

Appendix 2.4 - POP emissions from mobile combustion sources

This appendix chapter provides additional information regarding the approaches applied for estimating exhaust POP emissions from mobile sources in:

- [Road Transport](#) (1.A.3.b i - iv)
- [Non-road Mobile Machinery](#) (1.A.2.g vii, 1.A.4.a ii/b ii/c ii, and 1.A.5.b)
- [Railways](#) (1.A.3.c)
- [Maritime_vessels](#) (1.A.3.d i, 1.A.3.d ii, 1.A.4.c iii, and 1.A.5.b)
- [Aircraft](#) (1.A.3.a and 1.A.5.b)

Road Transport

For **exhaust emissions of Benzo[a]Pyrene, Benzo[b]Fluoranthene, Benzo[k]Fluoranthene, and Indeno[1,2,3-c,d]Pyrene** the tier2 emission factors as provided in the 2023 EMEP/EEA Guidebook, Chapter 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv (Update 2025), tables 3-18 to 3-26 ¹⁾ are being used:

Table 3-18: Tier 2 exhaust emission factors for passenger cars, NFR 1.A.3.b.i

| Type | Technology | PM2.5 | ID(1,2,3,cd)P | B(k)F | B(b)F | B(a)P |
|--------------|----------------------|----------------|---------------|----------|----------|----------|
| Units | | g/km | g/km | g/km | g/km | g/km |
| Notes | | PM2.5=PM10=TSP | | | | |
| Petrol Mini | Euro 4 - 98/69/EC II | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 5 - EC 715/2007 | 0.0014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 up to 2016 | 0.0014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2017-2019 | 0.0016 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2020+ | 0.0016 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| Petrol Small | PRE ECE | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | ECE 15/00-01 | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | ECE 15/02 | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | ECE 15/03 | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | ECE 15/04 | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | Open Loop | 0.0022 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | Euro 1 - 91/441/EEC | 0.0022 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 2 - 94/12/EEC | 0.0022 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 3 - 98/69/EC I | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 4 - 98/69/EC II | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 5 - EC 715/2007 | 0.0014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 up to 2016 | 0.0014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2017-2019 | 0.0016 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2020+ | 0.0016 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |

| | | | | | | |
|-----------------------------|----------------------|--------|----------|----------|----------|----------|
| Diesel Medium | Conventional | 0.2209 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 1 - 91/441/EEC | 0.0842 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 2 - 94/12/EEC | 0.0548 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 3 - 98/69/EC I | 0.0391 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 4 - 98/69/EC II | 0.0314 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 5 - EC 715/2007 | 0.0021 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 up to 2016 | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 2017-2019 | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 2020+ | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| Diesel Large SUV- Executive | Conventional | 0.2209 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 1 - 91/441/EEC | 0.0842 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 2 - 94/12/EEC | 0.0548 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 3 - 98/69/EC I | 0.0391 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 4 - 98/69/EC II | 0.0314 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 5 - EC 715/2007 | 0.0021 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 up to 2016 | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 2017-2019 | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 6 2020+ | 0.0015 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| LPG | Conventional | 0.0022 | 1.00E-08 | 1.00E-08 | 0.00E+00 | 1.00E-08 |
| | Euro 1 - 91/441/EEC | 0.0022 | 1.00E-08 | 1.00E-08 | 0.00E+00 | 1.00E-08 |
| | Euro 2 - 94/12/EEC | 0.0022 | 1.00E-08 | 1.00E-08 | 0.00E+00 | 1.00E-08 |
| | Euro 3 - 98/69/EC I | 0.0011 | 1.00E-08 | 1.00E-08 | 0.00E+00 | 1.00E-08 |
| | Euro 4 - 98/69/EC II | 0.0011 | 1.00E-08 | 1.00E-08 | 0.00E+00 | 1.00E-08 |
| 2-Stroke | Conventional | n.a. | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| Hybrid Petrol Small | Euro 4 - 98/69/EC II | n.a. | 3.9E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| Hybrid Petrol Medium | Euro 4 - 98/69/EC II | n.a. | 3.9E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| Hybrid Petrol Large | Euro 4 - 98/69/EC II | n.a. | 3.9E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| E85 | Euro 4 - 98/69/EC II | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| CNG | Euro 4 - 98/69/EC II | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |

Table 3-20: Tier 2 exhaust emission factors for light commercial vehicles, NFR 1.A.3.b.ii

| Type | Technology | PM2.5 | ID(1,2,3,cd)P | B(k)F | B(b)F | B(a)P |
|--------|----------------------|--------------------|---------------|----------|----------|----------|
| Units | | g/km | g/km | g/km | g/km | g/km |
| Notes | | PM2.5=PM10 =TSP | | | | |
| Petrol | Conventional | 0.0023 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| | Euro 1 - 93/59/EEC | 0.0023 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 2 - 96/69/EEC | 0.0023 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 3 - 98/69/EC I | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 4 - 98/69/EC II | 0.0011 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 5 - EC 715/2007 | 0.0014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 up to 2017 | 0.0012 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2018-2020 | 0.0012 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 6 2021+ | 0.0012 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| Diesel | Conventional | 0.356 | 2.54E-06 | 2.87E-06 | 3.30E-06 | 2.85E-06 |
| | Euro 1 - 93/59/EEC | 0.117 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 2 - 96/69/EEC | 0.117 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 3 - 98/69/EC I | 0.0783 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 4 - 98/69/EC II | 0.0409 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 5 - EC 715/2007 | 0.0010 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 6 up to 2017 | 0.0009 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 6 2018-2020 | 0.0009 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |
| | Euro 6 2021+ | 0.0009 | 7.00E-07 | 1.90E-07 | 6.00E-07 | 6.30E-07 |

Table 3-22: Tier 2 exhaust emission factors for heavy-duty vehicles, NFR 1.A.3.b.iii

| Type | Technology | PM2.5 | ID(1,2,3,c d)P | B(k)F | B(b)F | B(a)P |
|-------------------|-------------------------|------------------------|-------------------|----------|----------|----------|
| Units | | g/km | g/km | g/km | g/km | g/km |
| Notes | | PM2.5=P M10=TS P | | | | |
| Petrol >3.5 t | Conventional | 0.000 | 1.03E-06 | 3.00E-07 | 8.80E-07 | 4.80E-07 |
| Diesel <=7.5 t | Conventional | 0.333 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.129 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.061 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.0566 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0106 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0106 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0005 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| Diesel 7.5 - 16 t | Conventional | 0.3344 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.201 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.104 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.0881 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0161 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0161 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0008 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| Diesel 16 - 32 t | Conventional | 0.418 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.297 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.155 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.13 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0239 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0239 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0012 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| Diesel >32 t | Conventional | 0.491 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.358 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.194 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.151 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0268 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0268 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0013 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |

Table 3-24: Tier 2 exhaust emission factors for buses, NFR 1.A.3.b.iii

| Type | Technology | PM2.5 | ID(1.2.3.cd)P | B(k)F | B(b)F | B(a)F |
|----------------------|-------------------------|----------------|---------------|----------|----------|----------|
| Units | | g/km | g/km | g/km | g/km | g/km |
| Notes | | PM2.5=PM10=TSP | | | | |
| Urban CNG Buses | Euro I - 91/542/EEC I | 0.0200 | n.a. | n.a. | n.a. | n.a. |
| | Euro II - 91/542/EEC II | 0.0100 | n.a. | n.a. | n.a. | n.a. |
| | Euro III - 2000 | 0.0100 | 3.00E-08 | 4.00E-08 | 8.00E-08 | 5.00E-08 |
| | EEV | 0.0050 | 1.00E-08 | 1.00E-08 | 1.00E-08 | 3.00E-08 |
| Urban Buses Standard | Conventional | 0.9090 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.4790 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.2200 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.2070 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0462 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0462 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0023 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| Coaches Standard | Conventional | 0.4700 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro I - 91/542/EEC I | 0.3620 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro II - 91/542/EEC II | 0.1650 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro III - 2000 | 0.1780 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro IV - 2005 | 0.0354 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro V - 2008 | 0.0354 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |
| | Euro VI | 0.0018 | 1.40E-06 | 6.09E-06 | 5.45E-06 | 9.00E-07 |

Table 3-26: Tier 2 emission factors for L-category vehicles, NFR 1.A.3.b.iv

| Type | Technology | PM2.5 | ID(1,2,3,cd)P | B(k)F | B(b)F | B(a)P |
|------------------------------------|---------------------|----------------|---------------|----------|----------|----------|
| Units | | g/km | g/km | g/km | g/km | g/km |
| Notes | | PM2.5=PM10=TSP | | | | |
| 2-stroke <50 cm ³ | Conventional | 0.176 | 2.06E-07 | 6E-08 | 1.76E-07 | 9.6E-08 |
| | Mop - Euro 1 | 0.045 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| | Mop - Euro 2 | 0.026 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| | Mop - Euro 3 and on | 0.018 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| 4-stroke <50 cm ³ | Conventional | 0.176 | 2.06E-07 | 6E-08 | 1.76E-07 | 9.6E-08 |
| | Mop - Euro 1 | 0.04 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| | Mop - Euro 2 | 0.007 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| | Mop - Euro 3 and on | 0.004 | 7.8E-08 | 5.2E-08 | 7.2E-08 | 6.4E-08 |
| 2-stroke >50 cm ³ | Conventional | 0.16 | n.a. | n.a. | n.a. | n.a. |
| | Mot - Euro 1 | 0.064 | n.a. | n.a. | n.a. | n.a. |
| | Mot - Euro 2 | 0.032 | n.a. | n.a. | n.a. | n.a. |
| | Mot - Euro 3 and on | 0.0096 | n.a. | n.a. | n.a. | n.a. |
| 4-stroke <250 cm | Conventional | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 1 | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 2 and on | 0.0035 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| 4-stroke 250 - 750 cm ³ | Conventional | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 1 | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 2 and on | 0.0035 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| 4-stroke >750 cm ³ | Conventional | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 1 | 0.014 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Mot - Euro 2 and on | 0.0035 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| Mini-cars | Conventional | 0.250 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 1 | 0.150 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 2 | 0.150 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 3 | 0.150 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 4 | 0.080 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| | Euro 5 | 0.001 | 1.62E-06 | 1.53E-06 | 1.95E-06 | 1.74E-06 |
| ATVs | Conventional | 0.200 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 1 | 0.080 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 2 | 0.040 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 3 | 0.040 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 4 | 0.010 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |
| | Euro 5 | 0.002 | 3.90E-07 | 2.60E-07 | 3.60E-07 | 3.20E-07 |

For further information on the actual emission factors derived from these default values and applied in the German emissions inventory, please refer to the overview chapter on [Emissions from Fuel Combustion in Road Vehicles](#).

Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008)²⁾ is used instead.

Non-road Mobile Machinery

Table 1: Tier1 default emission factors applied to NRMM

| | B[a]P | B[b]F | B[k]F | I[...]P | PAH 1-4 | PCDD/F |
|--|--------|-------|-------|----------|---------|-------------------|
| | [mg/T] | | | | | [µg/T] |
| Diesel oil | 698 | 1.164 | 801 | 184 | 2,847 | 1.62 ³ |
| Biodiesel¹ | 806 | 1.343 | 924 | 212 | 3,284 | 1.87 |
| Gasoline fuels - 4-stroke | 919 | 919 | 90 | 204 | 2,131 | 2.76 ³ |
| Gasoline fuels - 2-stroke² | 919 | 919 | 90 | 204 | 2,131 | 57.5 ³ |
| LPG (1.A.4.a ii only) | 4.35 | 0.00 | 4.35 | 4.35 | 13.04 | NE |

¹ values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

² no separate values available for 2-stroke-mix including 1:50 lube oil

³ tier1 values derived from Rentz et al. (2008) ³⁾

Railways

For **exhaust emissions of Benzo[a]Pyrene, Benzo[b]Fluoranthene, Benzo[k]Fluoranthene, and Indeno[1,2,3-c,d]Pyrene**, tier1 emission factors as provided in the EMEP/EEA Guidebook 2023 in chapters 1.A.3.c and 1.A.3.b (Update 2024) are applied. Here, as no tier1 defaults are provided for B[k] and I[123cd]P, the values provided for road heavy-duty vehicles are applied instead, as proposed in Table 3-9 in chapter 1.A.3.c of the EMEP/EEA Guidebook 2023.

Table 3-1 Tier 1 emission factors for railways

| Tier 1 emission factor | | | | | |
|----------------------------|---|---------------|-------------------------|-------|--------------------------|
| | Code | Name | | | |
| NFR Source Category | 1.A.3.c | Railways | | | |
| Fuel | Gas Oil/Diesel | | | | |
| Not applicable | HCH, PCB, HCB | | | | |
| Not estimated | SOx, Pb, Hg, As, PCDD/F, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene | | | | |
| Pollutant | Value | Unit | 95% confidence interval | | Reference |
| | | | Lower | Upper | |
| NOx | 52.4 | kg/tonne fuel | 25 | 93 | Aggregated Tier 2 method |
| CO | 10.7 | kg/tonne fuel | 6 | 19 | Guidebook (2006) |
| NM VOC | 4.65 | kg/tonne fuel | 2 | 8 | Guidebook (2006) |
| NH ₃ | 0.007 | kg/tonne fuel | 0.004 | 0.012 | Guidebook (2006) |
| TSP | 1.52 | kg/tonne fuel | 3 | 23 | Aggregated Tier 2 method |
| PM10 | 1.44 | kg/tonne fuel | 2 | 16 | Aggregated Tier 2 method |
| PM2.5 | 1.37 | kg/tonne fuel | 2 | 14 | Aggregated Tier 2 method |
| Cd | 0.01 | g/tonne fuel | 0.003 | 0.025 | Guidebook (2006) |
| Cr | 0.05 | g/tonne fuel | 0.02 | 0.2 | Guidebook (2006) |
| Cu | 1.7 | g/tonne fuel | 0.5 | 4.9 | Guidebook (2006) |
| Ni | 0.07 | g/tonne fuel | 0.02 | 0.2 | Guidebook (2006) |
| Se | 0.01 | g/tonne fuel | 0.003 | 0.025 | Guidebook (2006) |
| Zn | 1 | g/tonne fuel | 0.3 | 2.5 | Guidebook (2006) |
| Benzo(a)pyrene | 0.03 | g/tonne fuel | 0.01 | 0.1 | Guidebook (2006) |
| Benzo(b)fluoranthene | 0.05 | g/tonne fuel | 0.02 | 0.2 | Guidebook (2006) |
| Benz(a)anthracene | 0.08 | g/tonne fuel | 0.03 | 0.2 | Guidebook (2006) |
| CO ₂ | 3140 | kg/tonne fuel | 3120 | 3160 | Guidebook (2006) |
| Dibenzo(a,h)anthracene | 0.01 | g/tonne fuel | 0.004 | 0.03 | Guidebook (2006) |

Notes

B(k)f & Indeno (1,2,3-cd) pyrene and dioxins emission factor values are not available for railway emissions. It is therefore recommended to use values corresponding to old technology heavy duty vehicles from the Exhaust Emissions from Road Transport chapter (1.A.3.b.iii).

BC fraction of PM (f-BC): 0.65. Source: for further information see Appendix A

Table 3-9: Tier 1 emission factors for B(b)F and B(a)P

| Category | Fuel | B(b)F | | | B(a)P | | |
|------------|-------------|-------------|----------|----------|-------------|----------|----------|
| | | (g/kg fuel) | | | (g/kg fuel) | | |
| | | Mean | Min | Max | Mean | Min | Max |
| PC | Petrol | 7.15E-06 | 4.08E-06 | 1.74E-05 | 5.81E-06 | 3.63E-06 | 9.51E-06 |
| | Diesel | 3.59E-05 | 1.72E-05 | 5.41E-05 | 3.20E-05 | 9.39E-06 | 4.82E-05 |
| | LPG | N/A | N/A | N/A | 1.98E-07 | 1.91E-07 | 1.98E-07 |
| LCV | Petrol | 6.44E-06 | 3.89E-06 | 1.51E-05 | 5.03E-06 | 3.46E-06 | 8.25E-06 |
| | Diesel | 2.70E-05 | 1.72E-05 | 3.82E-05 | 2.41E-05 | 9.39E-06 | 3.41E-05 |
| HDV | Diesel | 2.12E-05 | 1.11E-05 | 5.30E-05 | 3.50E-06 | 1.83E-06 | 8.76E-06 |
| | CNG (Buses) | 1.48E-05 | 9.82E-06 | 1.76E-05 | 2.44E-06 | 1.62E-06 | 2.91E-06 |
| L-category | Petrol | 1.09E-05 | 6.01E-06 | 2.72E-05 | 8.12E-06 | 5.34E-06 | 1.84E-05 |

From these tier1 defaults, energy-related EF presented in chapter 1.A.3.c - Railways have been derived and are applied in the German emissions inventory.

Inland Vessels and Ships in 1.A.3.d ii

Table 2: Tier1 default emission factors applied to inland ships and vessels

| | B[a]P | B[b]F | B[k]F | I[...] _p | PAH 1-4 ² | HCB | PCBs | PCDD/F |
|------------------------------|------------------|--------------------|------------------|---------------------|----------------------|-------------------|-------------------|-------------------|
| | [mg/T] | | | | | | | [µg/T] |
| Diesel oil | 698 ⁴ | 1,164 ⁴ | 801 ⁵ | 184 ⁵ | 2,847 | 1.86 ³ | 0.88 ³ | 93.0 ⁷ |
| Biodiesel¹ | 806 | 1,343 | 924 | 212 | 3,284 | 1.02 | 2.15 | 107 |

¹ similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel

² sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P

³ tier1 defaults from ⁴⁾, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2

⁴ tier1 defaults from ⁵⁾, Chapter: 1.A.3.c Railways: Diesel, Table 3-1

⁵ tier1 defaults from ⁶⁾, Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

Maritime Vessels

The following table provides the tier1 EF applied for POPs from ships and vessels in both civil and military operation in NFR categories 1.A.3.d i -International Maritime Navigation, 1.A.3.d ii - National Navigation (Shipping), 1.A.4.c iii - Fishery and 1.A.5.b iii - Other: Military Navigation.

Table 3: Tier1 default emission factors applied to maritime ships and vessels

| | B[a]P | B[b]F | B[k]F | I[...] _p | PAH 1-4 ² | HCB | PCBs | PCDD/F |
|-----------------------------------|------------------|--------------------|------------------|---------------------|----------------------|-------------------|-------------------|-------------------|
| | [mg/T] | | | | | | | [µg/T] |
| Diesel oil | 698 ⁴ | 1,164 ⁴ | 801 ⁵ | 184 ⁵ | 2,847 | 1.86 ³ | 0.88 ³ | 93.0 ⁷ |
| Biodiesel¹ | 806 | 1,343 | 924 | 212 | 3,284 | 2.15 | 1.02 | 107 |
| Heavy Fuel oil⁶ | 741 | 1,235 | 849 | 195 | 3,020 | 3.46 | 14.1 | 98.7 |

¹ similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel

² sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P

³ tier1 defaults from ⁷⁾, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2

⁴ tier1 defaults from ⁸⁾, Chapter: 1.A.3.c Railways: Diesel, Table 3-1

⁵ tier1 defaults from ⁹⁾, Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

⁶ derived from default for fossil diesel oil, but adapted to specific NCV of heavy fuel oil

⁷ tier1 value derived from ¹⁰⁾

Here, the specific tier1 default emission factors available from the latest (2023) version of the EMEP/EEA Guidebook have not yet been implemented in the inventory but will be applied with the next annual submission. (see also:)

Aircraft

The EMEP/EEA Guidebook 2023 does not provide specific defaults for POP emissions from the combustion of jet kerosene and aviation gasoline, stating that for for aviation gasoline these emissions are *not estimated* (NE). Therefore, the inventory compiler decided to apply the tier1 EF for **PAHs** from gasoline fuel used in non-road mobile machinery here.

Furthermore, both **HCB** and **PCBs** emissions are stated as *not applicable* in ¹¹⁾, chapter 1.A.3.a, 1.A.5.b Aviation, Table 3.3 - Tier 1 emission factors for NFR 1.A.3.a.ii.(i): Civil aviation (domestic, LTO).

As the Party assumes that POP emissions from the combustion of jet kerosene are unlikely to occur, these emissions are reported as *not applicable* (NA).

Tabel 4 provides the emission factors applied for PAH emissions from aircraft in 1A.3.a and 1.A.5.b ii as derived from tier1 EF for **PAHs** from gasoline fuel used in non-road mobile machinery:

Table 4: Tier1 default emisison factors applied to aircraft, in mg/TJ

| | B[a]P | B[b]F | B[k]F | I[...]p | PAH 1-4 | PCDD/F |
|--------------------------|--------------|--------------|--------------|----------------|----------------|---------------|
| Kerosene | NA | NA | NA | NA | NA | NA |
| Aviation gasoline | 126 | 182 | 90 | 205 | 602 | NE |

^{1), 11)} EMEP/EEA (2023): EMEP/EEA air pollutant emission inventory guidebook 2023, Copenhagen, 2023.

^{2), 3), 10)} 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: <https://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer>

^{4), 5), 6), 7), 8), 9)} EMEP/EEA (2019): EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019.