AVIATION AND CLIMATE CHANGE: A COMPARISON OF THE OVERFLIGHTS OF THE BELGIAN TERRITORY AND THE LOCAL AVIATION ACTIVITIES

J. Matheys[1], T. Festraets[2], J. Van Mierlo[1], C. Macharis[2], N. Sergeant[1], J.-M. Timmermans[1]
[1]Department of Electrical Engineering and Energy Technology, Building Z,
[2]MOSI-T Transport and Logistics, Building M,
Vrije Universiteit Brussel
Pleinlaan 2, 1050 Brussels
Belgium

OVERVIEW

This paper is written in the context of an analysis of issues related to the inclusion of air transport into European and international climate policy. The analysis of these policy options is of particular interest for Belgium given the intensity of air traffic in and over the Belgian territory. This paper provides an overview of the aviation related CO_2 and H_2O emissions from Belgian aviation as well as an estimation of these emissions due to the overflights of the Belgian airspace.

Besides the well-known CO_2 emissions, which occur during the combustion of any fuel, aviation induces the formation of condensation trails (contrails) and possibly also the development of cirrus clouds. As water emissions are the main trigger to these phenomena, a calculation of the water emissions was performed next to the calculation of CO_2 emissions. In order to be able to analyse these different contributions, it was required to evaluate the overflying traffic. The use of grouped inzones and outzones allowed to aggregate the overflights to enable the drawing of tendencies. The zone where an aircraft enters and exits the national airspace determines the length of its trip over the country. Based on the average fuel consumption of type aircraft during the cruise phase, the total emissions of CO_2 and H_2O over the Belgian territory are calculated.

The comparison of the emissions due to aviation activities on the Belgian territory (with a landing or take-off on one of the Belgian airports) with the emissions due to the aircraft performing overflights through the Belgian airspace was performed. Although some uncertainties still exist regarding the exact effect of contrails and cirrus cloud formation on climate, this analysis shows that next to the CO_2 emissions produced by aviation, the local climate in Belgium might be influenced significantly by air traffic transiting through its air space. Moreover, the analysis shows that overflights of the Belgian territory result in a comparable amount of CO_2 and H_2O emissions as compared to the local flight activities.

1. INTRODUCTION

The possibility of integrating the aviation sector in the climate policy is more and more considered both at the European level and in the context of the United Nations Framework Convention on Climate Change.

On a worldwide scale CO_2 is, by far, the emission that impacts climate in the strongest way. However, aviation presents some specific characteristics regarding other emissions in that sense that a large fraction of the pollutants are emitted in the higher troposphere and in the lower stratosphere.

NOx emissions of subsonic aircraft tend to decrease the lifetime of the greenhouse gas CH_4 that is present in the atmosphere. On the other hand NOx emissions tend to increase ozone production. Ozone is a very short-lived greenhouse gas.

Besides this, aviation induces condensation trails (contrails) and possibly also the formation of cirrus clouds. The total impact of aviation on climate is believed to be two- to four-fold (FIG 1) that of CO_2 alone (Sausen et al., 2005).

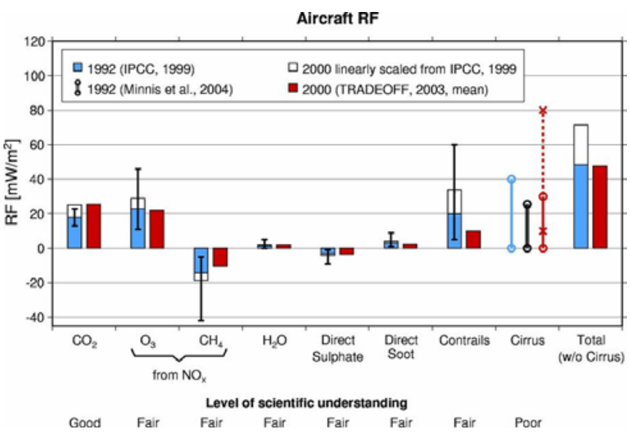

FIG 1. Climate effects of aviation including the level of scientific understanding of the different impacts (Sausen et al., 2005).

Based on some results from the TRADEOFF project, Sausen et al. (2005) performed an update on radiative forcing (the difference between incoming radiative energy and outgoing radiative energy of the Earth) from aviation and compared different studies dealing with aviation and radiative forcing (FIG 1 and TAB 1). In this table the radiative forcing of several types of emissions is provided together with the estimation of the total radiative forcing excluding cirrus clouds formation (incl.

CO_2, H_2O, O_3 formation from NOx, CH_4 depletion from NOx, contrail formation). As the uncertainty towards the radiative forcing of contrails is still quite big (TAB 1), the focus of this paper will be on CO_2 and H_2O emissions (as an indication towards the formation of contrails and cirrus clouds) and not specifically on the formation of cirrus clouds.

RF [mW/m²]	CO_2	H_2O	Contrails	Total (excl. cirrus, incl. NOx)
IPCC (1999)	18.0	1.5	20.0	48.5
IPCC (1999) scaled to 2000	25.0	2.0	33.9	71.3
Tradeoff (2000)	25.3	2.0	10.0	47.8

TAB 1. Radiative forcing from aviation [mW/m²] (Sausen et al., 2005). Total includes CO_2, H_2O, O_3 formation from NOx, CH_4 depletion from NOx, Contrail formation).

The fact that next to CO_2 some other local climate-influencing emissions occur make it relevant to compare the climate influencing emissions induced by the aviation sector in Belgium (aviation activities on Belgian airports) with the climate influencing emissions of the overflights of the Belgian air space. Therefore a calculation of the overflying traffic will be performed and the type of emissions on which the highest level of certainty exists (CO_2 and H_2O) will be computed. In order to be able to analyse these different contributions it is required to evaluate the overflying traffic. On the basis of data of Belgocontrol (Belgium and Luxembourg Air Traffic Management services), an evaluation of the number of flights over the country can be executed. The use of grouped inzones and outzones allows to aggregate the overflights. The precise place where an aircraft enters and exits a given inzone or outzone strongly influences the length of its trip in the national airspace.

The use of grouped inzones and outzones allows to aggregate the overflights. The precise place where an aircraft enters and exits a given inzone or outzone strongly influences the length of its trip in the national airspace (FIG 3).

Obviously, the location of Belgium in the intensely overflown FLAP area (the area located in between the airports of Frankfurt-London-Amsterdam-Paris) plays an important role in this examination. It appears that as the country is located in one of the world's most busy aviation areas, local climate could be significantly influenced by flights not operating from or to any Belgian airport.

FIG 2 provides an overview of the evolution of the number of passengers in the Belgian airports over the last decade. The figure shows that just like the rest of the world, the Belgian traffic was strongly affected by the 9/11 events. However another local factor that strongly reduced traffic in 2001 and 2002 is the bankruptcy of the Belgian national carrier Sabena on the 7th of November 2001 (Statbel, 2007).

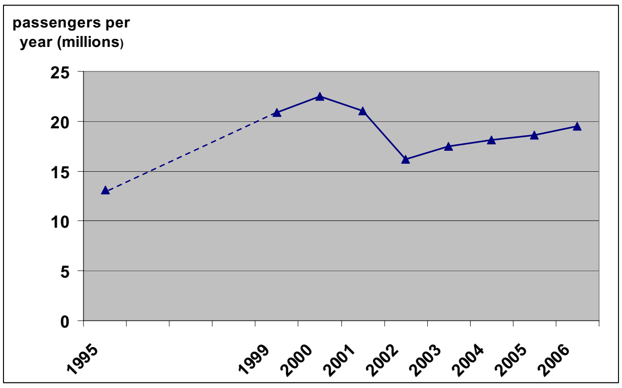

FIG 2. Evolution of the total number of passengers (in millions) in the Belgian airports (excluding transit passengers remaining in the same aircraft).

Since 2002 the traffic is slowly recovering and since last year the passenger numbers are reaching pre-2001 levels. Altogether with the fact that 2006 is the most recent fully completed year for which data are available, this is the reason why the comparisons made in this paper will be based on this reference year.

2. METHODOLOGY

The emission data will be analysed for the year 2006. As can be seen from the evolution of the traffic, 2006 is a year with traffic that comes closer to pre-Sabena bankruptcy and pre-9/11 figures in Belgium.

2.1. Flight information

Flight information concerning the aviation activities is provided by the air traffic control and civil air navigation services in Belgium and Luxembourg (Belgocontrol). These data include all IFR (Instrument Flight Rules) activities throughout the Belgian and Luxembourgish airspace.

Amongst other data, the provided database includes:
airport of departure

- airport of arrival
- type of aircraft
- distance covered in the national airspace
- the places of entrance and exit of the national airspace

This allows us to aggregate the flights in 'overflights' and 'local activity flights' (flights with a landing/take-off on one of the Belgian airports). Inzones and outzones have been allocated to the national airspace in order to determine where the aircraft enter or leave the country (FIG 3).

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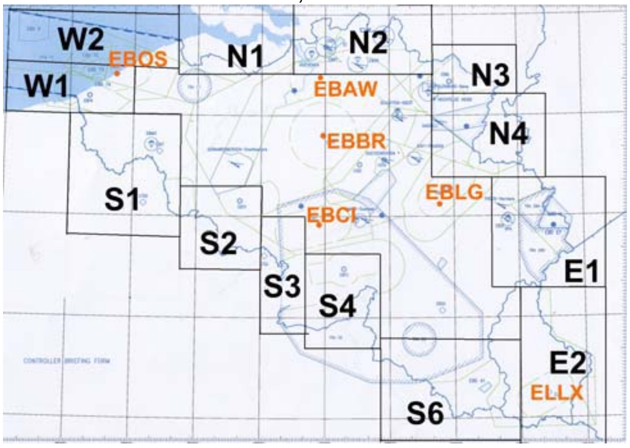

FIG 3. Indication of the inzones and outzones of the Belgium-Luxembourg airspace. The main airports are indicated in orange (adapted from Belgocontrol).

2.2. Coupling emissions to flight information

The fuel consumption in the Belgian territory and its consequent emissions depend on the type of aircraft, the occurring flight phase and the covered distance. As the air traffic control database is responsible for the Luxembourg air traffic control as well, some filters are needed for the Luxembourgish activities. Therefore flights having both ELLX (FIG 3) as an origin or a destination as well as E1, E2 or S6 as an inzone or an outzone will be excluded of the analysis. This is due to the fact that these flights are neither overflights of the Belgian territory, neither a local Belgian activity, but can be considered as local Luxembourgish aviation activities. The emissions linked to aircraft with a maximum take-off weight (MTOW) of less than 20.000kg will not be considered.

2.2.1. Emissions due to local activities

It is considered that a flight had local activities in Belgium when the origin or destination of the flight is one of the following main Belgian airports: Brussels National airport (EBBR), Brussels South Charleroi airport (EBCI), Deurne-Antwerp airport (EBAW), Liège-Bierset airport (EBLG) or Ostend-Bruges airport (EBOS) (FIG 3). The emissions of the local activities are calculated by adding the LTO emissions of the different aircraft to the cruise emissions of these aircraft in the Belgian airspace. The EMEP/Corinair (2003) (TAB 2) data are used for the LTO cycle emissions. Obviously, the approach landing and taxi-in fuel use and emissions will be allocated to arriving aircraft, while the taxi-out, take-off and climb-out fuel use and emissions will be allocated to departing aircraft.

Aircraft type	Fuel	CO_2	H_2O
A310	1540.5	4853	1895
A320	802.3	2527	987
A330	2231.5	7029	2745
A340	2019.9	6363	2484.5
BAC1-11	681.6	2147	838
BAe146	569.5	1794	701
B727	1412.8	4450	1738
B737 100	919.7	2897	1131
B737 400	825.4	2600	1015
B747 100-300	3413.9	10754	4199
B747 400	3402.2	10717	4185
B757	1253	3947	1541
B767 300 ER	1617.1	5094	1989
B777	2562.8	8073	3152
DC9	876.1	2760	1078
DC10	2381.2	7501	2929
F28	666.1	2098	819
F100	744.4	2345	916
MD82	1003.1	3160	1234

TAB 2. Type aircraft with emission factors and fuel consumption for LTO (kg/LTO) (EMEP/Corinair, 2003).

The total fuel use was calculated by adding the average fuel uses of the different type aircraft which were obtained through a linear regression of the fuel use/emission data for the climb-cruise-descent data provided in EMEP/Corinair (2003).

The average fuel uses per km for the different type aircraft for the assessed flight phases are provided in TAB 3.

Aircraft type	Fuel	CO_2	H_2O
A310	4.85	15.28	5.97
A320	2.74	8.63	3.37
A330	6.48	20.41	7.97
A340	7.04	22.18	8.66
BAC1-11	2.53	7.97	3.11
BAe146	2.76	8.69	3.39
B727	4.45	14.02	5.47
B737 100	2.84	8.95	3.49
B737 400	3.03	9.54	3.73
B747 100-300	11.93	37.58	14.67
B747 400	10.88	34.27	13.38
B757	3.84	12.10	4.72
B767 300 ER	5.27	16.60	6.48
B777	7.64	24.07	9.40
DC9	3.07	9.67	3.78
DC10	9.00	28.35	11.07
F28	2.41	7.59	2.96
F100	2.55	8.03	3.14
MD82	3.46	10.90	4.26

TAB 3. Average fuel use per km and CO_2, H_2O emissions during the climb-cruise-descent phase for the different type aircraft (kg/km) (Adapted from EMEP/Corinair, 2003).

2.2.2. Emissions due to overflights

All of the flights in the database not having one of the airports mentioned in 2.2.1 as an origin or a destination are considered to be overflights. As overflights occur at an important number of different flight levels, processing the data for every single flight level would lead to an excessive number of subcategories, which would impair the drawing of any conclusions. Therefore a standard fuel consumption during the cruise phase is allocated to each aircraft type. Just like for the calculation of the emissions due to the national activities, the emissions due to overflying aircraft are obtained through linear regression of the fuel use/emission data of the type aircraft (TAB 3). The fuel consumption and emissions are then multiplied by the distance covered by these aircraft in the national airspace. For a number of aircraft included in the flight database, there was no equivalent mentioned in EMEP/Corinair (2003). Therefore, some equivalent type aircraft have been determined by the authors (TAB 4).

As a consequence, in this study, the emissions allocated to the type aircraft in EMEP/Corinair (2003) will be used for these aircraft.

ICAO Code	Type aircraft
A306	A310
A30B	A310
A3ST	A310
AT72	F28
ATP	F28
CRJ1	BAC1-11
CRJ2	BAC1-11
CRJ7	BAC1-11
DH8A	F28
DH8C	F28
DH8D	F28
E120	F28
E135	F28
E145	F28
E170	BAe146
F50	F28
F70	F100
RJ1H	BAe146
RJ70	BAe146
RJ85	BAe146

TAB 4: Allocation of type aircraft to a list of included aircraft.

3. TRAFFIC DENSITY

Based on the flight database, an overview of the aviation activities in Belgium was obtained. However, to draw conclusions, it is essential to aggregate the data. FIG 4 shows the density of traffic in 2006 between Belgian airports and inzones/outzones, while FIG 5 shows the density of overflight routes for the same year between the different inzones and outzones. Both of the figures only show routes where the traffic is higher than 20.000 flights.

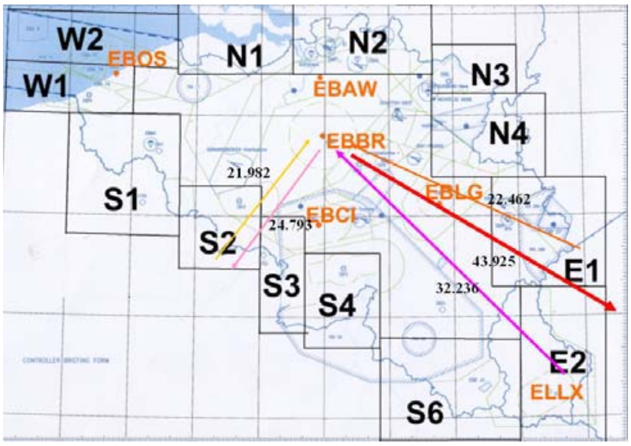

FIG 4. Overview of the local activity routes with more than 20.000 registered flights in 2006 (adapted from Belgocontrol).

As can be seen from FIG 4 and FIG 5, the intensity of the traffic over the country is much higher than the intensity of the traffic originating from the Belgian airports.

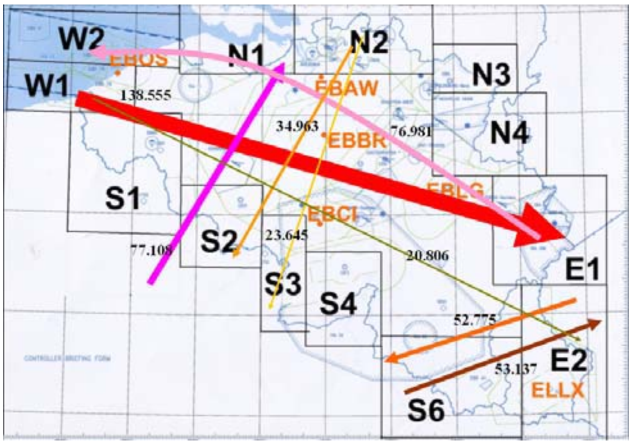

FIG 5. Overview of the inzone-outzone combinations with more than 20.000 overflights registered in 2006 (adapted from Belgocontrol).

4. QUANTIFICATION OF THE EMISSIONS

When taking the excluding parameters described in chapter 2 into account (MTOW>20.000kg; exclusion of ELLX-E1, ELLX-E2, ELLX-S6, E1-ELLX, E2-ELLX and S6-ELLX flights), the proportion of movements for which fuel consumption and emissions can be determined is of 98.8%, representing 98.7% of the kilometres flown by these aircraft in the Belgian airspace. The remaining 1.2% of the movements corresponds to aircraft for which finding a well-matching equivalent in the list of type aircraft mentioned in TAB 2 and TAB 3 was not straightforward. However, it is clear that there's a sufficient proportion of the flights for which emissions and fuel consumption can be calculated in order to enable the drawing of conclusions regarding overflight emissions and local activities emissions.

4.1. Local activities

As can be seen from TAB 5, the fuel used for local aviation activities in the Belgian airspace is more or less equally used for the LTO cycle and to cover the distance to the country borders. The highest numbers of movements are performed with A320, B737-400 type and BAe146 type representative aircraft.

Aircraft type	Movements	Fuel (LTO)	Fuel (distance)	Total fuel	Total CO_2	Total H_2O
A310	8462	6520468	6124148	12644616	39830541	15552878
A320	51755	20851884	17870135	38722020	121974362	47628084
A330	2603	2902943	2525418	5428361	17099336	6676884
A340	21	20957	20810	41767	131565	51373
B727	20	13579	10969	24548	77328	30195
B737 100	19791	9010402	7485164	16495566	51961033	20289546
B737 400	46840	19590243	16791381	36381624	114602114	44749397
B747 100-300	4923	8411850	9132904	17544754	55265974	21580047
B747 400	2213	3764119	3127434	6891553	21708391	8476610
B757	13485	8450134	6484889	14935023	47045323	18370079
B767 300 ER	6130	4955289	5001130	9956418	31362718	12246395
B777	10	12814	10001	22815	71866	28062
BAC1-11	10664	3633853	3404130	7037983	22169646	8656719
BAe146	69833	19909271	25200200	45109471	142094834	55484650
DC10	3494	4085497	4669353	8754851	27577779	10768466
DC9	25	10699	9333	20032	63101	24640
F100	5804	2158979	1571608	3730588	11751351	4588623
F28	19912	6650183	5423604	12073788	38032432	14850759
MD82	6546	3283937	2865202	6149138	19369786	7563440
Total	272531	124237101	117727814	241964915	762189481	297616845

TAB 5. Total number of LTO cycles and related emissions (grouped by corresponding representative aircraft type) [kg].

4.2. Overflights

TAB 6 shows that most of the movements operated over Belgium are performed with A320 and B734 (representative) type aircraft. These two types of representative aircraft, altogether with the bigger B747 100-300, B747-400 and B777 representative aircraft are also responsible for an important share of the total emissions of CO_2 and H_2O over the country. When comparing the total fuel consumption of local aviation activities and the total fuel consumption of the overflights (TAB 6 and FIG 6), it appears that the fuel consumption of the overflights is almost twice (1.939 times) higher than for the local activities. Logically, the same applies for CO_2 and H_2O emissions.

Aircraft type	Movements	km	Fuel	CO_2	H_2O
A310	21125	3477268	16864749	53123961	20743642
A320	174270	30958867	84827296	267205984	104337575
A330	17761	4077135	26419834	83222478	32496396
A340	13397	3190548	22461456	70753588	27627591
B727	843	131200	583840	1839096	718123
B737 100	23646	4434157	12593006	39667970	15489398
B737 400	179889	30937022	93739176	295278404	115299186
B747 100-300	3918	939088	11203320	35290458	13780084
B747 400	19690	4005443	43579218	137274537	53602438
B757	25136	6077723	23338455	73516134	28706300
B767 300 ER	22737	5600041	29512219	92963488	36300029
B777	24525	4850868	37060632	116740990	45584577
BAC1-11	27057	3663050	9267516	29192675	11399044
BAe146	19717	4361645	12038140	37920140	14806912
DC10	8840	1727678	15549102	48979671	19125396
DC9	36	3655	11221	35346	13802
F100	20239	3298006	8409915	26491231	10344195
F28	39079	7390917	17812109	56108145	21908895
MD82	7922	1146808	3967956	12499060	4880585
Total	649827	120271118	469239161	1478103356	577164168

TAB 6. Amount of km covered and emissions by overflying aircraft in the Belgian airspace (grouped by corresponding representative aircraft type) [kg].

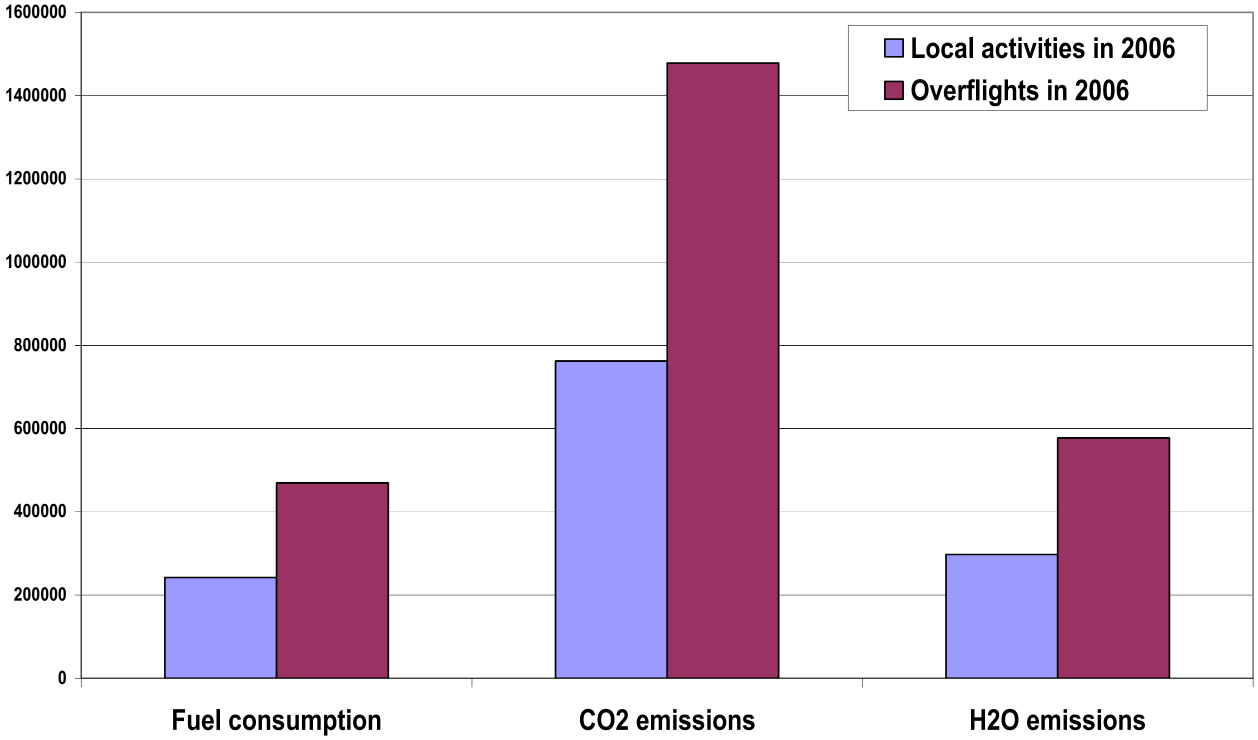

FIG 6. Comparison of fuel consumption, CO_2 emissions and H_2O emissions of local aviation activities and overflights of the Belgian territory in 2006 (tonnes).

5. CONCLUSIONS

Within the methodology definition provided in paragraph 2, some conclusions can be drawn concerning the aviation sector and its fuel consumption in and over Belgium. Belgium is located in one of the most busy air traffic zones in the world. This study showed that the share of the Belgian aviation activities in the total amount of emissions within the national borders is about twice as low as the emissions due to overflying traffic. The share of the Belgian local activities in the fuel consumption within the national borders was about 34% in 2006. As a consequence, the overflights of the Belgian territory are certainly not negligible and even result in a more important amount of greenhouse gas emissions within the national air space. This emphasizes the potential importance of local climate impacts on Belgium due to the overflights and this aspect should be kept in mind when wanting to implement both some national and international policies towards tackling climate change.

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