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 occuring 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_2**	**NO_x**	**NH_3**	**NMVOC**	**CO**	**BC**	**Pb**	**Hg**	**Cd**	**Diox**	**PAH**	**HCB**	**TSP**	**PM_{10}**	**$PM_{2.5}$**
1.A.3.a ii(i)	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-	-/-	-/-	-/-

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

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

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

Methodology

Actitvity 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
Jet Kerosene	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
Aviation Gasoline	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. (2019c) [1)] &: Gores (2019) [2)]

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
Jet Kerosene	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
Aviation Gasoline	368	346	311	293	283	283	276	255	236	248	237	234	237	246	234	232	248	229
Σ 1.A.3.a ii (i)	**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**	**8,647**

source: Knörr et al. (2019c) [3)] &: Gores (2019) [4)]

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)) [5)] and have since then been compiled, revised and maintained in TREMOD AV [6)].

Furthermore, the **newly implemented EF(BC)** have been estimated via f-BCs as provided in the 2019 EMEP/EEA Guidebook [7)], 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
JET KEROSENE																		
NH_3	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
NMVOC	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
NO_x	295	324	287	277	276	281	290	300	304	309	312	311	310	312	321	322	316	308
SO_x	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
BC[1]	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

PM[2]	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
CO	212	211	275	291	292	286	280	266	260	254	252	260	265	265	252	255	262	276
AVIATION GASOLINE																		
NH_3																		
NMVOC																		
NO_x																		
SO_x																		
BC[1]																		
PM[2]																		
TSP[3]																		
CO																		

[1] estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in [8)]
[2] EF(PM,,2.5,,) also applied for PM,,10,, and TSP (assumption: > 99% of TSP from diesel oil combustion consists of PM,,2.5,,)
[3] 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 1-4**	= **PCDD/F**			
=									= [g/TJ]					= [mg/TJ]	= [µg/TJ]			
~ Kerosene	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE	= NE			
~ Aviation gasoline	> 9,481	**1**		> 0.005	> 0.200	> 0.007	> 0.145	> 0.103	> 0.053	> 0.005	> 0.758	> 126	> 182	> 90	> 205	> 602	= NE	
1																		

> 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.

gallery size="medium" : 1A3aii(i)_SOx.png : 1A3aii(i)_CO.png gallery

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

gallery size="medium" : 1A3aii(i)_Pb.png gallery

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 L/TO 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 L/TO for domestic flights, in %

	1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Submission 2021	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
Submission 2020	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
absolute change	-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
relative change	-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**
JET KEROSENE																	
Submission 2021	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
Submission 2020	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
absolute change	602	-431	849	912	948	862	694	810	306	-521	87	355	-196	-251	85	642	707
relative change	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%
AVIATION GASOLINE																	
Submission 2021	368	346	311	293	283	283	276	255	236	248	237	234	237	246	234	232	248
Submission 2020	2.438	1.142	1.120	698	653	611	638	594	568	614	558	496	472	553	407	403	389
absolute change	-2.070	-796	-809	-405	-370	-328	-362	-339	-332	-366	-321	-262	-235	-307	-173	-171	-141
relative change	-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%
TOTAL FUEL CONSUMPTION																	
Submission 2021	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
Submission 2020	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
absolute change	-1.467	-1.227	40	507	578	534	331	471	-27	-887	-234	93	-430	-557	-87	471	566
relative change	-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 based on information available from the 2019 EMEP/EEA Guidebook [9)] and Eurocontrol's AEM model [10)]. Here, among others, the EF for SO,,2,, from jet kerosene has been replaced by new and more reliable data showing no sulphur reduction since 1990.

Furthermore, all EF applied for aviation gasoline have been revised widely based on better knowlegde but with no significant impact on the emission inventory.

Table 6: Revised country-specific emission factors for jet kerosene, in [kg/TJ]

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NON-METHANE VOLATILE ORGANIC COMPUNDS - NMVOC																	
Submission 2021																	
Submission 2020																	
absolute change																	
relative change																	
NITROGEN OXIDES																	
Submission 2021																	
Submission 2020																	
absolute change																	
relative change																	
SULPHUR OXIDES																	
Submission 2021																	
Submission 2020																	
absolute change																	
relative change																	
BLACK CARBON - BC																	
Submission 2021																	
Submission 2020																	
absolute change																	
relative change																	
PARTICULATE MATTER - PM																	
Submission 2021																	
Submission 2020																	
absolute change																	
relative change																	
CARBON MONOXIDE - CO																	
Submission 2021																	
Submission 2020																	
absolute change																	

relative change																	

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 x EF(Pb). The applied procedure is similar to the one used for calculating TSP emissions from leaded gasoline used in road transport.

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bibliography : 1 : Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOD-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 (TREMOD AV) 2018 - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-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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