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.

Category Code	**Method**													
1.A.3.b i	T1, T3													
	AD													
	NS, M													
	EF													
	CS, M, D													
Key Category	**SO_2**	**NO_x**	**NH_3**	**NMVOC**	**CO**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**BC**	**Pb**	**Hg**	**Cd**	**Diox**	**PAH**
1.A.3.b i	-/-	L/T	-/-	L/T	L/T	-/-	L/T	L/T	L/T	L/T	-/-	-/-	L/-	-/-

Category Code	Method	AD	EF
1.A.3.b i	T1, T3	NS, M	CS, M, D

Key Category	SO_2	NO_x	NH_3	NMVOC	CO	TSP	PM_{10}	$PM_{2.5}$	BC	Pb	Hg	Cd	Diox	PAH	HCB
1.A.3.b i	-/-	L/T	-/-	L/T	L/T	-/-	L/T	L/T	L/T	L/T	-/-	-/-	L/-	-/-	-

Methodology

Detailed information on the methods applied is provided in the superordinate chapter .

Activity data

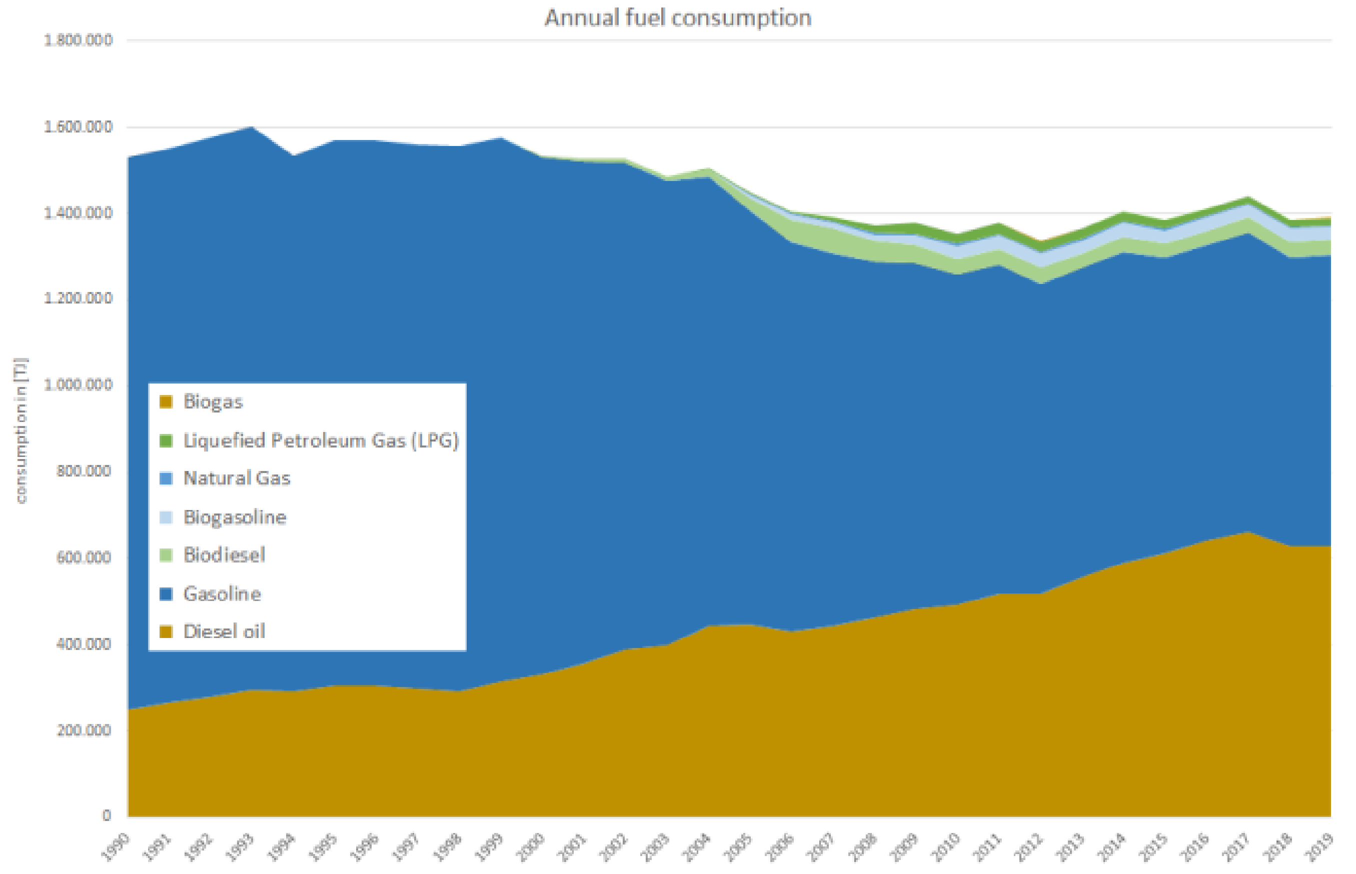
Specific consumption data for passenger cars is generated within TREMOD [1].

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	251,081	304,573	330,544	447,843	491,684	517,460	518,642	556,149	589,801	612,084	641,130	661,289	629,483	628,079
Gasoline	1,280,592	1,263,563	1,198,941	960,365	766,348	763,397	719,091	718,322	721,165	685,429	685,497	695,259	668,949	675,555
LPG	138	138	94	2,357	21,823	23,613	23,532	23,077	21,464	18,963	16,799	15,377	16,153	17,332
CNG	0	0	0	1,604	5,351	5,494	5,140	4,380	4,483	4,476	3,590	3,247	3,332	3,412
Biodiesel	0	475	3,662	29,928	37,696	36,105	36,603	32,982	36,244	33,481	33,989	35,303	36,591	35,762
Biogasoline	0	0	0	6,597	29,609	31,292	31,866	30,792	31,361	29,728	29,775	29,312	30,078	29,136
Biogas	0	0	0	0	0	0	734	867	1,130	755	844	1,009	897	1,561
Σ 1.A.3.b i	**1,531,811**	**1,568,749**	**1,533,241**	**1,448,694**	**1,352,511**	**1,377,360**	**1,335,609**	**1,366,568**	**1,405,647**	**1,384,915**	**1,411,625**	**1,440,795**	**1,385,484**	**1,390,837**

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


Annual fuel consumption
consumption in [TJ]
1.800.000
1.600.000
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
Biogas
Liquefied Petroleum Gas (LPG)
Natural Gas
Biogasoline
Biodiesel
Gasoline
Diesel oil
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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2016
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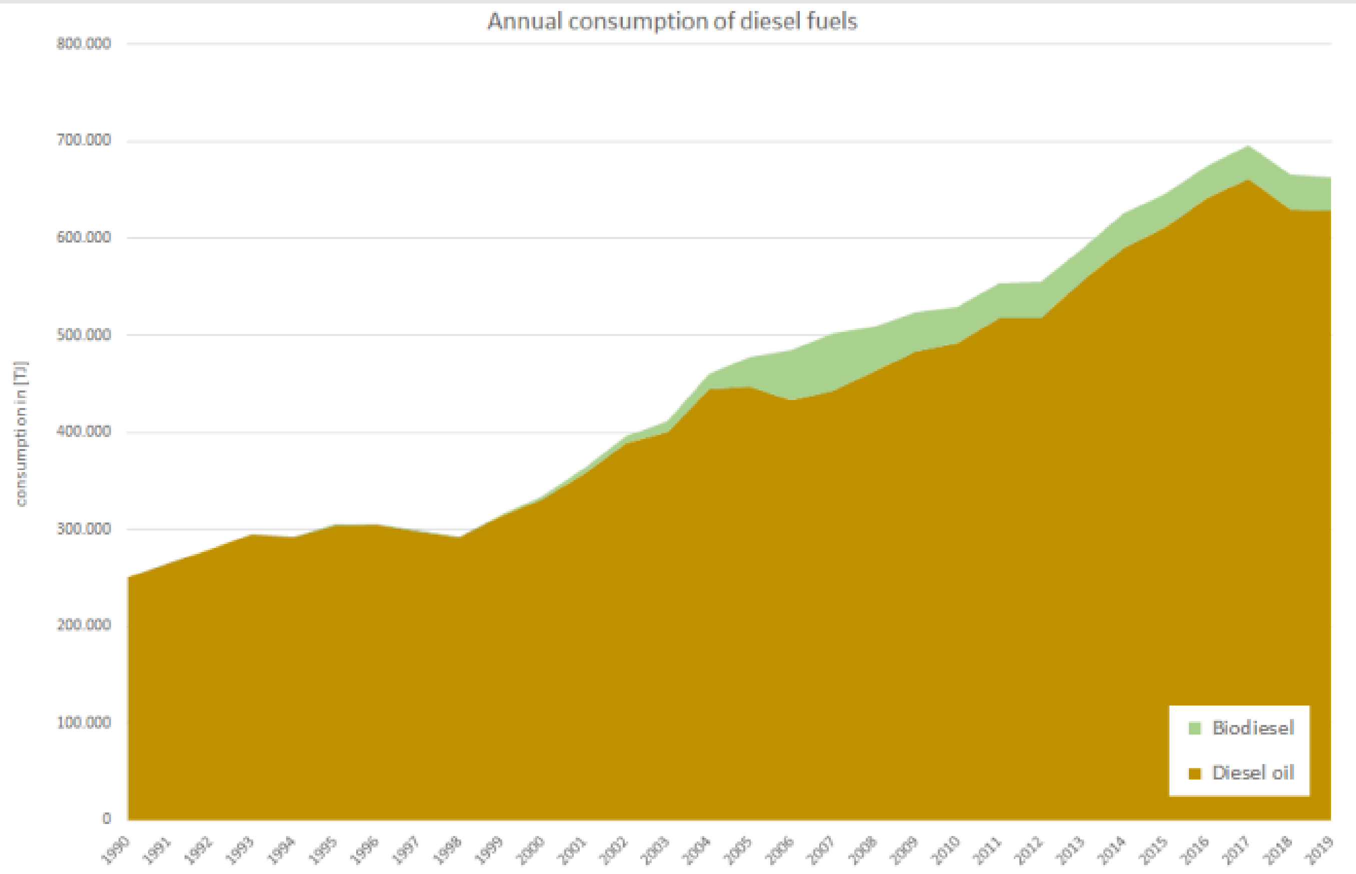
2019


Annual consumption of diesel fuels
consumption in [TJ]
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0
Biodiesel
Diesel oil
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
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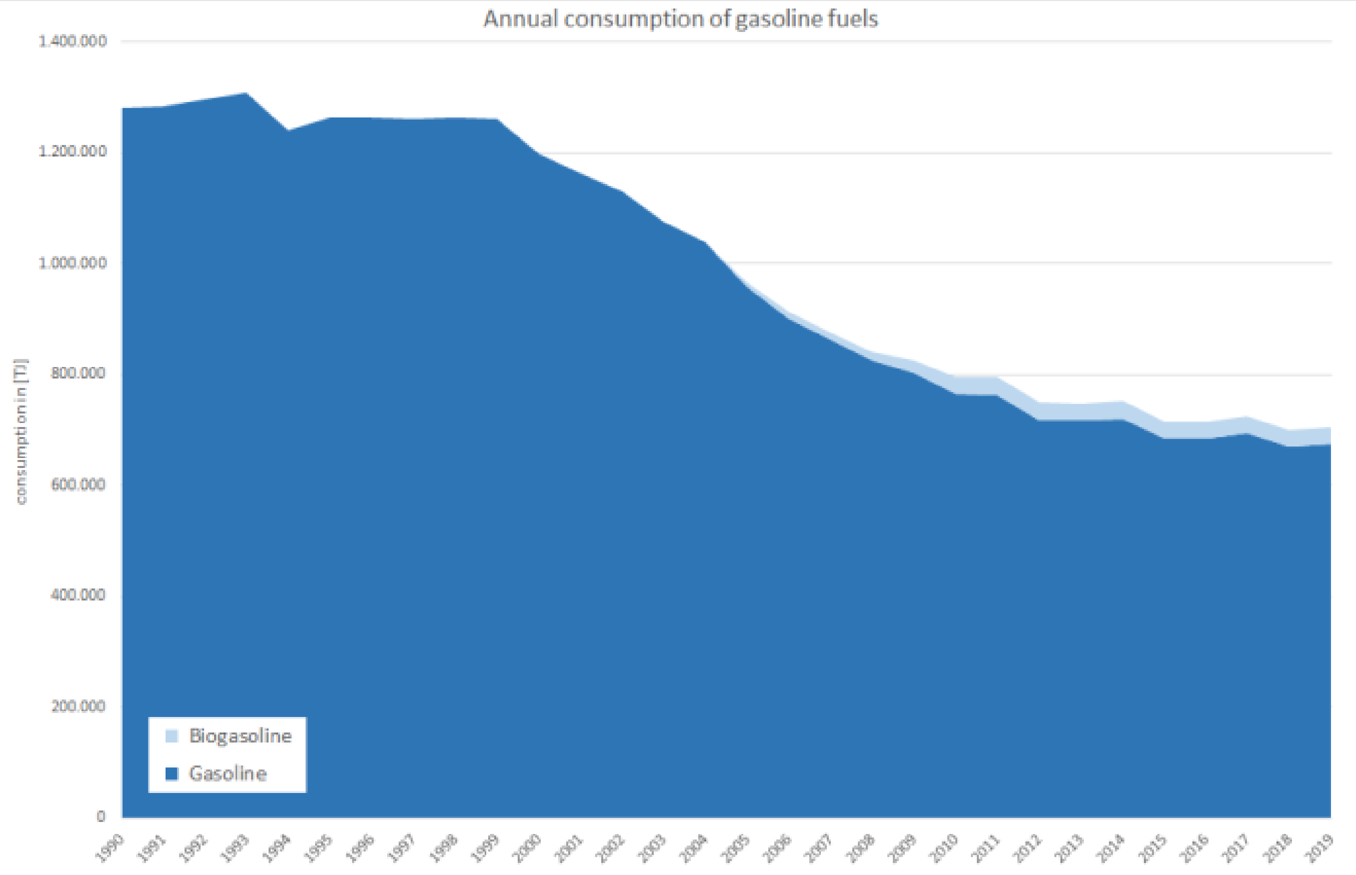
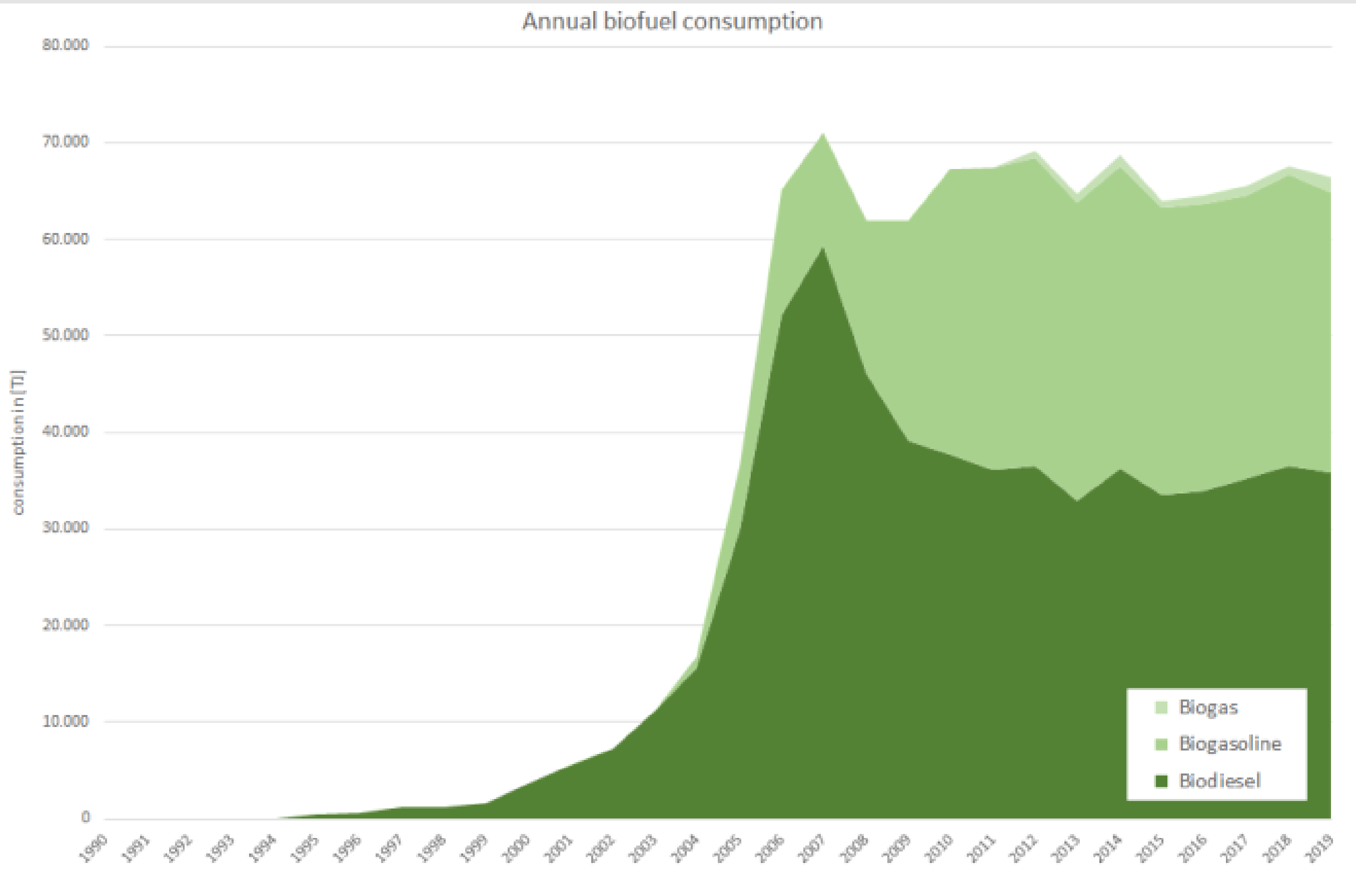
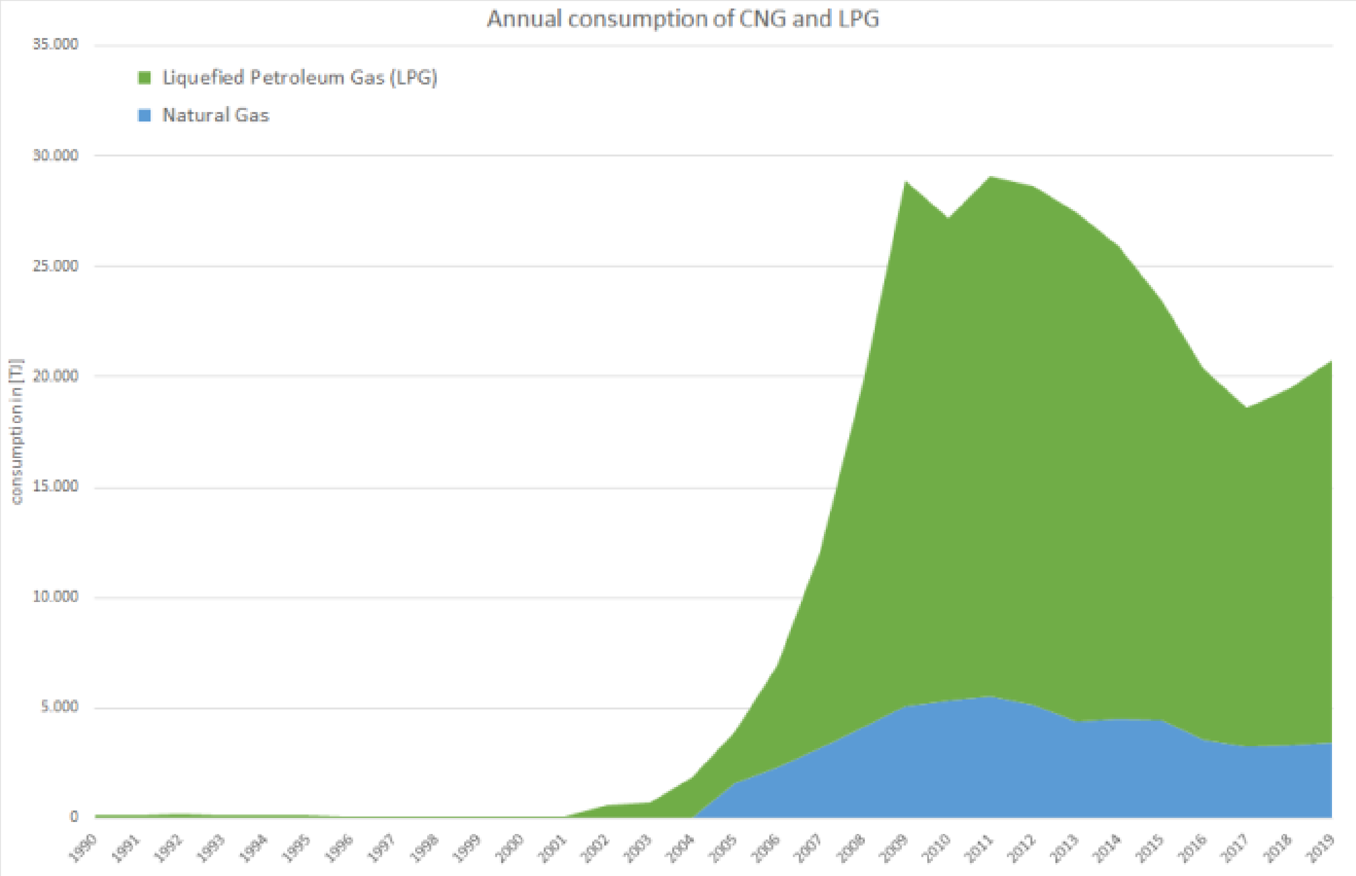
2014
2015
2016
2017
2018
2019


Annual consumption of gasoline fuels
consumption in [TJ]
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
Biogasoline
Gasoline
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019


Annual biofuel consumption
consumption in [TJ]
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0
Biogas
Biogasoline
Biodiesel
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019



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 comprehendible way here.

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

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline fuels[1]																		
NH_3	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		
NMVOC[2]	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		
SO_2	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		
BC[5]	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		
PM[3]	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		
TSP[4]	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 fuels[1]																		

NH_3	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		
NMVOC	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		
SO_2	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		
BC[5]	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		
PM[3]	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																		
NH_3	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		
NMVOC	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		
SO_2	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		
BC[5]	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		
PM[3]	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) & Biogas[6]																		
NH_3				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		
NMVOC				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		
SO_2				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		
BC[5]				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		
PM[3]				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 NMVOC from gasoline evaporation!
[3] EF($PM_{2.5}$) also applied for PM_{10} 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 then 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	
CNG[2] & biogas[3]	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	

LPG[4]	NE	NE	NE	NE	NE	NE	NE	NE	NE	4.35	0.00	4.35	4.35	13.0	
all fuels															0.000006

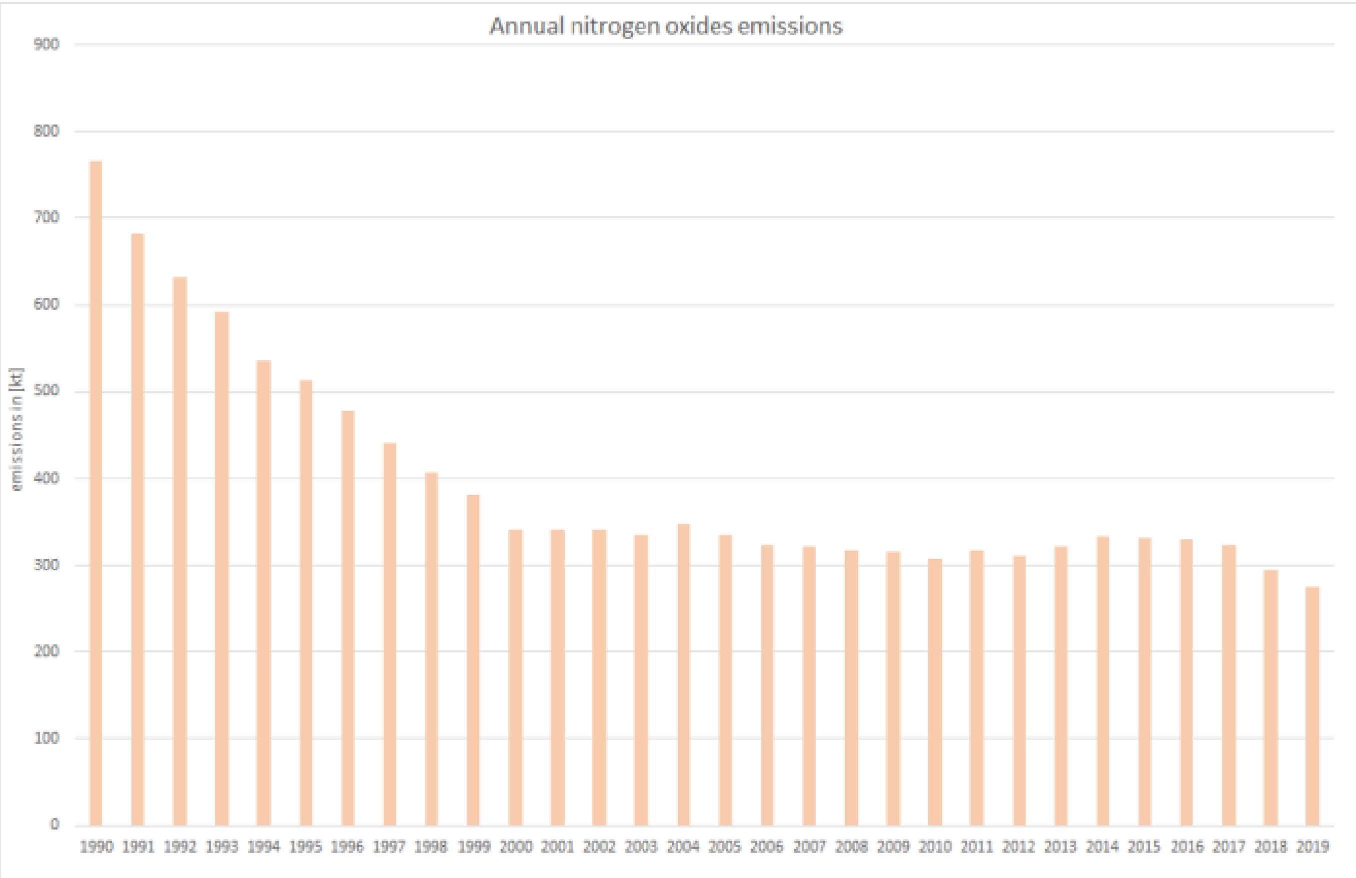
[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
[2] no specific default available from [6)]; value derived from CNG powered busses
[3] no specific default available from [7)]; values available for CNG also applied for biogas
[4] no specific default available from [8)]; value derived from LPG powered passenger cars

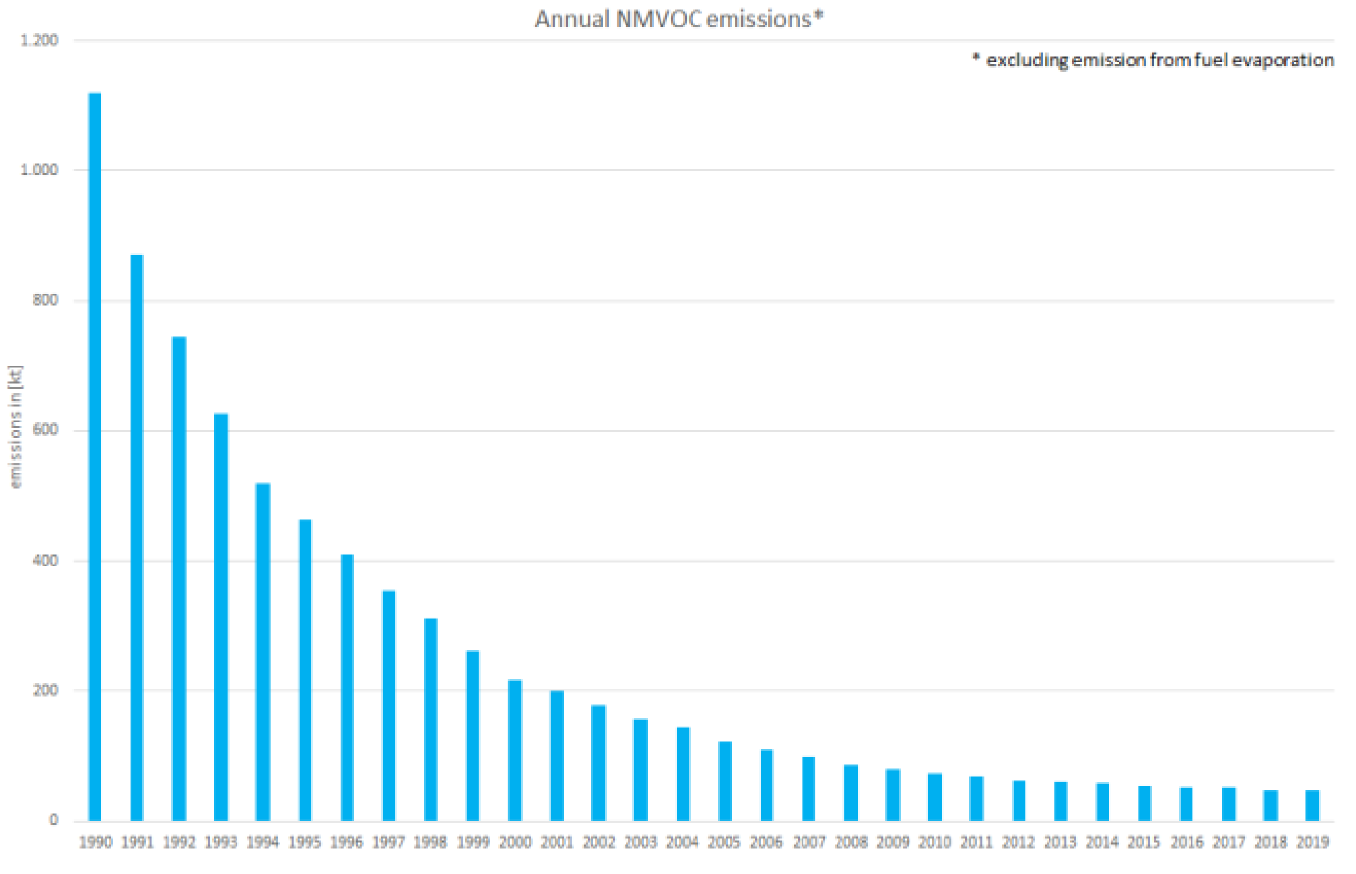
Discussion of emission trends

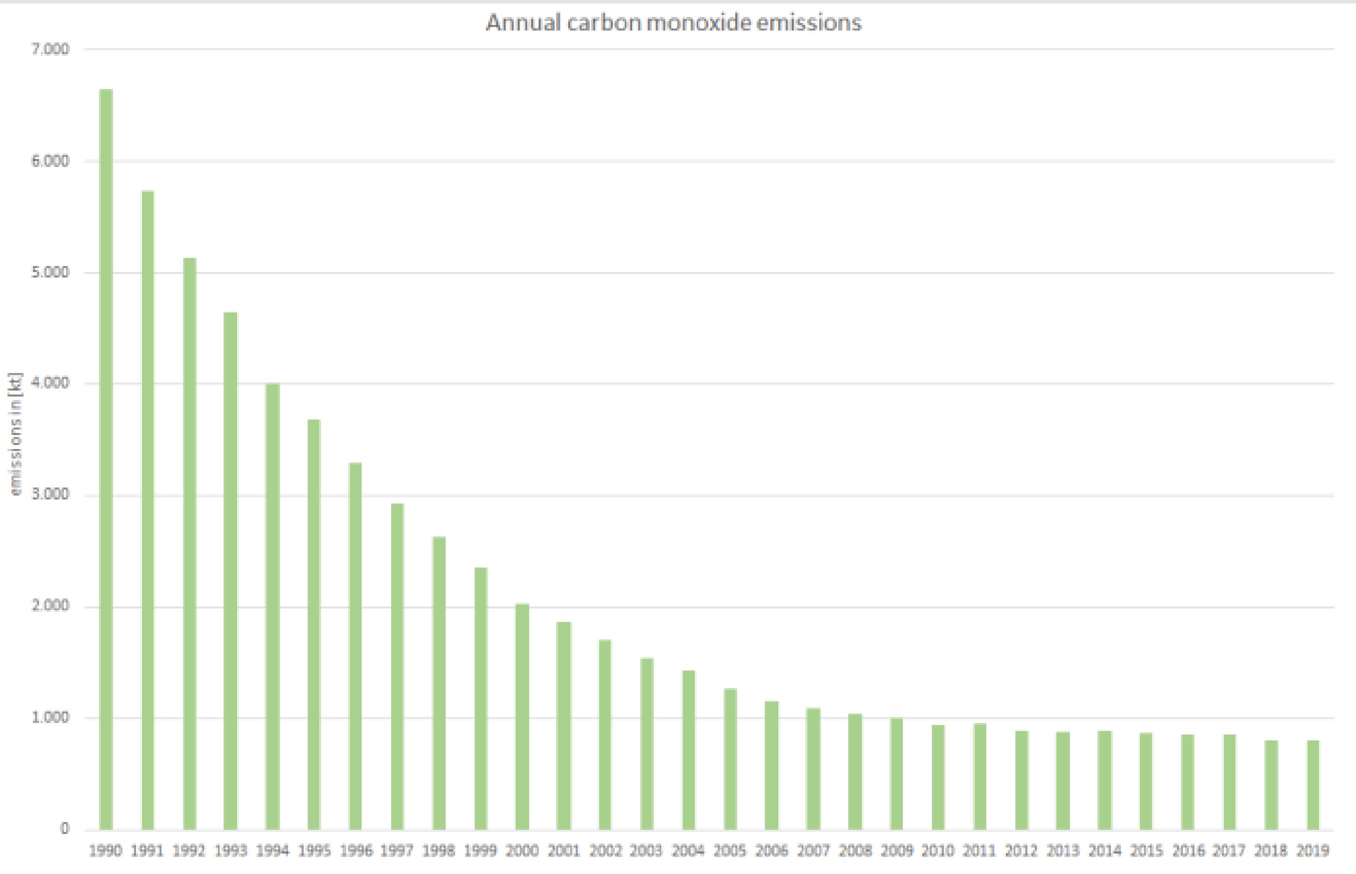
> **NFR 1.A.3.b i** is key category for **NH,,3,,**, **NO,,x,,**, **NMVOC**, **CO**, **PM,,2.5,,** and **PM,,10,,**.

Non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO,,x,,), and carbon monoxide (CO)

Since 1990, exhaust emissions of **nitrogen oxides**, **NMVOC**, 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.

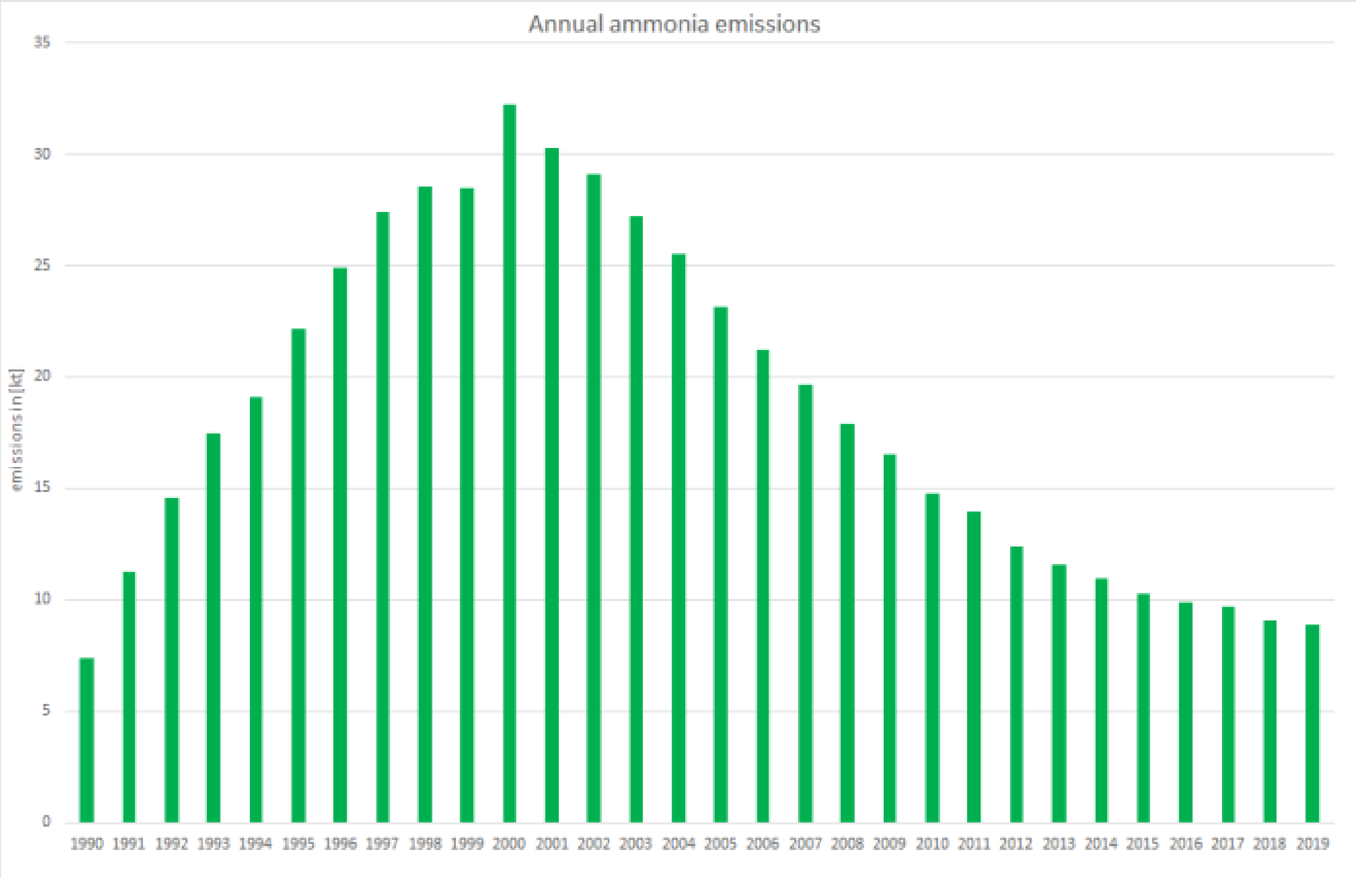


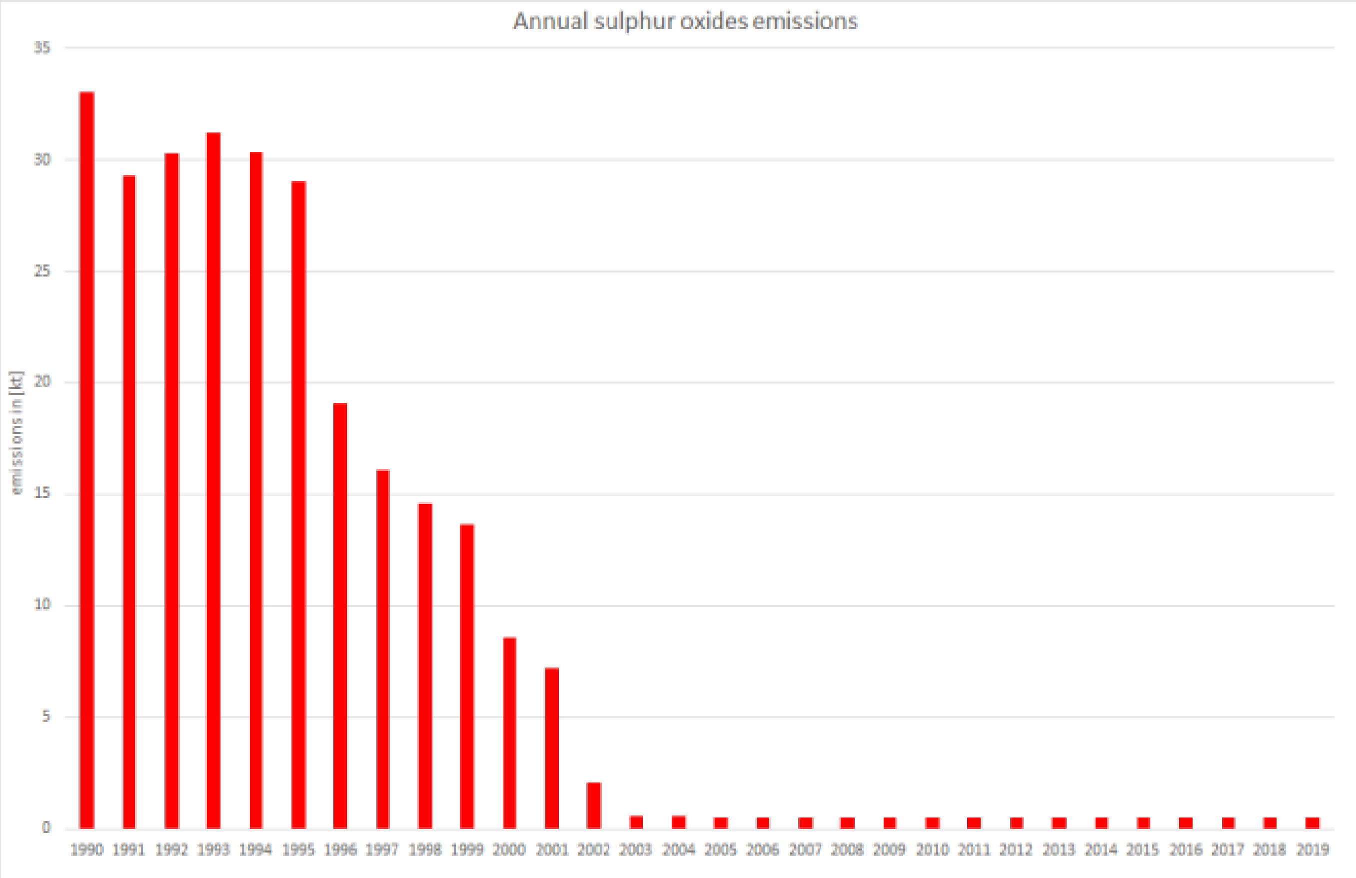




Ammonia (NH,,3,,) and sulphur dioxide (SO,,2,,)

As for the entire road transport sector, the trends for **sulphur dioxide** (SO,,2,,) and **ammonia** (NH,,3,,) exhaust emissions from passenger cars show charcteristics very different from those shown above: Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of SO,,2,, 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.



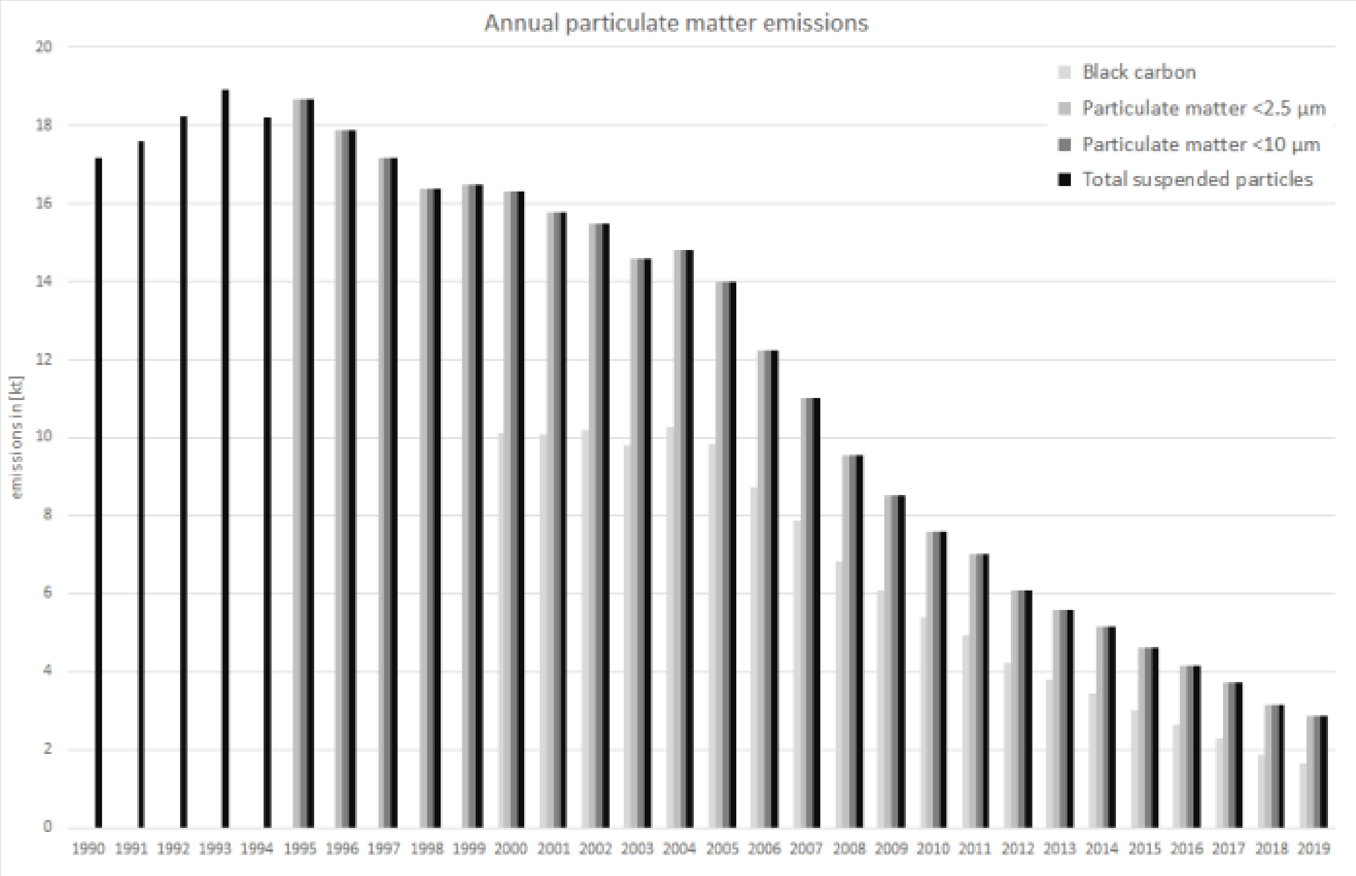


Particulate Matter (BC, PM,,2.5,,, PM,,10,,, and TSP)

(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 qickly 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 overastimated 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”).



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

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**	**80/100**[1]	**50**	**25**	**5**	**5**

[1] for direct injection engines

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.

<u>Table 4: Revised fuel consumption data, in terajoules</u>

	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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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%	
BIOGASOLINE																	
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%	
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	
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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 comprehendible 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

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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.