Cargo Carbon Calculator Zurich Airport

ZÜRICH AIRPORT

Contents

1. Introduction

1.1 Carbon management Zurich Airport

The contribution of global aviation to the climate change is relatively small with approximately 2% of all anthropogenic CO_2-emissions. Flughafen Zürich AG as the airport operator is part of the aviation system and commits itself to a climate protecting development of aviation, even if it only takes responsibility for approximately 10% of the CO_2-emissions of the airport system.

Flughafen Zürich AG will further reduce its CO_2-emissions while considering the legal and economic framework at the airport. The airport operator has set the goals to reduce the CO_2-emissions to 30,000 tons in 2020 and to 20,000 tons in 2030. Currently, Flughafen Zürich AG emits approximately 25,400 t of CO_2 in Scopes 1 and 2 (2014).

1.2 Airport Carbon Accreditation stakeholder engagement

Flughafen Zürich AG participates in the ACI EUROPE *Airport Carbon Accreditation* and is currently accredited on Level 3 (on the 3 year renewal cycle). As such, the airport operator is committed to engage with the stakeholders at the airport and to guide or to influence them to address their own carbon emissions accordingly. The total of the Scope 3 emissions (total from origin to destination) is close to 3.5 million tons of CO_2 (in 2014). This includes global air traffic as well as aircraft handling and all surface access traffic for all users of the airport.

1.3 Project

Following discussions with stakeholders from the air freight industry in Switzerland and based on work related to carbon emissions from the cargo operations at Zurich airport [1], Zurich airport undertook to work on a method to quantify carbon emissions from Zurich airport cargo operations not only at the airport or from the aircraft, but along the whole shipment process (door-to-door). The work aims to assist cargo operators to more easily quantify their carbon footprint from air cargo operations through Zurich airport and thus raise awareness about the resulting carbon emissions.

The anticipated goal is to provide robust information and a set of emission indices to be applied to cargo operations from door to door. Such information could then be used to build other assessment tools a like simple carbon calculator or for benchmarking other studies.

2. Cargo Emission Calculation Method

2.1 Cargo shipment process

The simplified cargo shipment process is illustrated in figure 1. This process is the basis for the data collection and emission table development.

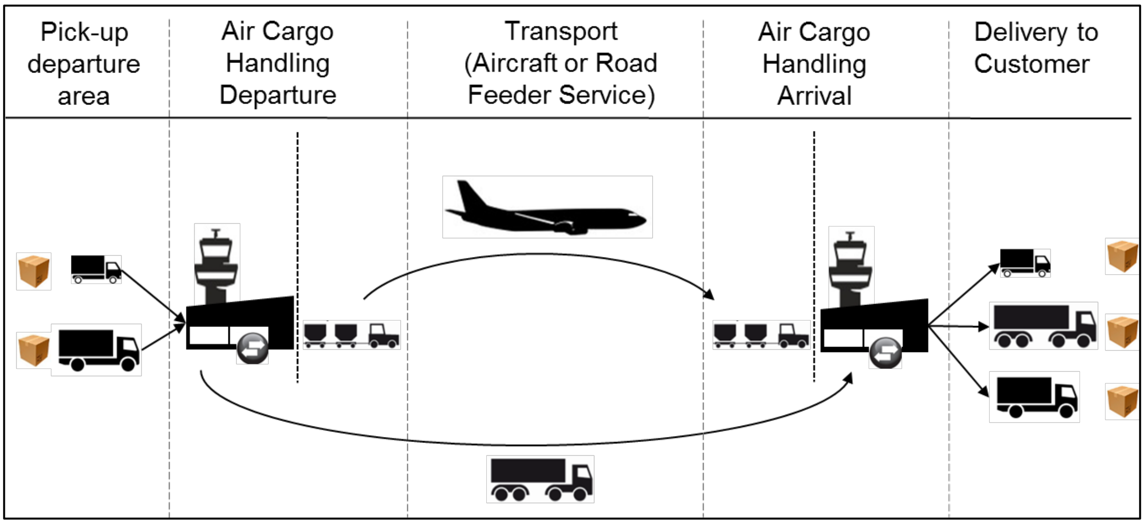

Figure 1 Door-to-door cargo shipment process from Zurich airport

If the shipment process occurs over several intervals, the handling and transport section can be repeated or combined accordingly.

Along the shipment process each step features several parameters that need to be considered. They may not have all the same influence in the final results. Table 1 shows such parameters and their relative contribution to the emissions.

Step	Parameter	Relevance in step	Relevance in full process
Pick up / delivery on site	Vehicle size and technology (truck, delivery van)	+	-
	Trip distance	++	+
	Speed and traffic pattern	-	-
Cargo handling: Infrastructure	Electricity mix (production), refrigeration	++	- -
	Heating (production)	+	- -
Cargo handling: Aircraft	GSE technology and use	-	- -
	Aircraft APU	++	+
Road Feeder Service	Vehicle technology	-	-
	Trip distance	++	+
Aircraft	Engine types	-	-
	Pay load factor	+	+
	Trip distance (incl. airport size for taxi-times)	++	++

++ high; + medium, - little, - - very little relevance

Table 1 Process steps and their relevance

2.2 Methodology and emission data

In order to develop emission factors, the traffic and cargo data 2014 for Zurich airport has been analyzed in detail. Additionally, supplement information from cargo handlers has been considered. For each transport segment, the traffic volume (number of trips per year), the capacity (tons of cargo/mail per flight), the trip length (distance travelled) and the fuel consumption for the trip (according to the means of transport) has been analyzed (see table 2). It has to be noted that virtually all cargo is combined belly-freight with hardly any dedicated cargo flights. To this end, the passenger transport capacity has been divided out.

2.2.1. Regional break down

In order to account for regional disparities (aircraft fleet mix, ground handling), several world regions have been defined and its data evaluated accordingly (figure 2). It is assumed that only for region 1 (Europe) cargo will be transported either by aircraft or trough Road Feeder Service (RFS).

Regions:

1. Europe
2. North America (Western part)
3. North America (Eastern part)
4. South America
5. Central and Southern Africa
6. Middle East and India
7. Asia/Pacific

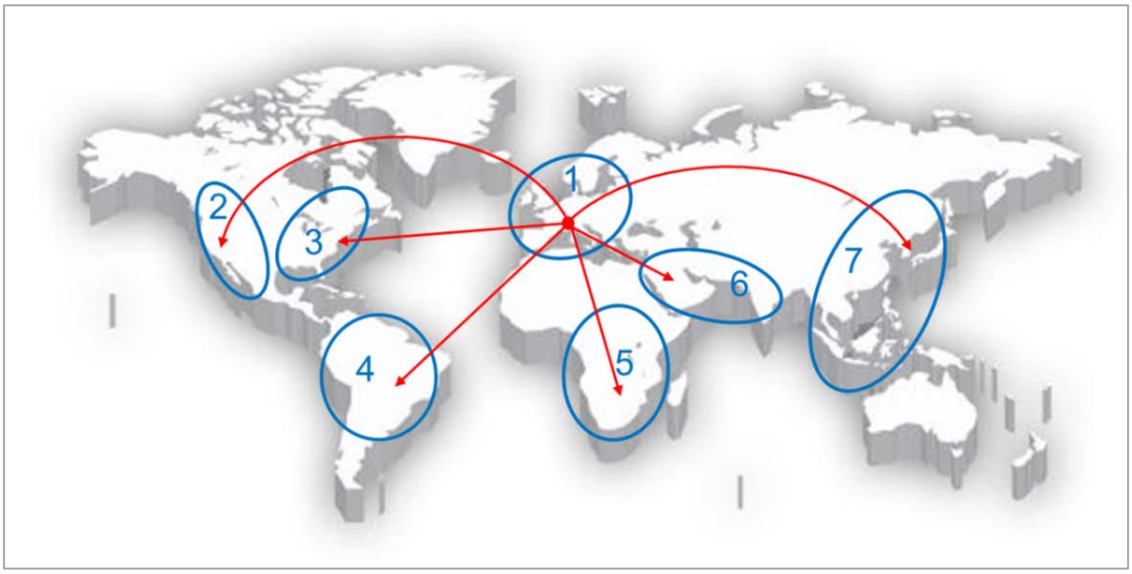

Figure 2 World regions for cargo emission analysis

2.2.2. Methodology description

<table>
<tr><th>Segment</th><th>Activities and Parameters</th><th>Distance / Duration</th><th>Emissions [Ref]</th></tr>
<tr><td>Pick up at origin and delivery at destination</td><td>Vehicle counts of average light duty vehicle (LDV) and truck, considering an average load factor and empty trips.</td><td>Road distance with mix of motorway and local roads (km) and different speeds</td><td>Fuel used per vehicle type, km and road type (t/km) [2]</td></tr>
<tr><td colspan="4">Air cargo handling (trans-shipment):</td></tr>
<tr><td>- Infrastructure</td><td>Heating/cooling and electricity of cargo facilities and installations (including refrigerated storage)</td><td>An average storage / processing time is assumed.</td><td>Heat from central energy plant (90% natural gas/10% oil; CHP) and electricity from public grid (MWh, depends on region)</td></tr>
<tr><td>- Ground handling</td><td>Loading/unloading aircraft, transport to/from cargo facility at airport with tractors (diesel and electric), other GSE (GPU) and aircraft APU. 2/3 of the emissions are attributed to departure and 1/3 to arrival.</td><td>n.a.</td><td>Diesel, CNG and electricity used (t and MWh) for GSE and GPU, kerosene for APU as required (considering some fixed ground power, depending on region).</td></tr>
<tr><td colspan="4">Transport:</td></tr>
<tr><td rowspan="2">- Aircraft</td><td rowspan="2">Actual aircraft mix to region specific destinations with individual engines-aircraft combinations, using the ICAO EEDB; payload calculation according to [7]</td><td rowspan="2">Great circle distance ZRH to destination airport (km) plus a correction factor [6]</td><td>LTO: Performance based LTO-cycle for airports using LASPORT [3]; longer taxi-times for large airports</td></tr>
<tr><td>Cruise: data table by DLR using ANCAT/EC2 and PIANO performance model [4]</td></tr>
<tr><td>- RFS (truck)</td><td>Average 40 ton truck, considering an average load factor and empty trips</td><td>Road distance (motorway and a small part main road) from ZRH to a destination airport (km)</td><td>Fuel used per km and road type (t/km) [2]</td></tr>
</table>

Table 2 Cargo transport methodology description

2.2.3. Aircraft emission methodology

Based on industry assumptions and findings, it is recommended to introduce a correction factor to the great circle distance (GCD) to accommodate for diversions from the GCD [6]. The table below shows the GCD correction factor suggested.

GCD	Correction to GCD
Less than 550 km	+ 50 km
Between 550 km and 5500 km	+ 100 km
Above 5500 km	+ 125 km

Table 3 GCD correction factors (Source: [6])

The information used to calculate the aircraft emission factors are the aircraft types serving the specific destination, the applicable flight block distance and the total payload, consisting of passengers and cargo.

For the calculation of the specific aircraft emission factor, the following equation has been applied:

$$EF_{Region} = \frac{FB_{Flightblock} * EI_{CO2}}{Distance_{Flightblock/Region} * payload} \qquad \text{[Eq. 1]}$$

Where:

EF_{Region} = Emission Factor per world region [kg CO_2/t*km]
$FB_{Flightblock}$ = Total Fuel Burn of aircraft to that region [kg fuel]
EI_{CO2} = Emission index for CO_2 [kg/kg fuel] (cf. table 2)
$Distance_{Flightblock/Region}$ = Distance [km] of flight block per specific world region
Payload[1] = Number of passengers (at 100 kg each),
+ Seat for each passenger (at 50 kg each)
+ Empty seats (assumed at average seat load factor of 90%)
+ Cargo (kg)

The emission for an aircraft cargo shipment to a specific region is calculated using the following equation:

CO_2 [kg] = EF_{Region} [kg CO_2/t*km] * Flight distance (GCD + correction factor) [km] * cargo mass [t] [Eq. 2]

[1] According to Reference [7]

2.2.4. Carbon emission factors

Where possible and depending on available data, the emissions of each segment have been determined by region. Where specific regional data is missing, the same values as for Zurich airport have been used.

Fuel / Energy	CO_2-factor	Comments
Kerosene	3.15 kg CO_2/kg	
Diesel	3.15 kg CO_2/kg	
Electricity	0.022 kg CO_2/kWh_{el} 0.687 0.522 0.252 0.477 0.296 0.221	Switzerland 1 Europe (other) 2/3 North America (East and West) 4 South America 5 Central-/South Africa 6 Middle East 7 Asia / Pacific
Heat (energy plant)	207.9 g CO_2/kWh_{th}	The same for all regions

Table 4 Emission factors for CO_2

2.3 Cargo Carbon Calculator

Based on the specific Zurich airport and industry data, a cargo carbon calculator can be developed. The relevant data and information is detailed in the annexe 1. However, this data only applies for Zurich airport as the origin and for the base year 2014. All transport segments are subject to technological developments and as such, all basic emission factors (e.g. for trucks, GSE or aircraft mix) will change annually. In order to account for regional disparities, several factors have been developed to offer variations (table 5).

	Segment	Selectable options
	Shipment	Weight Refrigerated or not (influences cargo electricity)
	Pick up at origin/destination	Distance Light duty vehicle or truck
	Cargo facility (origin/destination)	Extended storage time (default is 10h)
	Aircraft handling	Region 1-7 (influences APU time and cargo electricity)
	Aircraft LTO	Airport size medium (taxi-emissions as in ZRH) or large (large = taxi emissions are doubled)
	Aircraft cruise	Distance (else average as default)

Table 5 Options for shipment and segments

Calculation example (with data from annexe 1):

"A 200kg unrefrigerated shipment goes by van from Basel City in Switzerland via Zurich Airport in a B767/A330 size aircraft to a tech campus 150 km outside of Boston, USA, delivered by a truck."

	Segment	**Distance (km)**	**Emission factor (g CO_2/tkm or /t)**	**CO_2 emissions (kg)**
	Pick-up Basel – Zurich Airport	90	263.84	4.75
	Cargo facility Zurich airport (departure)	---	4,789	0.96
	Aircraft handling Zurich airport (departure)	---	1,883.6	0.38
	Aircraft APU or GPU (departure)	---	956.14	0.19
	Region 3: LTO-cycle	---	135,921	27.18
	Cruise flight (GCD+corr)	6,152	499.7	614.82
	Aircraft APU or GPU (arrival)	--	2,177	0.44
	Aircraft handling Boston airport (arrival)	---	1,883.6	0.38
	Cargo facility Boston airport (arrival)	---	16,674	3.33
	Delivery Boston to Tech Campus	150	116.84	3.51
	Total CO_2 emissions	**6,392**	**---**	**655.94**

Table 6 Cargo Carbon Calculator example

The summary break down for this example is:

- Pick up/delivery on road: 1.2%
- Trans-shipment at airports: 0.5%
- Aircraft shipment: 98.3%

In order to cover more destination regions than the seven regions indicated in figure 2, it is possible to add additional flight segments as deemed appropriate. For example, a shipment from Zurich to Australia could be covered by a flight segment "region 7" followed by a flight segment "region 6" or a shipment to the Caribbean could be a flight of segments "region 3+ region 1". While the uncertainty of the overall result may increase, it would still be more accurate than simply choosing only the first and closest destination region.

The model provides a best possible estimate. However, due to the many variables, there are three main areas of uncertainties in the model:

- Operational data on distances, load factors, use of vehicle and speed
- Performance based modelling, specifically for the aircraft (LTO and cruise)
- Destination infrastructure and local factors (energy provision, heating/cooling, aircraft handling)

All uncertainties can be reduced in the future by more advanced modelling and improvement of input data.

3. Zurich Airport Cargo Carbon Emission Calculations

Figure 3 shows the total cargo carbon emissions from outbound Zurich airport in 2014. In 2014, a total of 74.6% of export cargo was aircraft transport and only 25.4% was road feeder service (RFS). As expected, the majority of emissions occur during the actual long-haul transport segment, provided it's an aircraft transport. 98% of all emissions of aircraft transported cargo originate from the aircraft itself. For RFS, this amount is only 54%.
On average, aircraft transported cargo amounted to 2,430 kg CO_2/t cargo and 99 kg CO_2/t cargo for RFS respectively. Obviously, road transport emits less CO_2; however, the range of RFS delivered cargo is relatively limited (European destinations only).

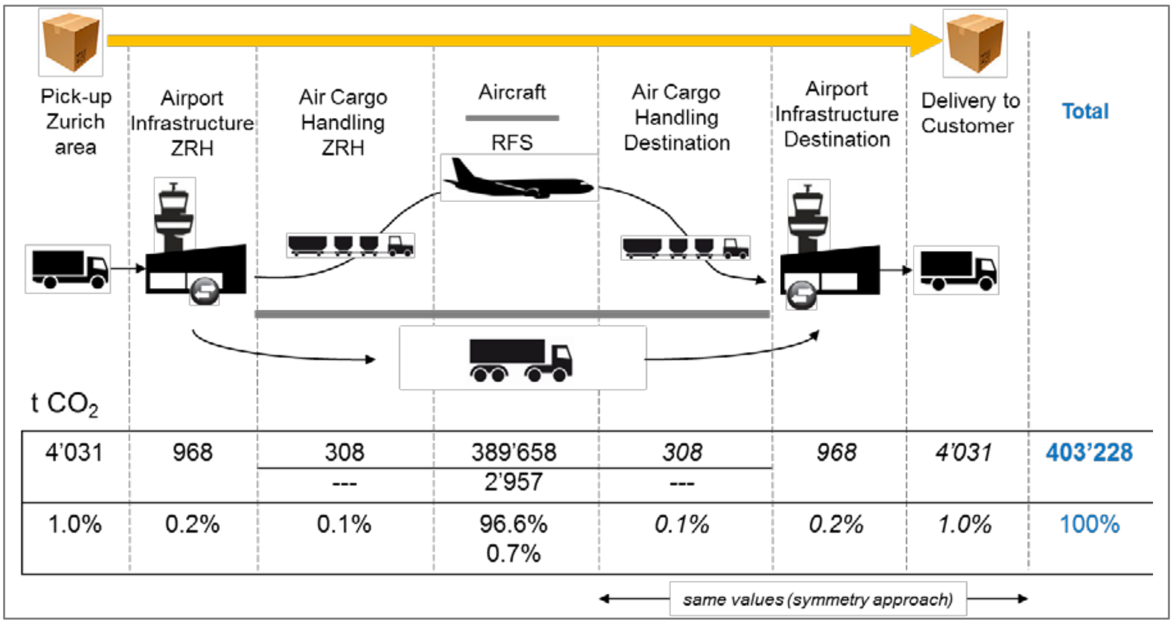

Figure 3 Global outbound Zurich cargo carbon emissions 2014 (export cargo)

With a wide range of data on air traffic and infrastructure available, other calculations can be done according to the information need. Zurich airport calculated the overall cargo operation emissions in 2012, which also included the cargo staff commuting [1].

4. Comparison with other Cargo Carbon Calculators

In order to assess the plausibility and also accuracy of the model, other publicly available carbon calculators have been used. For a limited set of possible cargo shipments, the aircraft emissions have been compared. It has to be noted that none of the other calculators considered include cargo delivery, airport facilities or aircraft handling. As such, only aircraft emissions (LTO and cruise) could be compared.

Cargo shipment (100 kg/1 pax), results in kg CO_2	**Zurich airport cargo calculator (100 kg)**	**United Airlines cargo calculator[2] (100 kg)**	**ICAO carbon calculator[3] (1 Pax)**
Zurich – Boston direct	327	399	384
Zurich – Atlanta via Washington	430	501	527
Zurich – Los Angeles direct	520	634	658
Zurich – Sao Paolo direct	541	639	757
Zurich – Sydney via Hong Kong	903	1,101	1,168
Zurich – Kuwait via Istanbul	230	259	297
Zurich – Johannesburg direct	450	--	658
Zurich – Moscow direct	146	146	159

Table 7 Cargo carbon calculator comparison (aircraft emission only)

The results show a fairly good consistency over the various calculators. In most cases, the differences are 20-25%. Further analysis between the Zurich calculator and ICAO calculator showed lower differences in the actual cruise phase and higher ones during the LTO. This difference can be explained by the use of the performance calculated LTO cycle in Zurich. Performance based calculations usually yield a 25% lower fuel burn than the certification LTO cycle.

Additional differences between the calculators are believed to be based on assumptions of the load factor. In the case of the Zurich calculator, actual 2014 passenger and cargo numbers have been used (fuel burn divided by payload and distance).

Furthermore, some calculated data, especially with specific aircraft/airline derived data, may include additional fuel burn like APU fuel which is sometimes accounted for in the route fuel. This may as well lead to different results.

Conclusions
To this end, the Zurich airport cargo carbon calculator provides a specific, yet quite accurate tool to model cargo emissions along the full shipment process (door-to-door).

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[2] Source: http://co2offsets.sustainabletravelinternational.org/ua/cargo/
[3] Accessed: March 2016

5. Annexe

5.1 Emission factors (Zurich Airport 2014)

Element	Unit	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
World Region		**Europe**	**North-America West**	**North-America East**	**South-America**	**Central- / South-Africa**	**Middle East**	**Asia / Pacific**
Zurich Airport								
Cargo pick up Zurich: Light duty vehicle (LDV)	g CO_2/tkm	262.84						
Truck	g CO_2/tkm	116.84						
Average distance	km	*tbd*						
Cargo facility Zurich Airport	g CO_2/t	4,793	4,793	4,793	4,793	4,793	4,793	4,793
Add-on time (>10h)	g CO_2/t*h	5	5	5	5	5	5	5
Add-on refrigeration	g CO_2/t	182	182	182	182	182	182	182
Add-on extra-time refr.	g CO_2/t*h	18	18	18	18	18	18	18
Aircraft ground handling at Zurich airport (GSE, GPU, APU)[1]	g CO_2/t	4,437	3,220	2,840	3,265	2,967	2,592	3,058
RFS (trucked freight)	g CO_2/tkm	120.9						
Average distance	km	833						
Air Transport from/to Other Airports								
Aircraft ground handling if departure airport (GSE, GPU, APU)[1]	g CO_2/t	4,437	7,035	6,237	7,206	4,675	3,804	3,058
A/C LTO “Medium Apt”	g CO_2/t	108,879	134,630	135,921	135,988	116,955	109,943	146,396
A/C LTO “Large Apt”	g CO_2/t	145,289	180,974	186,960	180,752	153,288	162,804	197,231
Aircraft Cruise	g CO_2/tkm	565.3	517.8	499.7	535.1	507.4	400.8	517.2
Average distance (GCD+corr. factor)	km	1,070	9,603	6,768	9,713	8,761	5,201	9,272
Aircraft ground handling if arrival airport (GSE, GPU, APU)	g CO_2/t	3,161	4,459	4,061	4,545	3,279	2,844	2,471
Cargo facility at trans-fer/ destination airport[2]	g CO_2/t	20,592	16,674	16,674	10,260	15,587	11,291	9,513
Add-on time (>10h)	g CO_2/t*h	169	128	128	62	117	73	54
Add-on refrigeration	g CO_2/t	562	427	427	206	390	242	181
Add-on extra-time refr.	g CO_2/t*h	56	43	43	21	39	24	18
Cargo delivery at desti-nation: LDV	g CO_2/tkm	262.84	262.84	262.84	262.84	262.84	262.84	262.84
Truck	g CO_2/tkm	116.84	116.84	116.84	116.84	116.84	116.84	116.84
Average distance	km	*tbd*	*tbd*	*tbd*	*tbd*	*tbd*	*tbd*	*tbd*

Table 8 Carbon emission factors for cargo process (Zurich Airport, 2014)

[1]The values for departures in Zurich differ from region to region as they reflect the stand position (remote/contact) and the resulting GPU/APU operating times and emissions.
[2]ZRH values are significantly lower due to energy mix

5.2 Abbreviations and glossary

A/C	Aircraft
ACI	Airports Council International
Airside	non-public accessible area of the airport
Apt	Airport
APU	Auxiliary Power Unit (provides electricity and air-conditioning to parked aircraft)
Ave.	Average
CHP	Combined Heat Power plant (providing heat and process energy to facilities)
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CO_{2e}	Carbon dioxide equivalent
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EEDB	Engine Emission Data Base (for aircraft engines >26.7 kN thrust)
GCD	Great Circle Distance (calculated between two points)
GPU	Ground Power Unit (provides electricity to parked aircraft)
GSE	Ground Support Equipment (used to handle cargo to/from parked aircraft)
ICAO	International Civil Aviation Organization
Landside	public accessible area of the airport
LASPORT	LASAT for Airports (local air quality emission and dispersion model)
LDV	Light duty vehicle (total weight 3.5 t; payload 1.0t)
LTO	Landing and Take-off (aircraft movement below 3,000 feet above ground)
MWh	Megawatt hours
Pax	Passenger (as a 100kg equivalent)
RFS	Road Feeder Service (trucked freight)
Scope 1	Direct emissions of Flughafen Zürich AG from its own controlled sources
Scope 2	Indirect emissions of Flughafen Zürich AG from the purchase of electricity
Scope 3	Direct emissions from all users of the Zurich airport system
t	metric ton
ZRH	Zurich Airport, Switzerland
Flightblock	The DLR model gives aircraft type specific FB/km factors depending in the stage length (ascent, cruise, descent); these factors are available for several stage lengths (e.g. 500nm, 1,000nm, etc, up to 5,000nm). For this model, the $FB_{Flightblock}$ of that stage length was selected that correlates best with the actual trip length.

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Figures

Tables

References

No.	Document Name
[1]	Flughafen Zürich AG: CO_2-Emissionen Cargo 2012. May 2013
[2]	Swiss Federal Office for Environment: Handbook on emission factors road traffic. HBEFA, 2.1
[3]	Janicke, Ulf: LASPORT 2.2, on www.janicke.de
[4]	Deutsches Institut für Luft- und Raumfahrt, DLR: CORSTD1 (Excel tables). March 1999
[5]	Airport Council International: ACERT (Airport Carbon Emission Reporting Tool). Version 3.2, May 2016.
[6]	ICAO Cargo Carbon Emissions Calculator Methodology, 2016
[7]	IATA Recommended Practice 1678

Version	Date	Name	Modifications
1.0	22.12.2015	Fleuti / Maraini	First edition
1.1a	04.04.2016	Fleuti / Maraini	Updated edition, reflecting ICAO/IATA information
1.1	27.05.2016	Fleuti / Maraini	Final Report

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