions, influenced only slightly by increases in fuel consumption and mileage. For **ammonia** emissions the increasing use of catalytic converters in gasoline driven cars in the 1990s lead to a steep increase whereas both the technical development of the converters and the ongoing shift from gasoline to diesel cars resulted in decreasing emissions in the following years.

[gallery size="medium"](#) : 1A3bi_EM_SO2.png : 1A3bi_EM_NH3.png [gallery](#)

++ Particulate Matter (BC, PM_{2.5}, PM₁₀, and TSP) (*from fuel combustion only; no wear/abrasion included*)

Starting in the middle of the 1990s, a so-called “diesel boom” began, leading to a switch from gasoline to diesel powered passenger cars. As the newly registered diesel cars had to meet the EURO2 standard (in force since 1996/'97) with a PM limit value less than half the EURO1 value, the growing diesel consumption was overcompensated quickly by the mitigation technologies implemented due to the new EURO norm. During the following years, new EURO norms came into force. With the still ongoing “diesel boom” those norms led to a stabilisation (EURO3, 2000/'01) of emissions and to another strong decrease of PM emissions (EURO4, 2005/'06), respectively. Over-all, the increased consumption of diesel in passenger cars was overestimated by the implemented mitigation technologies. The table below shows the evolution of the limit value for particle emissions from passenger cars with diesel engines.

With this submission, Black Carbon (BC) emissions are reported for the first time. Here, EF are estimated based on as fractions of PM as provided in ⁹⁾. Due to this fuel-specific fractions, the trend of BC emissions reflects the ongoing shift from gasoline to diesel (“dieselisation”).

gallery size="medium" : 1A3bi_EM_PM.PNG gallery

Table: EURO norms and their effect on limit values of PM emissions from diesel passenger cars

~ exhaust emission standard (EURO norm)	= Euro 1	= Euro 2	= Euro 3	= Euro 4	= Euro 5	= Euro 6
in force for type approval since:	= 1 Jul 1992	= 1 Jan 1996	= 1 Jan 2000	= 1 Jan 2005	= 1 Sep 2009	= 1 Sep 2014
in force for initial registration since	= 1 Jan 1993	= 1 Jan 1997	= 1 Jan 2001	= 1 Jan 2006	= 1 Jan 2011	= 1 Jan 2015
~ resulting PM limit value in [mg/km]	= 180	= 80/100¹	= 50	= 25	= 5	= 5
1						

Recalculations

Compared to submission 2020, recalculations were carried out due to a routine revision of the TREMOD software and the revision of several National Energy Balances (NEB).

Here, **activity data** were revised within TREMOD.

Table 4: Revised fuel consumption data, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
DIESEL OIL																	
Submission 2021	23,131	19,972	24,124	23,030	21,811	21,678	20,902	20,202	19,039	18,591	17,555	17,548	17,996	17,777	18,080	18,456	
Submission 2020	22,049	16,628	19,184	20,151	20,306	17,167	17,492	17,657	17,384	18,033	17,840	18,540	19,289	18,641	18,609	18,809	
absolute change	1,082	3,344	4,940	2,878	1,505	4,511	3,410	2,544	1,655	558	-285	-992	-1,293	-863	-529	-352	
relative change	4,91%	20,1%	25,8%	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-1,87%	
BIODIESEL																	
Submission 2021	0	0	0	158	314	293	400	577	736	762	778	752	783	771	785	778	

Submission 2020	0	0	0	138	293	232	334	504	672	739	791	795	839	808	808	801	
absolute change	0	0	0	20	22	61	65	73	64	23	-13	-43	-56	-37	-23	-23	
relative change	0.00	0.00	0.00	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-2,82%	
GASOLINE																	
Submission 2021	23,131	19,972	24,124	23,030	21,811	21,678	20,902	20,202	19,039	18,591	17,555	17,548	17,996	17,777	18,080	18,456	
Submission 2020	22,049	16,628	19,184	20,151	20,306	17,167	17,492	17,657	17,384	18,033	17,840	18,540	19,289	18,641	18,609	18,809	
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Submission 2020	0	0	0	138	293	232	334	504	672	739	791	795	839	808	808	801	
absolute change	0	0	0	20	22	61	65	73	64	23	-13	-43	-56	-37	-23	-23	
relative change	0.00	0.00	0.00	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-2,82%	
CNG																	
Submission 2021	23,131	19,972	24,124	23,030	21,811	21,678	20,902	20,202	19,039	18,591	17,555	17,548	17,996	17,777	18,080	18,456	
Submission 2020	22,049	16,628	19,184	20,151	20,306	17,167	17,492	17,657	17,384	18,033	17,840	18,540	19,289	18,641	18,609	18,809	
absolute change	1,082	3,344	4,940	2,878	1,505	4,511	3,410	2,544	1,655	558	-285	-992	-1,293	-863	-529	-352	
relative change	4,91%	20,1%	25,8%	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-1,87%	
BIOGAS																	
Submission 2021	0	0	0	158	314	293	400	577	736	762	778	752	783	771	785	778	
Submission 2020	0	0	0	138	293	232	334	504	672	739	791	795	839	808	808	801	
absolute change	0	0	0	20	22	61	65	73	64	23	-13	-43	-56	-37	-23	-23	
relative change	0.00	0.00	0.00	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-2,82%	
LPG																	
Submission 2021	0	0	0	158	314	293	400	577	736	762	778	752	783	771	785	778	
Submission 2020	0	0	0	138	293	232	334	504	672	739	791	795	839	808	808	801	
absolute change	0	0	0	20	22	61	65	73	64	23	-13	-43	-56	-37	-23	-23	
relative change	0.00	0.00	0.00	14,3%	7,41%	26,3%	19,5%	14,4%	9,52%	3,09%	-1,60%	-5,35%	-6,71%	-4,63%	-2,84%	-2,82%	
TOTAL FUEL CONSUMPTION																	
Submission 2021	23,131	19,972	24,124	23,188	22,125	21,971	21,302	20,779	19,775	19,354	18,336	18,304	18,783	18,554	18,871	19,242	
Submission 2020	22,049	16,628	19,184	20,290	20,598	17,399	17,827	18,162	18,056	18,773	18,631	19,335	20,128	19,449	19,417	19,609	
absolute change	1,082	3,344	4,940	2,898	1,527	4,572	3,475	2,617	1,719	581	-295	-1,030	-1,345	-895	-545	-368	
relative change	4.91%	20.1%	25.8%	14.3%	7.41%	26.3%	19.5%	14.4%	9.52%	3.09%	-1.58%	-5.33%	-6.68%	-4.60%	-2.81%	-1.88%	

Due to the variety of tier3 **emission factors** applied, it is not possible to display any changes in these data sets in a comprehensible way.



For more information on recalculated emission estimates



reported for Base Year and 2018, please see the pollutant-specific recalculation tables following chapter [8.1 - Recalculations](#).

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

FAQs

bibliography : 1 : Knörr et al. (2019a): 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 1960-2030, sowie TREMOD 6.02, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2019. : 2 : Keller et al., (2019): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: <http://www.hbefa.net/e/index.html> - Dokumentation, Bern, 2019. : 3 : EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view>; 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-bibliography>

¹⁾ (bibcite 1)

²⁾ (bibcite 2)

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⁴⁾ (bibcite 3)

⁵⁾ (bibcite 4)

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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 dilution (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.