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

Short description

Category Code	Method					AD					EF				
1.A.3.a i (ii)	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 (ii)	*not included in key category analysis*														

In NFR category *1.A.3.a i (ii) - Internatinal Civil Aviation: Cruise* emissions from international flights from German airports during cruise stage (above 3,000 feet of altitude) are reported.

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

Methodology

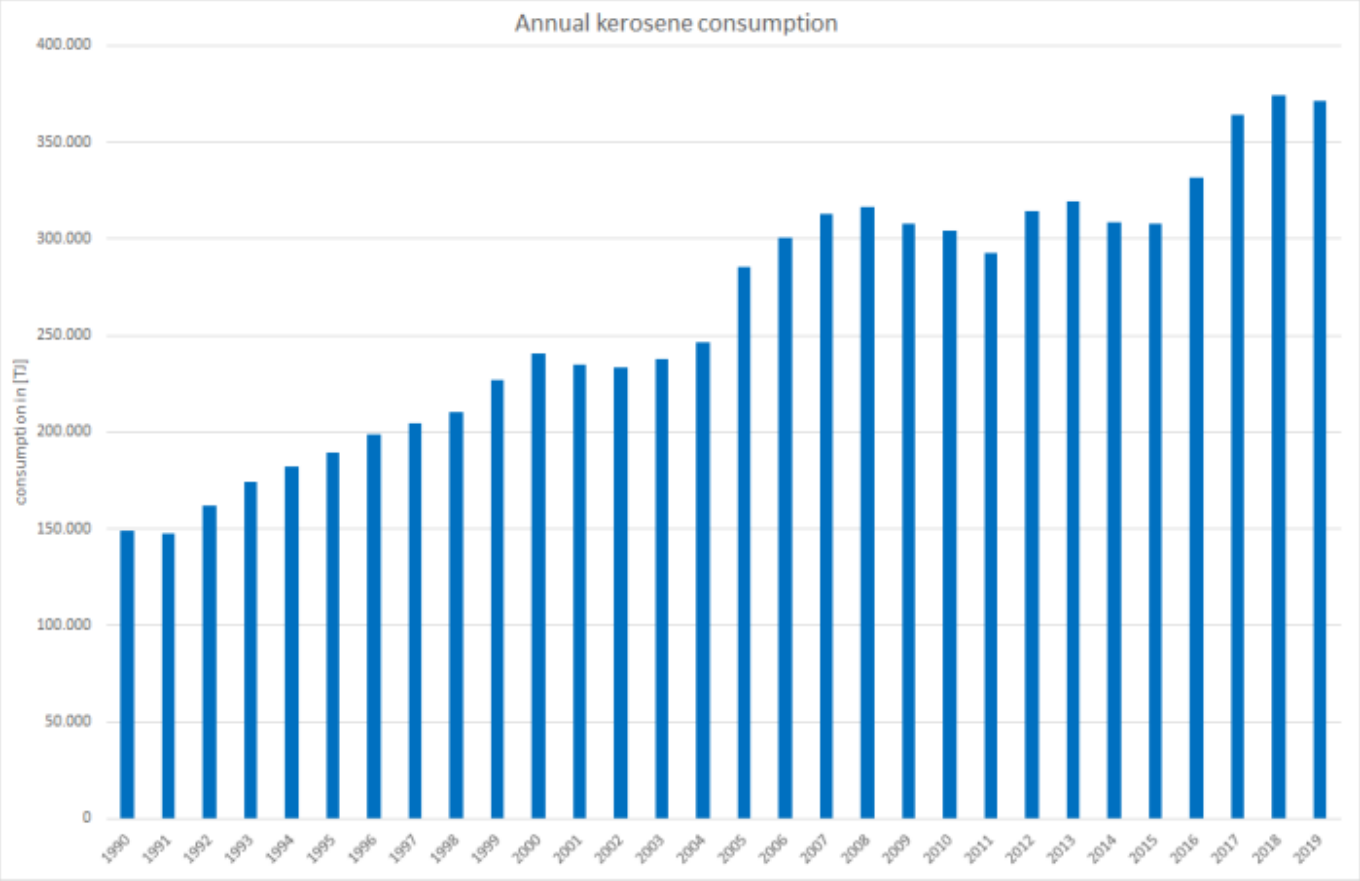
Actitvity Data

Specific jet kerosene consumption during LTO-stage is calculated within TREMOD AV as described in the superordinate chapter on civil aviation.

Table 1: annual jet kerosene consumption during cruise-stage, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Jet kerosene	149,007	189,185	240,680	285,709	301,032	312,607	316,629	307,916	304,544	292,898	314,325	319,548	308,755	307,982	331,809	363,932	374,434	371,033	171,306
Avgas	494	211	220	149	146	138	138	126	124	106	97.9	86.4	76.1	98.6	36.0	36.4	32.2	23.4	12.1

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



Emission factors

All country specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 [3)] and have since then been compiled, revised and maintained in TREMOD AV [4)].

For more information, please see the 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	2020
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	3.97
NMVOC	13.3	8.96	5.98	5.27	5.15	5.02	4.89	4.77	4.66	4.53	4.39	4.39	4.71	4.35	4.17	4.23	4.32	4.26	4.29
NO_x	313	317	329	338	338	342	343	346	352	354	360	362	362	366	370	372	373	376	379
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	19.6
PM[1]	1.89	1.96	2.03	1.93	1.91	1.89	1.85	1.83	1.81	1.80	1.79	1.77	1.74	1.73	1.73	1.74	1.75	1.73	1.72
BC[2]	3.94	4.08	4.23	4.02	3.98	3.93	3.86	3.81	3.77	3.74	3.72	3.69	3.62	3.59	3.61	3.62	3.64	3.61	3.59
CO	73.8	61.6	47.7	42.4	41.5	40.6	39.7	38.6	37.8	37.3	37.0	36.8	40.1	36.2	34.2	34.2	34.7	34.1	34.4
AVGAS																			
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	468	498	477	462	452	451	461	470	460	523	519	518	506	515	430	437	449	466	446
NO_x	103	109	103	100	98	97	99	100	97	111	109	110	104	108	68.7	69.8	73.7	81.7	71.5
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	0.46
BC	0.40	0.42	0.41	0.40	0.40	0.40	0.41	0.41	0.41	0.44	0.44	0.44	0.45	0.44	0.47	0.47	0.47	0.46	0.47
$PM_{2.5}$	2.69	2.80	2.74	2.68	2.65	2.67	2.70	2.76	2.74	2.96	2.96	2.93	2.97	2.95	3.11	3.14	3.13	3.08	3.12
PM_{10}	2.69	2.80	2.74	2.68	2.65	2.67	2.70	2.76	2.74	2.96	2.96	2.93	2.97	2.95	3.11	3.14	3.13	3.08	3.12
TSP	17.9	18.0	17.9	17.9	17.8	17.8	17.9	17.9	17.9	18.1	18.1	18.1	18.1	18.1	18.3	18.3	18.3	18.2	18.3
CO	20,915	22,610	21,827	21,055	20,659	21,024	21,402	22,335	22,225	25,229	25,303	24,882	25,753	25,200	29,832	30,337	30,216	29,164	30,558

[1] EF(TSP) also applied for PM_{10} and $PM_{2.5}$ (assumption: > 99% of TSP consists of $PM_{2.5}$)
[2] estimated via a f-BC of 0.48 as provided in [5)], Chapter: 1.A.3.a, 1.A.5.b Aviation, page 49: “Conclusion”.

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

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trend discussion for Key Sources

> NFR 1.A.3.a i (ii) - International Civil Aviation - Cruise is **not included in the national emission totals** and hence **not included in the key category analysis**.

Recalculations

Activity data have been revised for all years within TREMOD AV to keep in line with information available from Eurocontrol's AEM model [6)].

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

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

JET KEROSENE																	
Submission 2021	149.007	189.185	240.680	285.709	301.032	312.607	316.629	307.916	304.544	292.898	314.325	319.548	308.755	307.982	331.809	363.932	374.434
Submission 2020	150.852	187.855	243.544	288.819	304.276	315.598	319.033	310.713	305.632	291.248	314.638	320.599	307.487	306.766	331.644	365.499	376.210
absolute change	-1.845	1.330	-2.863	-3.110	-3.244	-2.991	-2.405	-2.797	-1.088	1.650	-313	-1.051	1.268	1.216	165	-1.567	-1.776
relative change	-1,22%	0,71%	-1,18%	-1,08%	-1,07%	-0,95%	-0,75%	-0,90%	-0,36%	0,57%	-0,10%	-0,33%	0,41%	0,40%	0,05%	-0,43%	-0,47%
AVGAS																	
Submission 2021	464	161	173	91,6	87,2	76,8	82,5	75,8	76,8	68,1	60,4	48,6	40,0	58,5	16,2	16,2	12,1
Submission 2020	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
absolute change	464	161	173	91,6	87,2	76,8	82,5	75,8	76,8	68,1	60,4	48,6	40,0	58,5	16,2	16,2	12,1

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 [7)].

Table 4: Revised country-specific emission-factors, 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	13,3	8,96	5,98	5,27	5,15	5,02	4,89	4,77	4,66	4,53	4,39	4,39	4,71	4,35	4,17	4,23	4,32
Submission 2020	13,4	9,47	5,93	5,44	5,35	5,20	5,07	4,95	4,91	4,81	4,70	4,70	4,64	4,65	4,46	4,52	4,64
absolute change	-0,12	-0,51	0,05	-0,17	-0,19	-0,18	-0,19	-0,19	-0,25	-0,28	-0,30	-0,31	0,07	-0,30	-0,29	-0,30	-0,32
relative change	-0,90%	-5,42%	0,92%	-3,05%	-3,60%	-3,43%	-3,65%	-3,80%	-5,08%	-5,78%	-6,43%	-6,59%	1,43%	-6,55%	-6,42%	-6,57%	-6,83%
NITROGEN OXIDES																	
Submission 2021	313	317	329	338	338	342	343	346	352	354	360	362	362	366	370	372	373
Submission 2020	308	313	319	330	331	334	335	339	346	349	354	354	354	354	359	361	362
absolute change	5,51	3,34	9,39	7,62	7,09	7,33	7,18	7,04	6,05	5,47	5,95	7,84	7,38	11,17	10,99	11,04	11,01
relative change	1,79%	1,07%	2,94%	2,31%	2,14%	2,19%	2,14%	2,08%	1,75%	1,57%	1,68%	2,22%	2,08%	3,15%	3,06%	3,06%	3,04%
SULPHUR OXIDES																	
Submission 2021	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
Submission 2020	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
absolute change	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
relative change	0,0%	0,0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLACK CARBON - BC																	
Submission 2021	1,89	1,96	2,03	1,93	1,91	1,89	1,85	1,83	1,81	1,80	1,79	1,77	1,74	1,73	1,73	1,74	1,75
Submission 2020	1,91	2,01	2,08	1,97	1,95	1,93	1,90	1,88	1,86	1,84	1,83	1,82	1,78	1,79	1,79	1,80	1,80
absolute change	-0,02	-0,06	-0,05	-0,04	-0,04	-0,04	-0,04	-0,05	-0,05	-0,05	-0,04	-0,05	-0,05	-0,06	-0,06	-0,06	-0,06
relative change	-1,2%	-2,8%	-2,4%	-2,1%	-2,2%	-2,3%	-2,3%	-2,4%	-2,6%	-2,5%	-2,3%	-2,5%	-2,7%	-3,5%	-3,3%	-3,4%	-3,1%
PARTICULATE MATTER - PM																	
Submission 2021	3,94	4,08	4,23	4,02	3,98	3,93	3,86	3,81	3,77	3,74	3,72	3,69	3,62	3,59	3,61	3,62	3,64
Submission 2020	3,98	4,19	4,33	4,11	4,07	4,02	3,95	3,91	3,87	3,84	3,81	3,78	3,72	3,72	3,74	3,74	3,76
absolute change	-0,05	-0,12	-0,10	-0,09	-0,09	-0,09	-0,09	-0,09	-0,10	-0,10	-0,09	-0,10	-0,10	-0,13	-0,12	-0,13	-0,12
relative change	-1,2%	-2,8%	-2,4%	-2,1%	-2,2%	-2,3%	-2,3%	-2,4%	-2,6%	-2,5%	-2,3%	-2,5%	-2,7%	-3,5%	-3,3%	-3,4%	-3,1%
CARBON MONOXIDE - CO																	
Submission 2021	73,8	61,6	47,7	42,4	41,5	40,6	39,7	38,6	37,8	37,3	37,0	36,8	40,1	36,2	34,2	34,2	34,7

Submission 2020	71,0	60,3	44,9	40,0	39,2	38,3	37,4	36,4	35,9	35,6	35,5	35,6	35,3	35,5	33,5	33,6	34,0
absolute change	2,77	1,30	2,84	2,39	2,22	2,30	2,24	2,21	1,90	1,73	1,45	1,17	4,76	0,73	0,67	0,57	0,65
relative change	3,90%	2,16%	6,32%	5,99%	5,66%	6,01%	5,98%	6,07%	5,29%	4,87%	4,07%	3,29%	13,48%	2,07%	1,99%	1,68%	1,90%

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.

[2)] Gores (2020): Inventartool zum deutschen Flugverkehrsinventar 1990-2018, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2020.
[3)] 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.
[5)] 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.
[6), 7)] Eurocontrol (2020): Advanced emission model (AEM); https://www.eurocontrol.int/model/advanced-emission-model; 2020.