

# 1.A.3.a ii (i) - Domestic Civil Aviation: LTO

## Short description

In NFR category *1.A.3.a ii (i) - Domestic Civil Aviation: LTO* emissions from domestic flights between German airports occurring during LTO stage (Landing/Take-off: 0-3,000 feet) are reported.

| Category Code | Method          |                 |                 |       |     | AD    |     |     |     |      | EF       |     |     |                  |                   |
|---------------|-----------------|-----------------|-----------------|-------|-----|-------|-----|-----|-----|------|----------|-----|-----|------------------|-------------------|
| 1.A.3.a ii(i) | T1, T2, T3      |                 |                 |       |     | NS, M |     |     |     |      | CS, D, M |     |     |                  |                   |
| Key Category  | SO <sub>2</sub> | NO <sub>x</sub> | NH <sub>3</sub> | NMVOC | CO  | BC    | Pb  | Hg  | Cd  | Diox | PAH      | HCb | TSP | PM <sub>10</sub> | PM <sub>2.5</sub> |
| 1.A.3.a ii(i) | -/-             | -/-             | -/-             | -/-   | -/- | -/-   | -/- | -/- | -/- | -    | -/-      | -   | -/- | -/-              | -/-               |

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

| Methods   |                                 |
|-----------|---------------------------------|
| <b>D</b>  | Default                         |
| <b>RA</b> | Reference Approach              |
| <b>T1</b> | Tier 1 / Simple Methodology *   |
| <b>T2</b> | Tier 2*                         |
| <b>T3</b> | Tier 3 / Detailed Methodology * |
| <b>C</b>  | CORINAIR                        |
| <b>CS</b> | Country Specific                |
| <b>M</b>  | Model                           |

\* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.

| AD - Data Source for Activity Data |                                      |
|------------------------------------|--------------------------------------|
| <b>NS</b>                          | National Statistics                  |
| <b>RS</b>                          | Regional Statistics                  |
| <b>IS</b>                          | International Statistics             |
| <b>PS</b>                          | Plant Specific data                  |
| <b>AS</b>                          | Associations, business organisations |
| <b>Q</b>                           | specific questionnaires, surveys     |
| EF - Emission Factors              |                                      |
| <b>D</b>                           | Default (EMEP Guidebook)             |
| <b>C</b>                           | Confidential                         |
| <b>CS</b>                          | Country Specific                     |
| <b>PS</b>                          | Plant Specific data                  |

In the following, information on sub-category specific AD, (implied) emission factors and emission estimates are provided.

## Methodology

## Activity Data

Specific jet kerosene consumption during LTO-stage is calculated within TREMOD AV as described in the [superordinate chapter](#).

Table 1: Percentual annual fuel consumption during LTO-stage of domestic flights

|                          | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| <b>Jet Kerosene</b>      | 30,2 | 29,4 | 27,9 | 27,6 | 27,5 | 27,3 | 27,3 | 27,3 | 27,6 | 27,7 | 28,0 | 27,9 | 27,7 | 27,7 | 28,1 | 28,3 | 28,4 | 28,1 |
| <b>Aviation Gasoline</b> | 18,9 | 36,0 | 33,6 | 50,2 | 52,1 | 55,4 | 51,6 | 51,2 | 49,9 | 46,7 | 49,1 | 54,0 | 56,8 | 51,4 | 61,8 | 62,0 | 68,0 | 76,0 |

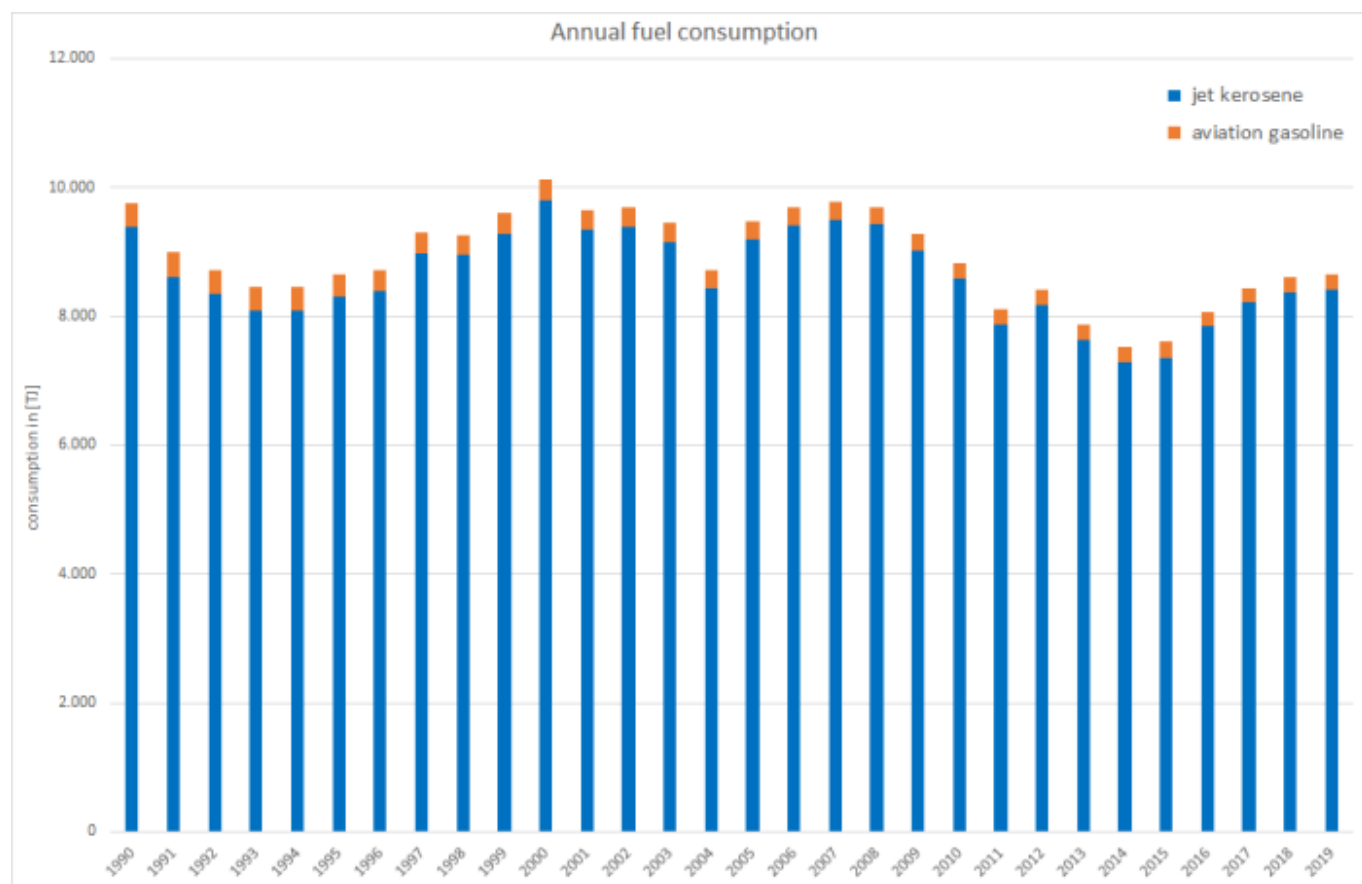
source: Knörr et al. (2020c) <sup>1)</sup> & Gores (2020) <sup>2)</sup>

As explained above, the use of aviation gasoline is - due to a lack of further information - assumed to entirely take place within the LTO-range.

Table 2: annual LTO fuel consumption for domestic flights, in terajoule

|                          | 1990         | 1995         | 2000          | 2005         | 2006         | 2007         | 2008         | 2009         | 2010         | 2011         | 2012         | 2013         | 2014         | 2015         | 2016         | 2017         | 2018         | 2019         |
|--------------------------|--------------|--------------|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>Jet Kerosene</b>      | 9,380        | 8,303        | 9,811         | 9,187        | 9,402        | 9,493        | 9,422        | 9,021        | 8,589        | 7,869        | 8,171        | 7,633        | 7,297        | 7,358        | 7,844        | 8,210        | 8,362        | 8,417        |
| <b>Aviation Gasoline</b> | 368          | 346          | 311           | 293          | 283          | 283          | 276          | 255          | 236          | 248          | 237          | 234          | 237          | 246          | 234          | 232          | 248          | 229          |
| <b>Σ 1.A.3.a ii (i)</b>  | <b>9,748</b> | <b>8,649</b> | <b>10,122</b> | <b>9,481</b> | <b>9,686</b> | <b>9,776</b> | <b>9,698</b> | <b>9,277</b> | <b>8,825</b> | <b>8,117</b> | <b>8,408</b> | <b>7,868</b> | <b>7,534</b> | <b>7,604</b> | <b>8,078</b> | <b>8,442</b> | <b>8,610</b> | <b>8,647</b> |

source: Knörr et al. (2020c) <sup>3)</sup> & Gores (2020) <sup>4)</sup>



## Emission factors

All country-specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 (Knörr, W., Schacht, A., & Gores, S. (2010)) <sup>5)</sup> and have since then been compiled, revised and maintained in TREMOD AV <sup>6)</sup>.

Furthermore, the **newly implemented EF(BC)** have been estimated via f-BCs as provided in the 2019 EMEP/EEA Guidebook <sup>7)</sup>, Chapter 1.A.3.a, 1.A.5.b Aviation, page 49: "Conclusion".

For more details, please see [superordinate chapter](#) on civil aviation.

Table 3: Country-specific emission factors, in kg/TJ

|                          | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| <b>JET KEROSENE</b>      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>NH<sub>3</sub></b>    | 3,98 | 3,95 | 3,95 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 | 3,97 |
| <b>NMVOC</b>             | 28,4 | 28,9 | 30,5 | 32,4 | 33,9 | 34,4 | 34,7 | 33,2 | 32,3 | 31,9 | 32,0 | 34,9 | 37,0 | 36,9 | 36,5 | 38,3 | 39,1 | 43,2 |
| <b>NO<sub>x</sub></b>    | 295  | 324  | 287  | 277  | 276  | 281  | 290  | 300  | 304  | 309  | 312  | 311  | 310  | 312  | 321  | 322  | 316  | 308  |
| <b>SO<sub>x</sub></b>    | 19,7 | 19,5 | 19,5 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 |
| <b>BC<sup>1</sup></b>    | 1,43 | 1,57 | 1,54 | 1,61 | 1,62 | 1,59 | 1,47 | 1,48 | 1,51 | 1,50 | 1,52 | 1,53 | 1,50 | 1,52 | 1,44 | 1,44 | 1,56 | 1,55 |
| <b>PM<sup>2</sup></b>    | 2,99 | 3,28 | 3,21 | 3,36 | 3,38 | 3,32 | 3,06 | 3,07 | 3,14 | 3,13 | 3,17 | 3,18 | 3,12 | 3,17 | 3,01 | 2,99 | 3,25 | 3,22 |
| <b>CO</b>                | 212  | 211  | 275  | 291  | 292  | 286  | 280  | 266  | 260  | 254  | 252  | 260  | 265  | 265  | 252  | 255  | 262  | 276  |
| <b>AVIATION GASOLINE</b> |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>NH<sub>3</sub></b>    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>NMVOC</b>             |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>NO<sub>x</sub></b>    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>SO<sub>x</sub></b>    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>BC<sup>1</sup></b>    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>PM<sup>2</sup></b>    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>TSP<sup>3</sup></b>   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| <b>CO</b>                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

<sup>1</sup> estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in <sup>8)</sup>

<sup>2</sup> EF(PM<sub>2.5</sub>) also applied for PM<sub>10</sub> and TSP (assumption: > 99% of TSP from diesel oil combustion consists of PM<sub>2.5</sub>)

<sup>3</sup> also including TSP from lead: EF(TSP) = 1.6 x EF(Pb) - see road transport



For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

Table 4: Tier1 emission factors for heavy-metal and POP exhaust emissions

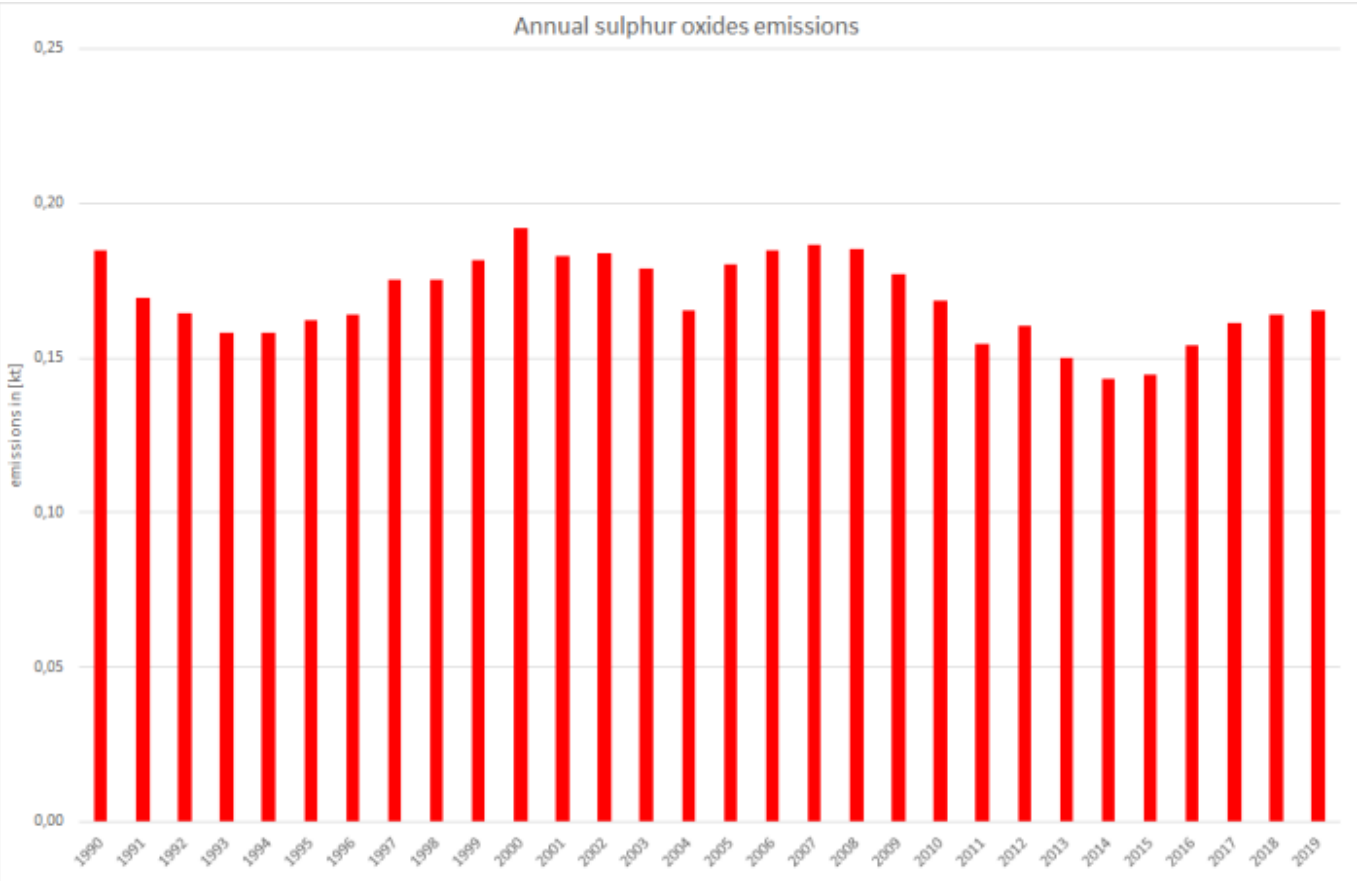
|                          | Pb                 | Cd    | Hg    | As    | Cr    | Cu    | Ni    | Se    | Zn    | B[a]P  | B[b]F | B[k]F | I[...]p | PAH<br>1-4 | PCDD/F |
|--------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|---------|------------|--------|
|                          | [g/T]              |       |       |       |       |       |       |       |       | [mg/T] |       |       |         | [µg/T]     |        |
| <b>Kerosene</b>          | NE                 | NE    | NE    | NE    | NE    | NE    | NE    | NE    | NE    | NE     | NE    | NE    | NE      | NE         | NE     |
| <b>Aviation gasoline</b> | 9,481 <sup>1</sup> | 0.005 | 0.200 | 0.007 | 0.145 | 0.103 | 0.053 | 0.005 | 0.758 | 126    | 182   | 90    | 205     | 602        | NE     |

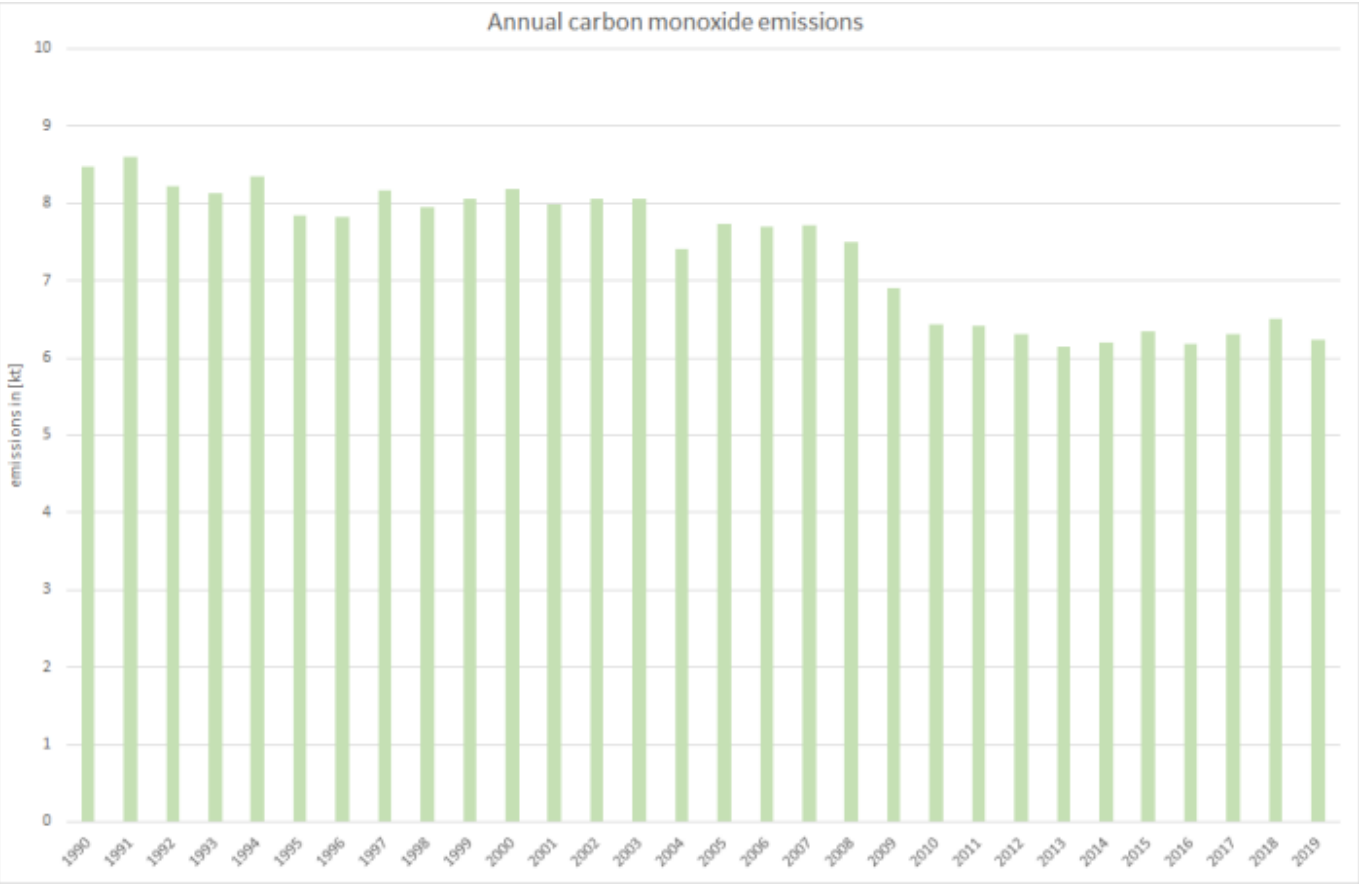
<sup>1</sup> calculated from the average lead content of AvGas 100 LL (low-lead) of 0.56 g Pb/liter

## Trend discussion for Key Sources

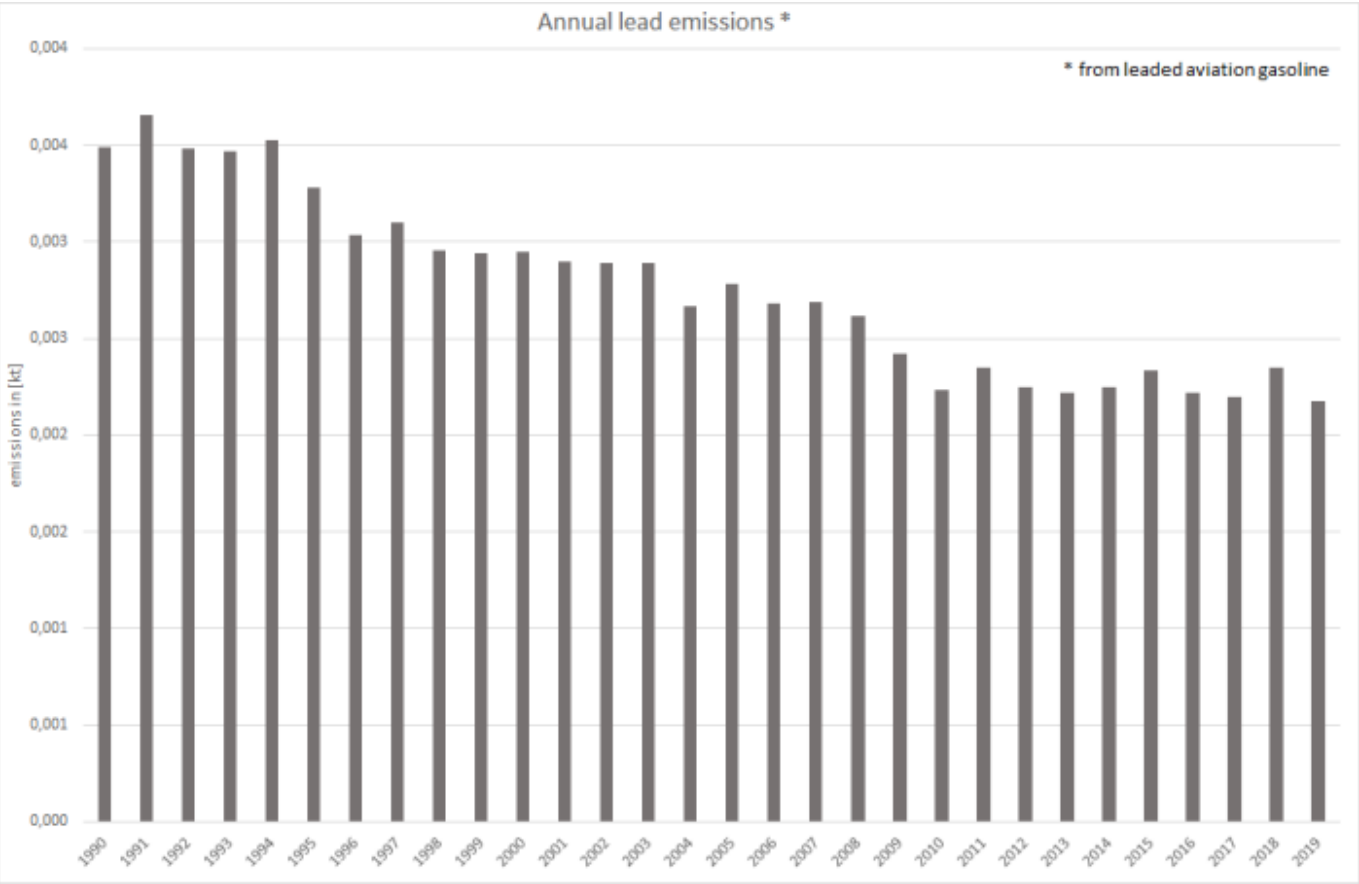
NFR 1.A.3.a ii (i) - Domestic Civil Aviation - LTO is **no key source**.

Where **sulphur oxides** emissions are dominated by jet kerosene due to the amount of fuel used, the majority of **carbon monoxide** stems from the consumption of avgas given the much higher emission factor applied to this fuel.





**Lead** emissions on the other hand, with no emission factor available for jet kerosene, are only calculated for avgas.



## Recalculations

### Activity data

In order to keep in line with the regularly updated data sets provided to the EEA by Eurocontrol, the average fuel use per LTO cycle has been updated again within TREMOD Aviation but with much smaller impact as in last year's submission.

Furthermore, as explained in the superordinate chapter, avgas consumption for international flights and outside the LTO range has been estimated for the first time for this submission, with the respective amounts of avgas re-allocated accordingly.

Resulting from this revision, the percentual shares of kerosene consumed during LTO within TREMOD AV have been recalculated as shown in Table 4.

Table 4: Revised percentual share of kerosene consumed during LTO for domestic flights, in %

|                        | 1990   | 1995   | 2000   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014  | 2015   | 2016   | 2017   | 2018   |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|
| <b>Submission 2021</b> | 30,2   | 29,4   | 27,9   | 27,6   | 27,5   | 27,3   | 27,3   | 27,3   | 27,6   | 27,7   | 28,0   | 27,9   | 27,7  | 27,7   | 28,1   | 28,3   | 28,4   |
| <b>Submission 2020</b> | 30,5   | 29,5   | 28,1   | 27,7   | 27,7   | 27,4   | 27,4   | 27,4   | 27,7   | 27,8   | 28,1   | 28,0   | 27,6  | 27,8   | 28,2   | 28,4   | 28,5   |
| <b>absolute change</b> | -0,29  | -0,10  | -0,13  | -0,11  | -0,11  | -0,11  | -0,10  | -0,11  | -0,11  | -0,13  | -0,13  | -0,13  | 0,07  | -0,12  | -0,10  | -0,10  | -0,11  |
| <b>relative change</b> | -0,94% | -0,33% | -0,45% | -0,39% | -0,40% | -0,42% | -0,37% | -0,40% | -0,41% | -0,45% | -0,45% | -0,48% | 0,24% | -0,43% | -0,37% | -0,35% | -0,40% |

Hence, the amount of kerosene allocated to sub-category 1.A.3.a ii (i) had to be revised accordingly:

Table 5: Revised fuel consumption data, in terajoule

|                               | 1990   | 1995   | 2000   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   |
|-------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b>JET KEROSENE</b>           |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| <b>Submission 2021</b>        | 9.380  | 8.303  | 9.811  | 9.187  | 9.402  | 9.493  | 9.422  | 9.021  | 8.589  | 7.869  | 8.171  | 7.633  | 7.297  | 7.358  | 7.844  | 8.210  | 8.362  |
| <b>Submission 2020</b>        | 8.777  | 8.734  | 8.962  | 8.276  | 8.455  | 8.631  | 8.728  | 8.212  | 8.284  | 8.390  | 8.084  | 7.278  | 7.492  | 7.609  | 7.758  | 7.568  | 7.655  |
| <b>absolute change</b>        | 602    | -431   | 849    | 912    | 948    | 862    | 694    | 810    | 306    | -521   | 87     | 355    | -196   | -251   | 85     | 642    | 707    |
| <b>relative change</b>        | 6,86%  | -4,94% | 9,48%  | 11,02% | 11,21% | 9,99%  | 7,95%  | 9,86%  | 3,69%  | -6,21% | 1,08%  | 4,88%  | -2,61% | -3,29% | 1,10%  | 8,48%  | 9,24%  |
| <b>AVIATION GASOLINE</b>      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| <b>Submission 2021</b>        | 368    | 346    | 311    | 293    | 283    | 283    | 276    | 255    | 236    | 248    | 237    | 234    | 237    | 246    | 234    | 232    | 248    |
| <b>Submission 2020</b>        | 2.438  | 1.142  | 1.120  | 698    | 653    | 611    | 638    | 594    | 568    | 614    | 558    | 496    | 472    | 553    | 407    | 403    | 389    |
| <b>absolute change</b>        | -2.070 | -796   | -809   | -405   | -370   | -328   | -362   | -339   | -332   | -366   | -321   | -262   | -235   | -307   | -173   | -171   | -141   |
| <b>relative change</b>        | -84,9% | -69,7% | -72,2% | -58,0% | -56,6% | -53,6% | -56,8% | -57,0% | -58,5% | -59,6% | -57,5% | -52,8% | -49,7% | -55,5% | -42,5% | -42,4% | -36,3% |
| <b>TOTAL FUEL CONSUMPTION</b> |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| <b>Submission 2021</b>        | 9.748  | 8.649  | 10.122 | 9.481  | 9.686  | 9.776  | 9.698  | 9.277  | 8.825  | 8.117  | 8.408  | 7.868  | 7.534  | 7.604  | 8.078  | 8.442  | 8.610  |
| <b>Submission 2020</b>        | 11.215 | 9.876  | 10.082 | 8.974  | 9.108  | 9.242  | 9.366  | 8.806  | 8.852  | 9.004  | 8.642  | 7.774  | 7.964  | 8.162  | 8.165  | 7.971  | 8.044  |
| <b>absolute change</b>        | -1.467 | -1.227 | 40     | 507    | 578    | 534    | 331    | 471    | -27    | -887   | -234   | 93     | -430   | -557   | -87    | 471    | 566    |
| <b>relative change</b>        | -13,1% | -12,4% | 0,40%  | 5,65%  | 6,34%  | 5,78%  | 3,54%  | 5,35%  | -0,30% | -9,85% | -2,70% | 1,20%  | -5,40% | -6,83% | -1,07% | 5,91%  | 7,03%  |

In parallel, the majority of **country-specific emission factors** has been revised within TREMOD AV



|                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| <b>relative<br/>change</b> |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|

The TSP emissions calculated depend directly on the reported lead emissions: The emission factor for TSP is 1.6 times the emission factor used for lead:  $EF(TSP) = 1.6 \times EF(Pb)$ . The applied procedure is similar to the one used for calculating TSP emissions from leaded gasoline used in road transport.

<sup>1), 3), 6)</sup> Knörr et al. (2020c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOT AV) 2018 - Revision des Modells zur Berechnung des Flugverkehrs (TREMOT-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2020.

<sup>2), 4)</sup> Gores (2020): Inventartool zum deutschen Flugverkehrsinventar 1990-2018, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2020.

<sup>5)</sup> Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOT-AV) : Endbericht. Endbericht zum F+E-Vorhaben 360 16 029, URL: <https://www.umweltbundesamt.de/publikationen/entwicklung-eines-modells-zur-berechnung>; Berlin & Heidelberg, 2012.

<sup>10)</sup> Eurocontrol (2020): Advanced emission model (AEM); <https://www.eurocontrol.int/model/advanced-emission-model>; 2019.