

1.A.3.c - Transport: Railways

Short description

In category *1.A.3.c - Railways*, emissions from fuel combustion in German railways and from the related abrasion and wear of contact line, braking systems and tyres on rails are reported.

Method	AD	EF	Key Category
T1, T2	NS, M	CS, D, M	L : TSP, PM _{2.5} , L&T : PM ₁₀ , PM _{2.5} , L : TSP

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	
AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys
EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Germany's railway sector is undergoing a long-term modernisation process, aimed at making electricity the main energy source for rail transports. Use of electricity, instead of diesel fuel, to power locomotives has been continually increased, and electricity now provides 80% of all railway traction power. Railways' power stations for generation of traction current are allocated to the stationary component of the energy sector (1.A.1.a) and are not included in the further description that follows here. In energy input for trains of German railways, diesel fuel is the only energy source that plays a significant role apart from electric power.

Hard Coal	576	250	250	255	314	345	357	352	341	339	340	340	340	340
Hard Coal Coke	0	0	431	0	0	0	0	0	0	0	0	0	0	0
Solids TOTAL	576	336	682	256	315	346	357	353	342	340	341	341	341	341
Σ 1.A.3.c	39.034	62.444	51.502	37.342	31.481	31.755	29.165	29.503	26.411	28.436	29.348	24.240	20.286	20.488

The use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may still be considered negligible.

Table 3: Annual transport performance, in Mio tkm (ton-kilometers)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Electric Traction	361,515	337,853	361,633	356,605	344,546	342,701	350,085	335,298	331,235	323,387	295,798	296,280	288,336	
Diesel Traction	98,812	58,805	37,237	26,540	26,702	27,403	26,791	23,768	23,734	21,397	21,484	21,365	19,580	
Σ 1.A.3.c	460,326	396,658	398,870	383,145	371,248	370,104	376,876	359,065	354,970	344,785	317,282	317,645	307,916	

[gallery size="medium" : 1A3c_AD\(TJ\).png : 1A3c_AD\(km\).png gallery](#)

Regarding particulate-matter and heavy-metal emissions from **abrasion and wear of contact line, braking systems, tyres on rails**, annual transport performances of railway vehicles with electrical and Diesel traction derived from Knörr et al. (2019a) ⁵⁾ are applied as activity data.

Emission factors

The (implied) emission factors used here for estimating **emissions from diesel fuel combustion** of very different quality: For main pollutants, CO and PM, annual tier2 IEF computed within the TREMOD model are used, representing the development of German railway fleet, fuel quality and mitigation technologies ⁶⁾. On the other hand, constant default values from (EMEP/EEA, 2019) ⁷⁾ are used for all reported PAHs and heavy metals and from Rentz et al. (2008) ⁸⁾ regarding PCDD/F. As no emission factors are available for HCB and PCBs, no such emissions have been calculated yet.

Regarding **emissions from solid fuels** used in historic steam engines, all emission factors displayed below have been adopted from small-scale stationary combustion.

Furthermore, regarding **emissions from abrasion and wear**, emission factors are calculated from PM₁₀, emission estimates directly provided by the German railroad company Deutsche Bahn AG. As these original emissions are only available as of 2013, implied EF(PM₁₀) were calculated from the emission estimates extrapolated backwards from 2013 to 1990 and the transport performance data available from TREMOD. Regarding PM_{2.5}, and TSP, due to lack of better information, a fractional distribution of 0.5 : 1 : 1 (PM_{2.5} : PM₁₀ : TSP) is assumed for now. Emission factors for emissions of copper, nickel and chrome are calculated via typical shares of the named metals in the contact line (copper) and in the braking systems (Ni and Cr). Other heavy metals contained in alloys used for the contact line (silver, magnesium, tin) are not taken into account here. Furthermore, emissions from other wear parts (e.g. the current collector) are not estimated. However, these components are not supposed to contain any of the nine heavy metals to be reported here (current collectors are made of aluminium alloys and coal).

Table 3: Annual country-specific emission factors for diesel fuels¹, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NH₃	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54
NM VOC	109	100	90,2	64,8	52,0	54,3	44,8	41,9	41,2	38,5	38,2	37,2	35,2	35,0
NO_x	1170	1207	1225	1111	970	990	919	899	886	826	801	775	747	724
SO_x	191	60,5	14,1	0,32	0,32	0,32	0,32	0,32	0,33	0,32	0,33	0,33	0,33	0,33
BC³	28,8	28,3	23,8	15,2	11,5	12,0	10,4	9,5	9,3	8,6	8,5	8,0	7,6	7,3
PM_{2,5}	44,4	43,6	36,6	23,4	17,7	18,5	16,0	14,6	14,3	13,3	13,1	12,4	11,7	11,2
PM₁₀	44,4	43,6	36,6	23,4	17,7	18,5	16,0	14,6	14,3	13,3	13,1	12,4	11,7	11,2
TSP²	44,4	43,6	36,6	23,4	17,7	18,5	16,0	14,6	14,3	13,3	13,1	12,4	11,7	11,2
CO	287	292	255	162	121	121	105	101	98,9	94,7	93,3	92,6	88,5	88,2

¹ due to lack of better information: similar EF are applied for fossil diesel oil and biodiesel

² EF(PM_{2,5}) also applied for PM₁₀ and TSP (assumption: >99% of TSP consists of PM_{2,5})

³ EFs calculated via f-BCs as provided in ⁹⁾: diesel fuels: 0.56 (Chapter: 1.A.3.c - Railways, Appendix A: tier1), solid fuels: 0.064 (Chapter: 1.A.4 - Small Combustion: Residential combustion (1.A.4.b): Table 3-3, Zhang et al., 2012)

Table 4: Emission factors applied for solid fuels, in kg/TJ

	NH₃	NM VOC	NO_x	SO_x	PM_{2,5}	PM₁₀	TSP	BC	CO
Hard coal	4.00	15.0	120	650	222	250	278	14.2	500
Hard coal coke	4.00	0.50	120	500	15.0	15.0	15.0	0.96	1,000

Table 4: Country-specific emission factors for abrasive emissions, in g/km

	PM_{2,5}	PM₁₀	TSP	BC	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Contact line ¹	0.00016	0.00032	0.00032	NA	NA	NA	NA	NA	NA	0.00033	NA	NA	NA
Tyres on rails ²	0.009	0.018	0.018	NA	NA								
Braking system ³	0.004	0.008	0.008	NA	NA	NA	NA	NA	0.00008	NA	0.00016	NA	NA
Current collector ⁴	NE	NE	NE	NE	NA								

¹ assumption: 100 per cent copper ² assumption: 100 per cent steel ³ assumption: steel alloy

containing Chromium and Nickel ⁴ typically: aluminium alloy + coal contacts; no particulate matter emissions calculated yet

NOTE: With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [footnote](#) 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. [footnote](#)

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](#)].

[!- [Table 5: Tier1 emission factors for heavy-metal and POP exhaust emissions](#)

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- + Discussion of emission trends

NFR 1.A.3.c is no key source.

Basically, for all unregulated pollutants, emission trends directly follow the trend in over-all fuel consumption.

Here, as emission factors for solid fuels tend to be much higher than those for diesel oil, emission trends are disproportionately effected by the amount of solid fuels used. Therefore, for the **main pollutants, carbon monoxide, particulate matter** and **PAHs**, emission trends show remarkable jumps especially after 1995 that result from the significantly higher amounts of solid fuels used.

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For all fractions of **particulate matter**, the majority of emissions generally result from abrasion and wear and the combustion of diesel fuels. Additional jumps in the over-all trend result from the use of lignite briquettes (1996-2001). Here, as the EF(BC) for fuel combustion are estimated via fractions provided in ¹⁰⁾, black carbon emissions follow the corresponding emissions of PM_{2.5},

gallery size="medium" : 1A3c EM PM.png : 1A3c EM PM10.png gallery

Due to fuel-sulphur legislation, the trend of **sulphur dioxide** emissions follows not only the trend in fuel consumption but also reflects the impact of regulated fuel-qualities. For the years as of 2005, sulphur emissions from diesel combustion have decreased so strongly, that the over-all trend shows a slight increase again due to the now dominating contribution of sulphur from the use of solid fuels.

gallery size="medium" : 1A3c EM SO2.png gallery

Regarding **heavy metals**, emissions from combustion of diesel oil and from abrasion and wear are estimated from tier1 default emission factors. Therefore, the emission trends reflect the development of diesel use and - for copper, chromium and nickel emissions resulting from the abrasion & wear of contact line and braking systems - the annual transport performance (see description of activity data above).

gallery size="medium" : 1A3c EM Cu.png : 1A3c EM Cd.png gallery

Recalculations

Given the revised NEB 2018, both the **activity data** for diesel oil and the annual amounts of blended biodiesel were revised accordingly.

Table 5: Revised fuel consumption, in terajoule

	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	
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%	
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	
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 routine revision of the TREMOD model ¹¹⁾, tier2 **emission factors** changed for recent years. Here, the revision results mainly from the consideration of revised NCvs for diesel oil as provided by the AGEb.

Table 6: Revised country-specific emission factors for diesel fuels, in kg/TJ

=	= 2005	= 2006	= 2007	= 2008	= 2009	= 2010	= 2011	= 2012	= 2013	= 2014	= 2015	= 2016	= 2017
< Nitrogen oxides - NO_x													
~ Submission 2020	> 1,111	> 1,058	> 1,028	> 1,010	> 991	> 970	> 990	> 919	> 899	> 886	> 826	> 801	> 775
~ Submission 2019	> 1,111	> 1,058	> 1,029	> 1,011	> 1,001	> 986	> 1,010	> 921	> 882	> 897	> 851	> 836	> 814
~ absolute change	> 0.00	> -0.75	> -0.44	> -1.81	> -9.91	> -15.63	> -19.97	> -2.05	> 16.27	> -10.45	> -25.27	> -34.82	> -38.70
~ relative change	> 0.00%	> -0.07%	> -0.04%	> -0.18%	> -0.99%	> -1.59%	> -1.98%	> -0.22%	> 1.84%	> -1.16%	> -2.97%	> -4.16%	> -4.75%
< Non-methane volatile organic compounds - NMVOC													
~ Submission 2020	> 64.8	> 61.8	> 57.3	> 55.6	> 51.2	> 52.0	> 54.3	> 44.8	> 42.2	> 41.2	> 38.5	> 38.2	> 37.2
~ Submission 2019	> 64.8	> 62.1	> 57.8	> 56.7	> 53.8	> 55.7	> 59.2	> 46.9	> 43.5	> 43.1	> 41.4	> 40.9	> 39.3
~ absolute change	> -0.04	> -0.33	> -0.48	> -1.05	> -2.60	> -3.79	> -4.84	> -2.09	> -1.33	> -1.95	> -2.87	> -2.66	> -2.08
~ relative change	> -0.06%	> -0.52%	> -0.83%	> -1.85%	> -4.85%	> -6.80%	> -8.18%	> -4.46%	> -3.06%	> -4.52%	> -6.93%	> -6.50%	> -5.30%
< Particulate matter - PM (PM_{2.5}, = PM₁₀, = TSP)													
~ Submission 2020	> 23.4	> 22.4	> 20.9	> 19.5	> 17.6	> 17.7	> 18.5	> 16.0	> 14.7	> 14.3	> 13.3	> 13.1	> 12.4
~ Submission 2019	> 23.4	> 22.5	> 21.1	> 19.9	> 18.2	> 18.6	> 19.8	> 16.6	> 14.8	> 15.4	> 14.7	> 14.6	> 13.7
~ absolute change	> -0.02	> -0.14	> -0.21	> -0.40	> -0.68	> -0.95	> -1.33	> -0.58	> -0.14	> -1.12	> -1.37	> -1.58	> -1.33

~ relative change	> -0.08%	> -0.62%	> -1.01%	> -2.03%	> -3.75%	> -5.07%	> -6.72%	> -3.48%	> -0.95%	> -7.25%	> -9.31%	> -10.79%	> -9.73%
< Black carbon - BC													
~ Submission 2020	> 15.2	> 14.5	> 13.6	> 12.7	> 11.4	> 11.5	> 12.0	> 10.4	> 9.5	> 9.3	> 8.6	> 8.5	> 8.0
~ Submission 2019	> 15.2	> 14.6	> 13.7	> 12.9	> 11.9	> 12.1	> 12.9	> 10.8	> 9.6	> 10.0	> 9.5	> 9.5	> 8.9
~ absolute change	> -0.01	> -0.09	> -0.14	> -0.26	> -0.45	> -0.61	> -0.87	> -0.38	> -0.09	> -0.73	> -0.89	> -1.03	> -0.87
~ relative change	> -0.08%	> -0.62%	> -1.01%	> -2.03%	> -3.75%	> -5.07%	> -6.72%	> -3.48%	> -0.95%	> -7.25%	> -9.31%	> -10.79%	> -9.73%
< Carbon monoxide - CO													
~ Submission 2020	> 162	> 152	> 141	> 134	> 123	> 121	> 121	> 105	> 101	> 98.9	> 94.7	> 93.3	> 92.6
~ Submission 2019	> 162	> 153	> 142	> 136	> 129	> 129	> 129	> 109	> 104	> 104	> 101	> 98.1	> 94.8
~ absolute change	> -0.09	> -0.73	> -1.08	> -2.26	> -6.12	> -8.14	> -8.30	> -3.77	> -2.33	> -4.92	> -5.81	> -4.83	> -2.26
~ relative change	> -0.05%	> -0.48%	> -0.76%	> -1.66%	> -4.75%	> -6.31%	> -6.42%	> -3.46%	> -2.24%	> -4.74%	> -5.78%	> -4.93%	> -2.38%



For more information on recalculated emission estimates for Base Year and 2018, please see the pollutant-specific recalculation tables following chapter [8.1 - Recalculations](#).

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023 (title: "Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland") carried out by Knörr et al. (2009) ¹²⁾.

Planned improvements

Besides the scheduled **routine revision** of TREMOD, no further improvements are planned for the next annual submission.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in ¹³⁾ 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 metals contained in 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.

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