

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

## Short description

In NFR category *1.A.3.a i (i) - International Civil Aviation: LTO* emissions during LTO stage (Landing/Take-off: 0-3,000 feet) are reported. In the following, information on sub-category specific AD, (implied) emission factors and emission estimates are provided.

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

## Methodology

### Activity Data

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

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

|                          | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| <b>Jet Kerosene</b>      | 8,17 | 7,80 | 8,19 | 8,00 | 7,97 | 7,95 | 7,91 | 7,86 | 7,90 | 7,81 | 7,92 | 7,98 | 7,98 | 8,09 | 8,11 | 8,13 | 8,18 | 8,15 |
| <b>Aviation Gasoline</b> | 5,24 | 11,8 | 11,1 | 19,1 | 20,5 | 23,2 | 20,4 | 20,2 | 19,8 | 17,3 | 19,1 | 22,2 | 26,3 | 20,8 | 42,2 | 43,7 | 51,4 | 61,6 |

source: Knörr et al. (2019c) <sup>1)</sup> & Gores (2019) <sup>2)</sup>

Table 2: annual LTO fuel consumption for international 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>      | 13.252 | 16.012 | 21.465 | 24.860 | 26.063 | 26.992 | 27.184 | 26.249 | 26.115 | 24.796 | 27.036 | 27.726 | 26.778 | 27.115 | 29.304 | 32.205 | 33.340 | 32.948 |
| <b>Aviation Gasoline</b> | 25,7   | 21,6   | 21,5   | 21,7   | 22,5   | 23,2   | 21,1   | 19,2   | 19,0   | 14,3   | 14,3   | 13,9   | 14,2   | 15,3   | 11,8   | 12,5   | 12,8   | 10,5   |

source: Knörr et al. (2019c) <sup>3)</sup> & Gores (2019) <sup>4)</sup>

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## 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>.

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

Table 2: Annual 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>             | 59,7   | 36,11  | 25,68  | 22,88  | 22,86  | 22,46  | 22,02  | 21,16  | 21,23  | 20,77  | 20,46  | 20,30  | 19,88  | 20,48  | 20,25  | 20,77  | 21,43  | 20,69  |
| <b>NO<sub>x</sub></b>    | 297    | 306    | 303    | 324    | 325    | 330    | 331    | 338    | 342    | 345    | 346    | 349    | 353    | 352    | 357    | 358    | 355    | 357    |
| <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>    | 1,78   | 1,63   | 1,45   | 1,37   | 1,33   | 1,28   | 1,25   | 1,23   | 1,21   | 1,20   | 1,18   | 1,17   | 1,15   | 1,14   | 1,13   | 1,12   | 1,12   | 1,10   |
| <b>PM<sup>2</sup></b>    | 3,71   | 3,40   | 3,02   | 2,86   | 2,76   | 2,66   | 2,60   | 2,56   | 2,52   | 2,49   | 2,46   | 2,44   | 2,40   | 2,38   | 2,35   | 2,33   | 2,33   | 2,30   |
| <b>CO</b>                | 249    | 227    | 236    | 219    | 217    | 211    | 209    | 203    | 203    | 199    | 199    | 197    | 194    | 196    | 192    | 192    | 195    | 192    |
| <b>AVIATION GASOLINE</b> |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| <b>NH<sub>3</sub></b>    | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     |
| <b>NMVOC</b>             | 459    | 484    | 466    | 469    | 455    | 456    | 460    | 475    | 470    | 521    | 514    | 515    | 521    | 514    | 495    | 494    | 528    | 548    |
| <b>NO<sub>x</sub></b>    | 73,1   | 68,7   | 71,7   | 71,7   | 73,6   | 71,5   | 70,6   | 66,4   | 66,1   | 56,0   | 55,9   | 57,6   | 60,1   | 55,9   | 53,7   | 53,3   | 52,5   | 56,0   |
| <b>SO<sub>x</sub></b>    | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   | 0,46   |
| <b>BC<sup>1</sup></b>    | 9,05   | 9,59   | 9,33   | 9,59   | 9,21   | 9,48   | 9,44   | 10,2   | 10,3   | 11,0   | 11,0   | 10,9   | 10,4   | 11,3   | 11,3   | 11,0   | 11,9   | 11,2   |
| <b>PM<sup>2</sup></b>    | 60,3   | 64,0   | 62,2   | 64,0   | 61,4   | 63,2   | 63,0   | 67,8   | 68,6   | 73,5   | 73,4   | 72,7   | 69,2   | 75,5   | 75,6   | 73,4   | 79,1   | 74,5   |
| <b>TSP<sup>3</sup></b>   | 75,5   | 79,1   | 77,4   | 79,1   | 76,6   | 78,4   | 78,1   | 83,0   | 83,8   | 88,7   | 88,5   | 87,9   | 84,3   | 90,7   | 90,8   | 88,5   | 94,3   | 89,6   |
| <b>CO</b>                | 20.188 | 20.764 | 20.440 | 20.152 | 20.057 | 20.400 | 20.612 | 21.105 | 21.199 | 22.662 | 22.769 | 22.422 | 22.168 | 22.650 | 23.205 | 23.427 | 23.210 | 22.827 |

<sup>1)</sup> estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in <sup>7)</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.

## Discussion of emission trends

NFR 1.A.3.a i (i) - International Civil Aviation - LTO is **no key category**.

## Recalculations

As mentioned in the superordinate chapter on 1.A.3.a, the LTO fuel consumptions applied in TREMOD AV have been adapted



| CARBON MONOXIDE - CO |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| Submission 2021      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Submission 2020      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| absolute change      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| relative change      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



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

## Uncertainties

For uncertainties information, please see [main chapter](#) on civil aviation.

## Planned improvements

For information on planned improvements, please see [main chapter](#) on civil aviation.

## FAQs

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**bibliography** : 1 : 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. : 2 : Knörr et al. (2019c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOT AV) 2019 - 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, 2019. : 3 : Gores (2019): Inventartool zum deutschen Flugverkehrsinventar 1990-2018, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2019. : 4 : EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view>; Copenhagen, 2019. : 5 : Eurocontrol (2019): Advanced emission model (AEM); <https://www.eurocontrol.int/model/advanced-emission-model>; 2019 **bibliography**

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<sup>1)</sup> (bibcite 2)

<sup>2)</sup> (bibcite 3)

<sup>3)</sup> (bibcite 2)

<sup>4)</sup> (bibcite 3)

<sup>5)</sup> (bibcite 1)

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<sup>7)</sup> (bibcite 4)

<sup>8)</sup> (bibcite 4)

<sup>9)</sup> (bibcite 5)