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KlimaLink standard method description

KlimaLink has set itself the goal of providing the tourism industry with a platform that makes the CO_2e emissions of various tourism service providers available at a central point.

The desire for a standardised calculation of climate emissions has risen sharply in the industry, and business travellers and holidaymakers are increasingly asking about the actual climate footprint of their trips.

There are already various methods for calculating greenhouse gas emissions in tourism. However, these methods do not delimit CO_2e emissions in a standardised way and determine emissions using different approaches and accuracies. The aim of KlimaLink is to make CO_2e emissions available to all users in the sector in a standard (consisting of various methods) according to the following criteria:

- CO_2e emissions are recorded systematically and with a high degree of accuracy.
- The CO_2e emissions of different service providers (flights, hotels, cruises, etc.) can be compared and categorised.
- The calculations are accurate enough to show travellers ways to reduce climate emissions even before they book.
- The calculations are accurate enough to be able to compare combined travel products of different types on the basis of absolute CO_2e emissions.
- The various methods work entirely with input data from the trips that are available to the travel industry in their systems as standard from tour operators and travel agents.
- The standard provides a unique CO_2e value for each input of travel components worldwide (flight, train journey, hire car, hotel accommodation, etc.). To this end, the individual methods specify fallback hierarchies that require less and less specific input data in descending tiers (method variants) in order to always deliver the best possible result under the circumstances.

This standard is based on the standard for CO_2e emissions calculation for business trips of the German Travel Management Association (VDR standard, latest version from 2016). The CO_2e calculation methods of this standard were developed by atmosfair specifically for the requirements of CO_2e reporting for business trips. The Institute for Sustainable Tourism (Inatour) further developed the VDR standard on behalf of Futouris e.V. and with technical and methodological input from atmosfair for the purpose of KlimaLink and the different requirements in tourism compared to business travel (including ex-ante assessment when booking the trip instead of ex-post reporting for the CO_2e balance sheets of companies). myclimate and other committed Klimalink member companies were also involved. The methodological and scientific content was also brought up to date with the latest research where necessary.

Together with Inatour, Futouris initiated and conducted the dialogue processes for this document with all stakeholders and in particular with the providers of similar standards such as IATA, Travalyst etc., and classified and evaluated the results from a scientific and tourism perspective. Where these third-party standards are integrated into the new KlimaLink standard, e.g. the use of the HCMI standard for calculating hotel emissions, these are identified in the text.

The various calculation methods are dynamic and are updated when new scientific findings or improved data availability require adjustments.

In anticipation of the EU Count Emissions Regulation, KlimaLink successfully had the calculation standard for air, rail and car/bus transport audited in 2024 by GUTCert[1] , an accredited certification body in Berlin, for compliance with ISO 14083, on which the EU Count Emissions Regulation is based.

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[1] https://www.gut-cert.de/en/home-en

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I. Requirements for the standard

A. Completeness and relevance

The KlimaLink standard covers the key areas of the tourism value chain: Hotel, train, flight, car, bus and ship. It covers the main CO_2e emissions and leaves out the negligible ones, such as local public transport at the destination.

B. Applicability and scientific rigour

The calculation of CO_2e emissions from mobility and overnight stays should be applicable worldwide. This concerns the determinability of the CO_2e emissions of each trip - whether tourism or business-induced - throughout the world with a minimum accuracy based on the availability of data and the relevance of the calculated travel component.

The aim is not to create a completely scientifically based method. This would be illusory in view of the existing uncertainties in individual elements of the calculation methods, as the availability and accuracy of data are subject to continuous change. Rather, the aim is to enable a sufficiently good calculation (minimum accuracy) that can be supported by a large number of stakeholders and therefore enables the objective - a standardised calculation across all service providers - to be achieved.

C. Minimum accuracy

The calculation methods described in this document are sufficient to achieve the minimum accuracy described.

1. Transparency

The calculation methods, the influencing factors to be taken into account and possible data sources are described in this standard. This means that every stakeholder can check the CO_2e emissions of their journey and have the calculation method explained to them on the Internet, at travel agencies or at other points of sale.

2. Independence

The input data used to calculate emissions should, as far as possible, come from independent sources and be verified or certified by third parties. Direct provision of service provider data (e.g. from hotels, car hire or rail companies) is also possible, provided these have been verified or certified by third parties. KlimaLink is able to check plausibility. However, for reasons of time and cost, it is not possible to carry out a complete quality control, as is usual with certifiers or other auditing companies. General approaches such as scope delimitations and standard emission factors are based as far as possible on the IPCC[2] , GHG Protocol[3] and other internationally recognised organisations.

3. Further development

The standard and its underlying methods are subject to continuous further development. Adjustments, updates and improvements are desired and necessary. Further development takes place in working groups consisting of experts from the member companies.

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[2] Intergovernmental Panel on Climate Change (IPCC)

[3] Greenhouse Gas Protocol

D. Operational system limits

1. Travel-specific emissions

When accounting for travel, the emissions that arise during the provision of the respective service and therefore relate specifically to the journey are considered first (e.g. emissions from paraffin consumption during a flight, including the mineral oil supply chain). In contrast, emissions in connection with infrastructure (e.g. facility management of the airport building) and means of transport (e.g. construction and maintenance of the aircraft) do not arise exclusively in the course of the journey in question, but as part of general investments that benefit all users. The methods described do not currently take these indirect emissions into account when balancing a journey.

2. Upstream emissions

The combustion process of raw materials, fuels or combustibles for the production of useful energy directly generates climate-impacting emissions, whereby the type and quantity depend on the fuel used and the technology and efficiency of the plants in the upstream chain (e.g. oil production, logistics and refining). These can be allocated to the tourism users and are to be recorded in the KlimaLink standard with appropriate accuracy as far as possible.

3. Non-CO emissions$_2$

In addition to CO_2 , other climate-impacting emissions (non-CO_2) such as nitrogen oxides (NO_x) or soot, which have a positive or negative impact on radiative forcing due to their physical and chemical properties in the atmosphere, are produced during the combustion of fuels in air traffic. While the climate impact of non-CO_2 emissions from combustion processes near the ground (e.g. car journeys, train journeys, hotels incl. upstream chain) is negligible compared to the effect of CO_2, non-CO_2 emissions in higher air layers have a considerable effect on the Earth's radiation budget when travelling by air. In general, the term CO_2e[4] is used throughout the standard.

E. Reporting

The KlimaLink standard determines ex-ante (before departure) emission factors of individual elements of a holiday or business trip based on the information on which the calculation request is based.

1. Flight

An emission factor corresponds to the CO_2e value of a flight for one person on a specific route (city pair). Based on the information contained in the calculation request and the source data on which the calculation is based, this emission factor can be specific to

- the aircraft type
- the airline
- the booking class

If one or more of these details are missing, an approximation is attempted by averaging over all possible options (e.g. over all airlines serving the specific city pair).

II. Calculation of flight emissions

The calculation of flight emissions is complex, as many different factors influence greenhouse gas emissions and their impact on the climate (in addition to other factors such as payload, distance and flight profile). Furthermore, calculating the proportionate emissions per passenger is complex. Factors such as seating, capacity utilisation and freight all play a role here.

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[4] CO_2 equivalents, the unit of measurement used to standardise the climate impact of different greenhouse gases.

To make matters worse, the actual fuel consumption for flights is not publicly available, as this is competition-relevant data. The possible methods are therefore dependent on calculations that map the actual values as accurately as possible from available data that can be acquired on the market.

Finally, there is also the "non-CO_2 climate effect" in the aviation sector, which is caused by flight emissions at high altitudes.[5] One of the main drivers here is the warming effect of contrails and cirrus clouds caused by flights. The warming effect also depends on factors such as day/night, flight altitude and climate zone, but can be estimated on average across all factors.

For business and private trips made by plane, the greenhouse gas emissions from the flight are usually the largest part of the total emissions - on average around 80 %. It is therefore necessary that the methodology used for flights reflects the actual CO_2e emissions as accurately as possible, as otherwise the accuracy of the overall result will be significantly impaired.

A. Consideration of non-CO_2 emissions from air traffic

1. Basics[6]

Global aviation accounts for around 3.5 per cent of man-made global warming to date. International science assesses all the factors that the aviation industry has contributed to climate change since its inception.[7] This includes emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x) and the effect of contrails and contrail cirrus.

This shows that only one third of the climate impact of aviation is attributable to CO_2 emissions. The other two thirds of the climate impact of aviation is due to non-CO_2 effects. Contrails and the resulting contrail cirrus are the most significant factor. The reason for this is particulate emissions of all kinds, which are emitted by aircraft engines. Given the right temperature and humidity of the ambient air, these act as condensation nuclei for small super cooled water droplets, which freeze into ice crystals and become visible as contrails in the sky. The ice crystals in the contrails can persist for several hours in cold and damp conditions at altitudes of around 8 to 12 kilometres and form contrail cirrus clouds.

These clouds can have a warming or cooling effect locally, depending on the time of day and the ground. Numerous research studies show that the warming effect predominates globally.

Nitrogen oxide emissions from air traffic lead to additional ozone in the upper troposphere and lower stratosphere, where they warm the climate. In addition, emissions such as water vapour, soot, aerosol and sulphate aerosol particles generate further smaller climate-relevant contributions. If all non-CO_2 effects are included, the share of aviation in global warming to date is calculated at around 3.5 per cent. The path to making aviation as climate-friendly as possible must take all these factors of the climate impact of flying into account.

2. Scientific studies and current state of research

A large number of scientific studies have been investigating the above-mentioned effects since 1990. There are still bandwidths with regard to the resulting uplift factor for high flight altitudes. However, the main effects have been identified since around 2010 and their quantitative impact

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[5] These additional climate impacts are referred to as non-CO_2 emissions and affect the part of the flight that takes place at high altitudes. Together with the pure CO_2 emissions, they have a greater global warming effect on average by a certain factor than the CO_2 emissions from fuel consumption alone. This is referred to as the uplift factor.

[6] Source of the chapter: German Aerospace Centre (DLR).

[7] Around half of the total cumulative CO_{2e} emissions were generated in the previous 20 years alone.

has already been narrowed down, meaning that the uplift factor has remained stable in the range of 2 to 4 for a decade, with an average value of 3.

Research has now reached a stage where the defined framework conditions and assumptions influence the uplift factor more than the residual uncertainties of atmospheric physics. These include, for example

- The selected calculation methods for the uplift factor: including the metrics Global Warming Potential GWP, Radiative Forcing RF or Global Temperature Potential GTP
- The selection of the time horizon with regard to the climate effects of contrails for the comparison of CO_2e emissions: e.g. 20, 50 or 100 years.
- The discount rate used to spread future harmful effects of CO_2e over long periods of time.

Table 1 shows a selection of high-ranking studies from the last 20 years.

Table 1 Research results on the uplift factor

Source	Author	Year	Metrics	Uplift factor	Mean value
IPCC SR aviation	Penner et al.	1999	RF_{1992}	2,0 - 4,0	2,7
IPCC FOAR	Solomon et al.	2007	RF_{2000}	1,9 - 4,7	-
MPI	Graßl, Brockhagen	2007	RF	1,9 - 4,7	-
UBA	Project Team	2008	RFI	2 - 5	3
Atmospheric Environment	Lee et al.	2010	GWP_{20-100}	1,9 - 4,8	-
UBA	Project Team	2019	various	-	3
EASA for EC	Project Team (i.a. DLR, CICERO, Manchester University)	2020	various	-	3
Atmospheric Environment	Lee et. al.	2020	GWP^*_{100}	-	3

While in the 1990s only wide ranges could be specified, research in the last ten years has concretised an average value of 3. In doing so, normative assumptions were made that are regarded as an established political consensus in international climate policy (Kyoto Protocol and Paris Agreement) and by the IPCC.

Many well-known, reputable organisations have publicly positioned themselves in this regard:

- UBA Uplift factor 3[8]
- EASA Uplift factor 3 [9]
- DLR Uplift factor 3[10]

In conclusion, it can be said that the integration of non-CO_2 emissions and their climate-impacting effects must be included in the calculation method of a flight standard. The uplift factor should be based on internationally recognised scientific findings. According to the stable state of research over the past decade, the uplift factor averages 3 and is included accordingly in the KlimaLink flight method.

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[8] https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/fb_klimawirkung_des_luftverkehrs_0.pdf and https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_97-2022_der_uba-co2-rechner_fuer_privatpersonen.pdf

[9] https://www.easa.europa.eu/en/downloads/120860/en

[10] https://www.dlr.de/de/forschung-und-transfer/themen/klimavertraegliches-fliegen/klimawirkung-luftverkehr

However, as the non-CO_2 effects of individual flights vary greatly (e.g. depending on the route), a specific calculation of non-CO_2 emissions per flight is generally desirable. However, a reliable data basis for this is currently still lacking. When relevant new study results are available that enable the precise calculation of non-CO_2 emissions for specific flights, the calculation methods used by KlimaLink will be adapted accordingly.

B. Method description

The factors described below determine the CO_2e emissions from air traffic. They represent a minimum set of the factors to be considered here. Other factors change fuel consumption considerably in some cases, but either cannot be recorded ex ante or are not significant enough overall to justify an increased data collection and calculation effort. These factors, which are not taken into account in the KlimaLink flight method, include

- General weather situation and associated air currents (jet stream, etc.).
- Economical flight operations: slow flight or SDA (Slow Descent Approach).
- Maintenance status of the respective aircraft and its engines.
- Special local airport requirements, such as the fastest possible climb for noise protection reasons.
- emissions caused by the operation of the airport (air conditioning, lighting, baggage/passenger transport, etc.) [11]
- Excessive passenger weight or baggage.[12]

1. Distance, selected flight route and detours

The distance travelled has a decisive impact on fuel consumption and therefore on the amount of CO_{2e} emissions. It must therefore be determined as precisely as possible. Airlines generally endeavour to fly the shortest possible route between two cities. In practice, however, the prescribed flight route is not a straight line. Due to unforeseen influences, the distance flown may be longer than this. The distance of a city pair is therefore determined using the great circle distance. A diversion is added to this. Empirical studies have shown that the absolute diversions is largely independent of distance, as shorter flights involve relatively greater detours than long-haul flights. The flight method therefore uses three generalised diversions lengths, which depend on three distance classes of the great circle distance and which the ICAO specifies in its method for flight calculations.

The influence of distance on specific fuel consumption is not linear. Section CC, Influencing variables and calculation formulas explains in detail how the method solves this challenge. It requires a sufficiently close-meshed grid of standard distances of all aircraft types. The following requirements therefore apply to this grid.

- Coverage: At least 32 standard distances for distances between 250 km and 18,000 km flight range (inclusion of future ultra-long-haul flights).
- Resolution: From 0 to 3,000 km maximum 250 km distance between neighbouring standard distances, from 3,000 km to 8,000 km maximum 500 km distance, from 8,000 km maximum 1,000 km distance.

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[11] In accordance with ISO 14083, hub emissions can be disregarded if they are considered negligible (5.2.3.a), see Fraport Environmental Statement 2020 https://www.fraport.com/de/nachhaltigkeit/umwelt-und-klima/umweltmanagement.html and IATA Airport Environmental Sustainability https://www.iata.org/contentassets/d1d4d535bf1c4ba695f43e9beff8294f/airport-environmental-sustainability-policy.pdf

[12] Instead of the previously assumed 100 kg for passenger and luggage, 105 kg is currently considered a more realistic value.

2. Exact aircraft type

Fuel consumption is heavily dependent on the aircraft type. Each aircraft is designed and optimised by the manufacturer for a specific range and passenger capacity. Operation outside these specifications generally means an increase in paraffin consumption per passenger. Depending on the airline and the aircraft it operates on the same city pair, the CO_2e emissions per passenger can therefore vary significantly. This aspect is included in the emissions calculation.

In addition, the portfolio of aircraft manufacturers consists of various aircraft families that include several models.[13] These models are in turn available in different variants and are optimised for different passenger numbers and distances. The exact aircraft type is therefore included in the CO_{2e} emissions calculation.

In practice, an aircraft type is defined by manufacturer, family, model and variant. The Klima-Link flight method therefore requires that the aircraft types are recorded by manufacturer, family, model and variant for each flight and included at this level of detail in the computer model-based fuel consumption calculations for standard distances and payloads (e.g. Boeing 777-200ER, see also section 5 on fuel weight, payload and flight profile). A restriction only to family and model or only by family via summarising hybrid aircraft leads to deviations of up to +/- 30 % and is therefore too imprecise for the method.

In some cases, it is not possible to use the booking data from the flight booking systems (flight number, date) to clearly identify the aircraft type. The reasons for this are, for example, because the airline has not stored this in the flight schedules or the flight schedules cannot display the aircraft type. This results in the following requirements for the method.

- **Coverage**: Includes all aircraft types of commercial aircraft of all manufacturers of international aircraft classes A and B (MTOW > 14 tonnes) on which tourist flights are offered. As soon as new aircraft types are used, they must be included in the method (see section 15 on the updates).
- **Tier 1**: Aircraft types are recorded for each individual flight at the manufacturer, family, model and variant level of detail and are included at this level in the calculation of fuel consumption with computer models at standard distances and standard payloads (see section 5 on fuel weight, payload and flight profile).
- **Tier 2**: Alternatively, in cases where the aircraft type is not fully included in the flight plans, the levels of detail relating to variant, model, family and manufacturer may be gradually omitted.
- **Tier 3**: If flight plans do not contain any information on the aircraft type, the fuel consumption per passenger and 100 passenger kilometres may alternatively be used generically with average values from independent environmental compendia such as the Federal Environment Agency, depending on at least ten flight distance classes from short to ultra-long haul.

3. Equipped with winglets / sharklets

Winglets or wingtips on the wingtips improve the aerodynamic properties of the aircraft and reduce fuel consumption. Reductions of up to approx. 3 % are possible. If an airline retrofits aircraft with winglets, this should be taken into account in the emissions calculation. However, not all aircraft types can be retrofitted with winglets.

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[13] For example, for the Airbus A320 the types A318, A319, A320, A321 or for the Boeing B737 NG the types B737-600, B737-700, B737-800, B737-900

When calculating fuel consumption for standard flights with a dedicated computer model (see section 5 on fuel weight, payload and flight profile) and subsequently CO_2e/pax calculation for flights, it must therefore be taken into account for each flight or booking whether the intended aircraft has been retrofitted with winglets or not.

If the aircraft type for a flight cannot be determined from the flight plan at the winglet level, winglet quotas for the aircraft type used within the operating airline can be applied for this flight as a fallback. The winglet quota indicates what percentage of the airline's aircraft of this aircraft type are fitted with winglets. This quota is then applied as an average value to the fuel savings previously determined with the computer model for all aircraft of this type of the airline.

4. Aircraft age and maintenance

The age of an aircraft has an influence on its fuel consumption. There are two aspects to consider here.

a) Age of the aircraft

During the service life of a machine, signs of wear and material fatigue can worsen the aerodynamics, for example, and cause higher fuel consumption. This can be minimised or avoided through good maintenance. The flight method here assumes that this is usually the case and therefore does not explicitly take the age of the aircraft into account in the CO_2e calculation.

b) Year of construction within a model variant

The year of manufacture also has an influence on fuel consumption. Particularly in the case of long-lasting models, newer machines may utilise better, fuel-saving technologies or materials that were not yet available in the older models. In the case of differences due to the year of manufacture, it can be assumed that the older machines will be retrofitted with the newer technologies, which will tend to even out the differences. However, as long as no suitable data is available on the market, this aspect cannot be calculated with sufficient accuracy.

5. Fuel weight, payload and flight profile

A flight is divided into the phases of take-off, climb, cruise, descent and landing. Take-off and climb in particular require a lot of paraffin. This is more important for short-haul flights than for medium and long-haul flights. The relative fuel consumption per passenger is therefore higher on short-haul flights than on medium-haul flights. Long-haul flights, on the other hand, have a higher specific consumption because the entire quantity of fuel has to be transported, the high weight of which has a negative effect on overall consumption.

In practice, this is the most challenging part of the CO_2e calculation. The heavier the aircraft on take-off and the longer the flight, the higher the absolute fuel consumption, with both factors having a clearly non-linear effect on the result. If an aircraft climbs more steeply, it consumes more fuel, but in turn reaches the flight altitudes at which drag decreases with lower densities, which leads to fuel savings. Only when the payload (passengers and additional cargo) is known can the amount of fuel to be refuelled be calculated as a first approximation, which then increases the take-off weight again (like additional payload). Therefore, a simple direct calculation of the fuel requirement is only possible with a high degree of error. Computer models such as Eurocontrol's Base of Aircraft Data (BADA), piano-x or commercial Aircraft Performance Monitoring models (APM) take these dependencies into account through iterations and can therefore calculate the actual fuel consumption with good accuracy for each individual flight.

For the aforementioned objectives of the KlimaLink flight method, it is therefore necessary that the basis of the fuel consumption calculation is, on the one hand, based on many standard flights for which such detailed computer models have calculated the fuel consumption. On the other hand, these standard flights can then be used as the basis for simplifying interpolations for the large number of daily KlimaLink flight calculations. In this way, the complexity of flights is adequately taken into account without generating a significant calculation effort in practice.

The KlimaLink flight method therefore requires that the consumption of standard flights be closely grouped, calculated both according to various standard distances (see Section 1 Distance) and according to various standard payloads, on the basis of which the interpolation for the many real flights can then be carried out.

Consumption on standard flights is to be calculated using dedicated models from the aviation industry that map the non-linear dependencies of fuel weight, flight distance, payload and flight profile with good accuracy for all aircraft types for various distances and payloads. The formulae for this calculation of consumption on standard flights and the interpolations based on them can be found in Section C.

6. Taxiing on the ground and reserve fuel

Aircraft still have to taxi from the terminal to the runway before take-off, consuming fuel and emitting CO_2e emissions that are not initially recorded in the flight profiles. The same applies to taxiing to the terminal after landing. The taxiing distance varies from airport to airport, so the consumption for taxiing also varies. Due to the relatively low weight, this effect can be taken into account with sufficient accuracy by adding a surcharge to the fuel consumption. For the average airports assumed here, this is already part of the fuel calculation of the dedicated computer models (see section 5 Fuel weight, payload and flight profile).

Every aircraft must carry reserve fuel to allow for any deviations from the planned route. The reserve fuel increases the take-off weight and thus the CO_2e emissions of a flight, sometimes significantly, and must therefore also be calculated. The determination of the required quantity is subject to the same complexity and similar dependencies as the determination of the actual fuel consumption and can be calculated accordingly by the computer models mentioned there for the standard distances and payloads.

7. Seating (number of seats on board)

The choice of aircraft type determines the maximum number of seats on board. However, the total number of seats installed in a particular aircraft type varies from airline to airline and even within an airline. This must be taken into account precisely for each flight, as it has a considerable influence on CO_2e emissions together with passenger capacity utilisation via the payload and thus the absolute fuel consumption.

- **Tier 1**: Seating is recorded for each individual flight for the exact configuration of the aircraft type used.
- **Tier 2**: The seating capacity of an aircraft type is averaged at airline level. This means, for example, that if an airline has several Boeing 777-200ERs in its fleet, half of which have 280 seats and half of which have only 260 seats, then at least the weighted average value of 270 seats must be used in the calculation.

8. Passenger load factor

The seating capacity in conjunction with the load factor results in the actual passenger payload transported, which, together with the baggage payload, is essential for the fuel consumption and emissions of the flight.

- **Time of the load factor data:** Although the flight is still in the future when the passenger makes the booking, the load factor must be estimated with the best probability from the recent past. For existing flights on the same city pair, the load factor data of the flight and the airline in the most recent previous year is used, for which the official data services such as ICAO-TFS and other data are available. For new flights offered by an airline for the first time in the current year, an approximate load factor is used that the airline was last able to achieve in the flight region (if not known, then alternatively the airline's global average) on a similar route length.
- **Tier 1:** The passenger load factor is included in the calculation of the payload and thus the fuel consumption for each individual flight.
- **Tier 2:** If the data sources do not show the passenger load factor for a single flight (combination of flight number and flight date), then the load factor data with averages on the following tiers can be used as a substitute in the following order:
  1. load factor per airline and aircraft type on the City-Pair, annual average.
  2. capacity utilisation per airline on the city pair, averaged over one year.
  3. load factor per airline, global average, broken down into domestic and international (if not available: global).
- **Tier 3:** Load factor per global average of all airlines, differentiated according to short, medium and long-haul routes (literature values).

9. Differentiation by seating class

Aircraft can be seated differently depending on the customer segment served. Not only the number of seats and the spacing of the rows of seats vary, but also the ratio of First Class, Business, Premium Economy and Economy seats. The classes take up different amounts of space per passenger, which means that different proportions of the absolute fuel consumption must be allocated to the respective seat class - Economy the least, First Class the most.

In contrast to the factors mentioned so far, the seat classes no longer influence the payload of an aircraft (this is determined by the number of passengers, which is calculated from the load factors (see section 8) and seating (see section 7)). The seat classes can therefore simply be applied to the average CO_2e footprint of the entire flight using a multiplier at the end of the calculation method. The multipliers express the space requirement of a seat in the respective class in relation to the space requirement of a seat in the lowest class (economy).

To map this factor in detail for all flights, the cabin layout of each individual aircraft would have to be measured, which is not possible in practice. However, it has been shown that the multipliers for seat classes worldwide only differ significantly between single and double aisle aircraft[14] , but are generally homogeneous within these two groups of aircraft with only minor deviations. IATA has therefore recently analysed globally valid multipliers for these two groups of aircraft in its CO_2e calculation standard and prescribed them for the calculation.

For these reasons, the KlimaLink flight method takes the seat classes into account as follows.

- **Tier 1**: Application of seat class multipliers derived for the respective aircraft type from the cabin layout of the respective airline. Weighted average values of the multipliers may also be used if an airline uses the same aircraft type several times but in different layouts.

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[14] Single aisle / narrow body: aircraft, usually for short and medium-haul routes with one aisle. Double aisle / wide body: wider, larger aircraft with two aisles for long-haul routes.

- **Tier 2**: Application of globally valid seat class multipliers, divided into single and double aisle aircraft according to the IATA method and with IATA data.

10. Additional freight capacity

The additional cargo capacity has the same effect on fuel consumption as the seating capacity. Available data sources show the additional cargo capacity of an airline's individual aircraft in *tonnes of cargo capacity*, analogous to the seating data. For this reason, the additional cargo capacity is also recorded in the KlimaLink flight method in the same way as passenger capacity.

- **Tier 1**: The cargo capacity is recorded for each individual flight for the exact configuration of the aircraft type used.
- **Tier 2**: The cargo capacity of an aircraft type is averaged at the level of an airline. This means, for example, that if an airline has several Airbus A 340s in its fleet and 50% of the aircraft have 12 tonnes and 50% only 6 tonnes of belly cargo capacity, then at least the weighted average value of 9 tonnes must be used in the calculation.

11. Utilisation of additional cargo

As with passenger load factors, the load factor also has a direct effect on the payload of additional cargo and thus on the absolute and subsequent specific fuel consumption. The KlimaLink method is defined for the load factor for additional cargo in the same way as for passenger load factors. This applies both to the time of the load factor data for additional cargo and to the three tiers, which ensure in descending order of accuracy that the method returns a defined value for all flights in practice.

12. Additional freight discount, destinations

Freight transported as additional cargo leads to additional fuel consumption, which can be deducted from the passengers, provided that the transported freight is not directly related to the journey. This leads to a reduction in the payload, which is charged to the passengers. This reduces the specific CO_2e emissions per passenger.

However, on tourist flights, additional cargo is often used to supply the destination, which is used by the passengers travelling on the flight. Therefore, the CO_2e deduction for passengers can only be made to a lesser extent here. There is currently no quantitative literature on the question of what proportion of the additional cargo on tourist flights is used for tourism purposes (e.g. import of certain foodstuffs). However, as the overall effect on CO_2 emissions is relatively small, the Klimalink method uses a flat-rate value at this point, which therefore applies to all tourist destinations served.

According to this flat-rate value, 50% of the additional cargo is categorised as tourism and 50% as non-tourism.
The total emissions of a flight are calculated using the full additional cargo. When allocating the emissions to individual passengers, however, only the emissions for the transport of the part of the additional cargo assumed to be tourist cargo are taken into account; the non-tourist part is not counted.

13. Upstream chain of paraffin production (well-to-wheel)

The well-to-wheel emission factors for paraffin must also be taken into account when calculating emissions from air travel. Three areas are relevant here:

1. Oil production in the source country: (drilling, production, expansion, flaring) and transport to the refinery.
2. Refinery: processing crude oil into paraffin.
3. Transport of paraffin from the refinery to the airport.

These emissions must be included because passengers, as paying customers, play a decisive role in CO_2 emissions in these areas.

The KlimaLink flight method sets the system limits for paraffin according to the WTW approach as opposed to the TTW approach, as described in DIN EN 16258. It thus includes the emissions of the upstream chain in the method. The non-CO_2 multiplier is not to be used for these emissions, just as for the CO_2 emissions of the flight at altitudes below 9 km.

14. Inclusion of non-CO emissions$_2$

As described in section I.D.3 in addition to CO_2 emissions, there are also other overall warming climate effects. On average, these climate effects have an impact at cruising altitude that is three times greater than the pure CO_2 effects. One tonne of CO_2 emitted together with the non-CO_2 emissions in the upper troposphere and lower stratosphere at cruising altitudes of over 9 km therefore has the same warming effect on the climate as three tonnes of pure CO_2.

The calculation method takes into account the additional climate impact of non-CO_2 emissions, but only for the proportion of flights at altitudes above 9 km. For short-haul flights, this share is lower than for long-haul flights and can also be zero, provided that the aircraft on short-haul flights do not climb above 9 km or cannot fly that high (e.g. many turboprop aircraft). Only the fuel consumption and thus the CO_2 emissions at altitudes above 9 km are to be determined and only these are to be multiplied by the mark-up factor for non-CO_2 emissions.

15. Data quality and updates

The timeliness and quality of the input data are important in order to obtain the corresponding quality of results with the differentiated method of KlimaLink.

a) quality

The input data in the Klimalink standard fulfils the quality requirements of independence and verification.

- **Independence**: The data should come from independent third-party sources (commercial data services, authorities and other official bodies such as UBA, Eurocontrol, etc.), as well as from peer-reviewed scientific publications. They must not come directly from the airlines, aircraft manufacturers or interest groups without having been checked by one of the aforementioned independent third parties.
- **Verification**: The data should at least have been checked for plausibility and consistency by the data provider.

b) Updates

The following update deadlines apply to the various data.

- Flight schedule data: monthly.
- Aircraft types: for each new aircraft type when it appears in the flight plans, including implementation of the standard fuel consumption in a suitable computer model.
- Fleet composition of the airlines: annually.

- Seating, additional cargo capacity: annually.
- Utilisation factors: annually (tiers 1 and 2), every five years (tier 3).
- Other scientific data, e.g. for non-CO_2, paraffin upstream chain: As soon as significant new and quantified findings are available from the scientific community that have been consistently confirmed by publications over a period of three years and have found their way into the specialist literature.

C. Influencing variables and calculation formulas

1. Variables

Variable	Description of the	Value / Unit
	Distances	
D_G	Large circle distance of a city pair	km
D_R	Surcharge for detours, flat rate, graduated according to large circle distance	km
D	Distance of the flight route of a city pair, (great circle + diversions)	km
D_o	Standard distance above distance D of the flight	km
D_u	Standard distance below the distance D of the flight	km
	Aircraft weights and loads	
TOW	Take Off Weight, take-off weight of the aircraft	tonnes
OEW	Operational Empty Weight, empty weight of the aircraft	tonnes
NL	Payload (passengers, baggage and additional cargo)	tonnes
PAX	Number of passengers on board a flight	-
S_c	Seating capacity on board the aircraft (number of seats available, total across all seating classes)	-
C_c	Cargo capacity for additional cargo (in addition to passenger baggage)	tonnes
LF_p and LF_c	Load factor for passengers and cargo (additional cargo)	%
NL_{80}, NL_{20}	Payload in the case of a passenger and cargo load factor of 80% and 20% respectively.	tonnes
	Fuel consumption and emission factors	
$F_{NL,D}$	Absolute fuel consumption of the flight in question, depending on the payload NL and the flight distance D	kg
$F_{NL20,D}$ $F_{NL80,D}$	Absolute fuel consumption of the flight under consideration, at 20% or 80% utilisation of the total payload, over the flight distance D	kg
$CO_{2,PAX}$	Specific CO_2 emissions per passenger	kg
EF_{TTW}	Emission factor for the conversion of fuel consumption into CO_2 emissions in the system limits Tank to Wheel (TTW)	kg CO_2 / kg fuel
EF_{WTW}	Emission factor for the conversion of fuel consumption into CO_2 emissions in the Well to Wheel (WTW) system limits	kg CO_2 / kg fuel

F_{Taxi}	Constant for fuel consumption per passenger when taxiing the aircraft at airports before take-off and after landing	kg
	Other factors	
$f_{winglet}$	Factor for percentage reduction in absolute fuel consumption due to winglets	%
$fcabin_{class}$	Factors for the differentiation of specific CO_2e emissions per passenger by seat class (Economy, Business, First Class)	-
f_{Target} area	Factor that reduces the discount on the specific fuel consumption per passenger for the additional cargo, because the additional cargo benefits the destination and the passenger.	50%
	Climate impact of contrails etc. (Non-CO)$_2$	
f_{NCO_2}	Factor for the climate impact of all emissions (CO_2 and non-CO_2) compared to the pure CO_2 emissions of flights at altitudes above 9000 metres. At lower flight altitudes, the factor is always set to 1.	3
f_{cruise}	Proportion of flight distance at altitudes above 9,000 m in relation to the total flight distance; necessary for the climate impact of non-CO emissions$_2$	%
CO_2e	CO_2 -equivalent emissions	kg
CO_2e_{PAX}	Specific CO_2 -equivalent emissions (per passenger)	kg

2. Calculation formula

The absolute fuel consumption F of a specific aircraft type on a specific flight is generally calculated as follows:

$F_{TOW, D} = f\ (TOW, D)$
with TOW = Take-Off-Weight;
D = flight distance; $D = D_G + D_R$ with D_G = great circle distance, D_R = roundabout (according to ICAO)
f = function, calculated with a dedicated computer model (see II.B.5)

TOW = OEW + NL + Taxi fuel + Trip fuel + Reserve fuel

With OEW = Operational Empty Weight of the aircraft hardware, depending on the aircraft type
NL = payload (sum of the weight of the passengers, their baggage and additional air freight as additional cargo)

a) Payload and distance: central overriding variables for fuel requirements

The take-off weight (TOW) of an aircraft (made up of the aircraft's hardware, the payload (NL) and the fuel tanked) and the distance are the two main variables controlled by the aircraft operator that determine the aircraft's fuel consumption on a flight.

KlimaLink requires the mapping of the two central variable factors distance and payload for each aircraft type in the above-mentioned non-linear interdependence (see section: Fuel weight, flight profile and altitude), but then allows an approximation. This is done by first precisely pre-calculating many and close-meshed combinations of different standard payloads and distances for each aircraft type using a computer model, and then interpolating the calculated fuel consumption for the respective flight of the aircraft type from these exact values (value matrix).

b) Exact computer model calculation for value matrix and subsequent interpolation

In practice, this means that the possible distances of an aircraft type are first broken down into standard distances (see section Flight distance). For each of the standard distances, which are once above and once below the actual distance D of the flight in question (D_o and D_u), the fuel consumption is then determined for payloads of 80 % and 20 % (NL_{80} and NL_{20}). The fuel consumption for the actual distance D and actual payload NL can then be linearly interpolated with good accuracy from these four precisely calculated combination values for an aircraft type.
Simpler methods that only use different standard distances, each with an average load factor, to calculate a basic consumption over a distance and then apply the real load factors of freight and passengers only as multipliers to this basic consumption, on the other hand, are too error-prone because they do not take the above-mentioned dependencies into account.

The definitions and formulae for implementing the Klimalink method flight are therefore as follows:

c) Definitions

NL = PAX*100kg + C; with NL = payload; C = additional cargo
PAX = S_c*LF_p; where S_c = seating capacity; LF_p = passenger load factor
C = C_c * LF_c with C_c = freight capacity; LF_c = load factor for additional freight;
$NL_{80} = PAX_{\text{(bei LFp of 80\%)}} * 100\text{kg} + C_c * 80\%$; $NL_{20} = PAX_{\text{(bei LFp of 20\%)}} * 100\text{kg} + C_c * 20\%$;

d) Calculation of fuel consumption, standard distances and standard payloads

Firstly, the standard values for F_{NL20} and F_{NL80} must be determined for each aircraft variant using a computer model of the quality class specified in this standard for the fuel calculation.

With the calculation of F_{NL20} and F_{NL80} at all standard distances and for all possible aircraft types using the two formulae above, the creation of the fuel consumption matrix is complete.

From this, the absolute fuel consumption of a flight $F_{NL, D}$ is calculated by linear interpolation from the four individual values of the fuel consumption matrix $F_{(NL_{20}, D_u)}$, $F_{(NL_{20}, D_o)}$, $F_{(NL_{80}, D_u)}$ and $F_{(NL_{80}, D_o)}$ in three steps as follows:

$$F_{NL20, D} = (\underline{(F_{(NL_{20}, D_o)}) - F_{(NL_{20}, D_u)}) (D - Du)} + F(NL_{20}, D_u))) * \text{fwinglet}(Do - Du)$$

$$F_{NL80, D} = (\underline{(F_{(NL_{80}, D_o)}) - F_{(NL_{80}, D_u)}) (D - Du)} + F(NL_{80}, D_u))) * {}_{\text{fwinglet}}(Do - Du)$$

$$F_{NL, D} \underline{= (FNL_{80, D} - FNL_{20, D}) (NL - NL_{20}}) + FNL_{20,} (NL_{80} - NL)_{20}$$

e) Calculation of specific CO_2e emissions per seat class, within the limits of WTW

The following formula is used to calculate the specific CO_2 emissions of a passenger, initially within the system limits Tank to Wheel (TTW):

$$CO_{2PAX,\,TTW} = FNL_{,\,D} * EF_{TTW} / PAX$$

In order to calculate the associated non-CO_2 emissions, the specific CO_2 emissions (kg CO_2 per passenger on a flight) must be supplemented with the additional climate impacts resulting from the non-CO_2 emissions of the flight (contrails, cirrus clouds, ozone formation, methane cooling, etc.).

$$CO_2e_{PAX,\,TTW} = (CO_{2PAX\,TTW} * (1 - f_{cruise})) + (CO_{2PAX\,TTW} * f_{cruise} * fNCO_2)$$

Finally, the emissions from the upstream chain of paraffin production must be included in order to transfer the specific CO_2e emissions from the TTW (Tank to Wheel) system limits to the desired WTW (Well to Wheel) system limits, as well as the differentiation of the specific CO_2e emissions into seat classes.

$$CO_2e_{PAX.\,WTW,\,cabin\,class} = (CO_2e_{PAX\,TTW} + (FNL_{,\,D} / PAX) * (EF_{WTW} - EF_{TTW})) * f_{cabin\,class}$$

This completes the calculation which, taking into account all the factors specified in the Klima-Link standard, provides the specific CO_2e emissions per passenger in their seat class in the desired system limits WTW.

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