# Updated Tier 1 and 2 emission factors and Tier 2 fuel split information for non-road machinery

**1. Introduction**

In the current version, the EMEP/EEA Guidebook Chapter on non road mobile machinery provides fuel related Tier 1 and Tier 2 emission factors and Tier 2 fuel split information for the years until 2010. These data were made available during the EMEP/EEA Guidebook revision in 2008 to support country Tier 1 and 2 emission estimates for the non road sector.

However, during the time after the Guidebook revision new engine technologies has entered the European fleet and in a few cases new emission information has also become available to support data updates to be made.

This note provides updated fuel related Tier 1 and Tier 2 emission factors for non-road machinery for the years until 2016, based on the detailed Tier 3 fuel consumption and emission factors from the German TREMOD NRMM model (IFEU, 2004; 2009; 2014) and country specific non road fleet and activity data from the Danish emission inventories (Winther, 2015).

The Tier 1 emission factors are calculated for the NFR sectors agriculture, forestry, industry, residential and commercial/institutional, split into the fuel/machinery types diesel, two-stroke gasoline and four-stroke gasoline. For Tier 2, the emission factors are further stratified into technology levels.

This note also includes the detailed Tier 3 fuel consumption and emission factors provided by the TREMOD model and further explains the Tier 3 emission calculation method, thus enabling countries to make Tier 3 estimates, given that country specific fleet and activity data are available at this level of detail.

**2. Emission factors for Tier 3**

The detailed fuel consumption and emission information is to a large extent taken from the German TREMOD NRMM model, developed by Institut für Energie- und Umweltforschung Heidelberg GmbH (IFEU), first documented in 2004 (IFEU, 2004) and later updated in 2009 and 2014 (IFEU 2009, 2014).

**2.1 Basis emission factors**

**Diesel**

For diesel engines the following technology levels are represented by emission factors: < 1981, 1981–1990, 1991–Stage I, Stage I, II, IIIA, IIIB and IV. The emission factors are further grouped into the engine size classes corresponding to the engine size classifications made in the EU emission directives for non road mobile machinery.

The factors for fuel consumption and NOx, VOC, CO and TSP emissions for technology levels until Stage II are gathered by IFEU (2004), based on measured data from a range of different measurement studies and data suggested from literature reviews (Euromot 1995; BUWAL 1996; FAT 2002; KBA 2002). For Stage IIIA, IIIB and IV technology levels currently no measurement data have been available as a basis for emission factor development. In these cases emission factors are estimated from the EU directive emission limits relevant for diesel non road machinery and agricultural tractors (c.f. Appendix 1) following the guidance given in Table 1 (c.f. IFEU, 2009).

Table 1 Derivation rules for Stage IIIA, IIIB and IV emission factors based on EU directive emission limits

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stage | NOx | VOC | PM | CO |
| Stage IIIA | Limit value – 10 %, from this: | Limit value – 10 % | Limit value – 40 % |
| 90 % | 10 % |
| Stage IIIB | Limit value – 10 % | Limit value – 30 % | Limit value | Limit value – 40 % |
| Stage IV | Limit value | Limit value – 30 % | Limit value | Limit value – 40 % |

Relevant for CO, VOC and PM, in cases where the generic emission factors exceed the Stage II ones, Stage II emission factors are used. For more explanation please refer to IFEU (2009)[[1]](#footnote-1). EMEP/Corinair (2013) is the source of N2O and NH3 emission factors, whereas the CH4 percentage share of total VOC of 2.4 % is taken from IFEU (2009). All baseline emission factors for diesel engines are shown in Table 2.

Table 2 Fuel consumption and emission factors for diesel non road engines (g/kWh)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Engine size | Emission Level | NOx | VOC | CO | N2O | NH3 | PM | FC |
| P<19 | <1981 | 12.00 | 5.00 | 7.00 | 0.035 | 0.002 | 2.80 | 300 |
| P<19 | 1981-1990 | 11.50 | 3.80 | 6.00 | 0.035 | 0.002 | 2.30 | 285 |
| P<19 | 1991-Stage I | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| P<19 | Stage I | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| P<19 | Stage II | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| P<19 | Stage IIIA | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| P<19 | Stage IIIB | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| P<19 | Stage IV | 11.20 | 2.50 | 5.00 | 0.035 | 0.002 | 1.60 | 270 |
| 19<=P<37 | <1981 | 18.00 | 2.50 | 6.50 | 0.035 | 0.002 | 2.00 | 300 |
| 19<=P<37 | 1981-1990 | 18.00 | 2.20 | 5.50 | 0.035 | 0.002 | 1.40 | 281 |
| 19<=P<37 | 1991-Stage I | 9.80 | 1.80 | 4.50 | 0.035 | 0.002 | 1.40 | 262 |
| 19<=P<37 | Stage I | 9.80 | 1.80 | 4.50 | 0.035 | 0.002 | 1.40 | 262 |
| 19<=P<37 | Stage II | 6.50 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 262 |
| 19<=P<37 | Stage IIIA | 6.08 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 262 |
| 19<=P<37 | Stage IIIB | 6.08 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 262 |
| 19<=P<37 | Stage IV | 6.08 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 262 |
| 37<=P<56 | <1981 | 7.70 | 2.40 | 6.00 | 0.035 | 0.002 | 1.80 | 290 |
| 37<=P<56 | 1981-1990 | 8.60 | 2.00 | 5.30 | 0.035 | 0.002 | 1.20 | 275 |
| 37<=P<56 | 1991-Stage I | 11.50 | 1.50 | 4.50 | 0.035 | 0.002 | 0.80 | 260 |
| 37<=P<56 | Stage I | 7.70 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 260 |
| 37<=P<56 | Stage II | 5.50 | 0.40 | 2.20 | 0.035 | 0.002 | 0.20 | 260 |
| 37<=P<56 | Stage IIIA | 3.81 | 0.40 | 2.20 | 0.035 | 0.002 | 0.20 | 260 |
| 37<=P<56 | Stage IIIB | 3.81 | 0.28 | 2.20 | 0.035 | 0.002 | 0.03 | 260 |
| 37<=P<56 | Stage IV | 3.81 | 0.28 | 2.20 | 0.035 | 0.002 | 0.03 | 260 |
| 56<=P<75 | <1981 | 7.70 | 2.40 | 6.00 | 0.035 | 0.002 | 1.80 | 290 |
| 56<=P<75 | 1981-1990 | 8.60 | 2.00 | 5.30 | 0.035 | 0.002 | 1.20 | 275 |
| 56<=P<75 | 1991-Stage I | 11.50 | 1.50 | 4.50 | 0.035 | 0.002 | 0.80 | 260 |
| 56<=P<75 | Stage I | 7.70 | 0.60 | 2.20 | 0.035 | 0.002 | 0.40 | 260 |
| 56<=P<75 | Stage II | 5.50 | 0.40 | 2.20 | 0.035 | 0.002 | 0.20 | 260 |
| 56<=P<75 | Stage IIIA | 3.81 | 0.40 | 2.20 | 0.035 | 0.002 | 0.20 | 260 |
| 56<=P<75 | Stage IIIB | 2.97 | 0.28 | 2.20 | 0.035 | 0.002 | 0.03 | 260 |
| 56<=P<75 | Stage IV | 0.40 | 0.28 | 2.20 | 0.035 | 0.002 | 0.03 | 260 |
| 75<=P<130 | <1981 | 10.50 | 2.00 | 5.00 | 0.035 | 0.002 | 1.40 | 280 |
| 75<=P<130 | 1981-1990 | 11.80 | 1.60 | 4.30 | 0.035 | 0.002 | 1.00 | 268 |
| 75<=P<130 | 1991-Stage I | 13.30 | 1.20 | 3.50 | 0.035 | 0.002 | 0.40 | 255 |
| 75<=P<130 | Stage I | 8.10 | 0.40 | 1.50 | 0.035 | 0.002 | 0.20 | 255 |
| 75<=P<130 | Stage II | 5.20 | 0.30 | 1.50 | 0.035 | 0.002 | 0.20 | 255 |
| 75<=P<130 | Stage IIIA | 3.24 | 0.30 | 1.50 | 0.035 | 0.002 | 0.20 | 255 |
| 75<=P<130 | Stage IIIB | 2.97 | 0.13 | 1.50 | 0.035 | 0.002 | 0.03 | 255 |
| 75<=P<130 | Stage IV | 0.40 | 0.13 | 1.50 | 0.035 | 0.002 | 0.03 | 255 |
| 130<=P<560 | <1981 | 17.80 | 1.50 | 2.50 | 0.035 | 0.002 | 0.90 | 270 |
| 130<=P<560 | 1981-1990 | 12.40 | 1.00 | 2.50 | 0.035 | 0.002 | 0.80 | 260 |
| 130<=P<560 | 1991-Stage I | 11.20 | 0.50 | 2.50 | 0.035 | 0.002 | 0.40 | 250 |
| 130<=P<560 | Stage I | 7.60 | 0.30 | 1.50 | 0.035 | 0.002 | 0.20 | 250 |
| 130<=P<560 | Stage II | 5.20 | 0.30 | 1.50 | 0.035 | 0.002 | 0.10 | 250 |
| 130<=P<560 | Stage IIIA | 3.24 | 0.30 | 1.50 | 0.035 | 0.002 | 0.10 | 250 |
| 130<=P<560 | Stage IIIB | 1.80 | 0.13 | 1.50 | 0.035 | 0.002 | 0.03 | 250 |
| 130<=P<560 | Stage IV | 0.40 | 0.13 | 1.50 | 0.035 | 0.002 | 0.03 | 250 |

a) In TREMOD NRMM the 37-56 kW and 56-75 kW size classes are represented by one 37-75 kW size group, and NOx emission factors for Stage IIIA, IIIB and IV are reported as 3.8, 3.4 and 2.1 g/kWh, respectively

**Gasoline**

For gasoline engines the emission factors distinguish between 2-stroke and 4-stroke engines further split into hand held (SH) and not hand held (SN) equipment. The emission factors are further grouped into the engine size classes (ccm) corresponding to the engine size classifications made in the EU emission directive 2002/88 for gasoline fuelled non-road machinery.

The following technology levels are represented by fuel consumption and emission factors: < 1981, 1981–1990, 1991–Stage I, Stage I and Stage II. The factors for fuel consumption and NOx, VOC, CO and TSP (2-stroke only) emissions are provided by IFEU (2004) and are to a large extent based on expert judgement taking into account specific measurement data, type approval values, and estimated emission increase for the part of engines from 1990 and older. For more details please refer to IFEU (2004). 4-stroke TSP emission factors in TREMOD NRMM come from USEPA (1999). EMEP/Corinair (2013) is the source of N2O and NH3 emission factors, whereas whereas the CH4 percentage shares of total VOC of 7.0 % and 3.4 % for 2-stroke and 4-stroke engines, respectively, are taken from IFEU (2009).

Table 3 Fuel consumption and emission factors for gasoline 2 stroke non road engines (g/kWh)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | Size code | Size classe | Emission Level | NOx | VOC | CO | N2O | NH3 | TSP | FC |
| 2-stroke | SH2 | 20<=S<50 | <1981 | 1 | 305 | 695 | 0.002 | 0.010 | 7 | 882 |
| 2-stroke | SH2 | 20<=S<50 | 1981-1990 | 1 | 300 | 579 | 0.002 | 0.010 | 5.3 | 809 |
| 2-stroke | SH2 | 20<=S<50 | 1991-Stage I | 1.1 | 203 | 463 | 0.002 | 0.010 | 3.5 | 735 |
| 2-stroke | SH2 | 20<=S<50 | Stage I | 1.5 | 188 | 379 | 0.002 | 0.010 | 3.5 | 720 |
| 2-stroke | SH2 | 20<=S<50 | Stage II | 1.5 | 44 | 379 | 0.002 | 0.010 | 3.5 | 500 |
| 2-stroke | SH3 | S>=50 | <1981 | 1.1 | 189 | 510 | 0.002 | 0.010 | 3.6 | 665 |
| 2-stroke | SH3 | S>=50 | 1981-1990 | 1.1 | 158 | 425 | 0.002 | 0.010 | 2.7 | 609 |
| 2-stroke | SH3 | S>=50 | 1991-Stage I | 1.2 | 126 | 340 | 0.002 | 0.010 | 1.8 | 554 |
| 2-stroke | SH3 | S>=50 | Stage I | 2 | 126 | 340 | 0.002 | 0.010 | 1.8 | 529 |
| 2-stroke | SH3 | S>=50 | Stage II | 1.2 | 64 | 340 | 0.002 | 0.010 | 1.8 | 500 |
| 2-stroke | SN1 | S<66 | <1981 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN1 | S<66 | 1981-1990 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN1 | S<66 | 1991-Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN1 | S<66 | Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN1 | S<66 | Stage II | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN2 | 66<=S<100 | <1981 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN2 | 66<=S<100 | 1981-1990 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN2 | 66<=S<100 | 1991-Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN2 | 66<=S<100 | Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN2 | 66<=S<100 | Stage II | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN3 | 100<=S<225 | <1981 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN3 | 100<=S<225 | 1981-1990 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN3 | 100<=S<225 | 1991-Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN3 | 100<=S<225 | Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN3 | 100<=S<225 | Stage II | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN4 | S>=225 | <1981 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN4 | S>=225 | 1981-1990 | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN4 | S>=225 | 1991-Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN4 | S>=225 | Stage I | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |
| 2-stroke | SN4 | S>=225 | Stage II | 0.5 | 155 | 418 | 0.002 | 0.010 | 2.6 | 652 |

Table 4 Fuel consumption and emission factors for gasoline 4 stroke non road engines (g/kWh)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | Size code | Size classe | Emission Level | NOx | VOC | CO | N2O | NH3 | TSP | FC |
| 4-stroke | SH2 | 20<=S<50 | <1981 | 2.4 | 33 | 198 | 0.002 | 0.03 | 0.09 | 496 |
| 4-stroke | SH2 | 20<=S<50 | 1981-1990 | 3.5 | 27.5 | 165 | 0.002 | 0.03 | 0.08 | 474 |
| 4-stroke | SH2 | 20<=S<50 | 1991-Stage I | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 451 |
| 4-stroke | SH2 | 20<=S<50 | Stage I | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 406 |
| 4-stroke | SH2 | 20<=S<50 | Stage II | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 406 |
| 4-stroke | SH3 | S>=50 | <1981 | 2.4 | 33 | 198 | 0.002 | 0.03 | 0.09 | 496 |
| 4-stroke | SH3 | S>=50 | 1981-1990 | 3.5 | 27.5 | 165 | 0.002 | 0.03 | 0.08 | 474 |
| 4-stroke | SH3 | S>=50 | 1991-Stage I | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 451 |
| 4-stroke | SH3 | S>=50 | Stage I | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 406 |
| 4-stroke | SH3 | S>=50 | Stage II | 4.7 | 22 | 132 | 0.002 | 0.03 | 0.06 | 406 |
| 4-stroke | SN1 | S<66 | <1981 | 1.2 | 26.9 | 822 | 0.002 | 0.03 | 0.09 | 603 |
| 4-stroke | SN1 | S<66 | 1981-1990 | 1.8 | 22.5 | 685 | 0.002 | 0.03 | 0.08 | 603 |
| 4-stroke | SN1 | S<66 | 1991-Stage I | 2.4 | 18 | 548 | 0.002 | 0.03 | 0.06 | 603 |
| 4-stroke | SN1 | S<66 | Stage I | 4.3 | 16.1 | 411 | 0.002 | 0.03 | 0.06 | 475 |
| 4-stroke | SN1 | S<66 | Stage II | 4.3 | 16.1 | 411 | 0.002 | 0.03 | 0.06 | 475 |
| 4-stroke | SN2 | 66<=S<100 | <1981 | 2.3 | 10.5 | 822 | 0.002 | 0.03 | 0.09 | 627 |
| 4-stroke | SN2 | 66<=S<100 | 1981-1990 | 3.5 | 8.7 | 685 | 0.002 | 0.03 | 0.08 | 599 |
| 4-stroke | SN2 | 66<=S<100 | 1991-Stage I | 4.7 | 7 | 548 | 0.002 | 0.03 | 0.06 | 570 |
| 4-stroke | SN2 | 66<=S<100 | Stage I | 4.7 | 7 | 467 | 0.002 | 0.03 | 0.06 | 450 |
| 4-stroke | SN2 | 66<=S<100 | Stage II | 4.7 | 7 | 467 | 0.002 | 0.03 | 0.06 | 450 |
| 4-stroke | SN3 | 100<=S<225 | <1981 | 2.6 | 19.1 | 525 | 0.002 | 0.03 | 0.09 | 601 |
| 4-stroke | SN3 | 100<=S<225 | 1981-1990 | 3.8 | 15.9 | 438 | 0.002 | 0.03 | 0.08 | 573 |
| 4-stroke | SN3 | 100<=S<225 | 1991-Stage I | 5.1 | 12.7 | 350 | 0.002 | 0.03 | 0.06 | 546 |
| 4-stroke | SN3 | 100<=S<225 | Stage I | 5.1 | 11.6 | 350 | 0.002 | 0.03 | 0.06 | 546 |
| 4-stroke | SN3 | 100<=S<225 | Stage II | 5.1 | 9.4 | 350 | 0.002 | 0.03 | 0.06 | 546 |
| 4-stroke | SN4 | S>=225 | <1981 | 1.3 | 11.1 | 657 | 0.002 | 0.03 | 0.09 | 539 |
| 4-stroke | SN4 | S>=225 | 1981-1990 | 2 | 9.3 | 548 | 0.002 | 0.03 | 0.08 | 514 |
| 4-stroke | SN4 | S>=225 | 1991-Stage I | 2.6 | 7.4 | 438 | 0.002 | 0.03 | 0.06 | 490 |
| 4-stroke | SN4 | S>=225 | Stage I | 2.6 | 7.4 | 438 | 0.002 | 0.03 | 0.06 | 490 |
| 4-stroke | SN4 | S>=225 | Stage II | 2.6 | 7.4 | 438 | 0.002 | 0.03 | 0.06 | 490 |

**LPG**

For LPG, the fuel use factor and the emission factors of CO, VOC and NOx are taken from IFEU (2004), based on measurements from Miersch (1999). The TSP emission factor comes from TNO CEPMEIP (2001), whereas the CH4 percentage share of total VOC of 5 % is taken from USEPA (2004). Due to lack of data, no distinction is made between technology levels.

Table 5 Fuel consumption and emission factors for LPG non road engines (g/kWh)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NOx | VOC | CO | NH3 | N2O | TSP | FC |
| 19 | 2.2 | 1.5 | 0.003 | 0.05 | 0.07 | 311 |

**2.2 Deterioration adjustment factors**

The adjustment factors due to engine wear provided by IFEU (2004) are shown in the Tables 6-8, for diesel engines and gasoline 2-stroke and 4-stroke engines, respectively. The values express for each emission level the maximum emission increase ratio corresponding with the average engine life time period for any specific type of equipment. For engines younger than average engine life time a linear interpolation is made between zero and the maximum adjustment factor. For engines older than average engine life time the maximum adjustment factor is used.

As an example from Table 6, the TSP emissions from a diesel engine becomes 47.3 % higher as the engine age reach average life time compared to the emissions from the engine as new. Reversely the NOx emissions from 2-stroke SN1 engines decrease by 60 % compared to new engines when average engine life time is reached (Table 7).

Table 6 Deterioration adjustment factors for diesel machinery relative to average engine life time

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Emission Level | NOx | VOC | CO | TSP |
| Before Stage I | 0.024 | 0.047 | 0.185 | 0.473 |
| Stage I | 0.024 | 0.036 | 0.101 | 0.473 |
| Stage II | 0.009 | 0.034 | 0.101 | 0.473 |
| Stage IIIA, IIIB, IV | 0.008 | 0.027 | 0.151 | 0.473 |

Table 7 Deterioration adjustment factors for gasoline 2-stroke engines relative to average engine life time

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | Size code | Size classe | Emission Level | NOx | VOC | CO | TSP |
| 2-stroke | SH1 | S<20 | <1981 | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH1 | S<20 | 1981-1990 | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH1 | S<20 | 1991-Stage I | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH1 | S<20 | Stage I | 0 | 0.24 | 0.24 | 0 |
| 2-stroke | SH1 | S<20 | Stage II | 0 | 0.24 | 0.24 | 0 |
| 2-stroke | SH2 | 20<=S<50 | <1981 | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH2 | 20<=S<50 | 1981-1990 | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH2 | 20<=S<50 | 1991-Stage I | 0 | 0.2 | 0.2 | 0 |
| 2-stroke | SH2 | 20<=S<50 | Stage I | 0 | 0.29 | 0.24 | 0 |
| 2-stroke | SH2 | 20<=S<50 | Stage II | 0 | 0.29 | 0.24 | 0 |
| 2-stroke | SH3 | S>=50 | <1981 | -0.031 | 0.2 | 0.2 | 0 |
| 2-stroke | SH3 | S>=50 | 1981-1990 | -0.031 | 0.2 | 0.2 | 0 |
| 2-stroke | SH3 | S>=50 | 1991-Stage I | -0.031 | 0.2 | 0.2 | 0 |
| 2-stroke | SH3 | S>=50 | Stage I | 0 | 0.266 | 0.231 | 0 |
| 2-stroke | SH3 | S>=50 | Stage II | 0 | 0.266 | 0.231 | 0 |
| 2-stroke | SN1 | S<66 | <1981 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN1 | S<66 | 1981-1990 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN1 | S<66 | 1991-Stage I | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN1 | S<66 | Stage I | -0.33 | 0.266 | 1.109 | 5.103 |
| 2-stroke | SN1 | S<66 | Stage II | -0.33 | 0 | 1.109 | 5.103 |
| 2-stroke | SN2 | 66<=S<100 | <1981 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN2 | 66<=S<100 | 1981-1990 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN2 | 66<=S<100 | 1991-Stage I | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN2 | 66<=S<100 | Stage I | -0.33 | 0.266 | 1.109 | 5.103 |
| 2-stroke | SN2 | 66<=S<100 | Stage II | -0.33 | 0 | 1.109 | 5.103 |
| 2-stroke | SN3 | 100<=S<225 | <1981 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN3 | 100<=S<225 | 1981-1990 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN3 | 100<=S<225 | 1991-Stage I | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN3 | 100<=S<225 | Stage I | -0.33 | 0.266 | 1.109 | 5.103 |
| 2-stroke | SN3 | 100<=S<225 | Stage II | -0.33 | 0 | 1.109 | 5.103 |
| 2-stroke | SN4 | S>=225 | <1981 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN4 | S>=225 | 1981-1990 | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN4 | S>=225 | 1991-Stage I | -0.6 | 0.201 | 0.9 | 1.1 |
| 2-stroke | SN4 | S>=225 | Stage I | -0.274 | 0 | 0.887 | 1.935 |
| 2-stroke | SN4 | S>=225 | Stage II | -0.274 | 0 | 0.887 | 1.935 |

Table 8 Deterioration adjustment factors for gasoline 4-stroke engines relative to average engine life time

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | Size code | Size classe | Emission Level | NOx | VOC | CO | TSP |
| 4-stroke | SN1 | S<66 | <1981 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN1 | S<66 | 1981-1990 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN1 | S<66 | 1991-Stage I | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN1 | S<66 | Stage I | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN1 | S<66 | Stage II | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN2 | 66<=S<100 | <1981 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN2 | 66<=S<100 | 1981-1990 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN2 | 66<=S<100 | 1991-Stage I | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN2 | 66<=S<100 | Stage I | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN2 | 66<=S<100 | Stage II | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN3 | 100<=S<225 | <1981 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN3 | 100<=S<225 | 1981-1990 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN3 | 100<=S<225 | 1991-Stage I | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN3 | 100<=S<225 | Stage I | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN3 | 100<=S<225 | Stage II | -0.3 | 1.753 | 1.051 | 1.753 |
| 4-stroke | SN4 | S>=225 | <1981 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN4 | S>=225 | 1981-1990 | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN4 | S>=225 | 1991-Stage I | -0.6 | 1.1 | 0.9 | 1.1 |
| 4-stroke | SN4 | S>=225 | Stage I | -0.599 | 1.095 | 1.307 | 1.095 |
| 4-stroke | SN4 | S>=225 | Stage II | -0.599 | 1.095 | 1.307 | 1.095 |
| 4-stroke | SH1 | S<20 | <1981 | 0 | 0 | 0 | 0 |
| 4-stroke | SH1 | S<20 | 1981-1990 | 0 | 0 | 0 | 0 |
| 4-stroke | SH1 | S<20 | 1991-Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH1 | S<20 | Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH1 | S<20 | Stage II | 0 | 0 | 0 | 0 |
| 4-stroke | SH2 | 20<=S<50 | <1981 | 0 | 0 | 0 | 0 |
| 4-stroke | SH2 | 20<=S<50 | 1981-1990 | 0 | 0 | 0 | 0 |
| 4-stroke | SH2 | 20<=S<50 | 1991-Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH2 | 20<=S<50 | Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH2 | 20<=S<50 | Stage II | 0 | 0 | 0 | 0 |
| 4-stroke | SH3 | S>=50 | <1981 | 0 | 0 | 0 | 0 |
| 4-stroke | SH3 | S>=50 | 1981-1990 | 0 | 0 | 0 | 0 |
| 4-stroke | SH3 | S>=50 | 1991-Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH3 | S>=50 | Stage I | 0 | 0 | 0 | 0 |
| 4-stroke | SH3 | S>=50 | Stage II | 0 | 0 | 0 | 0 |

The deterioration factor for a given machinery type at a given time depends on the engine-size class (only for gasoline), the emission level and the average engine life time. For diesel and gasoline 2-stroke engines the deterioration factor is generally expressed as

 (18)

where DF = deterioration factor, K = engine age (between 0 and average life time), LT = average lifetime, y = engine-size class and z = emission level.

For gasoline 4-stroke engines the deterioration factor is calculated as:

 (19)

No deterioration is assumed for fuel consumption (all fuel types) or for LPG engine emissions and, hence, DF = 1 in these situations.

**2.3 Transient adjustment factors**

The adjustment factors due to transient engine operations are provided by IFEU (2014) based on measurements for high and low engine loads from USEPA (2010) and supplementary emission information from TU Graz.

Table 9 Transient operation adjustment factors for diesel engines

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Emission Level | Load | Load factor | NOx | VOC | CO | TSP | FC |
| Stage II and prior | High | >0.45 | 0.95 | 1.05 | 1.53 | 1.23 | 1.01 |
| Stage IIIA | High | >0.45 | 1.04 | 1.05 | 1.53 | 1.47 | 1.01 |
| Stage IIIB-IV | High | >0.45 | 1 | 1 | 1 | 1 | 1 |
| Stage II and prior | Middle | 0.25≤LF≤0.45 | 1.025 | 1.67 | 2.05 | 1.6 | 1.095 |
| Stage IIIA | Middle | 0.25≤ LF≤0.45 | 1.125 | 1.67 | 2.05 | 1.92 | 1.095 |
| Stage IIIB-IV | Middle | 0.25≤ LF≤0.45 | 1 | 1 | 1 | 1 | 1 |
| Stage II and prior | Low | <0.25 | 1.1 | 2.29 | 2.57 | 1.97 | 1.18 |
| Stage IIIA | Low | <0.25 | 1.21 | 2.29 | 2.57 | 2.37 | 1.18 |
| Stage IIIB-IV | Low | <0.25 | 1 | 1 | 1 | 1 | 1 |

**2.4 Tier 3 emission calculation**

By using the country specific fleet and activity data, number of engines, engine size, load factors and annual hours of operation, for each machinery type, together with stratified basis emission factors (Section 2.1), deterioration factors (Section 2.2) and transient adjustment factors (Section 2.3), the emissions are calculated as:



Where N = number of engines, P = engine size (kW), HRS = annual working hours, EFBasis = Basis fuel consumption/emission factors, TF = transient emission adjustment factor, DF = deterioration adjustment factor.

**2.5 Recreational craft**

For recreational craft, the emission factors for the conventional technology levels are estimated by IFEU (2004). For newer engines complying with the EU Directive 2003/44 emission limits, the emission factors for CO, VOC, NOx and TSP are estimated as 80 % of the relevant emission legislation value. If the estimated emission factor exceeds the conventional emission factor, the latter value is used.

The EU Directive 2003/44 comprises the emission legislation limits for diesel engines, and for 2-stroke and 4-stroke gasoline engines, respectively. The CO and VOC emission limits depend on engine size (kW) and the inserted parameters presented in the Directive 2003/44 calculation formulas shown in Table 10. For NOx, a constant limit value is given for each of the three engine types. For TSP, the constant emission limit regards diesel engines only.

Table 10 EU Directive 2003/44 emission limits for recreational craft (g/kWh).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Engine type | Impl. date | CO=A+B/Pn | HC=A+B/Pn | NOx | TSP |
|  |  | A | B | n | A | B | n |  |  |
| 2-stroke gasoline | 1/1 2007 | 150.0 | 600.0 | 1.0 | 30.0 | 100.0 | 0.75 | 10.0 | - |
| 4-stroke gasoline | 1/1 2006 | 150.0 | 600.0 | 1.0 | 6.0 | 50.0 | 0.75 | 15.0 | - |
| Diesel | 1/1 2006 | 5.0 | 0.0 | 0 | 1.5 | 2.0 | 0.5 | 9.8 | 1.0 |

Table 11 shows the technology specific fuel consumption and emission factors for recreational craft for appropriate engine size categories used in the TREMOD NRMM model.

Table 11 Emission factors for conventional and 2003/44 directive engines used by pleasure craft

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | VOC | CO | NOx | TSP | Fuel |
| 2-Stroke outboard engines (conventional) |  |
| 0 - 3 kW | 341 | 532 | 4 | 10 | 791 |
| 3 - 12 kW | 257 | 427 | 2 | 10 | 791 |
| > 12 kW | 172 | 374 | 3 | 10 | 791 |
| 2-Stroke outboard engines (Directive 2003/44) |   |
| 0 - 3 kW | 83 | 440 | 4 | 10 | 791 |
| 3 - 12 kW | 42 | 184 | 2 | 10 | 791 |
| > 12 kW | 30 | 134 | 3 | 10 | 791 |
| 4-Stroke outboard engines (conventional) |   |
| 0 - 3 kW | 121 | 585 | 5 | 0.08 | 426 |
| 3 - 12 kW | 24 | 520 | 7 | 0.08 | 426 |
| > 12 kW | 14 | 390 | 10 | 0.08 | 426 |
| 4-Stroke outboard engines (Directive 2003/44) |   |
| 0 - 3 kW | 34 | 440 | 5 | 0.08 | 426 |
| 3 - 12 kW | 14 | 184 | 7 | 0.08 | 426 |
| > 12 kW | 8 | 134 | 10 | 0.08 | 426 |
| 4-Stroke inboard engines (conventional) |   |
| 75 - 130 kW | 10 | 346 | 12 | 0.08 | 426 |
| 4-Stroke inboard engines (Directive 2003/44) |   |
| 75 - 130 kW | 6 | 125 | 12 | 0.08 | 426 |
| Diesel inboard engines (conventional) |   |
| < 15 kW | 3.8 | 6 | 11.5 | 2.3 | 285 |
| 15 - 50 kW | 2.2 | 5.5 | 18 | 1.4 | 281 |
| > 50 kW | 2 | 5.3 | 8.6 | 1.2 | 275 |
| Diesel inboard engines (Directive 2003/44) |   |
| < 15 kW | 1.7 | 4 | 7.8 | 0.8 | 285 |
| 15 - 50 kW | 1.5 | 4 | 7.8 | 0.8 | 281 |
| > 50 kW | 1.3 | 4 | 7.8 | 0.8 | 275 |

**3. Updated Tier 1 and 2 emission factors and Tier 2 fuel split information**

As explained in the introduction updated Tier 1 and 2 fuel related emission factors and Tier 2 fuel split information are calculated, based on the detailed Tier 3 fuel consumption and emission factors from the German TREMOD NRMM model and the country specific non road fleet and activity data from the Danish emission inventories. Updated Tier 1 and Tier 2 emission factors are provided for VOC (NMVOC and CH4), CO, NOx ,TSP, N2O and NH3 as well as fuel split percentage values on a Tier 2 level according to engine technologies.

Specifically for diesel engines, the emission factor updates for N2O and NH3 is solely due to the the updated fuel consumption factors in g/kWh used in combination with fleet activity data to derive the fuel related emission factors.

For diesel machinery in general, data are added for the new Stage IIIB and IV engine emission technology stages which have entered into the fleet between 2011-2013 and 2014-2015, respectively, depending on engine size. Updates of the existing Guidebook emission factors are made primarily based on updated data for the Stage IIIA technologies and updated values for the transient factors used for the engine technologies up to Stage IIIA.

For NMVOC and CH4 all emission factors for diesel and gasoline fuelled engines are updated based on the NMVOC-CH4 split of total VOC used in the TREMOD model.

For gasoline and LPG fuelled engines no further updates are made of the existing emission factors.

The final Tier 1 (Guidebook Table 3-1) and Tier 2 (Guidebook Table 3-2) fuel related emission factors for diesel fuelled engines in agriculture, forestry and industry, as well as gasoline 2-stroke and 4-stroke engines (used across non road sectors) are available from the attached spreadsheet.

The attached spreadsheet also contains the updated Tier 2 fuel split percentages per engine age/engine technology for the above mentioned diesel and gasoline engine categories (Guidebook Tables 3-5 to 3-9). The associated fuel split percentages per engine age (Guidebook Tables 3-3 and 3-4) are not updated in this work due to lack of more precise fuel split information.

**6. References**

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**Appendix 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Stage/engine**  | **CO** | **VOC** | **NOx** | **VOC+NOx** | **PM** | **Diesel machinery** | **Tractors** |
| **size [kW]** |  |  |  |  |  |  | **Implement. date** | **EU** | **Implement.** |
|  | **[g/kWh]** | **EU Directive** | **Transient** | **Constant** | **Directive** | **date** |
| Stage I  |  |  |  |  |  |  |  |  |  |  |
| 37<=P< 75 | 6.5 | 1.3 | 9.2 | - | 0.85 | 97/68 | 1/4 1999 | - | 2000/25 | 1/7 2001 |
|  |  |  |  |  |  |  |  |  |  |  |
| Stage II |  |  |  |  |  |  |  |  |  |  |
| 130<=P< 560 | 3.5 | 1 | 6 | - | 0.2 | 97/68 | 1/1 2002 | 1/1 2007 | 2000/25 | 1/7 2002 |
| 75<=P< 130 | 5 | 1 | 6 | - | 0.3 |  | 1/1 2003 | 1/1 2007 |  | 1/7 2003 |
| 37<=P< 75 | 5 | 1.3 | 7 | - | 0.4 |  | 1/1 2004 | 1/1 2007 |  | 1/1 2004 |
| 18<=P< 37 | 5.5 | 1.5 | 8 | - | 0.8 |  | 1/1 2001 | 1/1 2007 |  | 1/1 2002 |
|  |  |  |  |  |  |  |  |  |  |  |
| Stage IIIA |  |  |  |  |  |  |  |  |  |  |
| 130<=P< 560 | 3.5 | - | - | 4 | 0.2 | 2004/26 | 1/1 2006 | 1/1 2011 | 2005/13 | 1/1 2006 |
| 75<=P< 130 | 5 | - | - | 4 | 0.3 |  | 1/1 2007 | 1/1 2011 |  | 1/1 2007 |
| 37<=P< 75 | 5 | - | - | 4.7 | 0.4 |  | 1/1 2008 | 1/1 2012 |  | 1/1 2008 |
| 19<=P< 37 | 5.5 | - | - | 7.5 | 0.6 |  | 1/1 2007 | 1/1 2011 |  | 1/1 2007 |
|  |  |  |  |  |  |  |  |  |  |  |
| Stage IIIB |  |  |  |  |  |  |  |  |  |  |
| 130<=P< 560 | 3.5 | 0.19 | 2 | - | 0.025 | 2004/26 | 1/1 2011 | - | 2005/13 | 1/1 2011 |
| 75<=P< 130 | 5 | 0.19 | 3.3 | - | 0.025 |  | 1/1 2012 | - |  | 1/1 2012 |
| 56<=P< 75 | 5 | 0.19 | 3.3 | - | 0.025 |  | 1/1 2012 | - |  | 1/1 2012 |
| 37<=P< 56 | 5 | - | - | 4.7 | 0.025 |  | 1/1 2013 | - |  | 1/1 2013 |
|  |  |  |  |  |  |  |  |  |  |  |
| Stage IV |  |  |  |  |  |  |  |  |  |  |
| 130<=P< 560 | 3.5 | 0.19 | 0.4 | - | 0.025 | 2004/26 | 1/1 2014 |  | 2005/13 | 1/1 2014 |
| 56<=P< 130 | 5 | 0.19 | 0.4 | - | 0.025 |  | 1/10 2014 |  |  | 1/10 2014 |

**Appendix 2**

Table 2.1: Country specific NRMM fleet and activity data used for Tier 3 (Denmark)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fuel type | Sector | EquipmentName (Eng) | Size (kW) | Size (S) | Engine | LoadFactor | Hours | Lifetime |
| Diesel | Agriculture | Tractors | 37-306 |  |  | 0,5 | 100-500 | 30 |
| Diesel | Agriculture | Harvesters | 50-310 |  |  | 0,8 | 50-200 | 25 |
| Diesel | Agriculture | Tractors (machine pools) | 37-306 |  |  | 0,5 | 750 | 7 |
| Diesel | Agriculture | Harvesters (machine pools) | 50-310 |  |  | 0,8 | 100 | 11 |
| Diesel | Agriculture | Self-propelled vehicles (machine pools) | 260 |  |  | 0,75 | 500 | 6 |
| Diesel | Agriculture | Self-propelled vehicles | 60 |  |  | 0,75 | 150 | 15 |
| Gasoline | Agriculture | ATV professional | 15 | 450 | 4-stroke | 0,5 | 400 | 8 |
| Gasoline | Agriculture | ATV private | 6 | 150 | 4-stroke | 0,5 | 200 | 4 |
| Gasoline | Agriculture | Sweepers | 3 | 110 | 4-stroke | 0,3 | 50 | 10 |
| Gasoline | Agriculture | Bedding machines | 3 | 120 | 4-stroke | 0,3 | 50 | 10 |
| Gasoline | Agriculture | Fodder trucks | 8 | 310 | 4-stroke | 0,4 | 200 | 10 |
| Gasoline | Agriculture | Scrapers | 3 | 110 | 4-stroke | 0,3 | 50 | 10 |
| Gasoline | Agriculture | Other (gasoline) | 5 | 191 | 4-stroke | 0,4 | 50 | 10 |
| Diesel | Forestry | Harvesters (forestry) | 60 |  |  | 0,5 | 1200 | 8 |
| Diesel | Forestry | Harvesters (forestry) | 100 |  |  | 0,5 | 1200 | 8 |
| Diesel | Forestry | Chippers | 105-175 |  |  | 0,5 | 1200 | 6 |
| Diesel | Forestry | Forwarders | 60-100 |  |  | 0,5 | 1200 | 8 |
| Diesel | Forestry | Tractors (silvicultural) | 105-175 |  |  | 0,5 | 800 | 6 |
| Diesel | Forestry | Tractors (other) | 45-75 |  |  | 0,5 | 100-400 | 15 |
| Diesel | Forestry | Chippers | 35 |  |  | 0,5 | 250 | 10 |
| Gasoline | Forestry | Chain saws (forestry) | 5 | 90 | 2-stroke | 0,4 | 800 | 3 |
| Diesel | Industry | Fork lifts 0-2 tons (diesel) | 35-120 |  |  | 0,27 | 650-1200 | 20 |
| Diesel | Industry | Track type dozers | 140 |  |  | 0,5 | 1100 | 10 |
| Diesel | Industry | Track type loaders | 100-150 |  |  | 0,5 | 1100 | 10 |
| Diesel | Industry | Wheel loaders (0-5 tons) | 20 |  |  | 0,5 | 1200 | 10 |
| Diesel | Industry | Wheel loaders (> 5,1 tons) | 120 |  |  | 0,5 | 1200 | 10 |
| Diesel | Industry | Wheel type excavators | 100 |  |  | 0,6 | 1200 | 10 |
| Diesel | Industry | Track type excavators (0-5 tons) | 20 |  |  | 0,6 | 1100 | 10 |
| Diesel | Industry | Track type excavators (>5,1 tons) | 120 |  |  | 0,6 | 1100 | 10 |
| Diesel | Industry | Excavators/Loaders | 50 |  |  | 0,45 | 700 | 10 |
| Diesel | Industry | Dump trucks | 60-180 |  |  | 0,4 | 900-1200 | 10 |
| Diesel | Industry | Mini loaders | 30 |  |  | 0,5 | 700 | 14 |
| Diesel | Industry | Telescopic loaders | 35 |  |  | 0,5 | 1000 | 14 |
| Diesel | Industry | Vibratory plates | 6 |  |  | 0,6 | 300 | 10 |
| Diesel | Industry | Refrigerating units (distribution) | 8 |  |  | 0,5 | 1250 | 6 |
| Diesel | Industry | Refrigerating units (long distance) | 15 |  |  | 0,5 | 200 | 7 |
| Diesel | Industry | Tampers/Land rollers | 30 |  |  | 0,45 | 600 | 14 |
| Diesel | Industry | Aereal lifts (diesel) | 30 |  |  | 0,4 | 400 | 10 |
| Diesel | Industry | Sweepers (diesel) | 30 |  |  | 0,4 | 300 | 10 |
| Diesel | Industry | High pressure cleaners (diesel) | 30 |  |  | 0,8 | 500 | 10 |
| Diesel | Industry | Generators (diesel) | 45 |  |  | 0,5 | 200 | 15 |
| Diesel | Industry | Kompressors (diesel) | 45 |  |  | 0,5 | 500 | 13 |
| Diesel | Industry | Tractors (transport, industry) | 50 |  |  | 0,4 | 500 | 30 |
| Diesel | Industry | Pumps (diesel) | 75 |  |  | 0,5 | 5 | 15 |
| Diesel | Industry | Asphalt pavers | 80 |  |  | 0,35 | 700 | 10 |
| Diesel | Industry | Airport GSE and other (light duty) | 100 |  |  | 0,5 | 400 | 10 |
| Diesel | Industry | Motor graders | 100 |  |  | 0,4 | 700 | 10 |
| Diesel | Industry | Airport GSE and other (medium duty) | 125 |  |  | 0,5 | 300 | 10 |
| Diesel | Industry | Refuse compressors | 160 |  |  | 0,25 | 1300 | 10 |
| Diesel | Industry | Airport GSE and other (Heavy duty) | 175 |  |  | 0,5 | 200 | 10 |
| Gasoline | Industry | Rammers | 2,5 | 90 | 2-stroke | 0,4 | 80 | 10 |
| Gasoline | Industry | Generators (gasoline) | 2,5 | 100 | 4-stroke | 0,4 | 80 | 10 |
| Gasoline | Industry | Drills | 3 | 110 | 2-stroke | 0,4 | 10 | 10 |
| Gasoline | Industry | Vibratory plates (gasoline) | 4 | 170 | 4-stroke | 0,5 | 200 | 10 |
| Gasoline | Industry | Pumps (gasoline) | 4 | 160 | 4-stroke | 0,4 | 300 | 5 |
| Gasoline | Industry | Kompressors (gasoline) | 4 | 151 | 4-stroke | 0,35 | 15 | 8 |
| Gasoline | Industry | Cutters | 4 | 80 | 4-stroke | 0,5 | 50 | 10 |
| Gasoline | Industry | Other (gasoline) | 5 | 191 | 4-stroke | 0,5 | 40 | 10 |
| Gasoline | Industry | High pressure cleaners (gasoline) | 5 | 191 | 4-stroke | 0,6 | 200 | 10 |
| Gasoline | Industry | Sweepers (gasoline) | 10 | 391 | 4-stroke | 0,4 | 150 | 10 |
| Gasoline | Industry | Slicers | 10 | 391 | 2-stroke | 0,7 | 150 | 10 |
| Gasoline | Industry | Aereal lifts (gasoline) | 20 | 500 | 4-stroke | 0,4 | 400 | 10 |
| LPG | Industry | Fork lifts 0-2 tons (LPG) | 33-120 |  | 4-stroke | 0,27 | 650 | 20 |
| Gasoline | Residential | Lawn movers (private) | 2,5-3,5 | 175 | 4-stroke | 0,4 | 15 | 8 |
| Gasoline | Residential | Cultivators (private-large) | 3,7 | 50 | 4-stroke | 0,6 | 1 | 15 |
| Gasoline | Residential | Cultivators (private-small) | 1 | 30 | 4-stroke | 0,6 | 1 | 5 |
| Gasoline | Residential | Chain saws (private) | 2 | 45 | 2-stroke | 0,3 | 5 | 10 |
| Gasoline | Residential | Riders (private) | 11 | 480 | 4-stroke | 0,5 | 25 | 12 |
| Gasoline | Residential | Shrub clearers (private) | 1 | 25 | 2-stroke | 0,6 | 5 | 10 |
| Gasoline | Residential | Hedge cutters (private) | 0,5 | 25 | 2-stroke | 0,5 | 10 | 10 |
| Gasoline | Residential | Trimmers (private) | 0,9 | 25 | 2-stroke | 0,5 | 20 | 10 |
| Gasoline | Residential | Other (gasoline) | 2 | 40 | 2-stroke | 0,5 | 20 | 10 |
| Gasoline | Residential | Garden shredders | 3 | 110 | 2-stroke | 0,7 | 20 | 10 |
| Gasoline | Residential | Wood cutters | 4 | 151 | 4-stroke | 0,5 | 15 | 10 |
| Gasoline | Residential | Suction machines | 4 | 160 | 2-stroke | 0,5 | 80 | 10 |
| Gasoline | Residential | Chippers | 10 | 391 | 2-stroke | 0,7 | 100 | 10 |
| Gasoline | Commercial/institutional | Lawn movers (professional) | 2,5-4,5 | 175 | 4-stroke | 0,4 | 200 | 4 |
| Gasoline | Commercial/institutional | Cultivators (professional) | 9 | 150 | 4-stroke | 0,6 | 360 | 8 |
| Gasoline | Commercial/institutional | Chain saws (professional) | 3 | 60 | 2-stroke | 0,4 | 350 | 3 |
| Gasoline | Commercial/institutional | Riders (professional) | 13 | 500 | 4-stroke | 0,5 | 330 | 5 |
| Gasoline | Commercial/institutional | Shrub clearers (professional) | 2 | 45 | 2-stroke | 0,6 | 200 | 4 |
| Gasoline | Commercial/institutional | Hedge cutters (professional) | 1 | 45 | 2-stroke | 0,5 | 300 | 4 |
| Gasoline | Commercial/institutional | Trimmers (professional) | 0,9 | 25 | 2-stroke | 0,5 | 200 | 4 |

Table 2.2: Country specific fleet and activity data for recreational craft used for Tier 3 (Denmark)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Fuel type** | **Boat type** | **Engine** | **Engine type** | **Size** | **Load** | **Hours** | **Lifetime** |
| Gasoline | Other boats (< 20 ft) | Out-board engine | 2-stroke | 8 | 0,5 | 30 | 10 |
| Gasoline | Yawls and cabin boats | Out-board engine | 2-stroke | 20 | 0,5 | 50 | 10 |
| Gasoline | Sailing boats (< 26 ft) | Out-board engine | 2-stroke | 10 | 0,5 | 5 | 10 |
| Gasoline | Speed boats | Out-board engine | 2-stroke | 25-50 | 0,5 | 50 | 10 |
| Gasoline | Water scooters | Built in | 2-stroke | 45 | 0,5 | 10 | 10 |
| Gasoline | Other boats (< 20 ft) | Out-board engine | 4-stroke | 8 | 0,5 | 30 | 10 |
| Gasoline | Yawls and cabin boats | Out-board engine | 4-stroke | 20 | 0,5 | 50 | 10 |
| Gasoline | Sailing boats (< 26 ft) | Out-board engine | 4-stroke | 10 | 0,5 | 5 | 10 |
| Gasoline | Speed boats | In-board engine | 4-stroke | 90 | 0,5 | 75 | 10 |
| Gasoline | Speed boats | Out-board engine | 4-stroke | 50 | 0,5 | 50 | 10 |
| Gasoline | Water scooters | Built-in | 4-stroke | 45 | 0,5 | 10 | 10 |
| Diesel | Motor boats (27–34 ft) | In-board engine |  | 150 | 0,5 | 150 | 15 |
| Diesel | Motor boats (> 34 ft) | In-board engine |  | 250 | 0,5 | 100 | 15 |
| Diesel | Motor boats (< 27 ft) | In-board engine |  | 40 | 0,5 | 75 | 15 |
| Diesel | Motor sailors | In-board engine |  | 30 | 0,5 | 75 | 15 |
| Diesel | Sailing boats (< 26 ft) | In-board engine |  | 30 | 0,5 | 25 | 15 |

1. Adjustment initially used for PM, and later on for CO and VOC (pers. comm. Christoph Heidt, IFEU (2014)) [↑](#footnote-ref-1)