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					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	L/T	L/T	-/-	-/-	L/T	L/T	-/-	L/T	L/T	L/T	-/-	-/-	-/-	-/-	-

Methodology

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

Activity data

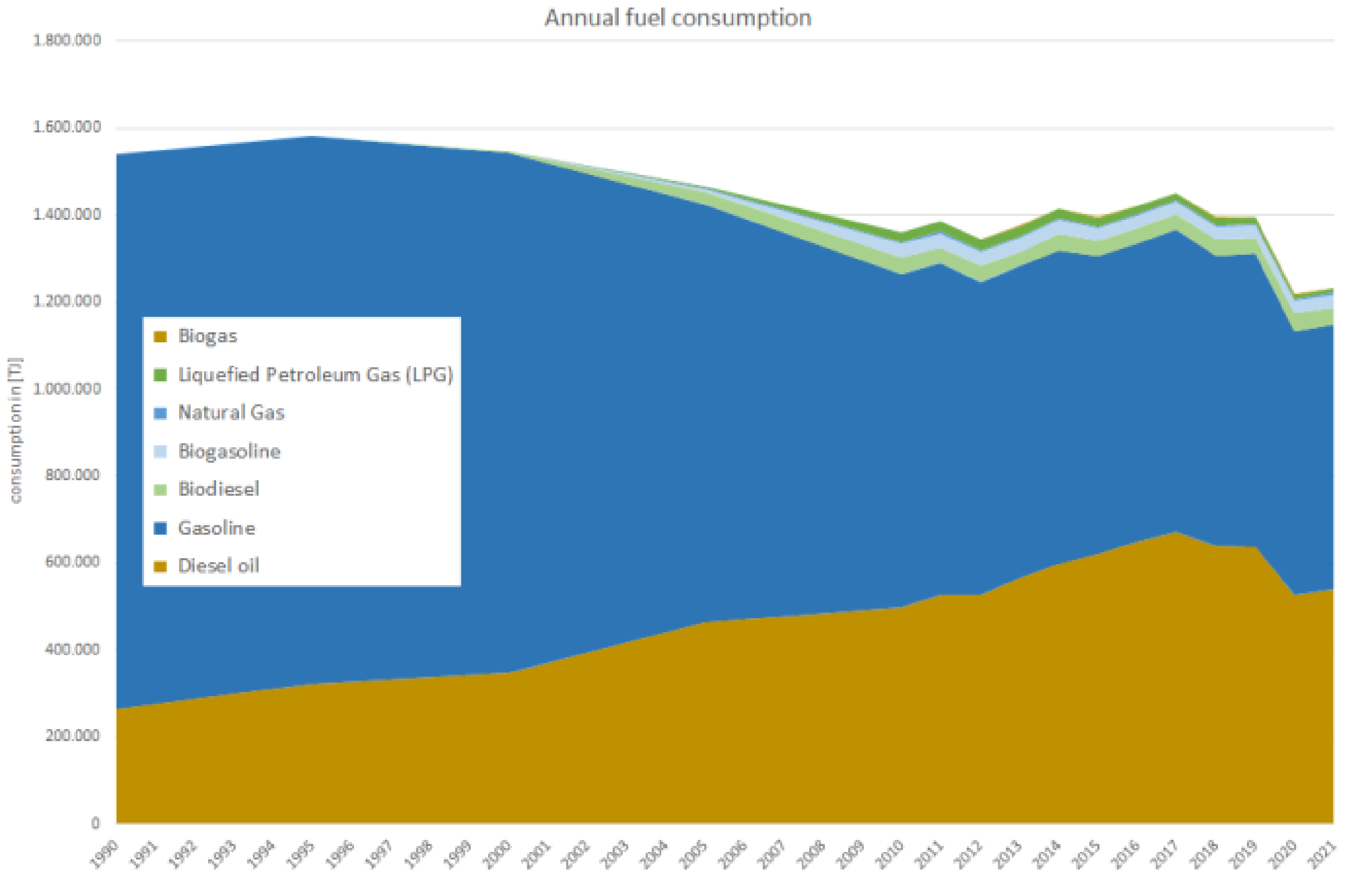
Specific consumption data for passenger cars is generated within TREMOD [1)].

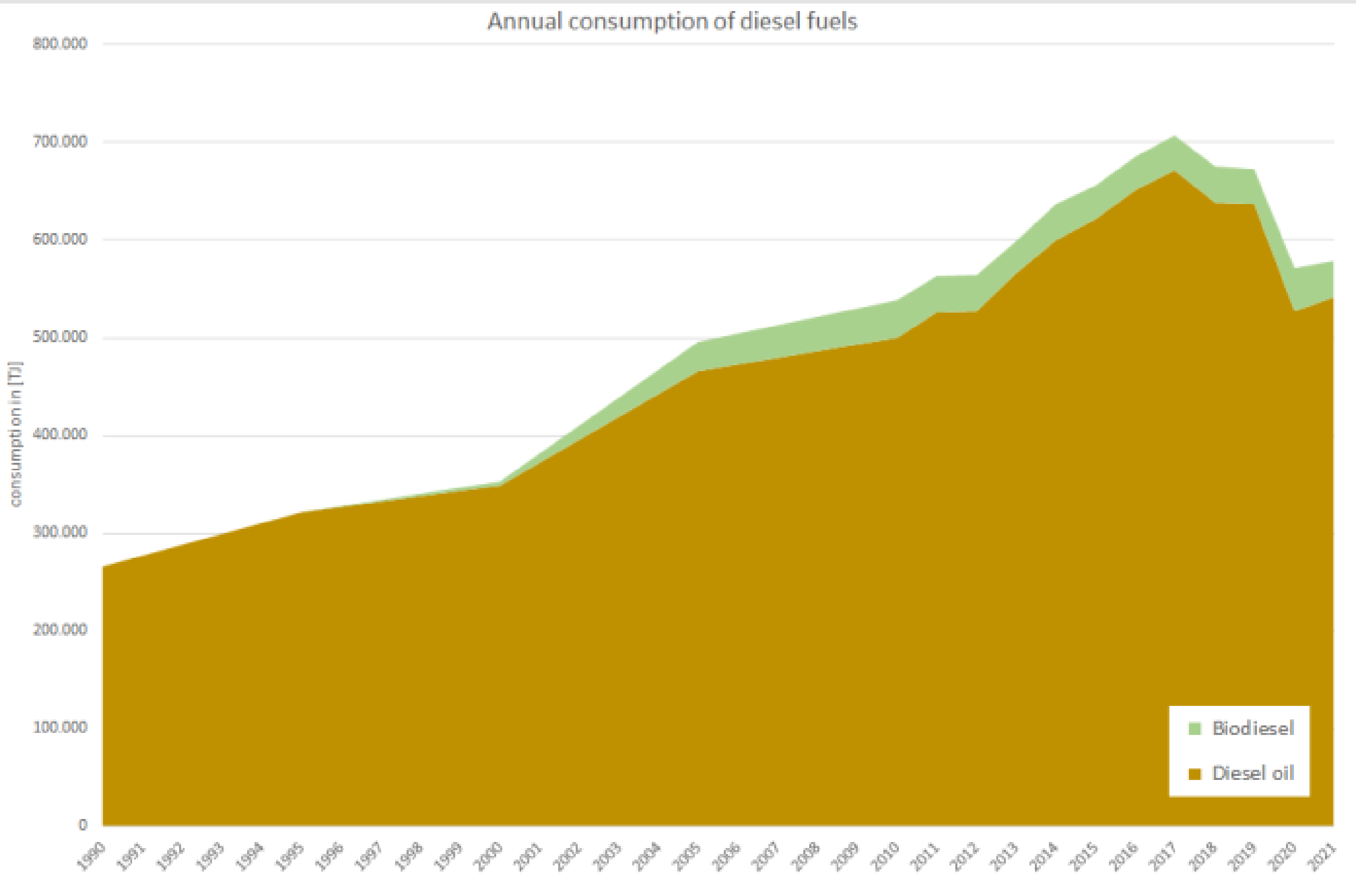
The following table gives an overview of annual amounts of the fuels consumed by passenger cars in Germany.

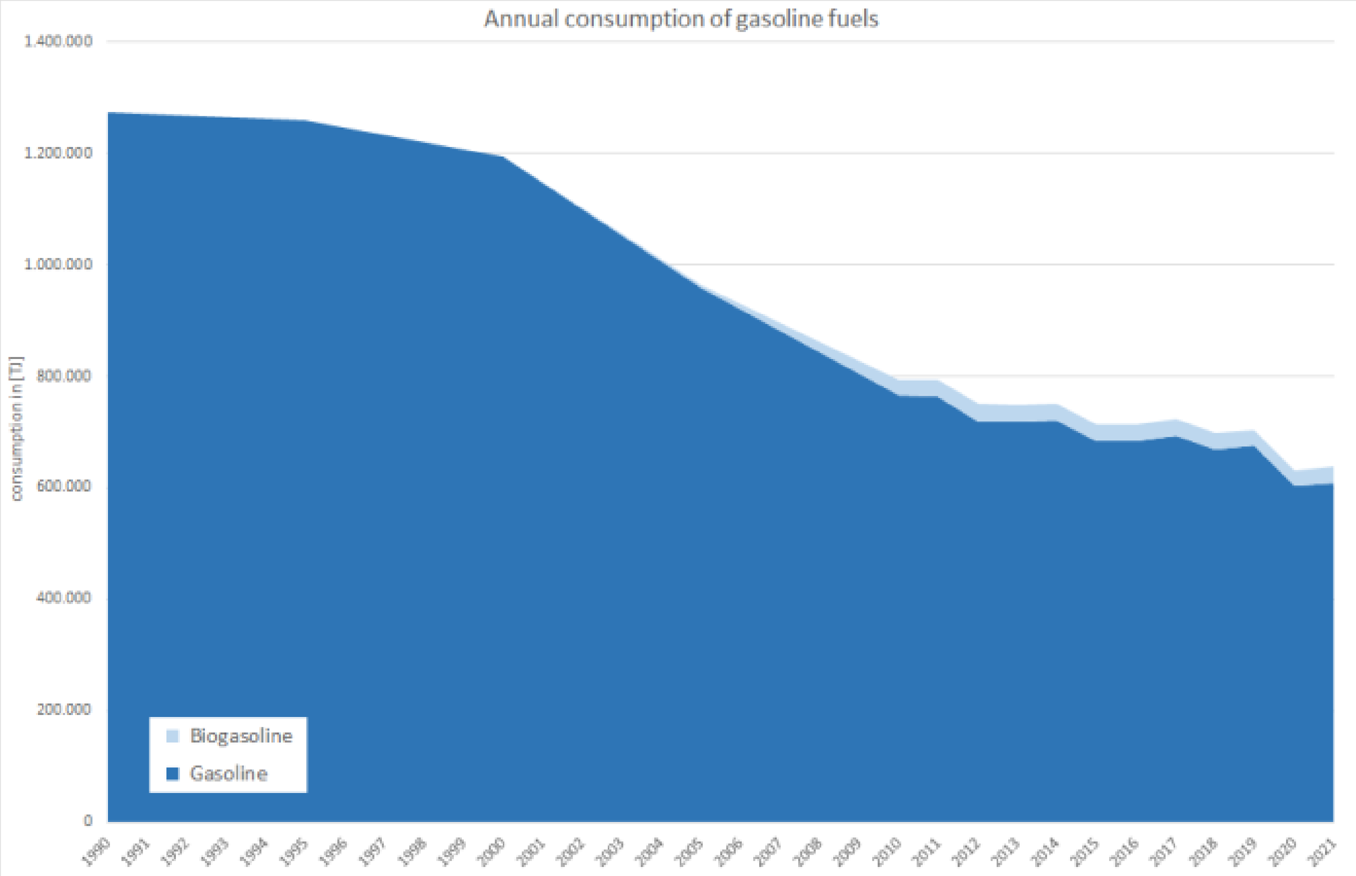
Table 1: Annual passenger car fuel consumption, in terajoule

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Diesel oil	266,175	321,615	348,554	465,228	500,087	621,924	650,647	670,928	639,059	636,988	527,477	540,968
Gasoline	1,273,347	1,258,708	1,194,743	958,090	765,293	684,668	684,770	694,572	668,293	674,830	604,043	609,663
LPG	138	138	94,0	2,357	21,823	18,963	16,799	15,377	16,153	14,602	9,551	9,500
CNG	0	0	0	1,625	5,366	4,419	3,533	3,590	3,271	3,766	3,754	4,199
Biodiesel	0	502	3,861	31,089	38,340	34,019	34,494	35,817	37,148	36,281	43,815	37,582
Biogasoline	0	0	0	6,582	29,568	29,695	29,744	29,283	30,049	29,105	27,577	29,004
Biogas	0	0	0	0	0	745	831	992	880	1,531	2,020	2,007
Σ 1.A.3.b i	**1,539,661**	**1,580,963**	**1,547,252**	**1,464,972**	**1,360,476**	**1,394,434**	**1,420,817**	**1,450,559**	**1,394,852**	**1,397,104**	**1,218,239**	**1,232,922**

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]
Biogas
Liquefied Petroleum Gas (LPG)
Natural Gas
Biogasoline
Biodiesel
Gasoline
Diesel oil


Annual consumption of diesel fuels
consumption in [TJ]
Biodiesel
Diesel oil



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 2: 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

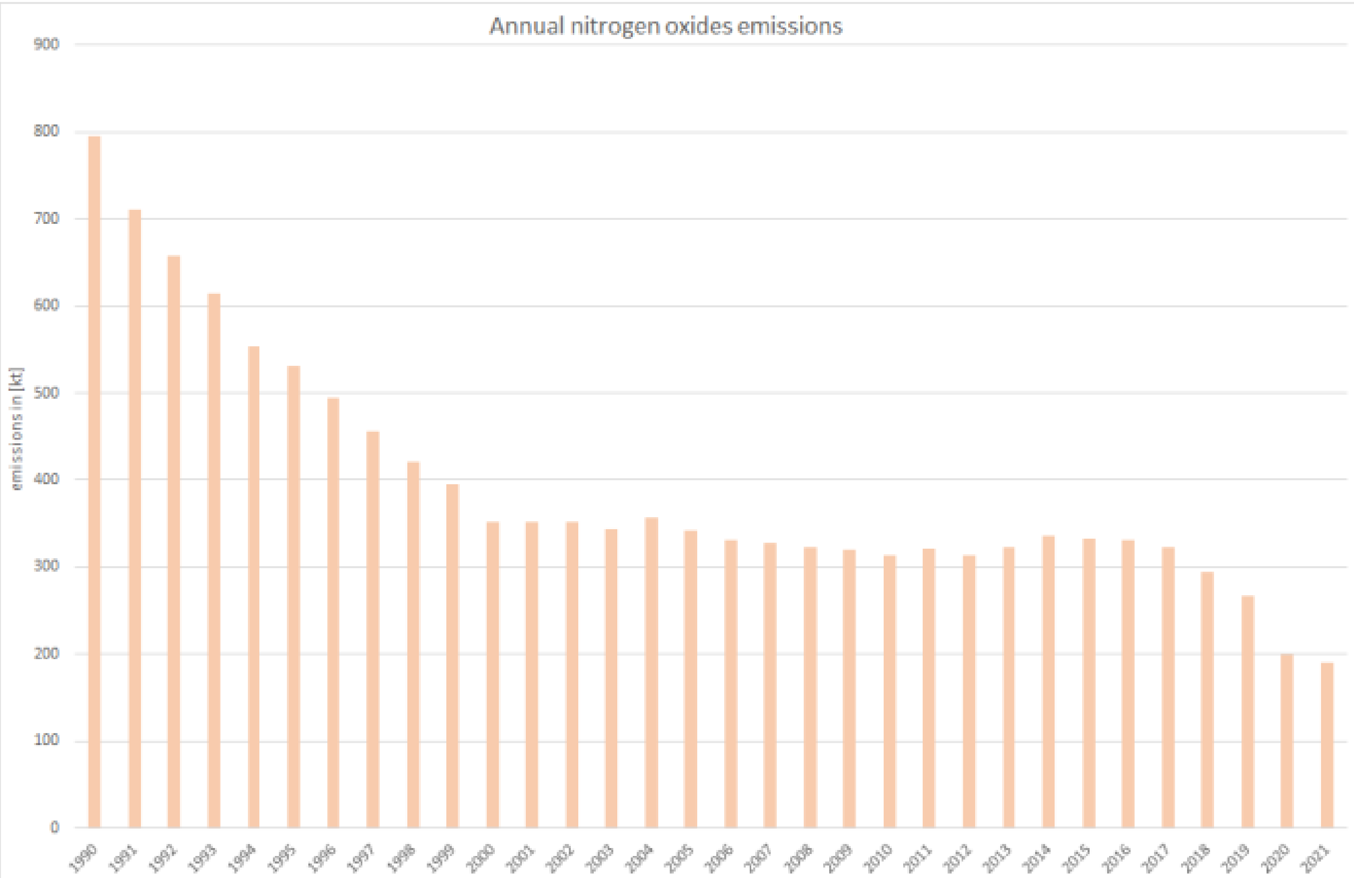
Discussion of emission trends

Table 3: 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/-

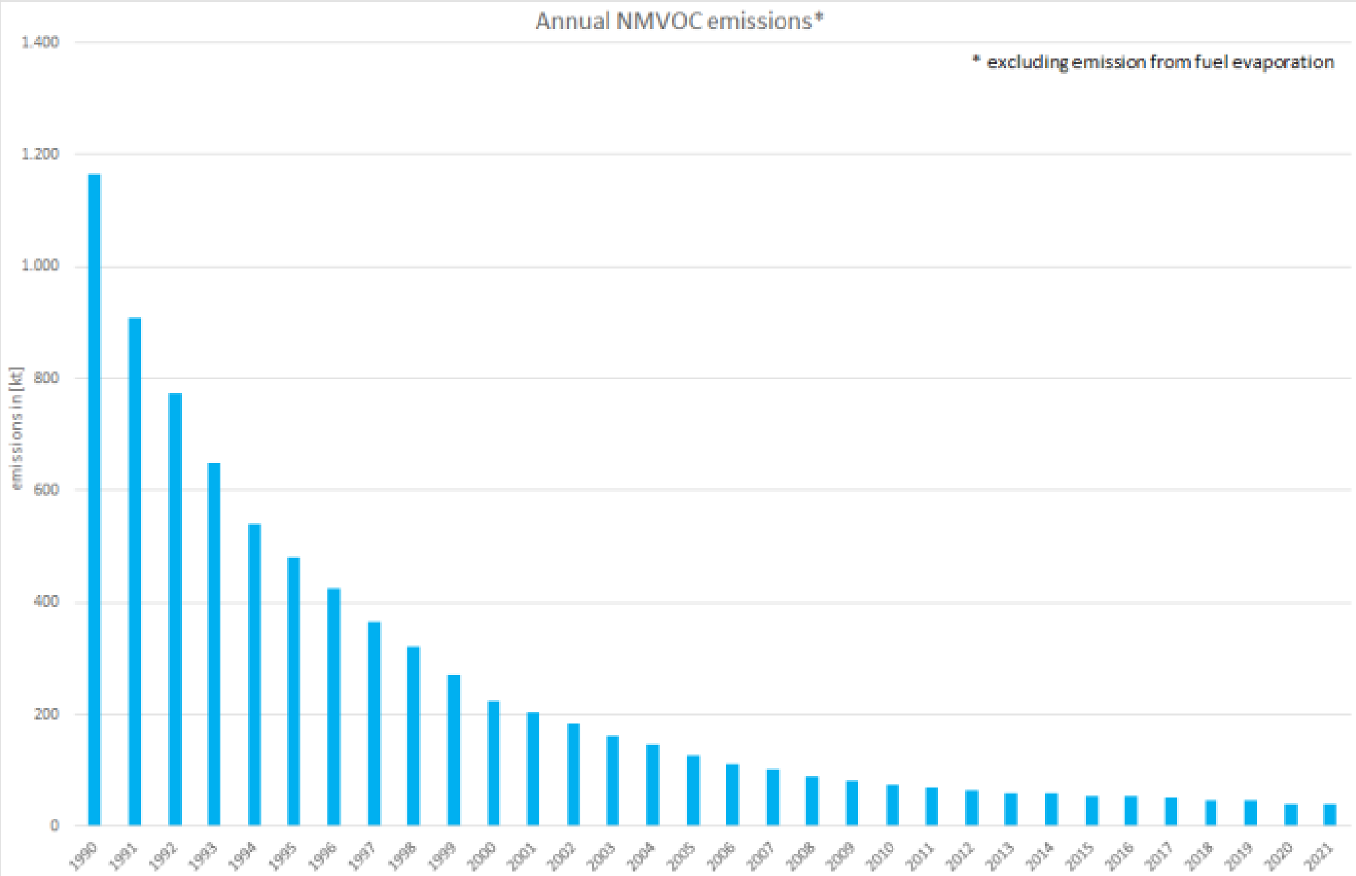
Non-methane volatile organic compounds, nitrogen oxides, and carbon monoxide

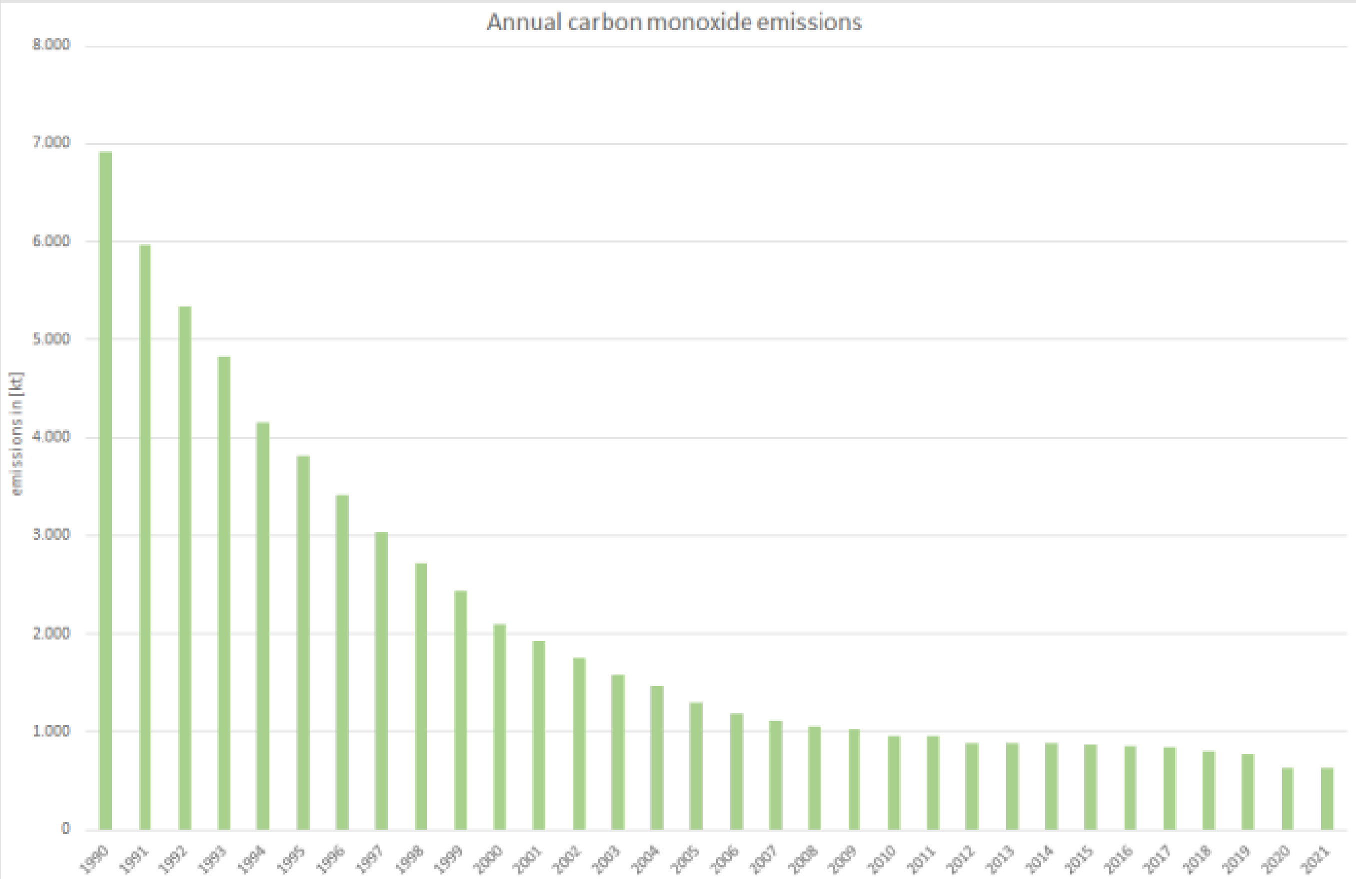
Since 1990, exhaust emissions of **nitrogen oxides**, **NMVOC**, and **carbon monoxide** have decreased sharply due to catalytic-converter use and engine improvements resulting from ongoing tightening of emissions laws and improved fuel quality.



exhaust emission standard (EURO norm)	**Euro 1**	**Euro 2**	**Euro 3**	**Euro 4**	**Euro 5**	**Euro 6a/b**	**Euro 6c**	**Euro 6d**
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	1 Sep 2018	1 Jan 2021
resulting PM limit value in [mg/km]								
Diesel			500	250	180	80		

exhaust emission standard (EURO norm)	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6a/b	Euro 6c	Euro 6d
Gasoline			150	80	60	60		

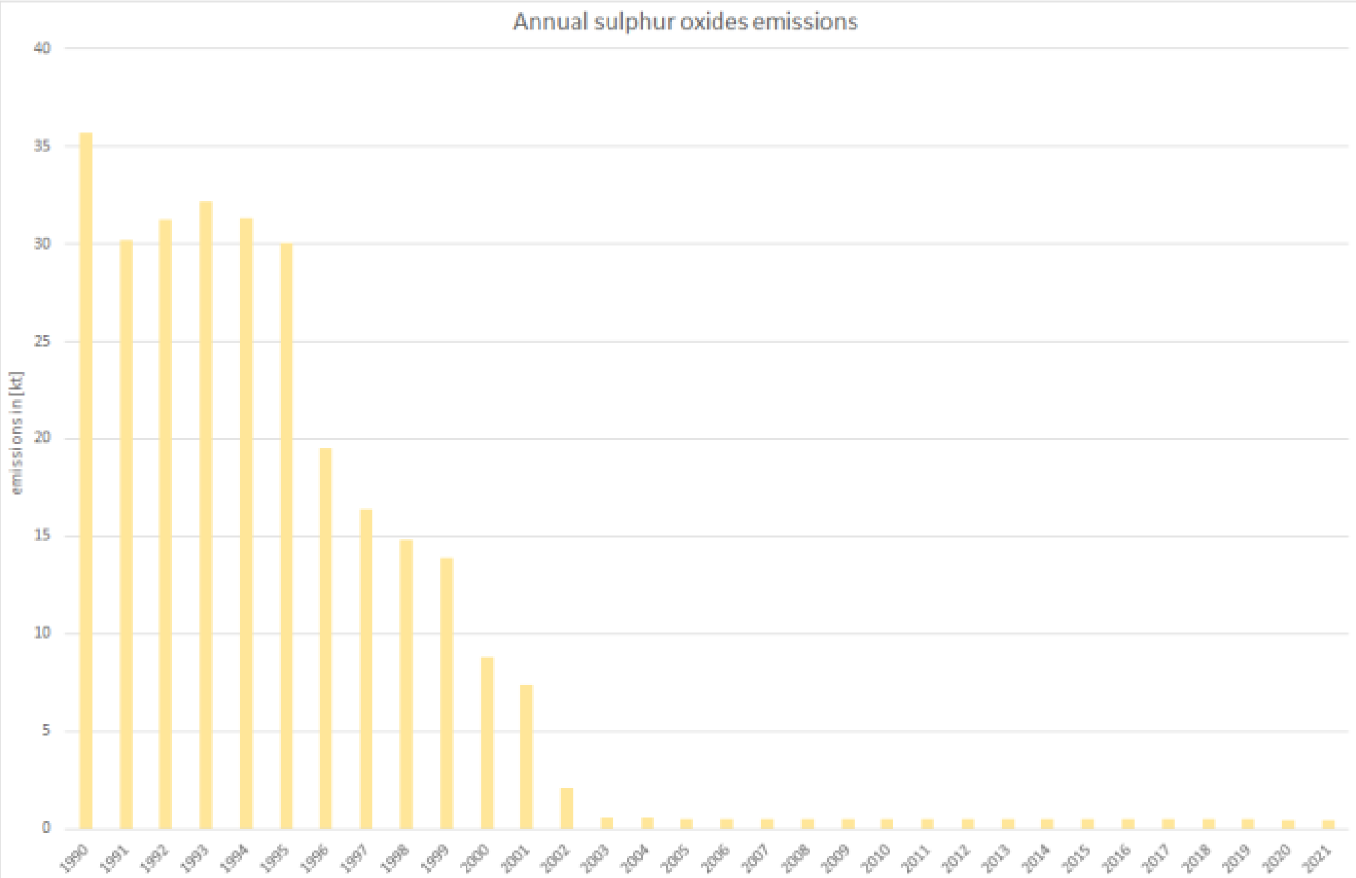




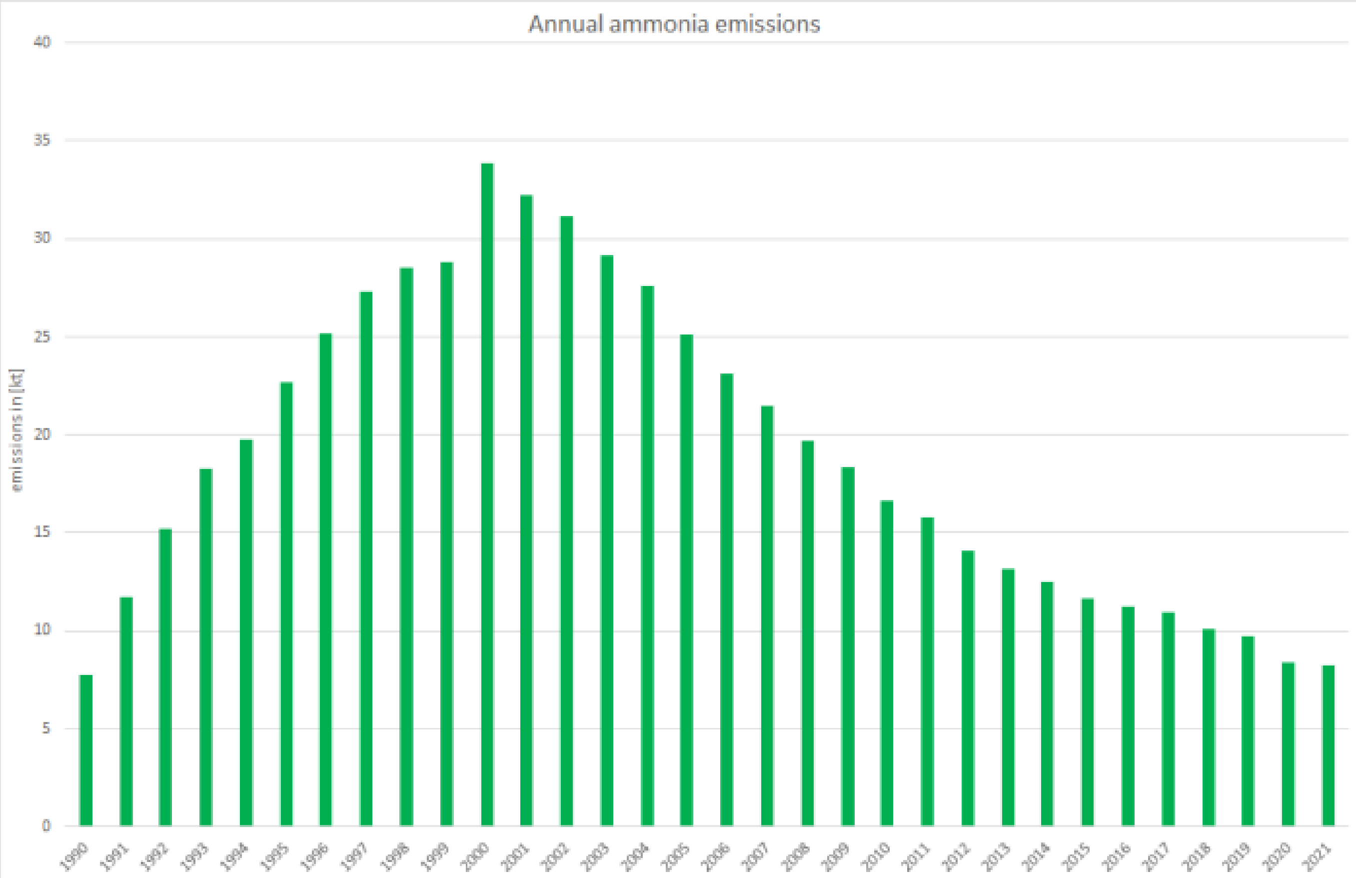
Ammonia and sulphur dioxide

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”).

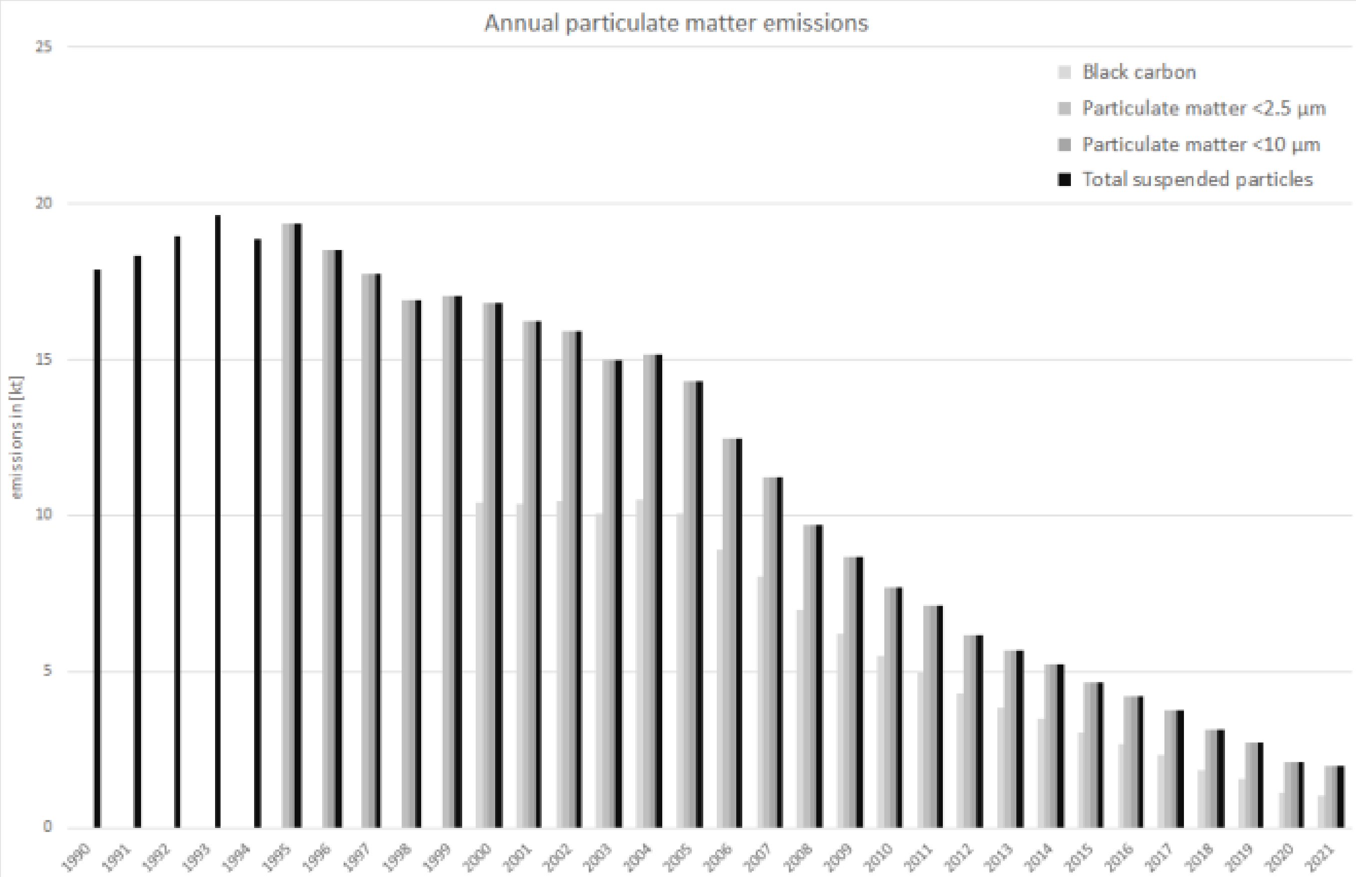


Table 4: EURO norms and their effect on limit values of PM emissions from diesel passenger cars

exhaust emission standard (EURO norm)	**Euro 1**	**Euro 2**	**Euro 3**	**Euro 4**	**Euro 5**	**Euro 6a/b**	**Euro 6c**	**Euro 6d**
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	1 Sep 2018	1 Jan 2021
resulting PM limit value in [mg/km]	**180**	**80/100**[1]	**50**	**25**	**4,5**			

[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 5: Revised fuel consumption data, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DIESEL OIL											
current Submission	266,175	321,615	348,554	465,228	500,087	621,924	650,647	670,928	639,059	636,988	527,477
previous Submission	251,081	304,573	330,544	447,843	491,676	612,125	640,924	661,185	630,091	628,890	522,536
absolute change	15,094	17,042	18,010	17,385	8,411	9,799	9,723	9,743	8,967	8,098	4,941
relative change	6,01%	5,6%	5,45%	3,88%	1,71%	1,60%	1,52%	1,47%	1,42%	1,29%	0,95%
BIODIESEL											

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
current Submission		502	3,861	31,089	38,340	34,019	34,494	35,817	37,148	36,281	43,815
previous Submission		475	3,662	29,928	37,695	33,483	33,979	35,297	36,626	35,820	43,406
absolute change		26,6	200	1,162	645	536	515	520	521	461	410
relative change		5,6%	5,4%	3,88%	1,71%	1,60%	1,52%	1,47%	1,42%	1,29%	0,94%
GASOLINE											
current Submission	1,273,347	1,258,708	1,194,743	958,090	765,293	684,668	684,770	694,572	668,293	674,830	604,043
previous Submission	1,280,592	1,263,563	1,198,941	960,365	766,348	685,451	685,537	695,328	669,083	675,721	605,570
absolute change	-7,244	-4,854	-4,198	-2,275	-1,055	-782	-768	-756	-791	-891	-1,527
relative change	-0,57%	-0,38%	-0,35%	-0,24%	-0,14%	-0,11%	-0,11%	-0,11%	-0,12%	-0,13%	-0,25%
BIOGASOLINE											
Submission 2023				6,582	29,568	29,695	29,744	29,283	30,049	29,105	27,577
Submission 2022				6,597	29,609	29,729	29,777	29,315	30,084	29,144	27,647
absolute change				-15,6	-40,8	-33,9	-33,3	-31,9	-35,5	-38,4	-69,9
relative change				-0,24%	-0,14%	-0,11%	-0,11%	-0,11%	-0,12%	-0,13%	-0,25%
COMPRESSED NATURAL GAS - CNG											
current Submission				1,625	5,366	4,419	3,533	3,590	3,271	3,766	3,754
previous Submission				1,604	5,351	4,443	3,562	3,623	3,297	3,786	4,421
absolute change				21,3	14,8	-24,2	-29,1	-33,0	-25,4	-19,6	-667
relative change				1,33%	0,28%	-0,54%	-0,82%	-0,91%	-0,77%	-0,52%	-15,1%
BIOGAS											
current Submission						745	831	992	880	1,531	2,020
previous Submission						749	838	1,001	887	1,539	2,028
absolute change						-4,08	-6,85	-9,11	-6,83	-7,99	-8,53
relative change						-0,54%	-0,82%	-0,91%	-0,77%	-0,52%	0%
LIQUEFIED PETROLEUM GAS - LPG											
current Submission	138	138	94	2,357	21,823	18,963	16,799	15,377	16,153	14,602	9,551
previous Submission	138	138	94	2,357	21,823	18,963	16,799	15,377	16,153	14,602	13,667
absolute change	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-4,115
relative change	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,0%	0,0%	0,0%	-30,1%
TOTAL FUEL CONSUMPTION											
current Submission	1,539,661	1,580,963	1,547,252	1,464,972	1,360,476	1,394,434	1,420,817	1,450,559	1,394,852	1,397,104	1,218,239
previous Submission	1,531,811	1,568,749	1,533,241	1,448,694	1,352,502	1,384,943	1,411,416	1,441,125	1,386,222	1,389,502	1,219,276
absolute change	7,850	12,214	14,011	16,278	7,974	9,491	9,401	9,434	8,630	7,602	-1,037
relative change	0,51%	0,78%	0,91%	1,12%	0,59%	0,69%	0,67%	0,65%	0,62%	0,55%	-0,09%

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 **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

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

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[1], [3] Knörr et al. (2022a): 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, 2022.
[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.