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

Short description

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

Methodology

Actitvity 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

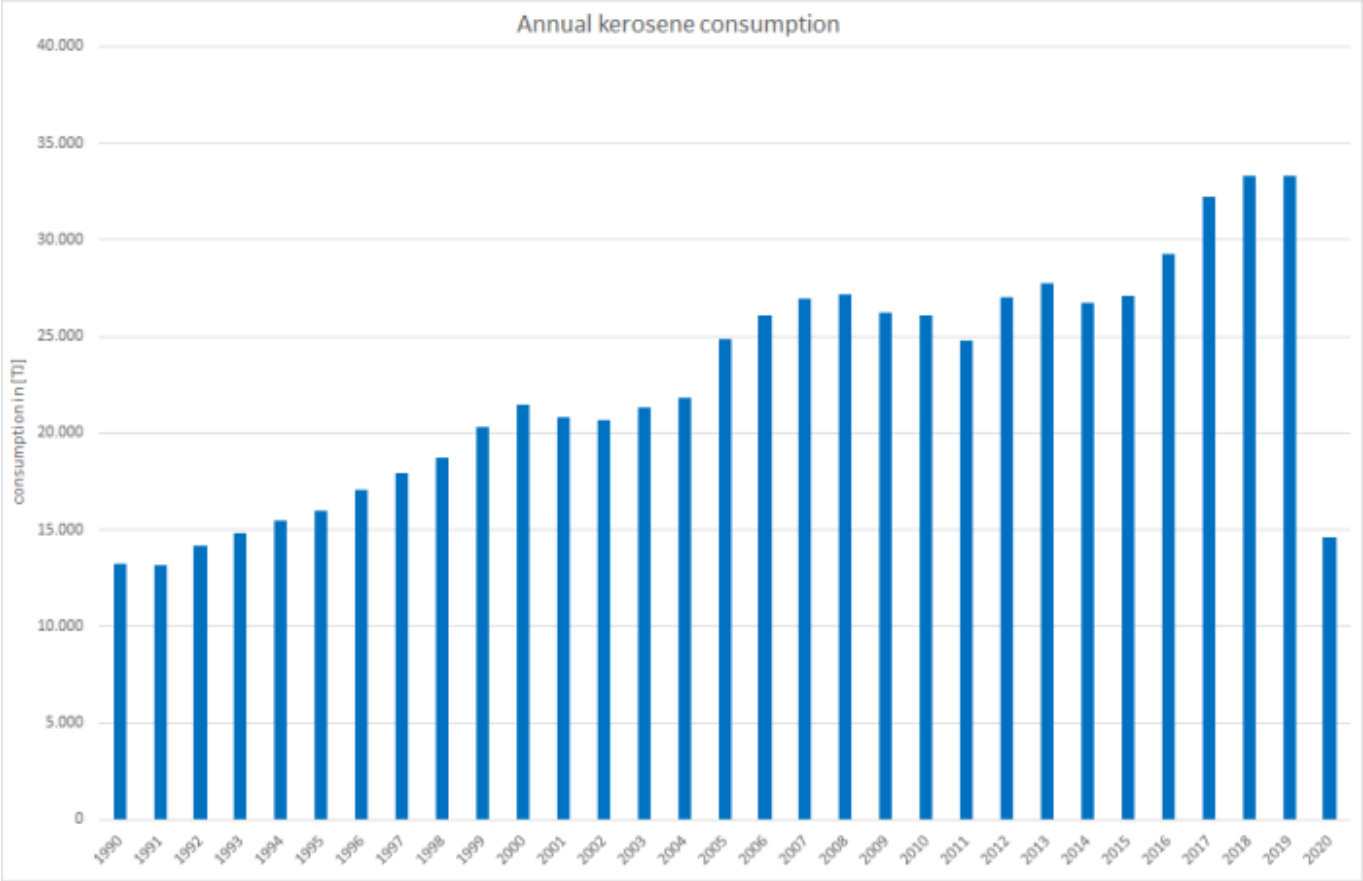
	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jet Kerosene	8,17	7,80	8,19	8,00	7,97	7,95	7,91	7,86	7,90	7,81	7,92	7,98	7,98	8,09	8,11	8,13	8,18	8,15
Aviation Gasoline	5,24	11,8	11,1	19,1	20,5	23,2	20,4	20,2	19,8	17,3	19,1	22,2	26,3	20,8	42,2	43,7	51,4	61,6

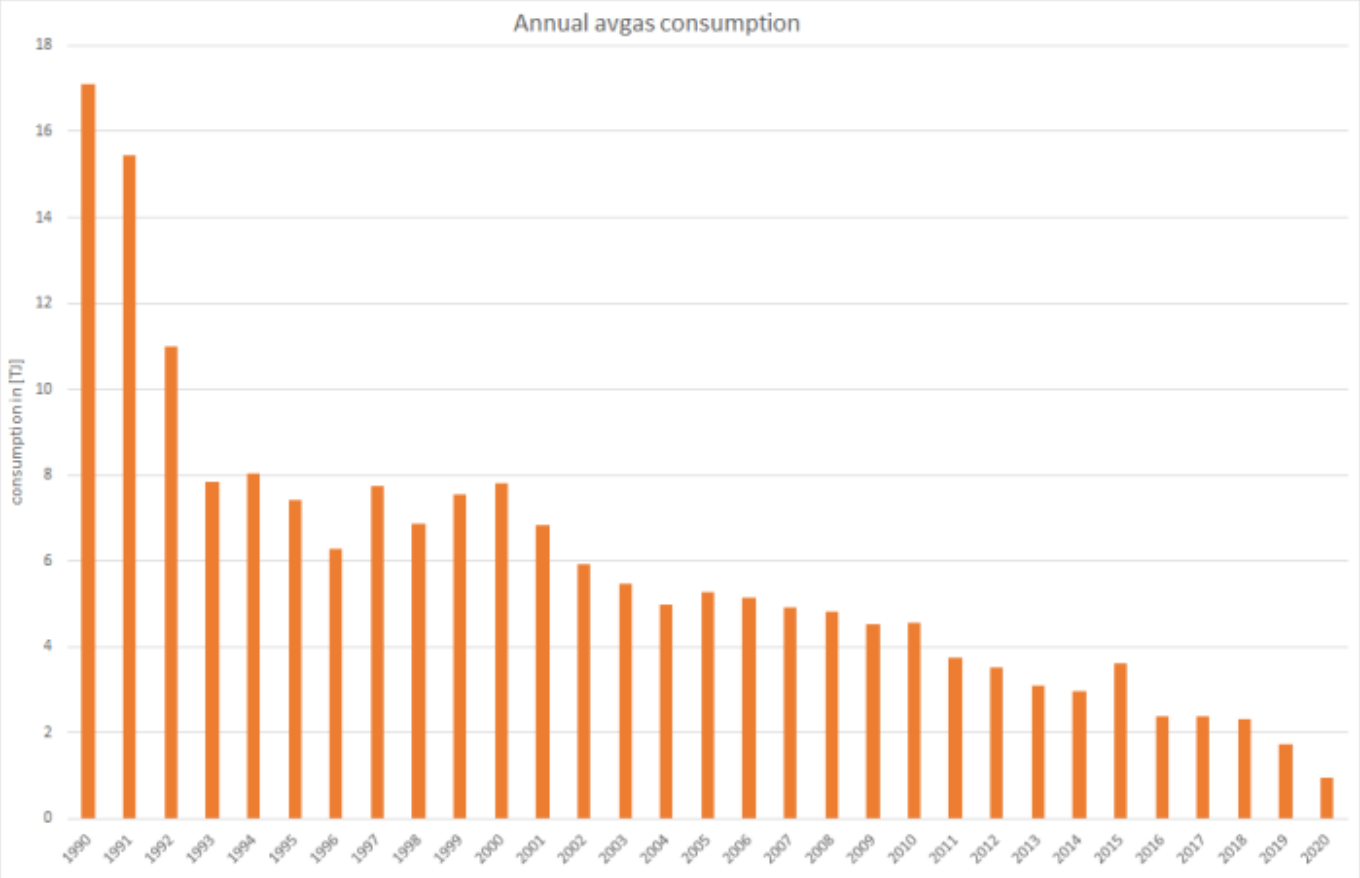
source: Knörr et al. (2020c) [1] &: Gores (2020) [2]

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
Jet Kerosene	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
Aviation Gasoline	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. (2020c) [3] &: Gores (2020) [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)].

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
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	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
NO_x	297	306	303	324	325	330	331	338	342	345	346	349	353	352	357	358	355	357
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]	1,78	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
PM[2]	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
CO	249	227	236	219	217	211	209	203	203	199	199	197	194	196	192	192	195	192
AVIATION GASOLINE																		
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	459	484	466	469	455	456	460	475	470	521	514	515	521	514	495	494	528	548
NO_x	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
SO_x	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
BC[1]	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
PM[2]	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
TSP[3]	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
CO	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

[1] estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in [7)]

[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.

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 to Eurocontrol AEM model and the underlying fleet composition.

Hence, the percentual annual shares of kerosene consumed during L/TO for international flights have been re-estimated...

Table 3: Revised percentual share of kerosene consumed during L/TO for international flights, in %

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2021	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
Submission 2020	8,31	7,84	8,21	8,02	7,98	7,96	7,92	7,87	7,91	7,82	7,95	8,05	8,15	8,24	8,26	8,28	8,32
absolute change	-0,15	-0,03	-0,02	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,03	-0,07	-0,17	-0,15	-0,15	-0,15	-0,15
relative change	-1,75%	-0,42%	-0,27%	-0,14%	-0,13%	-0,15%	-0,16%	-0,18%	-0,17%	-0,17%	-0,34%	-0,85%	-2,05%	-1,79%	-1,80%	-1,82%	-1,78%

... and the amounts of kerosene allocated to sub-category 1.A.3.a i (i) were revised accordingly:

Table 4: Revised kerosene usage in 1.A.3.a i (i), in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2021	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
Submission 2020	13.676	15.973	21.785	25.168	26.381	27.295	27.439	26.538	26.256	24.701	27.164	28.075	27.274	27.546	29.875	32.999	34.160
absolute change	-424	39	-320	-308	-318	-304	-255	-289	-141	95	-128	-350	-497	-431	-571	-794	-820
relative change	-3,10%	0,25%	-1,47%	-1,22%	-1,21%	-1,11%	-0,93%	-1,09%	-0,54%	0,39%	-0,47%	-1,24%	-1,82%	-1,56%	-1,91%	-2,40%	-2,40%

Furthermore, for the first time, the use of aviation gasoline (avgas) for international flights has been estimated. These amounts have been re-allocated from NFR 1.A.3.a ii (i), where 100% of avgas consumption has been allocated so far.

Table 5: Amounts of avgas consumed during the L/TO stage of international flights from Germany, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2021	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
Submission 2020	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
absolute change	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

In parallel, the majority of **country-specific emission factors** has been revised within TREMOD AV based on information available from the Eurocontrol's AEM model, taking into account the development of fleet composition and engine technology.

Table 6: Revised country-specific emission factors applied for jet kerosene

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NH,,3,,																	
Submission 2020	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

Submission 2019	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00
absolute change	-0,02	-0,05	-0,05	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03
relative change	-0,48%	-1,16%	-1,16%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%	-0,70%
NMVOC																	
Submission 2020	59,7	36,1	25,7	22,9	22,9	22,5	22,0	21,2	21,2	20,8	20,5	20,3	19,9	20,5	20,2	20,8	21,4
Submission 2019	56,6	37,1	25,0	22,6	22,8	22,5	22,1	21,3	21,9	21,8	21,8	21,7	21,2	21,9	21,7	22,3	23,0
absolute change	3,14	-1,02	0,71	0,31	0,05	-0,06	-0,09	-0,13	-0,66	-1,03	-1,29	-1,42	-1,36	-1,46	-1,42	-1,55	-1,58
relative change	5,54%	-2,74%	2,84%	1,39%	0,22%	-0,25%	-0,41%	-0,63%	-3,02%	-4,72%	-5,94%	-6,55%	-6,42%	-6,67%	-6,57%	-6,93%	-6,86%
NO,,x,,																	
Submission 2020	297	306	303	324	325	330	331	338	342	345	346	349	353	352	357	358	355
Submission 2019	283	299	285	307	310	314	316	324	330	333	334	337	343	340	345	347	345
absolute change	13,45	7,01	17,86	16,20	15,07	15,54	14,96	14,73	12,65	11,89	11,46	11,67	9,20	11,91	11,48	10,91	10,60
relative change	4,75%	2,34%	6,26%	5,27%	4,86%	4,94%	4,73%	4,55%	3,84%	3,57%	3,43%	3,46%	2,68%	3,50%	3,33%	3,15%	3,08%
BC																	
Submission 2020	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
Submission 2019	1,20	1,19	1,19	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20
absolute change	0,58	0,44	0,26	0,17	0,13	0,08	0,05	0,03	0,01	0,00	-0,02	-0,03	-0,05	-0,06	-0,07	-0,08	-0,08
relative change	48,2%	36,8%	21,6%	14,6%	10,7%	6,72%	4,06%	2,69%	1,16%	-0,04%	-1,56%	-2,21%	-3,99%	-4,79%	-5,85%	-6,74%	-6,76%
PM																	
Submission 2020	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
Submission 2019	2,50	2,48	2,48	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,50	2,49	2,49	2,49
absolute change	1,21	0,91	0,54	0,36	0,27	0,17	0,10	0,07	0,03	0,00	-0,04	-0,06	-0,10	-0,12	-0,15	-0,17	-0,17
relative change	48,2%	36,8%	21,6%	14,6%	10,7%	6,72%	4,06%	2,69%	1,16%	-0,04%	-1,56%	-2,21%	-3,99%	-4,79%	-5,85%	-6,74%	-6,76%
CO																	
Submission 2020	249	227	236	219	217	211	209	203	203	199	199	197	194	196	192	192	195
Submission 2019	225	214	209	192	192	188	186	181	186	185	188	187	182	186	182	183	185
absolute change	23,3	13,1	27,7	27,0	24,4	23,3	22,4	21,4	16,5	13,3	11,4	10,5	11,8	9,91	9,36	8,63	9,46
relative change	10%	6,13%	13,3%	14,0%	12,7%	12,4%	12,0%	11,8%	8,87%	7,17%	6,05%	5,59%	6,49%	5,32%	5,14%	4,72%	5,10%

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

[1), 3), 6)] Knörr et al. (2020c): 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, 2020.
[2), 4)] Gores (2020): Inventartool zum deutschen Flugverkehrsinventar 1990-2018, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2020.
[5)] 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.
[7)] 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.