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**					**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**	**PCDD/F**	**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

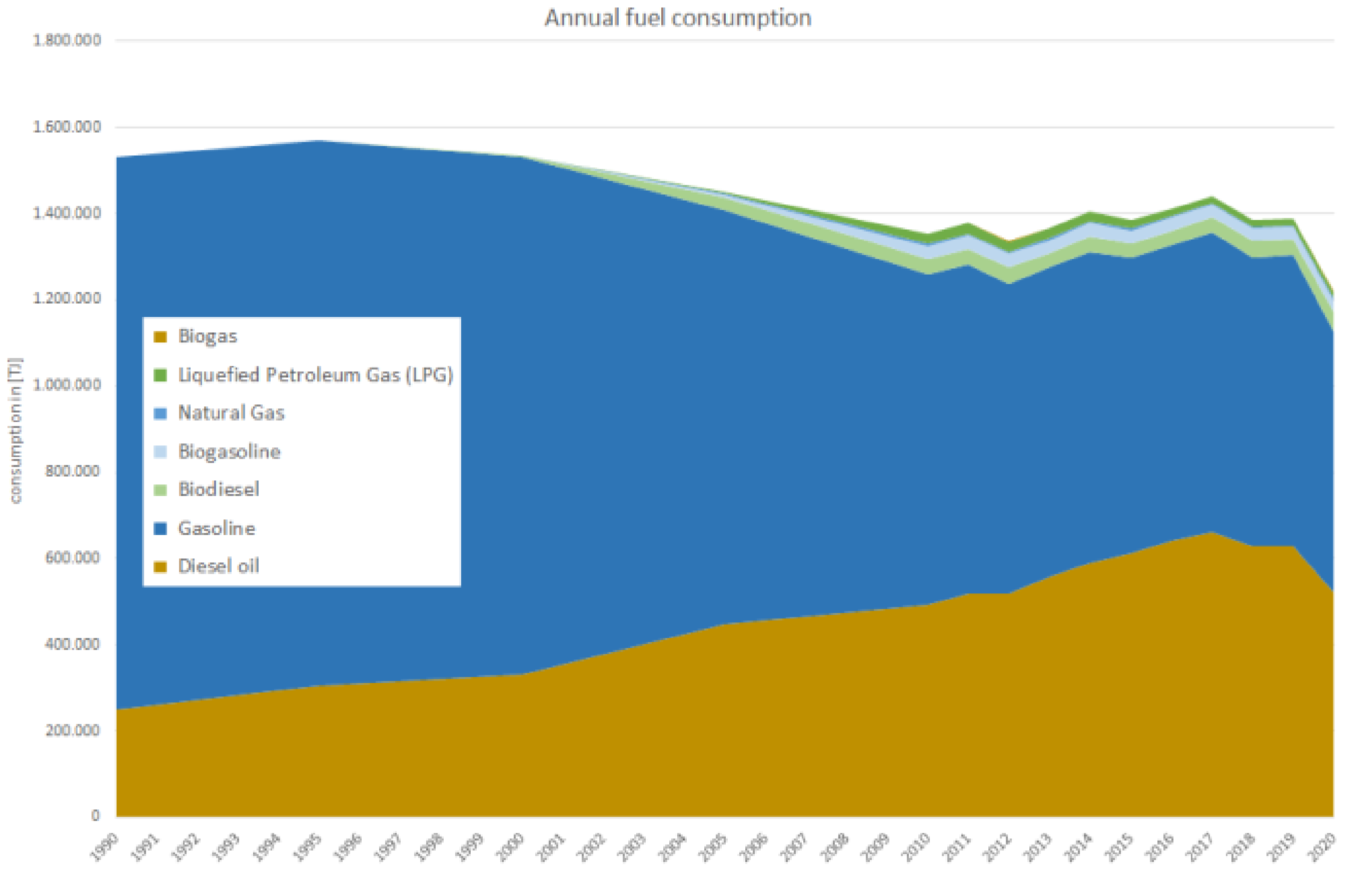
Specific consumption data for passenger cars is generated within TREMOD [1].

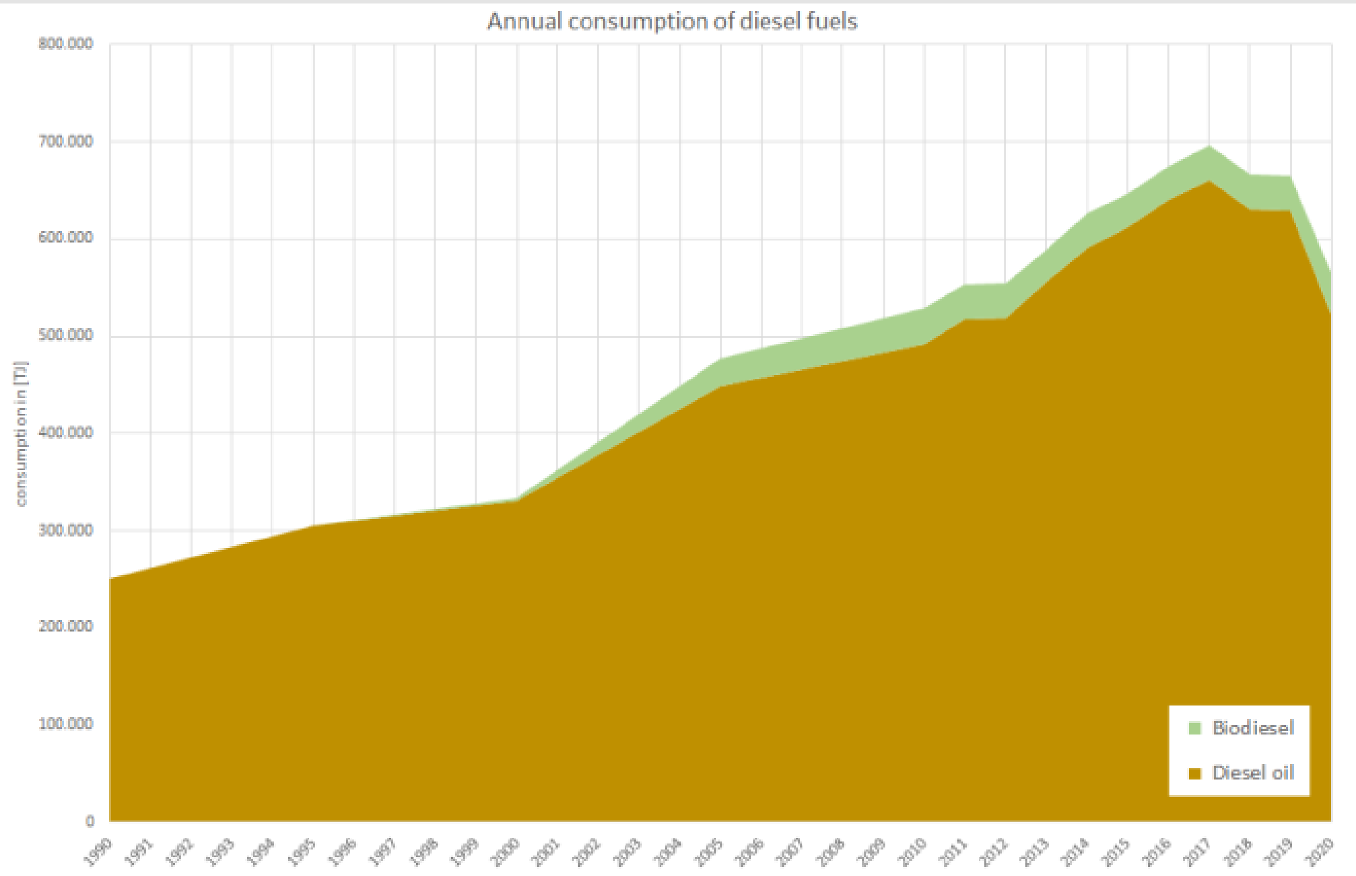
The following table gives an overview of annual amounts of the fuels consumed by passenger cars in Germany.

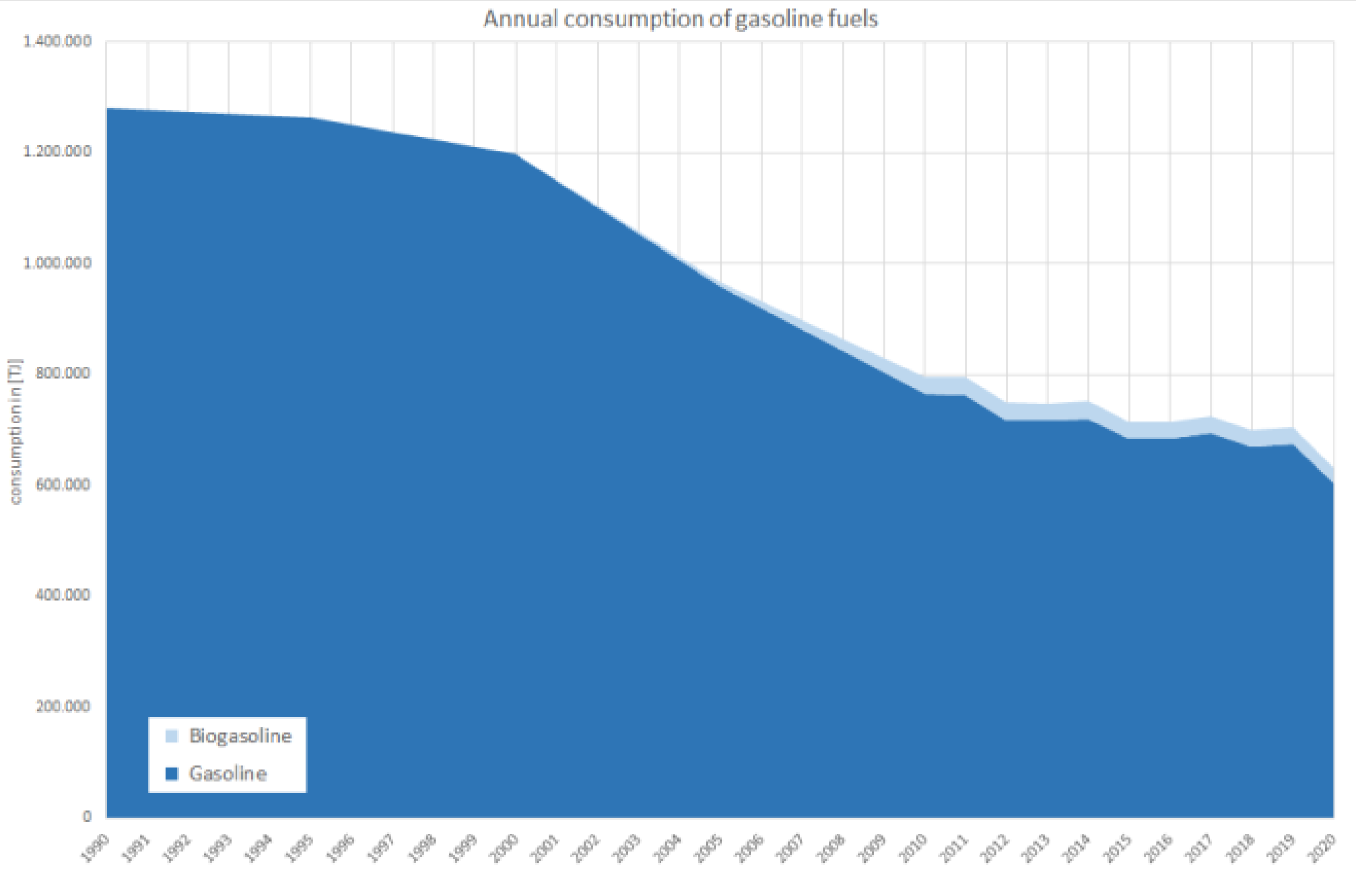
Table 1: Annual passenger car fuel consumption, in terajoule

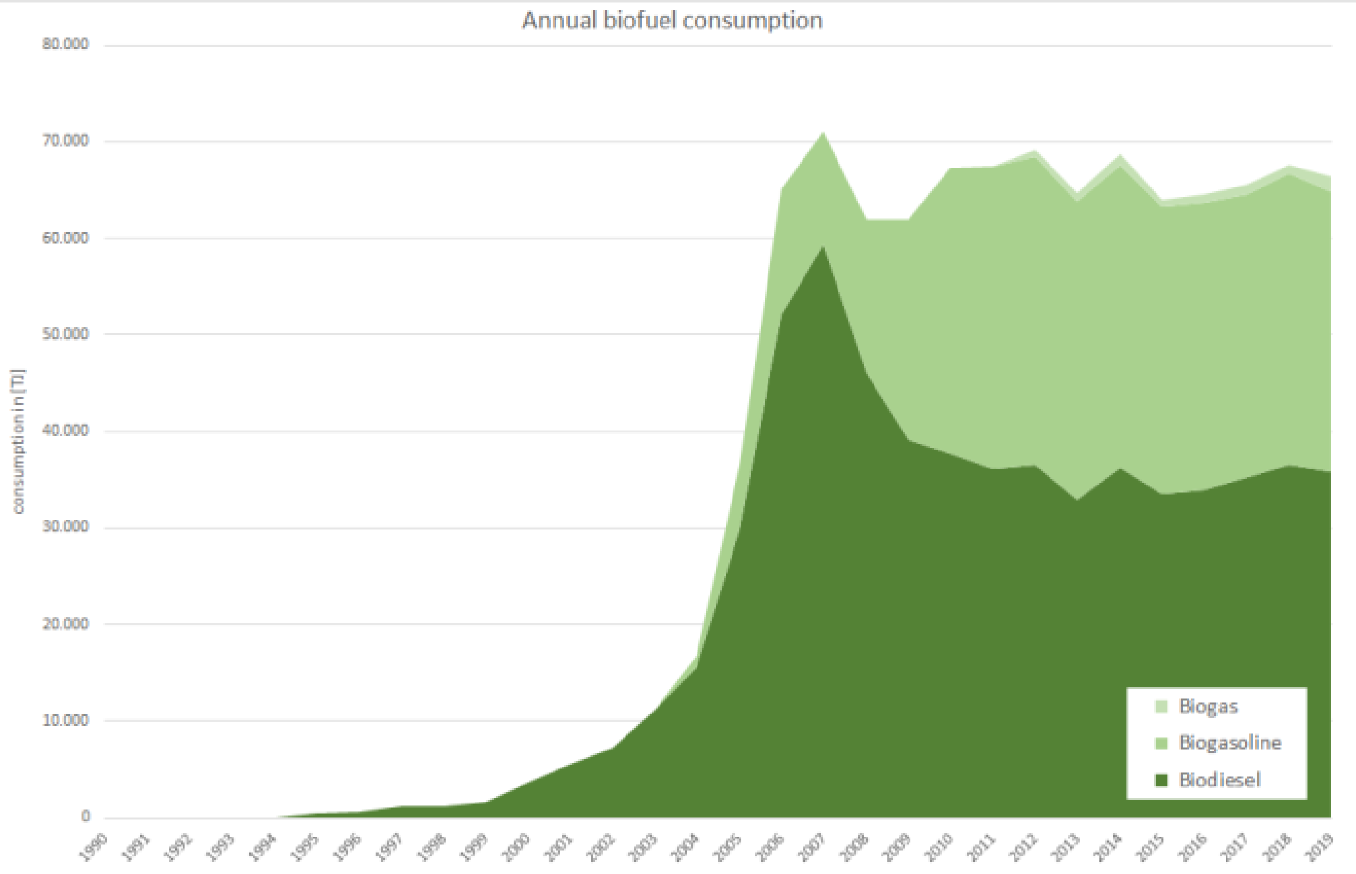
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Diesel oil	251.081	304.573	330.544	447.843	491.676	517.444	518.614	556.128	589.881	612.125	640.924	661.185	630.091	628.890	522.536
Gasoline	1.280.592	1.263.563	1.198.941	960.365	766.348	763.397	719.090	718.324	721.175	685.451	685.537	695.328	669.083	675.721	605.570
LPG	138	138	94	2.357	21.823	23.613	23.532	23.077	21.464	18.963	16.799	15.377	16.153	14.602	13.667
CNG	0	0	0	1.604	5.351	5.494	5.140	4.378	4.464	4.443	3.562	3.623	3.297	3.786	4.421
Biodiesel	0	475	3.662	29.928	37.695	36.104	36.601	32.981	36.249	33.483	33.979	35.297	36.626	35.820	43.406
Biogasoline	0	0	0	6.597	29.609	31.292	31.866	30.792	31.362	29.729	29.777	29.315	30.084	29.144	27.647
Biogas	0	0	0	0	0	0	734	866	1.125	749	838	1.001	887	1.539	2.028
Σ 1.A.3.b i	**1.531.811**	**1.568.749**	**1.533.241**	**1.448.694**	**1.352.502**	**1.377.342**	**1.335.578**	**1.366.546**	**1.405.720**	**1.384.943**	**1.411.416**	**1.441.125**	**1.386.222**	**1.389.502**	**1.219.276**

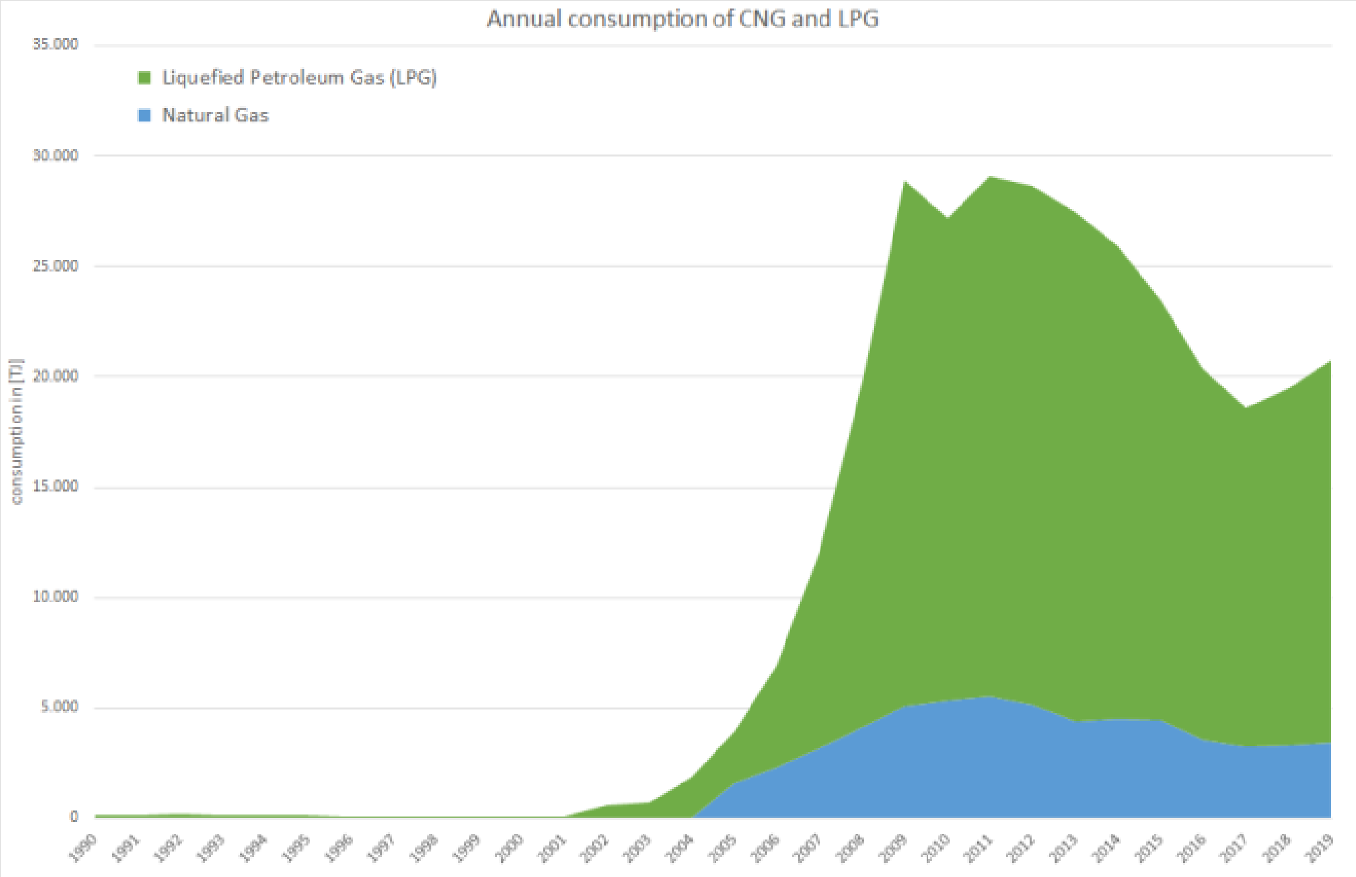
Here, the following charts underline the ongoing shift from gasoline to diesel-powered passenger cars, that started around 1999/2000.


Annual fuel consumption
1.800.000
1.600.000
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
consumption in [TJ]
Biogas
Liquefied Petroleum Gas (LPG)
Natural Gas
Biogasoline
Biodiesel
Gasoline
Diesel oil
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 2020


Annual consumption of diesel fuels
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0
consumption in [TJ]
Biodiesel
Diesel oil
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 2020


Annual consumption of gasoline fuels
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
consumption in [TJ]
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 2020


Annual biofuel consumption
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0
consumption in [TJ]
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.

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

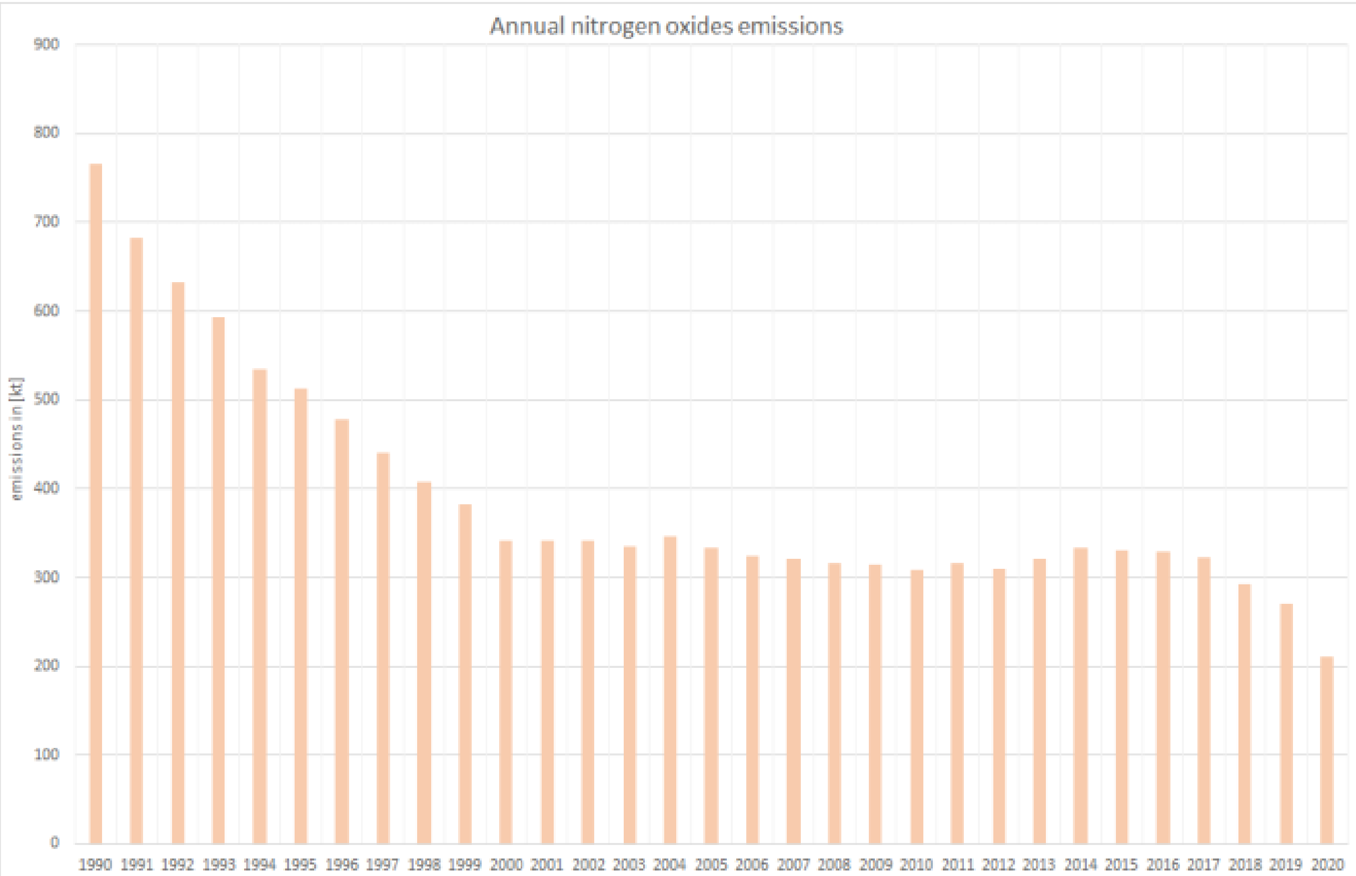
Discussion of emission trends

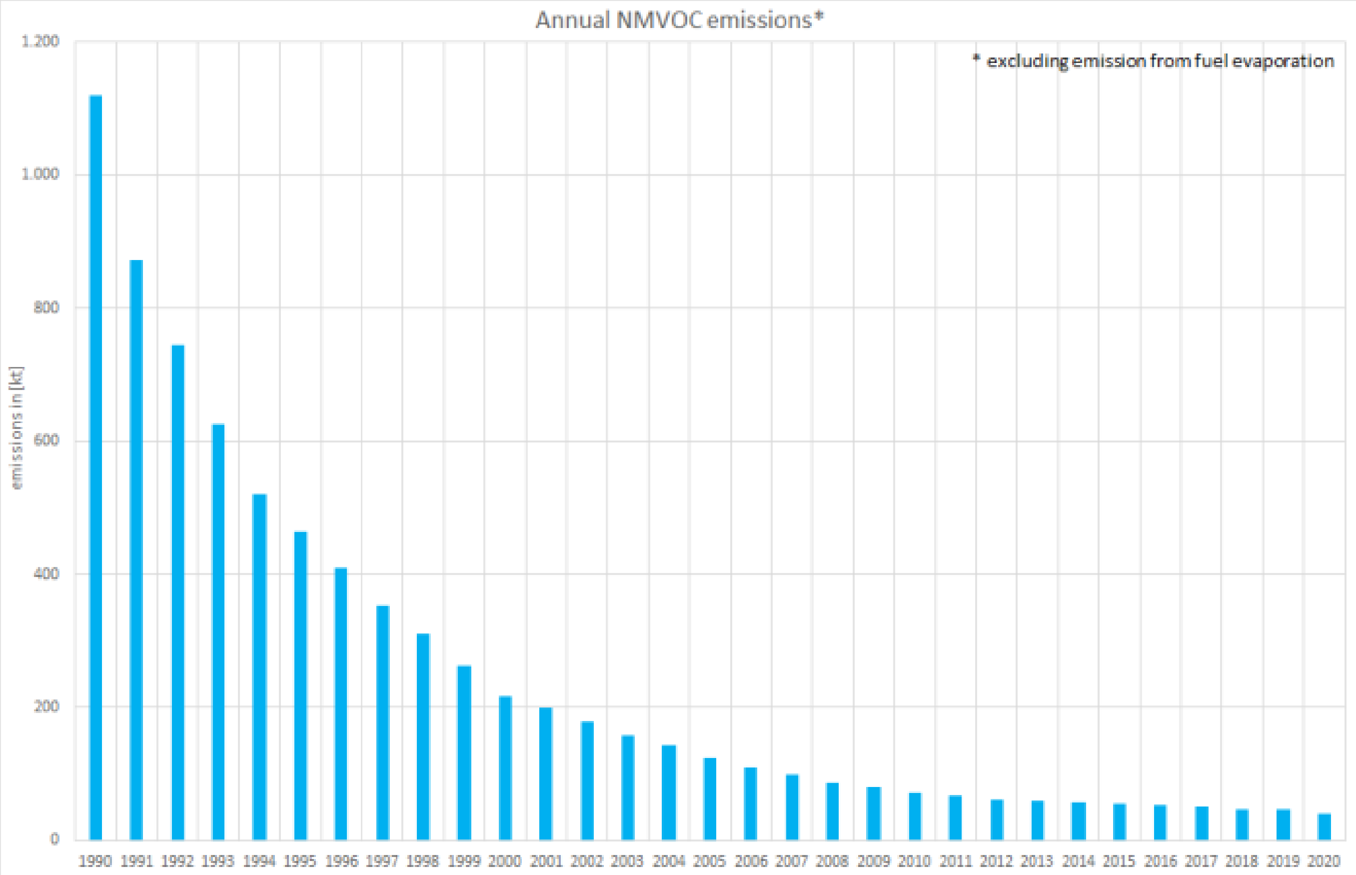
Table: Outcome of Key Category Analysis

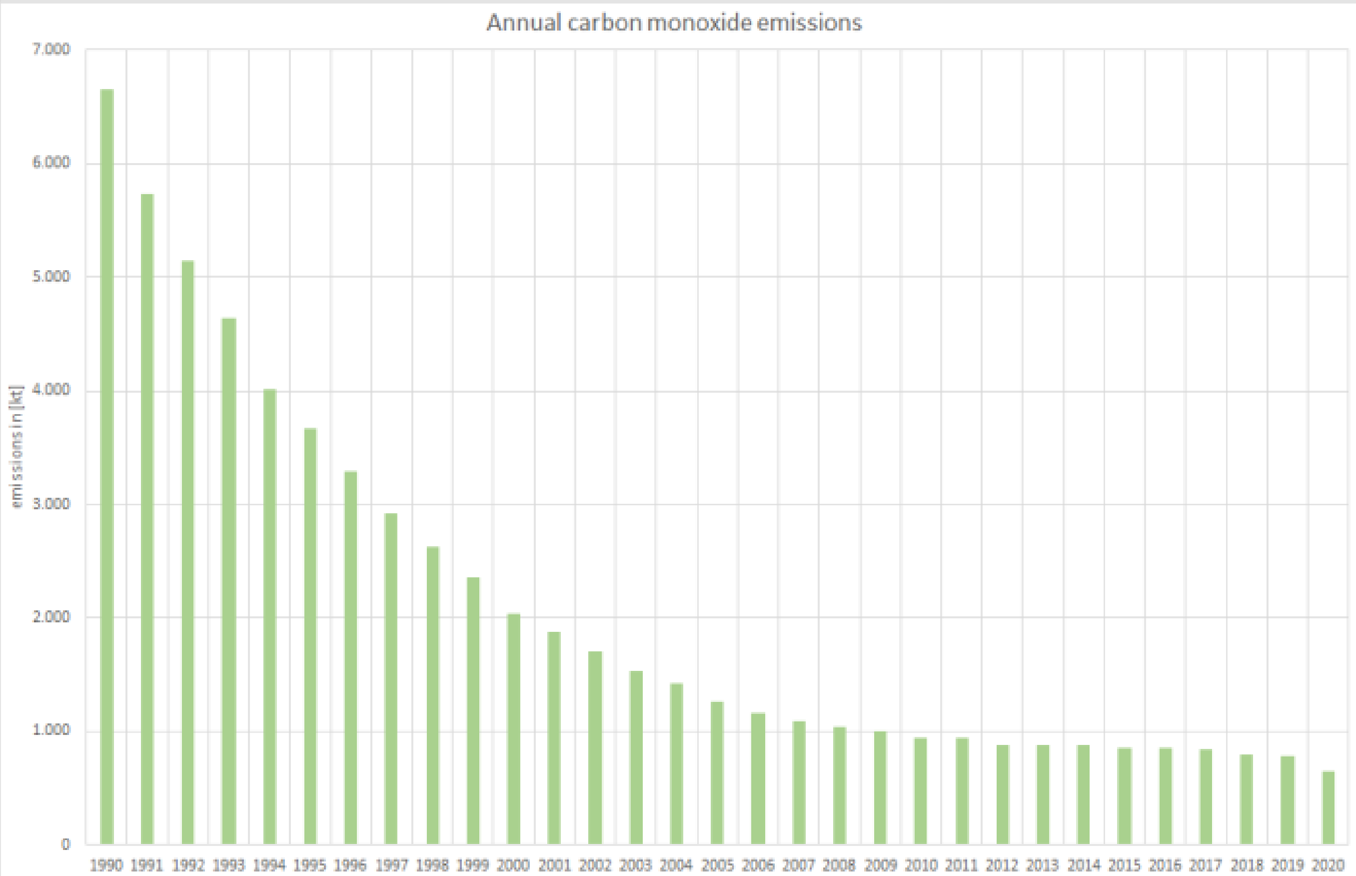
for:	NO_x	NMVOC	CO	PM_{10}	$PM_{2.5}$	BC	Pb	PCDD/F
by:	Level & Trend	L/T	L/T	L/T	L/T	L/T	L/T	L/-

Non-methane volatile organic compounds, nitrogen oxides, and carbon monoxide

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.



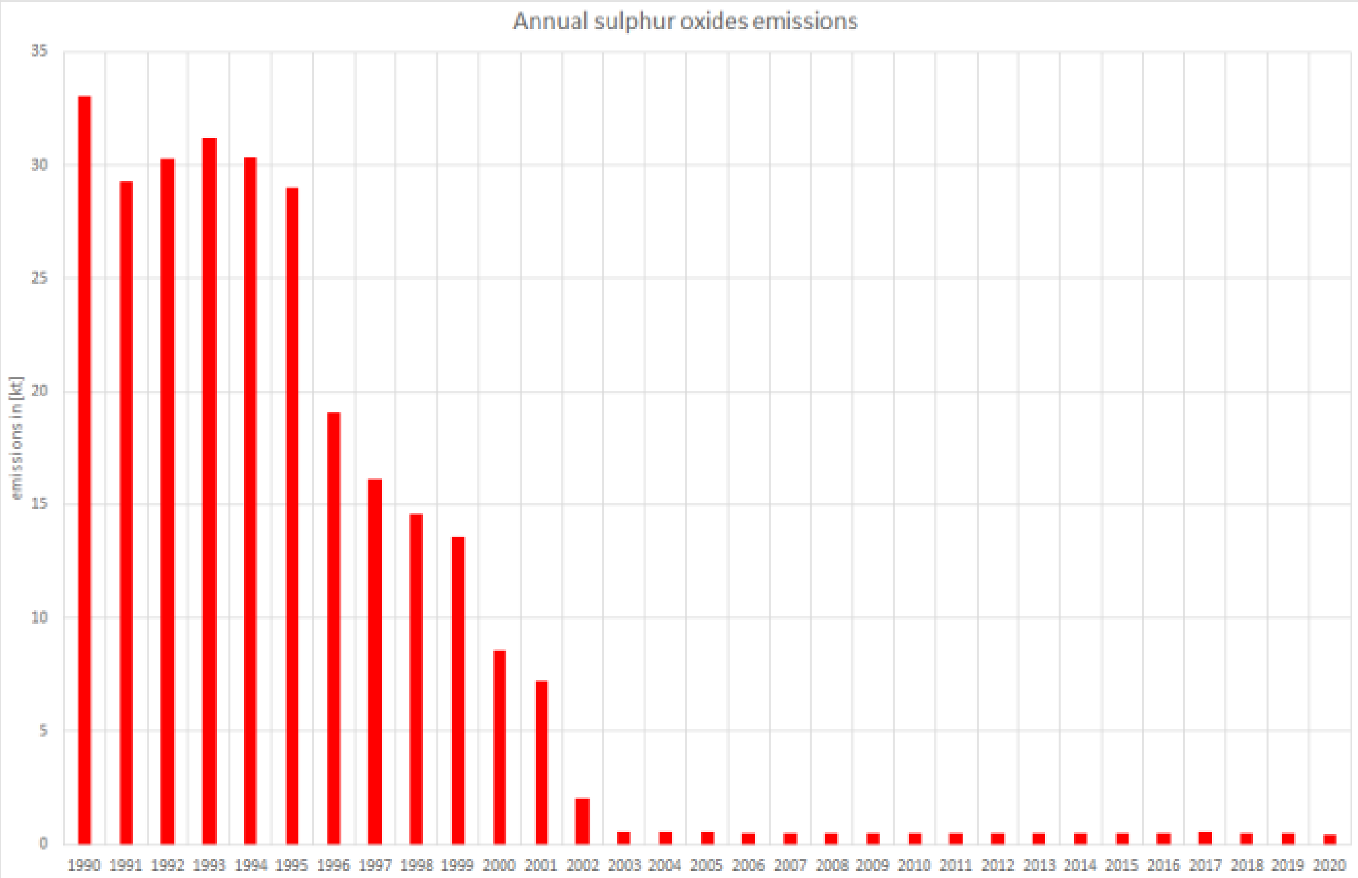




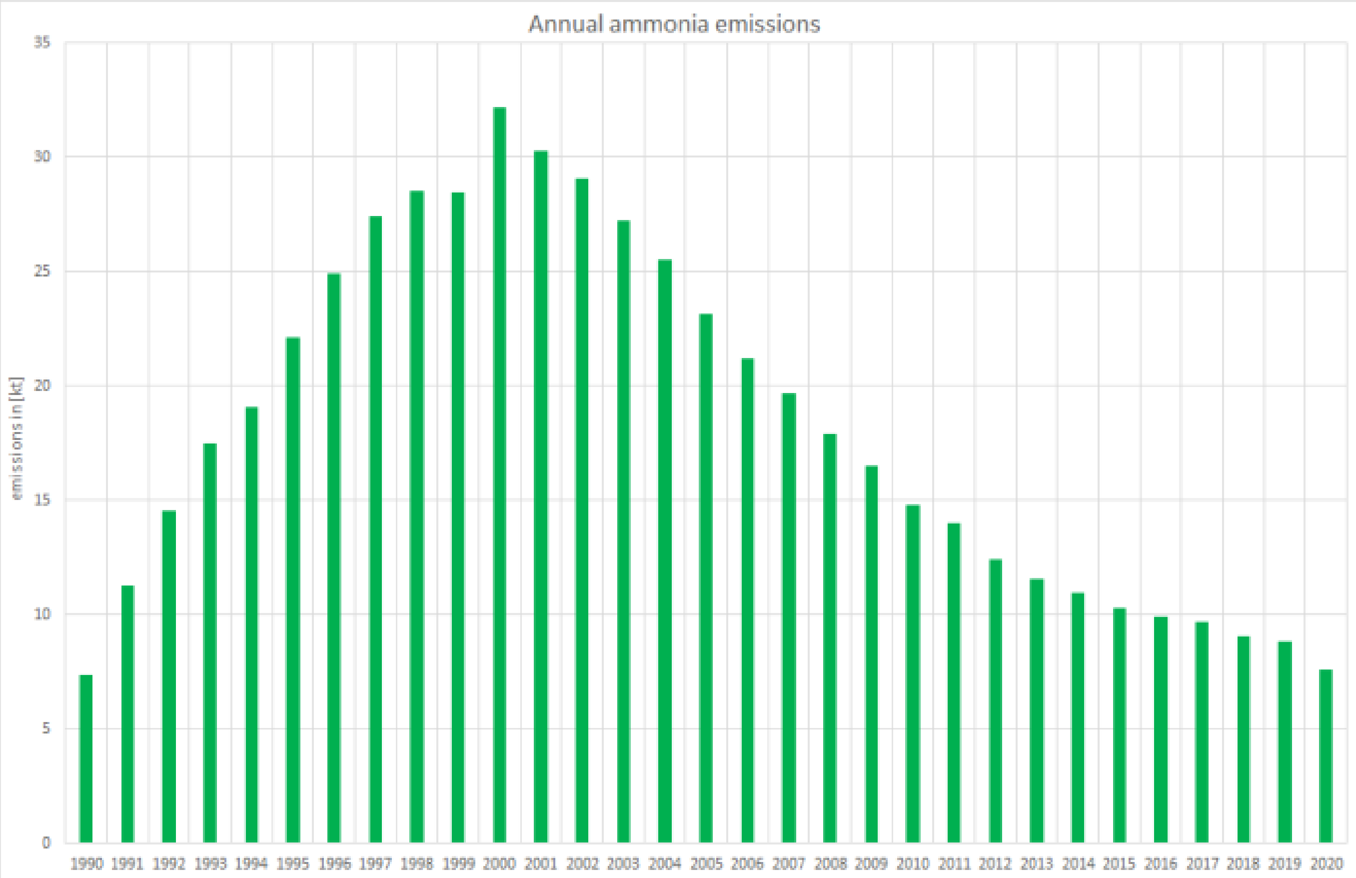
Ammonia and sulphur dioxide

As for the entire road transport sector, the trends for **sulphur dioxide** and **ammonia** 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 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 & Black carbon

(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”).

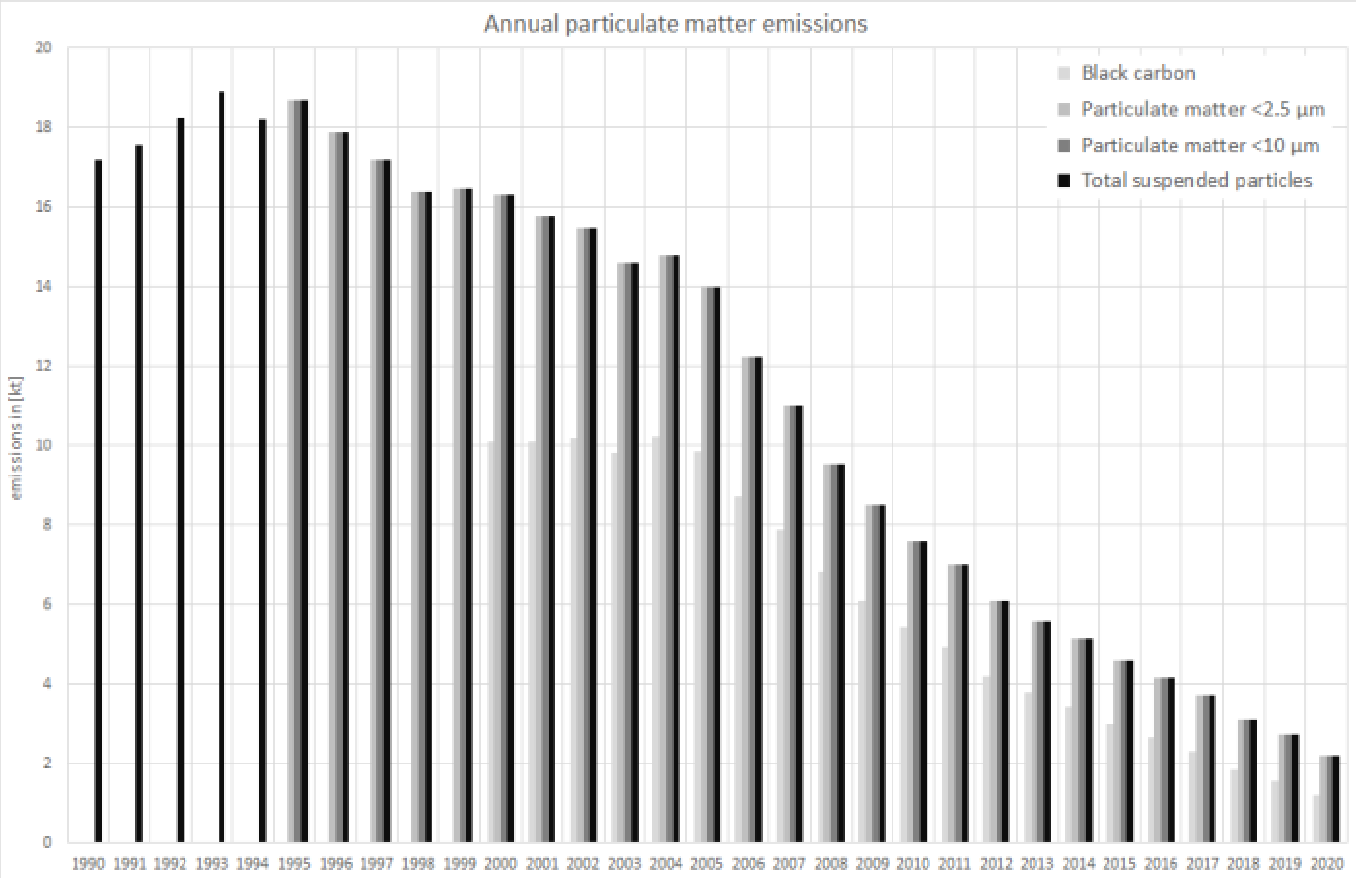


Table: EURO norms and their effect on limit values of PM emissions from diesel passenger cars

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**	**80/100**[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.

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	251.081	304.573	330.544	447.843	433.071	443.483	462.982	483.943	491.684	517.460	518.642	556.149	589.801	612.084	641.130	661.289	629.483
Submission 2020	253.892	305.128	324.929	440.663	437.146	446.880	465.304	485.728	492.791	518.198	518.957	556.096	589.674	593.962	621.938	641.476	610.293
absolute change	-2.811	-555	5.615	7.180	-4.075	-3.397	-2.322	-1.785	-1.107	-738	-315	53	127	18.122	19.192	19.813	19.190
relative change	-1,11%	-0,2%	1,73%	1,63%	-0,93%	-0,76%	-0,50%	-0,37%	-0,22%	-0,14%	-0,06%	0,01%	0,02%	3,05%	3,09%	3,09%	3,14%
BIODIESEL																	
Submission 2021		475	3.662	29.928	52.216	59.334	46.126	39.097	37.696	36.105	36.603	32.982	36.244	33.481	33.989	35.303	36.591
Submission 2020		476	3.600	29.343	52.587	59.599	46.163	38.936	37.500	35.842	36.337	32.710	35.928	32.198	32.732	34.022	35.226
absolute change		-0,87	62	585	-371	-265	-37	160	196	262	267	272	316	1.283	1.258	1.281	1.365
relative change		-0,18%	1,73%	1,99%	-0,71%	-0,44%	-0,08%	0,41%	0,52%	0,73%	0,73%	0,83%	0,88%	3,99%	3,84%	3,77%	3,88%
GASOLINE																	
Submission 2021	1.280.592	1.263.563	1.198.941	960.365	900.551	863.738	826.374	802.616	766.348	763.397	719.091	718.322	721.165	685.429	685.497	695.259	668.949

Submission 2020	1.275.916	1.260.078	1.196.370	958.621	899.359	862.416	825.308	801.658	765.478	762.566	718.328	717.580	720.676	684.853	684.954	694.769	668.337
absolute change	4.676	3.485	2.571	1.744	1.193	1.322	1.065	958	870	830	762	742	489	576	543	489	612
relative change	0,37%	0,28%	0,21%	0,18%	0,13%	0,15%	0,13%	0,12%	0,11%	0,11%	0,11%	0,10%	0,07%	0,08%	0,08%	0,07%	0,09%
BIOGASOLINE																	
Submission 2021				6.597	12.981	11.666	15.800	22.931	29.609	31.292	31.866	30.792	31.361	29.728	29.775	29.312	30.078
Submission 2020				6.585	12.964	11.648	15.779	22.904	29.575	31.257	31.833	30.760	31.340	29.703	29.752	29.291	30.051
absolute change				12,0	17,2	17,9	20,4	27,4	33,6	34,0	33,8	31,8	21,3	25,0	23,6	20,6	27,5
relative change				0,18%	0,13%	0,15%	0,13%	0,12%	0,11%	0,11%	0,11%	0,10%	0,07%	0,08%	0,08%	0,07%	0,09%
CNG																	
Submission 2021				1.604	2.280	3.174	4.146	5.062	5.351	5.494	5.140	4.380	4.483	4.476	3.590	3.247	3.332
Submission 2020				1.608	2.286	3.182	4.155	5.072	5.361	5.505	5.151	4.389	4.519	4.492	3.603	3.257	3.980
absolute change				-4,25	-6,04	-7,89	-9,02	-9,76	-10,1	-10,4	-11,0	-8,9	-35,9	-16,0	-12,5	-10,3	-647
relative change				-0,26%	-0,26%	-0,25%	-0,22%	-0,19%	-0,19%	-0,19%	-0,21%	-0,20%	-0,80%	-0,36%	-0,35%	-0,32%	-16,3%
BIOGAS																	
Submission 2021											734	867	1.130	755	844	1.009	897
Submission 2020											736	868	1.139	757	847	1.013	930
absolute change											-1,58	-1,76	-9,06	-2,70	-2,95	-3,20	-33,6
relative change											-0,21%	-0,20%	-0,80%	-0,36%	-0,35%	-0,32%	-3,61%
LPG																	
Submission 2021	138	138	94,0	2.357	4.605	8.942	15.652	23.842	21.823	23.613	23.532	23.077	21.464	18.963	16.799	15.377	16.153
Submission 2020	138	138	94,0	2.357	4.605	8.942	15.652	23.842	21.823	23.613	23.532	23.077	21.464	18.963	16.799	15.377	13.570
absolute change	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	0,00	0,00	2.583
relative change	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%	0,00%	0,0%	19,0%
TOTAL FUEL CONSUMPTION																	
Submission 2021	1.531.811	1.568.749	1.533.241	1.448.694	1.405.704	1.390.337	1.371.079	1.377.491	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
Submission 2020	1.529.946	1.565.820	1.524.993	1.439.177	1.408.947	1.392.667	1.372.362	1.378.140	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
absolute change	1.865	2.929	8.248	9.516	-3.242	-2.330	-1.282	-649	-18	379	736	1.089	908	19.988	21.000	21.591	23.098
relative change	0,12%	0,19%	0,54%	0,66%	-0,23%	-0,17%	-0,09%	-0,05%	0,00%	0,03%	0,06%	0,08%	0,06%	1,46%	1,51%	1,52%	1,70%

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.

[1), 3)] Knörr et al. (2020a): 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 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2020.

[2)] Keller et al. (2017): 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, 2017.

[4), 6), 7), 8), 9)] 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.

[5)] 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

[1] 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.