

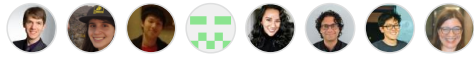
About

Emission estimation model for flights

travelimpactmodel.org/

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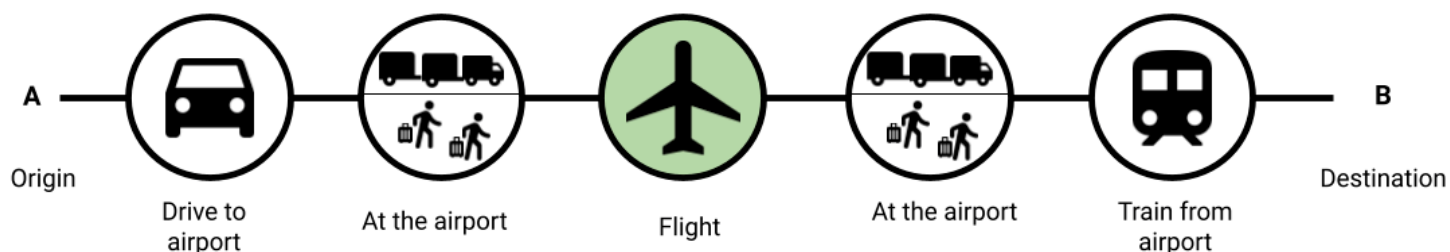
Travel Impact Model 3.0.0

<http://www.travelimpactmodel.org>

Background

In this document we describe the modeling assumptions and input specifications behind the Travel Impact Model (TIM), a state of the art emission estimation model that Google's Travel Sustainability team has compiled from several external data sources. The TIM predicts greenhouse gas (GHG) emissions for future flights to help travelers plan their travel.

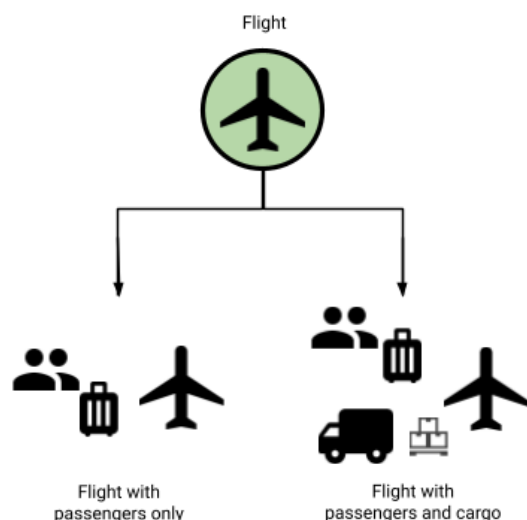
ISO 14083 defines a user's travel journey from when they leave their origin (point A) to when they arrive at their destination (point B). Figure 1^[1] below illustrates an example of a user's travel journey. To calculate the total emissions of this user's journey, ISO 14083 recommends summing up the emissions produced by each individual piece of the journey. In this example, it includes the emissions created driving to the airport, the emissions to run the origin airport, the flight's emissions, the emissions to run the destination airport, and the train's emissions to the user's destination. The Travel Impact Model only estimates the flight's emissions, highlighted in green.



(Figure 1^[2])

As shown in Figure 2^[3], the TIM supports two types of flights:

- multi-class flights with passengers
- multi-class flights with passengers and cargo



(Figure 2^[4])

Model overview

The TIM is a model^[5] designed to estimate GHG emissions generated from an aircraft transporting passengers with or without cargo from an origin to destination. For each flight, the TIM considers several factors, such as an estimate of the distance flown between the origin and destination airports, and the aircraft type being used for the route. Actual GHG emissions at flight time may vary depending on factors not known at modeling time, such as speed and altitude of the aircraft, the actual flight route, and weather conditions at the time of flight.

Flight level emission estimates

Flight level CO₂e estimates

The Travel Impact Model estimates fuel burn based on the Tier 3 methodology for emission estimates from the [Annex 1.A.3.a Aviation 2023](#) published by the European Environment Agency (EEA).

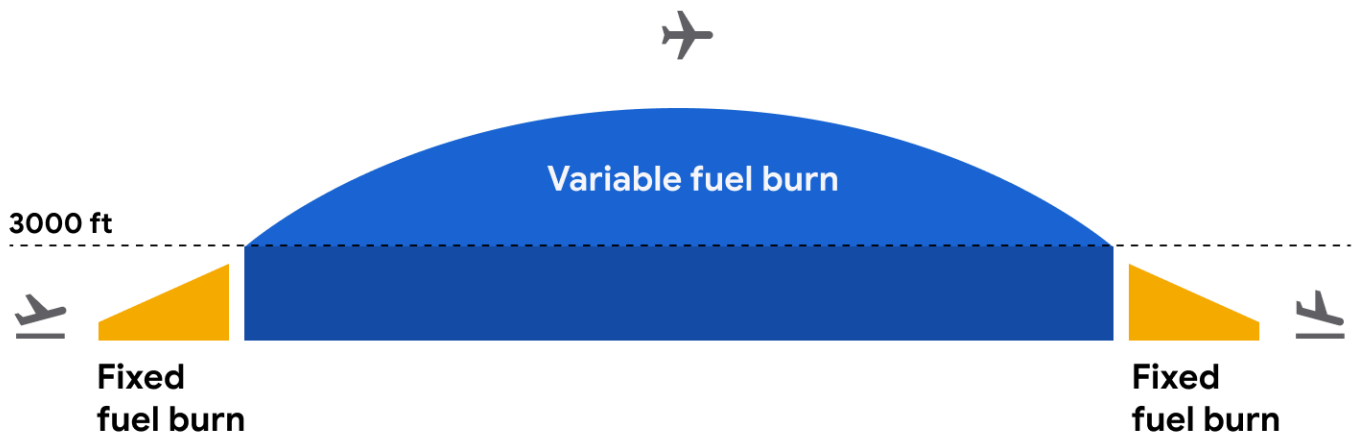
There are several resources about the EEA model available:

- the main [documentation](#)
- the [data set](#)
- further [documentation](#) on pre-work for the EEA model

Additionally, the Travel Impact Model uses the fuel burn to emissions conversion factor to align with the [ISO 14083](#) Fuel Heat Combustion factor and [CORSA Life Cycle Assessment](#)^[6], and breaks down emissions estimates into Well-to-Tank (WTT) and Tank-to-Wake (TTW) emissions.

Tank-to-Wake emissions account for emissions produced by burning jet fuel during flying, take-off and landing. Well-to-Tank emissions account for emissions generated during the production, processing, handling and delivery of jet fuel. Well-to-Wake (WTW) emissions is the sum of Well-to-Tank (WTT) and Tank-to-Wake (TTW) emissions.

The EEA model takes the efficiency of the aircraft into account. As shown in Figure 3, a typical flight is modeled in two stages: *take off and landing* (LTO, yellow) and *cruise, climb, and descend* (CCD, blue).



(Figure 3)

For each stage, there are aircraft-specific and distance-specific fuel burn estimates. Table 1 shows an example fuel burn forecast for a Boeing 787-9 (B789) aircraft:

Aircraft	Distance (NM)	LTO fuel forecast (kg)	CCD fuel forecast (kg)
B789	500	1638	5852
B789	1000	1638	10874
B789
B789	5000	1638	52962
B789	5500	1638	58072

(Table 1)

By using these numbers together with linear interpolation or extrapolation, it is possible to deduce the emission estimate for flights of any length on supported aircraft:

- Interpolation is used for flights that are in between two distance data points. As a theoretical example, a 5250 nautical miles (NM) flight on a Boeing 787-9 will burn approximately 55517 kg of fuel during the CCD phase (where 55517 equals $52962 + (58072 - 52962)/2$, with figures for 5000 NM and 5500 NM taken from Table 1).
- Extrapolation is used for flights that are either shorter than the smallest supported distance, or longer than the longest supported distance for that aircraft type.
- The Lower Heating Value from ISO 14083 (43.1 MJ/kg for jet kerosene averaged over EU and US numbers from [source](#) Table K.1 and Table K.3 respectively) and CORSIA Carbon Intensity value (74 gCO₂e/MJ from [source](#) Table 5) are used to calculate the jet fuel combustion to CO₂e conversion factor of 3.1894. The CORSIA Life Cycle Assessment methodology is used to calculate a WTT CO₂e emissions factor of 0.6465 (WTT 15g CO₂e/MJ added to the TTW 74 gCO₂e/MJ Carbon Intensity to total up to the WTW lifecycle Carbon Intensity of 89 gCO₂e/MJ from [source](#) page 24 and Table 7). The factors used are as follows:

Life Cycle Stage	Carbon Intensity Value from CORSIA (g CO ₂ e/MJ)	Lower Heating Value from ISO 14083 (MJ/kg)	Factor (kg CO ₂ e/kg)
Tank-To-Wake (TTW)	74	43.1	3.1894 (= 74 * 43.1 / 1000)
Well-To-Tank (WTT)	15 (= 89 - 74)	43.1	0.6465 (= 15 * 43.1 / 1000)
Well-To-Wake (WTW)	89	43.1	3.8359 (= 89 * 43.1 / 1000)

CO₂e is short for CO₂ equivalent and includes Kyoto Gases (GHG) as described [here](#). Warming effects produced by short-lived climate pollutants and contrail-induced cirrus clouds are not yet included in CO₂e as calculated by the Travel Impact Model. We are working with our stakeholders in the [governance body](#) to add non-CO₂ effects to the model.

There is information for most commonly-used aircraft types in the EEA data, but some are missing. For missing aircraft types, one of the following alternatives is applied in ranked order:

- *Supported by winglet/sharklet correction factor:* For all aircraft (with a corresponding IATA code) with a winglet or sharklet variant for which no native data exists (see [Appendix A](#)), a 3% discount factor will be applied on top of EEA estimates. The correction factor will be applied to the LTO and CCD numbers of the comparable type in the EEA database. We are basing the 3% factor on a literature review as a conservative estimate ([Airbus](#), [AviationBenefits](#), [Boeing](#), [Cirium](#), [NASA](#), [SimpleFlying](#)).
- *Supported by fallback to previous generation aircraft type:* If there are estimates in the EEA data set for a previous generation aircraft type in the same family, from the same manufacturer, the previous generation aircraft is used for the estimate.
- *Supported by fallback to least efficient aircraft in the family:* For umbrella codes that refer to a group of aircraft, the least efficient aircraft in the family will be assumed.
- *Supported by fallback to similar aircraft type:* If there are estimates in the EEA data set for a similar aircraft, it is used for the estimate.
- *Not supported:* For aircraft types for which none of the cases above apply, there are no emissions estimates available.

See [Appendix A](#) for a table with detailed information about aircraft type support status.

Distance adjustment

Actual flight paths are usually longer than the great-circle distance (GCD) between origin and destination airport due to several factors, like the flown route, airport congestion, airspace restrictions, and bad weather avoidance.

The TIM includes distance adjustment factors based on historical flight tracking data from ADS-B. These adjustment factors were developed at Imperial College London by [Teoh et al.](#) who found that on average, the actual distance flown is roughly 5% higher than the great-circle distance, and that this percentage varies across regions and routes. The data cleaning approach is described [here](#).

The distance adjustment is performed as follows:

1. If available, apply the [route-based adjustment factor data](#) for the given origin airport and destination airport. This factor represents the ratio between the average flown distance on the route and its great-circle distance.
2. Otherwise, if available, apply the [country-based adjustment factor data](#) for the given origin airport country and destination airport country. This factor represents the ratio between the average flown distance for all flights between the origin airport country and destination airport country and their corresponding great-circle distances.
3. Otherwise, in the rare case where no adjustment factor is available, apply a factor of 1.052 which represents the mean lateral inefficiency increase (+5.2%) for 2019 data from [Teoh et al.](#) (see page 18), which is used for the distance adjustment factor.

Data sources

Used for flight level emissions:

- EMEP/EEA air pollutant emission inventory guidebook 2023 Annex 1 version v1.5_18_09_2024 ([link](#))
- Teoh et al., The high-resolution Global Aviation emissions Inventory based on ADS-B (GAIA) for 2019 - 2021: Origin-destination statistics ([link](#))
- CORSIA Eligible Fuels Life Cycle Assessment Methodology ([link](#))
- ISO 14083 ([link](#))

Breakdown from flight level to individual level

In addition to predicting a flight's emissions, it is possible to estimate the emissions for an individual passenger on that flight. To perform this estimate, it's necessary to perform an individual breakdown based on three relevant factors:

1. Number of total seats on the plane in each seating class (first, business, premium economy, economy)
2. Number of occupied seats on the plane
3. Amount of cargo being carried

The emission estimates are higher for premium economy, business and first seating classes because the seats in these sections take up more space. As a result, those seats account for a larger share of the flight's total emissions. Different space allocations on narrow and wide-body aircraft are considered using separate weighing factors.

Data sources

Used to determine which aircraft type was used for a given flight:

- Aircraft type from published flight schedules

Used to determine seating configuration and calculate emissions per available seat:

- Aircraft Configuration/Version (ACV) from published flight schedules
- Fleet-level aircraft configuration information from the "Seats (Equipment Configuration) File" provided by [OAG](#)

Primary fallback for missing seat configuration

If there are no individual seat configuration numbers for a flight available from the published flight schedules, we query the fleet-level seating data for a unique match by carrier and aircraft. This is only possible in cases where a carrier uses the same seating configuration for all their aircraft of a certain aircraft model.

Outlier detection and basic correctness checking

If there are no individual seat configuration numbers for a flight available from the published flight schedules, nor from the fleet-level data, or if they are incorrectly formatted or implausible, the TIM uses aircraft-specific medians derived from the overall dataset instead. Basic correctness checks based on reference seat configurations for the aircraft are performed, specifically:

- The *calculated total seat area* for a flight is the total available seating area. This is calculated based on seating data and seating class factors. For example, the total seat area for a wide-body aircraft would be:

$$\begin{aligned}
 &1.0 * \text{num_economy_class_seats} + \\
 &1.5 * \text{num_premium_economy_class_seats} + \\
 &4.0 * \text{num_business_class_seats} + \\
 &5.0 * \text{num_first_class_seats}
 \end{aligned}$$



- The *reference total seat area* for an aircraft is roughly the median total seat area.
- During a *comparison* step: If the *calculated total seat area* for a given flight is within certain boundaries of the reference for that aircraft, the filed seating data from published flight schedules is used. Otherwise the *reference total seat area* is used.

Factors details

Seating class factors

Seating parameters follow [IATA RP 1726](#). An analysis of seat pitch and width in each seating class in typical plane configurations confirmed the accuracy of these factors.

Cabin Class	Narrow-body aircraft	Wide-body aircraft
Economy	1	1
Premium Economy	1	1.5
Business	1.5	4
First	1.5	5

Cargo mass fraction

Belly cargo carried on passenger flights is a contributor to total emissions. We apportion emissions by mass. The cargo mass fraction (CMF) is defined as the cargo mass divided by total payload, which is defined as the sum of cargo mass and passenger mass. Passenger mass (including passenger's baggage) is approximated by multiplying the number of passengers by 100kg, as defined in ISO 14083, Section A.4.2.

As the cargo mass fraction determines the amount of emissions apportioned to belly cargo, the remainder is apportioned to passengers. The TIM uses a tiered approach to determine cargo mass fraction. High resolution, specific data (i.e. by carrier, route, and aircraft class) is preferred where available, and in the absence of more granular data the model falls back to coarser aggregations when no suitable high resolution options are available.

For consistency with passenger load factors, we also exclude March 2020 to February 2022, due to the effects of the COVID-19 pandemic.

Tier 1: Highly specific cargo mass fraction

- Where data is available for a given carrier, route, and aircraft class (distinguishing narrowbody and widebody aircraft), use the average cargo mass fraction over the last 6 years.
- Where data is available for the given route and aircraft class, but not the specific carrier, use the average cargo mass fraction across all carriers over the last 6 years.
- If fewer than 2000 flights are available for averaging, we do not calculate an average and instead fallback to the "Coarse cargo mass fraction tier" described below.

Tier 2: Coarse cargo mass fraction

- Where specific data is not available, use average cargo mass fraction data, matching distance band and aircraft class over the last 6 years.
- Distance bands are defined in 1000 km intervals, i.e. distances 1 km to 1000 km, 1001 km to 2000km, etc., are grouped together. The distance is determined between origin and destination using the great-circle distance.

The TIM uses historical data provided by the U.S. Department of Transportation Bureau of Transportation Statistics to determine cargo mass fraction values. The coarse aggregations by distance band and aircraft class are also used to forecast cargo carried for flights outside the United States.

Load factors

Passenger load factors are predicted based on historical passenger statistics. The TIM uses a tiered approach to determine passenger load factors. High resolution, specific data (i.e. by route) is preferred where available, and in the absence of more granular data, the model falls back to a generic value (i.e. global default).

Tier 1: Highly specific passenger load factors

1. For flights within, to, and from the United States and its territories, we consider the T-100 historical dataset from the [US Department of Transportation Bureau of Transportation Statistics](#) (see below for more details).
 - When the data is available for a given carrier, route, and month of travel, we calculate the aggregate passenger load factors, looking back up to six years.
 - When the data is available for a given carrier and month of travel, but not the specific route, we use the average passenger load factor across all the routes, up to six years back.
 - If fewer than three years of data are available, we consider ch-aviation load factors described below.
2. For all other flights, we consider the historical load factor data provided by [ch-aviation](#):
 - When the data is available for a given carrier and month of travel, we calculate the aggregate passenger load factors, looking back up to six years.
 - If fewer than three years of data are available, we use the global average fallback value instead as described below ("*Global default passenger load factor*").

Tier 2: Global default passenger load factor

- For all other flights for which an equivalent public-domain dataset with similar granularity is not currently available, the TIM falls back to use a load factor value of **84.5%**. This value is derived from [historical data for the U.S.](#) from 2019.
- An analysis of load factors sourced from publicly available airline investor reports indicates that this value is a good approximation for the passenger load factor globally.

Load factor data source specifics

- Only data from the last six years is used.
- Data is updated on a monthly basis (TIM version number will not increase).
- Any month of data for which the overall load factor (aggregated over all airlines and routes) differs more than 10% from the average load factor since 2017 is removed as an outlier month. March 2020–February 2022 (inclusive) are removed from the data as a result.
- To account for patterns of seasonality that do not correspond with the exact month of travel (e.g. public holidays), the previous and next month are taken into account for the average load factor of any given month of travel. E.g. For future flights in March, we aggregate over all flights in February, March, and April.

Example emission estimation

For this example, we'll use a flight from Zurich (ZRH) to San Francisco (SFO) on a Boeing 787-9 aircraft with the following seating configuration.

Cabin Class	Seats
Economy	188
Premium Economy	21
Business	48
First	0

To get the total emissions for the flight, let's follow the process below:

1. Calculate great-circle distance between ZRH and SFO: 9369 km (= 5058.9 nautical miles (NM))
2. Look up the static LTO numbers and the distance-based CCD number from aircraft performance data (see Table 1), and interpolate fuel burn for a 9369 km long flight:
 - LTO 1638 kg of fuel burn
 - CCD 54802 kg of fuel burn calculated like this and rounded:
 - Apply distance adjustment factor as described [here](#) to determine adjusted distance: $5058.9 * 1.0273 = 5197.00797$ NM
 - The EEA model assumes that the aircraft travels 17 NM of the complete distance of the flight during the LTO cycle. Subtract 17 NM from the adjusted distance to account for the distance travelled in the LTO phase: $5197.00797 - 17 = 5180.00797$ NM = 5180 NM (rounded)
 - Calculate the fuel burn for 5180 NM by interpolating between the known fuel burn values at 5000 NM (52962 kg) and 5500 NM (58072 kg): $52962 \text{ kg} + (5180 \text{ NM} - 5000 \text{ NM}) * (58072 \text{ kg} - 52962 \text{ kg}) / (5500 \text{ NM} - 5000 \text{ NM}) = 54801.6 \text{ kg}$
3. Sum LTO and CCD number for total flight-level result (rounded): $1638 \text{ kg} + 54802 \text{ kg} = 56440 \text{ kg}$ of fuel burn
4. Convert from fuel burn to CO₂e emissions for total flight-level result:
 - Well-to-Tank (WTT) emissions in kg of CO₂e (rounded): $56440 * 0.6465 = 36488$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e (rounded): $56440 * 3.1894 = 180010$
 - Well-to-Wake (WTW) emissions in kg of CO₂e (rounded): $(56440 * 0.6465) + (56440 * 3.1894) = 216498$

Once the total flight emissions are computed, we apportion emissions between belly cargo and passengers:

1. Use the cargo mass fraction of 8% to apportion 8% of the emissions to belly cargo, and correspondingly 92% of emissions to passengers. All values rounded to kg.
 - Well-to-Tank (WTT) cargo emissions in kg of CO₂e: $36488 * 0.08 = 2919$
 - Tank-to-Wake (TTW) cargo emissions in kg of CO₂e: $180010 * 0.08 = 14401$
 - Well-to-Wake (WTW) cargo emissions in kg of CO₂e: $216498 * 0.08 = 17320$
 - Well-to-Tank (WTT) passenger emissions in kg of CO₂e: $36488 * 0.92 = 33569$
 - Tank-to-Wake (TTW) passenger emissions in kg of CO₂e: $180010 * 0.92 = 165609$
 - Well-to-Wake (WTW) passenger emissions in kg of CO₂e: $216498 * 0.92 = 199178$

Once the total flight emissions are computed, let's compute the per passenger break down:

1. Determine which seating class factors to use for the given flight. In the ZRH-SFO example, we will use the wide-body factors (Boeing 787-9).

2. Calculate the equivalent capacity of the aircraft according to the following

$$C = \text{first_class_seats} * \text{first_class_multiplier} + \\ \text{business_class_seats} * \text{business_class_multiplier} + \dots$$

In this specific example, the estimated area is:

$$0 * 5 + 48 * 4 + 1.5 * 21 + 188 * 1 = 411.5$$

3. Divide the total CO₂e emissions by the equivalent capacity calculated above to get the CO₂e emissions per economy seat.

- Well-to-Tank (WTT) emissions in kg of CO₂e: $33569 / 411.5 = 81.577$
- Tank-to-Wake (TTW) emissions in kg of CO₂e: $165609 / 411.5 = 402.452$
- Well-to-Wake (WTW) emissions in kg of CO₂e: $81.577 + 402.452 = 484.029$

4. Emissions per seat for other cabins can be derived by multiplying by the corresponding cabin factor.

- First:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $81.577 * 5 = 407.885$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $402.452 * 5 = 2012.26$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $484.029 * 5 = 2420.145$
- Business:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $81.577 * 4 = 326.308$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $402.452 * 4 = 1609.808$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $484.029 * 4 = 1936.116$
- Premium Economy:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $81.577 * 1.5 = 122.366$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $402.452 * 1.5 = 603.678$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $484.029 * 1.5 = 726.044$
- Economy:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: 81.577
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: 402.452
 - Well-to-Wake (WTW) emissions in kg of CO₂e: 484.029

5. Scale to estimated load factor 0.845 by apportioning emissions to occupied seats. This results in per-passenger emissions:

- First:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $407.885 \text{ kg} / 0.845 = 482.704 \text{ kg}$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $2012.26 \text{ kg} / 0.845 = 2381.373 \text{ kg}$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $2420.145 \text{ kg} / 0.845 = 2864.077 \text{ kg}$
- Business:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $326.308 \text{ kg} / 0.845 = 386.163 \text{ kg}$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $1609.808 \text{ kg} / 0.845 = 1905.098 \text{ kg}$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $1936.116 \text{ kg} / 0.845 = 2291.262 \text{ kg}$
- Premium Economy:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $122.366 \text{ kg} / 0.845 = 144.812 \text{ kg}$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $603.678 \text{ kg} / 0.845 = 714.412 \text{ kg}$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $726.044 \text{ kg} / 0.845 = 859.224 \text{ kg}$
- Economy:
 - Well-to-Tank (WTT) emissions in kg of CO₂e: $81.577 \text{ kg} / 0.845 = 96.541 \text{ kg}$
 - Tank-to-Wake (TTW) emissions in kg of CO₂e: $402.452 \text{ kg} / 0.845 = 476.275 \text{ kg}$
 - Well-to-Wake (WTW) emissions in kg of CO₂e: $484.029 \text{ kg} / 0.845 = 572.815 \text{ kg}$

Note that the model generates emission estimates for all cabin classes, including cabin classes where the seat count is zero, as cabin classifications are not always consistent across data providers. Therefore, providing estimates for all cabin classes simplifies integration of the TIM's data with other datasets.

In cases where flight emissions data is sourced from the EASA [flight emissions label](#), estimates will not be generated for any cabin class not explicitly included in the label.

Contrails impact prediction

The Travel Impact Model estimates the contrail warming impact potential per flight. This impact is communicated through classifications, or "buckets," which represent the warming impact relative to the fuel burn emissions for that specific flight.

Caveats and limitations

Contrail formation and their resulting warming effects are highly dependent on specific weather conditions on the day of a flight. Specifically, contrail formation is heavily influenced by atmospheric humidity, temperature, and wind conditions at high altitudes. This makes precise predictions impossible at the time of booking. Therefore, the contrail impact information we provide can only represent the potential risk of contrail warming for a given flight.

To overcome this predictive challenge, we analyze extensive historical meteorological data alongside past aircraft flight paths, identifying recurring geospatial and temporal patterns related to contrail formation. These patterns are then applied to future flight schedules, generating an estimated range of potential warming. Our model achieves this by first calculating the warming impact if contrails were to persist, and then multiplying this by the probability that persistent contrails will actually form for a given flight. While this estimate lacks the precision to predict the exact outcome of a specific flight, it provides a reliable directional trend when the impact of that flight is considered over a broader timeframe, such as a year or season.

That's how the Travel Impact Model (TIM) provides customers with emissions information at the time of booking a flight that is happening in the future.

Contrail warming impact is categorized into relative impact levels ("buckets") compared to the fuel burn emissions for the flight. This means that the contrail impact is assessed in comparison to the warming effect of the carbon dioxide released from burning fuel.

Recommended best practices

- 1. Acknowledge Uncertainty:** When presenting contrail impact levels to users, emphasize that these levels represent the risk of contrail warming. For example, use phrases like:
 - "Risk of high contrail impact"
 - "High likelihood of contrail warming impact."
 - "Moderate potential for contrail warming"
- 2. Keep Contrail Impact Separate from Fuel Burn Emissions:** Avoid combining these metrics into a single value. Due to the inherent uncertainty in contrail warming impact, it's not yet possible to create a combined metric that is both accurate and easily understandable for users.
- 3. Consider Both Contrail Impact and Fuel Burn:** Do not rely solely on contrail impact levels when making decisions. Both fuel burn and contrail impact contribute significantly to climate impact and should be taken into account. Because fuel burn impact is currently more predictable, it should remain the main impact factor communicated.
- 4. Avoid CO₂e Conversion:** Do not convert contrail impact levels into a CO₂e value. This can create a misleading impression of precision. It's best to represent contrail warming impact using the established impact level categories.
- 5. Aggregate for Multi-Leg Journeys:** For trips with multiple flights, you can combine contrail impact levels relative to each flight's fuel burn. Since the contrail impact is relative to fuel burn emissions, the values can be aggregated for multi-leg flights. It is recommended to use the mean relative impact of each bucket range for computing this aggregate. Since the highest impact category has no upper limit, a value of 1.2 is used as a representative mean for calculations to ensure a consistent and conservative approach.

Example 1

Bucket ranges: LOW [0.0, 0.2), MODERATE [0.2, 1.0), HIGH [1.0, ∞)

Flight A: fuel burn = 100 kg CO₂e, contrail impact = LOW



Flight B: fuel burn = 50 kg CO2e, contrail impact = HIGH

$$\begin{aligned} \text{Aggregate} &= (100\text{kg} * (0.1 \text{ for LOW}) + 50\text{kg} * (1.2 \text{ for HIGH})) / (\text{total fuel burn}) \\ &= 70\text{kg} / 150\text{kg} \\ &= 0.4667 \end{aligned}$$

Aggregate classification: MODERATE contrail impact bucket

Example 2

Bucket ranges: LOW [0.0, 0.2), MODERATE [0.2, 1.0), HIGH [1.0, ∞)

Flight A: fuel burn = 50 kg CO2e, contrail impact = MODERATE

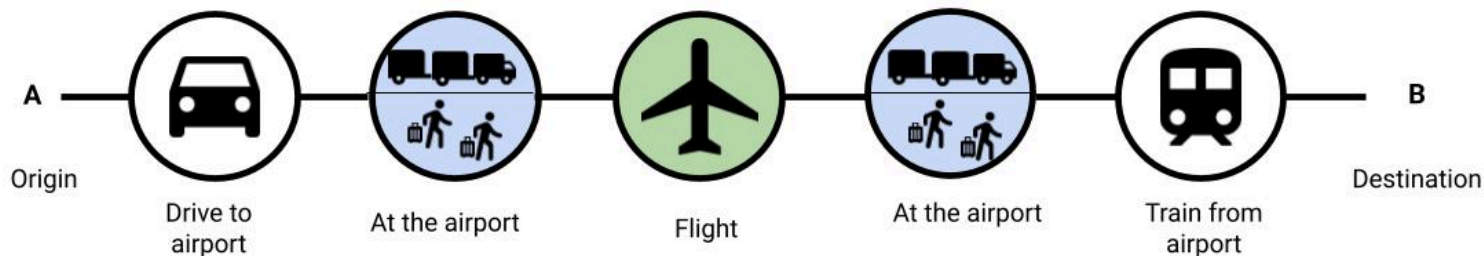
Flight B: fuel burn = 500 kg CO2e, contrail impact = HIGH

$$\begin{aligned} \text{Aggregate} &= (50\text{kg} * (0.6 \text{ for MODERATE}) + 500\text{kg} * (1.2 \text{ for HIGH})) / (\text{total fuel burn}) \\ &= 630\text{kg} / 550\text{kg} \\ &= 1.15 \end{aligned}$$

Aggregate classification: HIGH contrail impact bucket

Airport emissions

The TIM estimates flight emissions only, but ISO 14083 recommends including the airport emissions, highlighted in blue below, when calculating the emissions for a user's journey. The airport emissions are emissions generated by a passenger while at the airport (i.e. electric walkways to move passengers, vehicles to move luggage, air conditioning, etc).



Following Airport Carbon Accreditation (ACA)'s [2024 annual report](#) (page 21), we suggest adding the global average value of 1.71 kg per passenger for every airport visited to the total flight emissions calculated.^[7]

Flight emissions label

The [Flight Emissions Label \(FEL\)](#) empowers passengers to make informed decisions by providing clear and trusted information about their carbon emissions, in accordance with Article 14 of the [ReFuelEU Aviation Regulation](#). It relies on real data from past flight performance to label flights in the future. The Flight Emissions Label (FEL) is calculated using aircraft operators data such as fuel purchases and consumption, aircraft seating configurations and cargo. This data is verified, and [EASA](#) processes it to estimate the emissions in accordance with the EN ISO 14083:2023 standard.

TIM users can easily access FEL via the TIM distribution network due to the interoperability of the two methodologies. For flights with FEL issued, these labels replace TIM estimates and are clearly marked as "EASA" to indicate the source.

Please refer to www.flightemissions.eu for more information about The Flight Emissions Label (FEL) and display guidelines.

Legal base for model data sharing

The GHG emission estimate data are available via API under the [Creative Commons Attribution-ShareAlike CC BY-SA 4.0](#) open source license ([legal code](#)).

API access

Developer documentation is available on the Google Developers site for the [Travel Impact Model API](#).

Versioning

The model will be developed further over time, e.g. with improved load factors methodology or more fine grained seat area ratios calculation. New versions will be published.

A full model version will have four components: **MAJOR.MINOR.PATCH.DATE**, e.g. 1.3.1.20230101. The four tiers of change tracking are handled differently:

- **Major versions:** Changes to the model that would break existing client implementations if not addressed (e.g. changes in data types or schema) or major methodology changes (e.g. adding new data sources to the model that lead to major output changes). We expect these to be infrequent but they need to be managed with special care.
- **Minor versions:** Changes to the model that, while being consistent across schema versions, change the model parameters or implementation.
- **Patch versions:** Implementation changes meant to address bugs or inaccuracies in the model implementation.
- **Dated versions:** Model datasets are recreated with refreshed input data but no change to the algorithms regularly.

Changelog

3.0.0

Added support for EASA label attribution, contrails impact, and ISO 14083 related documentation updates.

2.0.0

Updating base model data to EEA 2023, adding support for cargo mass fraction, and introducing distance adjustment.

1.10.0

Migrating data sources for aircraft performance for some aircraft models.

1.9.1

Expanding T-100 coverage to include US territories. See [section on load factors](#) for information on the T-100 dataset.

1.9.0

Adding carrier-level passenger load factors from [ch-aviation](#) for flights that are not already covered by the T-100 dataset from the [US Department of Transportation Bureau of Transportation Statistics](#). Also adjusting the load factors outlier exclusion criteria from 20% to 10% deviation from average load factor since 2017, resulting in removing March 2020–February 2022 (inclusive) (previously March 2020–February 2021). See the [section on load factors](#) for more details.

1.8.0

Adding Well-to-Tank (WTT) and Tank-to-Wake (TTW) emissions break-downs to all flight emissions. Updating the jet fuel combustion to CO₂ conversion factor from the minimum value of 3.1672 to the value of 3.1894 (using Lower Heating Value from ISO 14083 and CORSIA Carbon Intensity value), and using the CORSIA Life Cycle Assessment methodology to implement a WTT CO₂e emissions factor 0.6465. Reference: [ISO](#), [CORSIA](#).

1.7.0

Updating the jet fuel combustion to CO₂ conversion factor from 3.15 based on the EEA methodology to 3.1672 to align with the [CORSIA methodology's](#) recommended factor.

1.6.0

Adding carrier and route specific passenger load factors for flights from, to, and within the U.S., taking seasonality patterns into account. We are using data from the [U.S. Department of Transportation Bureau of Transportation Statistics](#). For more details, see the [section on load factors](#).

1.5.1

Adding a fleet-level source for seating configuration data. For airlines that don't file seating configuration information in flight schedules but use the same seating configuration for all their aircraft of a certain model, a fall back to the "Seats (Equipment Configuration) File" provided by OAG is performed.

1.5.0

Following recent discussions with academic and industry partners, we are adjusting the TIM to focus on CO₂ emissions. While we strongly believe in including non-CO₂ effects in the model long-term, the details of how and when to include these factors requires more input from our stakeholders as part of a governance model that's in development. With this change, we are provisionally removing contrails effects from our CO₂e estimates but will keep the labeling as "CO₂e" in the model to ensure future compatibility.

We believe CO₂e factors are critical to include in the model, given the emphasis on them in the IPCC's AR6 report. We want to make sure that when we do incorporate them into the model, we have a strong plan to account for time of day and regional variations in contrails' warming impact. We are committed to providing consumers the most accurate information as they make informed choices about their travel options.

We continue to invest into research and collaborate with leading scientists, NGOs, and partners to better incorporate contrails and other non-GHG impact into our model, and we look forward to sharing updates at a later date.

1.4.0

Initial public version of the Travel Impact Model.

Limitations

The model described in this document produces estimates of GHG emissions. Emission estimates aim to be representative of what the typical emissions for a flight matching the model inputs would be. Estimates might differ from actual emissions based on a number of factors. All calculation results use the TIM model and no default GHG emissions intensities are used as fallbacks. The TIM does not use country-specific GHG emissions factors and therefore, it is not recommended for official reporting purposes in those locations where country specific factors are mandated.

Aircraft types: The emissions model accounts for the equipment type as published in the flight schedules. The majority of aircraft types in use are covered. See [Appendix A](#) for a list of supported aircraft types.

Some aircraft types are supported by falling back to a related model thought to have comparable emissions. See [Flight level emission estimates](#) for more details.

If no reasonable approximation is available for a given aircraft, the model will not produce estimates for it.

Engine information: Beyond the aircraft type, there are other aircraft characteristics that can have an effect on the flight emissions (e.g. engine type, engine age, etc.) that are not currently included when computing emission estimates.

Fuel type: The emissions model assumes that all flights operate on 100% conventional fuel. Alternative fuel types (e.g. Sustainable Aviation Fuel) are not supported.

Seat configurations: If there are no seat configurations individual numbers for a flight available from published flight schedules, or if they are incorrectly formatted or implausible, aircraft specific medians derived from the overall dataset are employed.

Contrail-induced cirrus clouds: In regions of high humidity, water vapor in the air condenses around particles of soot from an aircraft's exhaust and freezes. This forms cloud-like trails of condensation, or contrails for short. Most contrails dissipate quickly, but for a small fraction of flights, atmospheric conditions align to produce contrails that persist and spread out, trapping heat in the atmosphere.

Empty flights: ISO 14083 defines empty flights as any additional flights with no passengers and no cargo that are required to happen in order to operate a passenger flight (i.e. repositioning flights, maintenance flights, etc). It recommends that the GHG emissions for a flight includes any empty flights required for that flight to operate. At present, we are unable to support empty flights due to lack of data available.

Data quality

See [technical brief](#) on TIM base model selection.

How to cite TIM in publications

You are welcome to use the Travel Impact Model (TIM) in your publications. When referencing the TIM, please cite it as in the following example:

Google. (2022, April). *Travel Impact Model (TIM)* (Version A.B.C.YYYYMMDD) [Computer software]. Retrieved September 28, 2024 via API, <https://github.com/google/travel-impact-model>

The TIM is a dynamic model that is regularly updated with new data and methodologies. To ensure that others can access the same data and calculations you used, it is essential to include the version number and retrieval date in your citation.

BibTeX example:

```
@misc{google_tim_2022,  
  institution = {Google},  
  title = {Travel Impact Model (TIM)},  
  year = {2022},  
  month = {April},  
  note = {Version A.B.C.YYYYMMDD. Retrieved September 28, 2024},  
  url = {https://github.com/google/travel-impact-model}  
}
```



If you access the TIM programmatically through the [API](#), please mention this in your citation as well.

Contact

We welcome feedback and enquiries. Please get in touch using this [form](#).

Glossary

CCD: The flight phases *Climb*, *Cruise*, and *Descend* occur above a flight altitude of 3,000 feet.

CO₂: Carbon dioxide is the most significant long-lived greenhouse gas in Earth's atmosphere. Since the Industrial Revolution anthropogenic emissions – primarily from use of fossil fuels and deforestation – have rapidly increased its concentration in the atmosphere, leading to global warming.

CO₂e: CO₂e is short for CO₂ equivalent, and is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential ([source](#)).

Contrail-induced cirrus clouds: Cirrus clouds are atmospheric clouds that look like thin strands. There are natural cirrus clouds, and also contrail induced cirrus clouds that under certain conditions occur as the result of a contrail formation from aircraft engine exhaust.

CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation, a carbon offset and reduction scheme to curb the aviation impact on climate change developed by the International Civil Aviation Organization.

Effective Radiative Forcing (ERF): Radiative forcing effects can create rapid responses in the troposphere, which can either enhance or reduce the flux over time, and makes RF a difficult proxy for calculating long-term climate effects. ERF attempts to capture long-term climate forcing, and represents the change in net radiative flux after allowing for short-term responses in atmospheric temperatures, water vapor and clouds.

European Environment Agency (EEA): An agency of the European Union whose task is to provide sound, independent information on the environment.

Google's Travel Sustainability team: A team at Google focusing on travel sustainability, based in Zurich (Switzerland) and Cambridge (U.S.), with the goal to enable users to make more sustainable travel choices.

Great-circle Distance: Defined as the shortest distance between two points on the surface of a sphere when measured along the surface of the sphere.

ICAO: The International Civil Aviation Organization, a specialized agency of the United Nations.

ISO 14083: The international standard that establishes a common methodology for the quantification and reporting of greenhouse gas (GHG) emissions arising from the operation of transport chains of passengers and freight ([source](#)), published by the International Organization for Standardization (ISO).

LTO: The flight phases *Take Off and Landing* occur below a flight altitude of 3000 feet at the beginning and the end of a flight. They include the following phases: taxi-out, taxi-in (idle), take-off, climb-out, approach and landing.

Radiative Forcing (RF): Radiative Forcing is the instantaneous difference in radiative energy flux stemming from a climate perturbation, measured at the top of the atmosphere.

Short Lived Climate Pollutants (SLCPs): Pollutants that stay in the atmosphere for a short time (e.g. weeks) in comparison to Long Lived Climate Pollutants such as CO₂ that stay in the atmosphere for hundreds of years.

Tank-to-Wake (TTW): Emissions produced by burning jet fuel during takeoff, flight, and landing of an aircraft.

TIM: The Travel Impact Model described in this document.

Well-to-Tank (WTT): Emissions generated during the production, processing, handling, and delivery of jet fuel.

Well-to-Wake (WTW): The sum of Well-to-Tank (WTT) and Tank-to-Wake (TTW) emissions.

Appendix

Appendix A: Aircraft type support

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Airbus A220	220	BCS3	Mapped to least efficient in family
Airbus A220-100	221	BCS1	Direct match in EEA
Airbus A220-300	223	BCS3	Direct match in EEA
Airbus A300-600	AB6	A306	Direct match in EEA
Airbus A300B2/B4	AB4	A30B	Direct match in EEA
Airbus A310	310	A310	Direct match in EEA
Airbus A310-300	313	A310	Direct match in EEA
Airbus A318	318	A318	Direct match in EEA
Airbus A318 (Sharklets)	31A	A318	Supported via winglet/sharklet correction factor
Airbus A318/319/320/321	32S	A321	Mapped to least efficient in family
Airbus A319	319	A319	Direct match in EEA
Airbus A319neo	31N	A321	Mapped to least efficient in family
Airbus A319 (Sharklets)	31B	A319	Supported via winglet/sharklet correction factor
Airbus A320	320	A320	Direct match in EEA
Airbus A320neo	32N	A20N	Direct match in EEA
Airbus A320 (Sharklets)	32A	A320	Supported via winglet/sharklet correction factor
Airbus A321	321	A321	Direct match in EEA
Airbus A321neo	32Q	A21N	Direct match in EEA
Airbus A321 (Sharklets)	32B	A321	Supported via winglet/sharklet correction factor

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Airbus A330	330	A332	Mapped to least efficient in family
Airbus A330-200	332	A332	Direct match in EEA
Airbus A330-300	333	A333	Direct match in EEA
Airbus A330-800neo	338	A332	Mapped onto older model
Airbus A330-900neo	339	A339	Direct match in EEA
Airbus A340	340	A345	Mapped to least efficient in family
Airbus A340-200	342	A345	Mapped to least efficient in family
Airbus A340-300	343	A343	Direct match in EEA
Airbus A340-500	345	A345	Direct match in EEA
Airbus A340-600	346	A346	Direct match in EEA
Airbus A350-1000	351	A35K	Direct match in EEA
Airbus A350	350	A35K	Mapped to least efficient in family
Airbus A350-900	359	A359	Direct match in EEA
Airbus A380	380	A388	Mapped to least efficient in family
Airbus A380-800	388	A388	Direct match in EEA
Antonov An-140	A40	A140	Direct match in EEA
Antonov AN148-100	A81	A148	Direct match in EEA
Antonov An-24	AN4	AN24	Direct match in EEA
Antonov An-26/30/32	AN6	AN26	Mapped to least efficient in family
Antonov An-26	A26	AN26	Direct match in EEA
Antonov An-32	A32	AN32	Direct match in EEA
ATR42/ATR72	ATR	AT72	Mapped to least efficient in family
ATR 42-300	AT4	AT43	Direct match in EEA
ATR 42-500	AT5	AT45	Direct match in EEA
ATR 72	AT7	AT72	Direct match in EEA
Avro RJ100	AR1	RJ1H	Direct match in EEA
Avro RJ85	AR8	RJ85	Direct match in EEA
Beechcraft 1900 Airliner	BE1	B190	Mapped to least efficient in family
Beechcraft 1900D Airliner	BEH	B190	Direct match in EEA
Boeing 717-200	717	B712	Direct match in EEA
Boeing 727-100	721	B721	Direct match in EEA
Boeing 737	737	B734	Mapped to least efficient in family
Boeing 737	73M	B732	Direct match in EEA
Boeing 737-200	732	B732	Direct match in EEA
Boeing 737-200	73L	B732	Direct match in EEA
Boeing 737-300	733	B733	Direct match in EEA

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Boeing 737-300	73N	B733	Direct match in EEA
Boeing 737-300 (Winglets)	73C	B733	Supported via winglet/sharklet correction factor
Boeing 737-400	734	B734	Direct match in EEA
Boeing 737-400	73Q	B734	Direct match in EEA
Boeing 737-500	735	B735	Direct match in EEA
Boeing 737-500 (Winglets)	73E	B735	Supported via winglet/sharklet correction factor
Boeing 737-600	736	B736	Direct match in EEA
Boeing 737-700	73G	B737	Direct match in EEA
Boeing 737-700	73R	B732	Direct match in EEA
Boeing 737-700 (Scimitar Winglets)	7S7	B737	Supported via winglet/sharklet correction factor
Boeing 737-700 (Winglets)	73W	B737	Supported via winglet/sharklet correction factor
Boeing 737-800	738	B738	Direct match in EEA
Boeing 737-800 (Scimitar Winglets)	7S8	B738	Supported via winglet/sharklet correction factor
Boeing 737-800 (Winglets)	73H	B738	Supported via winglet/sharklet correction factor
Boeing 737-900	739	B739	Direct match in EEA
Boeing 737-900 (Winglets)	73J	B739	Supported via winglet/sharklet correction factor
Boeing 737MAX 7	7M7	B734	Mapped onto older model
Boeing 737MAX 8	7M8	B38M	Direct match in EEA
Boeing 737MAX 9	7M9	B39M	Direct match in EEA
Boeing 737MAX 10	7M1	B734	Mapped onto older model
Boeing 747-300/747-100/200 SUD	743	B744	Mapped to least efficient in family
Boeing 747	747	B744	Mapped to least efficient in family
Boeing 747-400	744	B744	Direct match in EEA
Boeing 747-400	74E	B744	Direct match in EEA
Boeing 747-8	74H	B744	Mapped onto older model
Boeing 757	757	B753	Mapped to least efficient in family
Boeing 757-200	752	B752	Direct match in EEA
Boeing 757-200 (Winglets)	75W	B752	Supported via winglet/sharklet correction factor
Boeing 757-300	753	B753	Direct match in EEA
Boeing 757-300 (Winglets)	75T	B753	Supported via winglet/sharklet correction factor

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Boeing 767	767	B764	Mapped to least efficient in family
Boeing 767-200	762	B762	Direct match in EEA
Boeing 767-300	763	B763	Direct match in EEA
Boeing 767-300 (Winglets)	76W	B763	Supported via winglet/sharklet correction factor
Boeing 767-400	764	B764	Direct match in EEA
Boeing 777	777	B773	Mapped to least efficient in family
Boeing 777-200/200ER	772	B772	Direct match in EEA
Boeing 777-200LR	77L	B772	Mapped onto newer model
Boeing 777-300	773	B773	Direct match in EEA
Boeing 777-300ER	77W	B77W	Direct match in EEA
Boeing 787	787	B789	Mapped to least efficient in family
Boeing 787-8	788	B788	Direct match in EEA
Boeing 787-9	789	B789	Direct match in EEA
Boeing 787-10	781	B78X	Direct match in EEA
Boeing (Douglas) MD-82	M82	MD82	Direct match in EEA
Boeing (Douglas) MD-83	M83	MD83	Direct match in EEA
Boeing (Douglas) MD-90	M90	MD90	Direct match in EEA
Bombardier Challenger 300	CL3	CL30	Direct match in EEA
Bombardier Regional Jet 550	CR5	CRJ7	Mapped to least efficient in family
British Aerospace 146	146	B463	Mapped to least efficient in family
British Aerospace 146-100	141	B461	Direct match in EEA
British Aerospace 146-200	142	B462	Direct match in EEA
British Aerospace 146-300	143	B463	Direct match in EEA
British Aerospace Jetstream	JST	JS41	Mapped to least efficient in family
British Aerospace Jetstream 31	J31	JS31	Direct match in EEA
British Aerospace Jetstream 32	J32	JS32	Direct match in EEA
British Aerospace Jetstream 41	J41	JS41	Direct match in EEA
Britten-Norman BN-2A/BN-2B Islander	BNI	BN2P	Direct match in EEA
Canadair Regional Jet	CRJ	CRJ9	Mapped to least efficient in family
Canadair Regional Jet 100	CR1	CRJ1	Direct match in EEA
Canadair Regional Jet 200	CR2	CRJ2	Direct match in EEA
Canadair Regional Jet 700	CR7	CRJ7	Direct match in EEA
Canadair Regional Jet 900	CR9	CRJ9	Direct match in EEA
Canadair Regional Jet 1000	CRK	CRJ9	Mapped to least efficient in family
Cessna 208B Caravan	CNF	C208	Direct match in EEA

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Cessna Citation	CNJ	C500	Direct match in EEA
Cessna Light Aircraft.	CNA	C208	Direct match in EEA
Cessna Light Aircraft (Single piston engine)	CN1	C208	Direct match in EEA
Cessna Light Aircraft (Twin piston engines)	CN2	C208	Direct match in EEA
Cessna Light Aircraft (Single Turboprop)	CNC	C208	Direct match in EEA
Cessna Light Aircraft (Twin Turboprop)	CNT	C208	Direct match in EEA
De Havilland-Bombardier DHC2 Beaver	DHP	DHC2	Direct match in EEA
De Havilland-Bombardier DHC6 Twin Otter	DHT	DHC6	Direct match in EEA
De Havilland-Bombardier DHC7 Dash 7	DH7	DHC7	Direct match in EEA
De Havilland-Bombardier DHC8 Dash 8	DH8	DH8D	Mapped to least efficient in family
De Havilland-Bombardier DHC8-100 Dash 8/8Q	DH1	DH8A	Direct match in EEA
De Havilland-Bombardier DHC8-200 Dash 8/8Q	DH2	DH8B	Direct match in EEA
De Havilland-Bombardier DHC8-300 Dash 8/8Q	DH3	DH8C	Direct match in EEA
De Havilland-Bombardier DHC8-400 Dash 8/8Q	DH4	DH8D	Direct match in EEA
Embraer 110 Bandeirante	EMB	E110	Direct match in EEA
Embraer 120 Brasilia	EM2	E120	Direct match in EEA
Embraer 170	E70	E170	Direct match in EEA
Embraer 170/195	EMJ	E190	Mapped to least efficient in family
Embraer 175	E75	E75S	Direct match in EEA
Embraer 175 (Enhanced Winglets)	E7W	E75L	Direct match in EEA
Embraer 190	E90	E190	Direct match in EEA
Embraer 190 E2	290	E290	Direct match in EEA
Embraer 195	E95	E195	Direct match in EEA
Embraer 195 E2	295	E295	Direct match in EEA
Embraer RJ 135/140/145	ERJ	E145	Mapped to least efficient in family
Embraer RJ135	ER3	E135	Direct match in EEA
Embraer RJ140	ERD	E145	Direct match in EEA
Embraer RJ145	ER4	E145	Direct match in EEA
Fairchild Dornier 228	D28	D228	Direct match in EEA
Fairchild Dornier 328JET	FRJ	J328	Direct match in EEA
Fairchild SA26/SA226/SA227 Merlin/Metro	SWM	SW4	Mapped to least efficient in family

Aircraft full name	IATA aircraft code	Mapping (ICAO aircraft code)	Support status
Fokker 50	F50	F50	Direct match in EEA
Fokker 70	F70	F70	Direct match in EEA
Fokker 100	100	F100	Direct match in EEA
Ilyushin Il-76	IL7	IL76	Direct match in EEA
Ilyushin Il-96	IL9	IL96	Direct match in EEA
Let 410	L4T	L410	Direct match in EEA
Pilatus PC-12	PL2	PC12	Direct match in EEA
Saab 2000	S20	SB20	Direct match in EEA
Saab 340B	SFB	SF34	Direct match in EEA
Saab 340	SF3	SF34	Mapped to least efficient in family
Sukhoi Superjet 100-95	SU9	SU95	Direct match in EEA
Tecnam P2012 Traveller	T12	P212	Direct match in EEA

Appendix B: Term mapping table

TIM terminology	ISO terminology
Actual emissions	Primary data as defined in 7.2.3 in ISO 14083 documentation
Airport	Hub operation categories (HOC), specifically a location where passengers are transferred from one mode of transport to another
Airport emissions	HOC's GHG emissions
Belly cargo	Freight transportation
Cargo	Freight
Empty flight	Empty trip
Flight	Transportation chain element (TCE), specifically a single aircraft transporting a group of passengers and potentially freight
Flight emissions	TCE's GHG emissions
Tank-to-Wake (TTW)	$G_{vo, TCE}$
Travel journey	Transportation chain
Type of flight	Transport operation category (TOC)
Well-to-Tank (WTT)	$G_{vep, TCE}$
Well-to-Wake (WTW)	G_{TCE}

Appendix C: Reporting details for passenger transport

This table shows the reporting details in the TIM as defined in ISO 14083 Table 2.

Reporting elements	Description
Identification of the services covered	All transport chain elements related to passenger transport by airplane for the next 11 months and the average airport emissions per passenger

Reporting elements	Description
Overall results on GHG emissions	Total emissions of an air transport chain per passenger is sum of all airport hub GHG emissions plus all flight GHG emissions for each passenger in that transport chain (e.g. If the transport chain is a non-direct flight from ZRH-BOS with a stop in LHR, the transport chain's GHG emissions will include the sum of airports' GHG emissions in ZRH, LHR, BOS and the flights GHG emissions for ZRH-LHR and LHR-BOS.)
Transport activity	Sum of flight GHG emissions The GHG emissions are Well-to-Wake (WTW) emissions that are the sum of the Well-to-Tank (WTT), the emissions of the production, processing and delivery of the fuel used, and Tank-to-Wake (TTW), the emissions created by the flight itself. The CORSIA methodology includes emissions for CO2, CH4 and N2O in its carbon intensity factor. Contrails and other Kyoto gases not mentioned are not included in the TIM GHG emissions value.
Transport activity distance	For flight GHG emissions, uses the great-circle distance plus the distance adjustment factor
Hub activity	Sum of all airport emissions The airport emissions can be calculated as 1.71 kgs * number of airport hubs visited.
Additional information	Additional information can be found in https://github.com/google/travel-impact-model and https://travelimpactmodel.org/governance

Appendix D: Model parameters

This table shows the TIM's model type as defined in ISO 14083 Table 3.

Model Type	Yes/No
Energy based	No
Activity based	Yes

This table shows the input parameters into the TIM as defined in ISO 14083 Table 3.

Parameter	Included?	Additional information
Aircraft Characteristics		
Aircraft type	Yes	Primary: Uses the specific aircraft model operating this flight from flight schedules data Modelled: Uses fallback as described in Appendix A
Engine age	No	
Engine type	Yes	Default value: Uses the base EEA model for most common engine types for a given aircraft operated in Europe
Fuel type	No	
Seating configuration	Yes	Primary: Uses the actual configuration for the aircraft model Modelled: Uses OAG fleet data, matching a unique config for the carrier and aircraft Default Value: Uses the typical configuration across all carriers
Journey Characteristics		

Parameter	Included?	Additional information
Airport locations	Yes	Primary: Uses exact longitude/latitude of the airport location
Aircraft energy	Yes	Modelled: Uses aircraft's EEA estimated fuel burn with the CORSIA lifecycle carbon intensity