Aviation Asset-level Emission Methodology

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2° investing initiative

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Introduction

Sector background

Global demand for air transport has doubled since 2000 in synchronicity with the sector's emissions. While energy efficiency improved annually by 3.2% from 2000 to 2014, the increasing number of flights off-set these efforts. Therefore, a decoupling of growth in demand and emissions is necessary in the next decades (IEA, 2020).

Moving forward, the absolute volume of passenger-km flown will continue to grow increasing aviation's share of global emissions.

Efficiency is a core cost driver for the aviation sector with fuel comprising 20% of most companies' operating expenses. Reducing a fleet's passenger-km fuel consumption can be achieved through two critical avenues: better fleet utilization and the acquisition of new, more efficient planes. Over the past decades, the average freight load factor and passenger occupancy has increased by 10% to 68% in 2017. And over the past half-century, the fuel consumption per km has declined by 1.3% from 1968 to 2014.

Despite a strong track record of reducing fleet intensity, the sector thus far has focused on marginal innovations over transformational. This reflects the fact that at least in the near term the are no viable low-carbon air-transport alternatives.

Document structure

The 2° Investing Initiative (2DII) developed open-source methodologies to calculate carbon dioxide (CO_2) emissions at the level of an individual asset for eight sectors (aviation, automotive, power, oil & gas, coal, shipping, cement, and steel).

This document describes the methodology step by step and suggests data sources that can be used to apply the methodology to calculate asset-level CO_2 emissions in the aviation sector. Publicly available data sources were used whenever possible. The asset-level activity data is however still largely unavailable in the public domain.

2DII works with its data spin off Asset Resolution (AR) to source asset-level capacity and/or production values and calculate asset-level emissions in the context of its research. AR sources asset-level data from leading industry data providers and carries out complementary research in house. This document gives insights into this asset-level data. Alternative sources can be used provided they comply with the data specifications as set out in the methodology.

Asset Definition

The emission methodology calculates the emission of CO_2 bottom-up for each asset (or aircraft). Aircrafts impact the climate through two key mechanisms: the emission of CO_2 which increase the atmospheric concentration of CO_2; and the emission of water (H_2O) vapor at high altitudes which leads to the formation of condensation trails. The condensation trails warm the atmosphere to a significant, but uncertain degree (Simone et al., 2013).

The emission methodology only accounts for the emission of CO_2 from the combustion of aviation fuel (i.e., scope 1 emissions), which accounts for the lions-share of the sector's emissions. The methodology does not consider scope 2 and 3 CO_2 emissions, such as biofuels' lifecycle emissions (IEA, 2020).

Emissions are calculated for "in service" passenger and freight / cargo aircrafts (see Table 1). Passenger and freight / cargo aviation account for 94% of the sector's fuel consumption (IEA, 2020).

Emission factor unit varies between passenger and freight to reflect the CO_2 emitted per km and unit of service, i.e., tonnes (t) of freight and number of passengers. This reflects a standard industry distinction between tonne-kilometre (TKM), the unit of measurement representing the transport of one tonne of freight by a defined mode of transport over one kilometre, and passenger-kilometre (PKM), the transport of one passenger over one kilometre (IATA, 2020). For passenger aircrafts, the emission methodology does not factor out fuel burn from belly freight.[1]

$$\text{TKM}_{a,f} = \text{Freight}_{\,a,f}\ [\text{t}]\ *\ \text{Flight distance}_{\,a,f}\ [\text{km}]$$

$$\text{PKM}_{a,f} = \text{Passenger}_{\,a,f}\ [\#] * \text{Flight distance}_{\,a,f}\ [\text{km}]$$

Where: a = asset, f = flight

Since rarely do planes operate at full capacity, to derive the PKM or TKM, the plane's maximum take-off weight (MTOW) or total seats must be adjusted to reflect the aircraft's load factor. In 2019, on average, the load-factor of freight aviation was 70% (of the plane's total MTOW) and for passenger aviation, 82% (of the total seats were occupied). The load factor will vary significantly depending on the operator, route, season, and economic conditions. As the aircraft's load factor is the core driver of revenue, operators closely guard flight and route specific load factors (IATA, 2020; ICAO, 2017).

The source of the asset-level data is AR. AR derives asset stock figures from the Cirium and in-house research (Cirium, 2021).

Table 1. Asset definition

Indicator	Definition
Parameter	Asset definition
Unit	Aircraft
Denotation	Asset *a* with technology and technology type
Technology	Passenger or freight aircraft (Cirium, 2021)
Technology Type	EUROCONTROL flight type (i.e., long-haul, medium-haul, and short-haul) (EUROCONTROL, 2021)
Identifier	Aircraft registration
Source	Cirium (2021)

[1] Some airlines will report the CO_2 per PKM excluding the fuel burn from belly freight, while other airlines choose to include belly freight. This methodology includes belly freight, applying a consistent approach to ensure comparability.

Asset-Level Emission Model

Emission Factor

The CO_2 emitted per km varies significantly between different aircraft variants and the flight distance (see Flight Distance). In civil aviation, younger and lighter aircrafts consume less fuel per km and therefore emit less CO_2 per km. Likewise, the take-off landing (LTO) cycle consumes more fuel per km than the aircraft's cruising sequence. Generally, the longer the flight distance, the lower the fuel burn-rate per km (ICAO, 2017). For passenger aircraft, the asset's annual emission factor is calculated as follows:

$$\text{Emission factor}_{a,y}\left[\frac{\text{t CO}_2}{\text{PKM}}\right] = \frac{\text{Emissions}_{a,y}\,[\text{t CO}_2]}{\left(\text{Load factor}_{a,y}\,[\%] * \text{Total seats}_{a}\,[\#] * \text{Flight distance}_{a,y}\,[\text{km}]\right)}$$

Where: a = asset, y = year, PKM = passenger-kilometre

For freight aircraft, the asset's annual emission factor is calculated as follows:

$$\text{Emission factor}_{a,y}\left[\frac{\text{t CO}_2}{\text{TKM}}\right] = \frac{\text{Emissions}_{a,y}\,[\text{t CO}_2]}{\left(\text{Load factor}_{a,y}\,[\%] * \text{MTOW}_{a}\,[\text{t}] * \text{Flight distance}_{a,y}\,[\text{km}]\right)}$$

Where: a = asset, y = year, MTOW = maximum take-off weight, TKM = tonne-kilometre

Absolute Emissions

The asset's annual emissions are calculated as such:

$$\text{Emissions}_{a,y}\,[\text{t CO}_2] = \sum_{a,y} \text{Fuel emission factor}_{a,d}\left[\frac{\text{t CO}_2}{\text{km}}\right] * \text{Flight distance}_{a,d,y}\,[\text{km}]$$

Where: a = asset, d = distance category, y = year

Table 2. Load factor

Indicator	Definition
Parameter	Load factor
Unit	%
Scope	Scope 1
Denotation	Load factor of the total freight or passenger capacity
Value applied	e.g., 80%
Granularity	Global-level
Source	IATA (2020)

Table 3. Maximum take-off weight

Indicator	Definition
Parameter	Maximum take-off weight
Unit	t
Scope	Scope 1
Denotation	Maximum take-off weight
Value applied	e.g., 25000
Granularity	Asset-level
Source	Cirium (2021)

Table 4. Total seats

Indicator	Definition
Parameter	Total seats
Unit	#
Scope	Scope 1
Denotation	Total seats of the asset
Value applied	e.g., 255
Granularity	Asset-level
Source	Cirium (2021)

Flight Distance

Aircraft flight data can be readily sourced from commercial providers and to a lesser degree from public data sources. The flight distance is calculated using the greater circle distance (GCD) formula (i.e., the shortest distance between two points on the surface of a sphere). To adjust for standard landing and take-off (LTO) procedures, correction factors are added to the flight's distance (see Annex) (ICAO, 2017).

For each aircraft, per distance category the cumulative distance flown per year is calculated. The different distance categories enable the distinction between the different fuel consumption factors. The longer the flight, the more efficient the fuel consumption factor (see Fuel Emission Factor). The annual distance flown by the asset is calculated as follows:

$$\text{Flight distance}_{a,d,y}[\text{km}] = \sum_{a,d,y} \text{Flight distance}_{a,f,d}[\text{km}] + \text{LTO correction}_{d}[\text{km}]$$

Where: a = asset, f = flight, d = distance category, y = year, LTO correction = Landing and take-off correction

Table 5. Flight distance

Indicator	Definition
Parameter	Flight distance
Unit	km
Scope	Scope 1
Denotation	Greater circle distance between the flight's origin and destination
Value applied	e.g., 10000
Granularity	Asset-level
Source	Cirium (2021)

Table 6. LTO correction

Indicator	Definition
Parameter	Landing and take-off correction
Unit	km
Scope	Scope 1
Denotation	Flight distance correction to account for landing and take-off sequences
Value applied	e.g., 100
Granularity	Asset-level
Source	ICAO (2017)

Fuel Emission Factor

The fuel consumptions factors were sourced from the International Civil Aviation Organization (ICAO, 2017). While the marginal intensity varies for every flight, aircraft fuel consumption figures, in the public domain, are aggregated over distance categories, e.g., a 737 over the flight distance 1000 km consumes 5.3 kg fuel per km. The more precise the distance category, the more accurate the fuel consumption per km. For each aircraft model, the ICAO provides fuel consumption figures for up to twenty-five distance categories (ICAO, 2017).[2] The asset's fuel emission factor is calculated as follows:

$$\text{Fuel emission factor}_{a,d}\left[\frac{\text{t CO}_2}{\text{km}}\right] = 0.00316\left[\frac{\text{t CO}_2}{\text{t fuel}}\right] * \text{Fuel consumption factor}_{a,d}\left[\frac{\text{t fuel}}{\text{km}}\right]$$

Where: a = asset, d = distance category, 3.16 = constant representing the number of tonnes of CO_2 emitted by burning a tonne of aviation fuel (IPCC, 2006).

Table 7. Fuel consumption factor

Indicator	Definition
Parameter	Fuel consumption factor
Unit	t aviation fuel per km
Scope	Scope 1
Denotation	Fuel consumption factor per flight distance category and aircraft model
Value applied	e.g., 4.83
Granularity	Asset-level
Source	ICAO (2017)[3]

[2] ICAO (2017) fuel consumption figures converted from kg aviation fuel per nautical mile to kg aviation fuel per km.

Outlook and Limitations

The asset-level emission model develops key indicators, the emission factor and the absolute emissions, to assess the CO2 emissions in the aviation sector. A limitation of this methodology is absence of aircraft or fleet specific load factors. Further work on improving the emission model, including more granular load-factors, fuel consumption figures for the next generation of aircraft, and benchmarking against external sources and methodologies is underway.

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