BOKU Carbon Offset System:

Basis of Calculation

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Calculation of carbon dioxide from aviation

In the following calculation, the carbon dioxide (CO_2) emissions per passenger for a particular route are calculated. In a first step, the kerosene consumption of the flight is calculated and converted to. CO_2. In the second step the CO_2 emissions per passenger are calculated.

Kerosene consumption

First of all the flight distance is calculated. The basis is the shortest distance (greater circle distance) between departure and arrival airports. The system uses a database containing the latitudes and longitudes of all airports. The greater circle distance formula calculates the shortest distance between the point of departure and arrival:

Greater Circle Distance = Radius * arccos[sin(L1/57.2958) * sin(L2/57.2958) + cos(L1/57.2958) * cos(L2/57.2958) * cos(l2/57.2958-l1/57.2958)][1]

To account for weather conditions, holding patterns etc., the greater circle distance is increased by 9%, the detour factor (AEA 2010: 24). As it is impossible to calculate the individual conditions of every flight, the average value of 9% is used:

Flight distance = greater circle distance * detour factor (1,09)

In calculating fuel consumption, different approaches are used for short and long haul flights. The *European Energy Agency* (2010: 13) suggests differentiating between short haul (<1,000 nautical miles[2]) and long haul (>1,000 nm). Based upon the model developed by My Climate (2010: 19), a weighted average of the consumption of aircraft types Airbus A320, Boeing 737 and 757 is used for calculating the consumption of short haul flights. For long haul flights a weighted average of the consumption of Airbus A340, Boeing 747, 767 and 777 is used. Fuel consumption data is taken from the *International Civil Aviation Organization* (ICAO 2010: 14).

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[1] Radius = Radius of planet earth (6378.7 km or 3437.74677 nm); L1 = Latitude of the departure airport; 57.2958 = 180/pi; B2 = Latitude of the arrival airport; l1 = longitude of the departure airport; L2 = longitude of the arrival airport

[2] 1 nm = 1,852 km

Aircraft	Consumption (kg kerosene), 750 nm
Airbus 320	4705.01
Boeing 737	4949.72
Boeing 757	6724.43

Example: short haul, 750 nm

The weighting is based upon EU passenger data for the EU27 for 2009 (EUROSTAT 2009). The total passenger figures for the aircraft in question are placed in relation to one another. This leads to the following weighting (Example: short haul):

Aircraft	Passengers, EU27: 2009	Weighting
Airbus 320	169,974,243	0.34
Boeing 737	291,273,225	0.59
Boeing 757	36,278,234	0.07
Total	497,525,702	1.00

The resulting percentages are used as a the basis for weighting the fuel consumption of the various aircraft types. Again using the example of a short haul flight the consumption of the Airbus A320 is multiplied by 0.34, the consumption of the Boeing 737 is multiplied by 0.59 and the consumption of the Boeing 757 is multiplied by 0.07. The sum of the three weighted consumption data forms the basis for the calculation:

Weighted consumption (750 nm) = (4705.01 * 0.34) + (4949.72 * 0.59) + (6724.43 * 0.07)

CO_2 Emissions

Having calculated the fuel consumption for the route in question, the kg kerosene combusted are converted to CO_2 emissions by multiplying by 3.15 (My Climate 2010: 20[3]).

To calculate the CO_2 emissions per passenger, the average number of seats, the average load-factor, a factor for flight class and for CO_2 equivalents are used. These calculations are based upon the model developed by My Climate (2010: 20).

To calculate the per passenger emissions, the CO_2 emissions of the flight are divided by the average number of seats on an aircraft ad multiplied by the load factor. The average number of seats is 155.2 for short haul and 286.2 for long haul. The average load-factor is 70% for short haul and 75% for long haul.

As such the formula for short haul flights is as follows:

CO_2 emissions (passenger) = CO_2 emissions (flight) * 3.15 / (155.2 * 0.70)

and for long haul:

CO_2 emissions (passenger) = CO_2 emissions (flight) * 3.15 / (286.2 * 0.75)

To account for the space required for business and first class seats, a factor is also applied for the class of seat flown. On short haul flights the factors applied are 0.95 (economy), 1.34 (business) and 1.9 (first). On long haul flights, the factors 0.78 (economy), 1.46 (business) and 2.4 (first) are applied.

For a short haul flight, flown business class the formula is as follows:

CO_2 emission (passenger & class flown) = CO_2 emissions (passenger) * 1.34

[3] Atmosfair (2010:3) calculates 3.16

Aviation causes the emission of a number of greenhouse gases (GHG) alongside CO_2. There have been many attempts to quantify the climate effects of these GHG, such as: Radiative Forcing Index - RFI, Absolute Global Warming Potential - AGWP (Fischer et. al. 2009) and Global Temperature Change Potential - GTCP or Integrated Change in Temperature over Time - ICTT (Kollmuss & Crimmins 2009). The first measure, RFI, has the problem that only past emissions are accounted for. The other three measures mentioned, weight the effects of the various greenhouse gases emitted very differently depending on the time period under consideration (i.e. 20, 50 or 100 years). As CO_2 has a comparably long atmospheric life-span, the longer the time frame under consideration, the smaller the factor with which CO_2 emissions are to be multiplied to convert the climate effect of other greenhouse gases (which have shorter atmospheric life-spans) into that of CO_2. Due to these and other uncertainties, there is no generally accepted measure to precisely express the climate effect of aviation in a uniform manner, i.e. CO_2-eq. Kollmuss und Crimmins, have summarized the state of knowledge and recommend multiplying the CO_2 emissions caused by the combustion of kerosene by a factor of (at least) 2, to account for the climate effect of other greenhouse gases:

$CO_{2\text{-eq}}$ emissions (passenger & class flown) = CO_2 emissions (passenger & class flown) * 2

Literature

Association of European Airlines (2010): 2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Available Online: http://www.defra.gov.uk/environment/business/reporting/pdf/101006-guidelines-ghg-conversion-factors.pdf (Accessed: 20.01.2011)

Atmosfair (2010): The Atmosfair emissions calculator. Available Online: https://www.atmosfair.de/fileadmin/user_upload/Medienecke/Downloadmaterial/Rund_um_atmosfair/Documentation_Calculator_DE_2008.pdf (Accessed: 21.10.2010)

European Energy Agency (2010): EMEP/CORINAIR Emission Inventory Guidebook. Group 8: Other mobile sources and machinery. Available Online: http://www.eea.europa.eu/publications/EMEPCORINAIR5/group_08.pdf (Accessed: 15.01.2011)

EUROSTAT (2009): Aircraft traffic data by reporting country. Data Available Online: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=avia_tf_acc&lang=de (Accessed: 20.01.2011)

Fischer, A. et. al. (2009): Flugverkehr und Klimaschutz. Ein Überblick über die Erfassung und Regulierung der Klimawirkungen des Flugverkehrs. *Gaia* 18:1. 32 – 40.

ICAO (2010): ICAO Carbon Emissions Calculator. Available Online: http://www2.icao.int/en/carbonoffset/Documents/ICAO%20MethodologyV3.pdf (Accessed: 15.12.2010)

Kollmuss, A. & Crimmins, A. (2009): Carbon Offsetting & Air Travel – Part 2: Non-CO_2 Emissions Calculations. Stockholm Environment Institute. SEI Discussion Paper. http://www.co2offsetresearch.org/PDF/SEI_Air_Travel_Emissions_Paper2_June_09.pdf (Accessed 20.01.2011)

My Climate (2010): Basis of calculation. Available Online: http://www.myclimate.org/uploads/media/Berechnungsgrundlagen_D.pdf (Accessed: 21.10.2010)