

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 ₁₀ , PM _{2.5} , L & T: PM ₁₀ , PM _{2.5} , L: TSP

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.

Method

Activity Data

Basically, total inland deliveries of *diesel oil* are available from the National Energy Balances (NEBs) (AGEB, 2019)¹⁾. This data is based upon sales data of the Association of the German Petroleum Industry (MWV)²⁾. As a recent revision of MWV data on diesel oil sales for the years 2005 to 2009 has not yet been adopted to the respective NEBs, this original MWV data has been used for this five years.

Data on the consumption of biodiesel in railways is provided in the NEBs as well, from 2004 onward. But as the NEBs do not provide a solid time series regarding most recent years, the data used for the inventory is estimated based on the prescribed shares of biodiesel to be added to diesel oil.

Small quantities of *solid fuels* are used for historical steam engines vehicles operated mostly for tourism and exhibition purposes. Official fuel delivery data are available for lignite, through 2002, and for hard coal, through 2000, from the NEBs. In order to complete these time series, a study was carried out in 2012 by Hedel, R., and Kunze, J. (2012)³⁾. During this study, questionnaires were provided to any known operator of historical steam engines in Germany. Here, due to limited data archiving, nearly complete data could only be gained for years as of 2005. For earlier years, in order to achieve a solid time series, conservative gap filling was applied. A follow-up study to gain original consumption data for 2015 was carried out in 2016 by Illichmann, S. (2016)⁴⁾.

Table 1: Overview of activity-data sources for domestic fuel sales to railway operators

Activity	data source / quality of activity data
combustion of:	
Diesel oil	1990-2004: NEB lines 74 and 61: 'Schienenverkehr' / 2005-2009: MWV annual report, table: 'Sektoraler Verbrauch von Dieselmotoren' / from 2010: NEB line 61
Biodiesel	calculated from official blending rates
Hard coal	1990-1994: NEB lines 74; 1995-2004: interpolated data; from 2005: original data from studies; 2016: forward extrapolation
Hard coal coke	1990-1997: NEB lines 74 and 61; 1998-2004: interpolated data; from 2005: original data from studies; 2016: forward extrapolation
Raw lignite	from 1990: NEB lines 74 and 61
Lignite briquettes	from 1990: NEB lines 74 and 61
abrasion and wear of contact line, braking systems and tyres on rails:	
transport performance data	in Mio ptkm (performance-ton-kilometers) derived from the TREMOD model

Table 2: Annual fuel consumption in German railways, in terajoules

	= 1990	= 1995	= 2000	= 2005	= 2010	= 2011	= 2012	= 2013	= 2014	= 2015	= 2016	= 2017	= 2018
~ Diesel Oil	> 38,458	> 31,054	> 25,410	> 18,142	> 14,626	> 14,730	> 13,514	> 13,771	> 12,283	> 13,321	> 13,775	> 11,344	> 10,961

~ Biodiesel	> 0	> 0	> 0	> 397	> 949	> 966	> 882	> 798	> 745	> 720	> 724	> 602	> 633				
~ Liquids TOTAL	> 38,458	> 31,054	> 25,410	> 18,539	> 15,575	> 15,696	> 14,396	> 14,569	> 13,028	> 14,041	> 14,499	> 11,946	> 11,594				
~ Lignite Briquettes	> 0.00	> 0.00	> 431.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00	> 0.00				
~ Raw Lignite	> 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				
~ Hard Coal	> 576	> 250	> 250	> 255	> 314	> 345	> 357	> 352	> 341	> 339	> 340	> 340	> 340				
~ Hard Coal Coke	> 0	> 86	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1				
Solids TOTAL	> 576	> 336	> 682	> 256	> 315	> 346	> 357	> 353	> 342	> 340	> 341	> 341	> 341				
Σ 1.A.3.c	~ 39,034	~ 31,390	~ 26,092	~ 18,795	~ 15,890	~ 16,041	~ 14,754	~ 14,921	~ 13,370	~ 14,381	~ 14,839	~ 12,287	~ 11,934				

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				
~ 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 fuels, in kg/TJ

Table with 14 columns representing years from 1990 to 2018 and rows for various pollutants including NH3, NMVOC, NOx, SOx, PM2.5, BC, and CO. Values are generally increasing over time.

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

Table with 10 columns for pollutants (NH3, NMVOC, NOx, SOx, PM2.5, PM10, TSP, BC, CO) and two rows for 'Hard coal' and 'Hard coal coke'.

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

Table with 13 columns for various pollutants (PM2.5, PM10, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn) and four rows for different rail components like 'Contact line', 'Tyres on rails', 'Braking system', and 'Current collector'.

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. 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.

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

Table with 18 columns for various pollutants (Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, B[a]P, B[b]F, B[k]F, I[...], PAH 1-4, HCB, PCBs, PCDD/F) and rows for different fuel types like 'Diesel oil', 'Biodiesel', 'Lignite Briquettes', 'Raw Lignite', 'Hard Coal', and 'Hard Coal Coke'.

< 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 2017**, 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) ¹¹⁾.

+ 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 ¹²⁾ 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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¹¹⁾ (bibcite 1)

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³⁾ (bibcite 3)

⁴⁾ (bibcite 4)

⁵⁾ (bibcite 5)

⁶⁾ (bibcite 4)

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