Guidance for Calculating Civil Aviation Scope 3 Emissions: Category 11 – Use of Sold Products

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Version 1

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Version History

Date	v#	Modified By	Section, Page(s) and Text Revised
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Executive summary

The International Aerospace Environmental Group (IAEG) identified that Scope 3, "Corporate Value Chain," Category 11, "Use of Sold Products," as defined by the Greenhouse Gas (GHG) Corporate Protocol, is one of the most relevant Scope 3 emissions categories for most aerospace companies.

IAEG therefore developed an industry-specific methodology and guidance materials, for voluntary consideration and use, to promote consistency of reporting approaches within the industry.

This is the initial version of the guidance. It focuses on civil aviation applications and is meant to complement the GHG Corporate Protocol Scope 3 emissions accounting and reporting standard and the associated technical guidance for calculating Scope 3, Category 11 emissions.

This document describes the industry-specific methodology and provides discussions on the input data needed for applying the methodology, as long with examples illustrating how the methodology may be applied for different types of manufacturers in the industry.

1 Acronyms, glossary and definitions

ATAG	Air Transport Action Group
AvGas	Aviation Gasoline
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EASA	European Union Aviation Safety Agency
ERF	Emission reduction factor
FAA	Federal Aviation Administration
GHG	Greenhouse gas
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
MTOM	Maximum takeoff mass
MZFM	Maximum zero fuel mass
RPK	Revenue passenger kilometers
RTK	Revenue tonne kilometers
SAF	Sustainable Aviation Fuel

Aircraft life in years. Average aircraft life from delivery to retirement measured by the number of years, often calculated based on historical fleet data.

Annual flight cycles. Average number of cycles flown annually. A flight cycle is normally defined as a flight starting from takeoff until landing,

Final (end-use) product. Product that is ready for sale and use by civil aviation operators, e.g., the aircraft

Fuel emission factor. Factor that converts a mass of fuel into a mass of fuel lifecycle emissions, expressed in carbon dioxide equivalent (CO_2e) using 100-year Global Warming Potential (GWP) values.

Greenhouse gas (GHG). Gases in the atmosphere that can absorb infrared radiation, trapping heat in the atmosphere. Emissions of GHG into the atmosphere due to human activity cause global warming. Per the Doha Amendment to the United Nations Framework Convention on Climate Change (UNFCCC)/Kyoto Protocol[1], there are seven recognized GHGs, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

GHG Corporate Protocol. The GHG Corporate Protocol refers to the *Corporate Accounting and Reporting Standard*[2] developed by the GHG Protocol Initiative, a multi-stakeholder collaboration convened by the World Resources Institute and World Business Council for Sustainable Development to design, develop and promote the use of accounting and reporting standards for business. The GHG Corporate Protocol defines emissions according to a reporting organization's operational boundaries into Scopes 1, 2, and 3 emissions.

GHG Protocol Technical Guidance for Calculating Scope 3 Emissions. The GHG Technical Guidance refers to the *Technical Guidance for Calculating Scope 3 Emissions (version 1.0), Supplement to the*

1 See the Doha amendment to the Kyoto Protocol (2012), available at: https://unfccc.int/process/the-kyoto-protocol/the-doha-amendment

2 See the *Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard, revised edition (2004)* as amended (2013), available at: https://ghgprotocol.org/corporate-standard

Corporate Value Chain (Scope 3) Accounting & Reporting Standard[3] developed by the GHG Protocol. It is a companion guide that provides technical guidance on the relevant calculation methods to assess Scope 3 emissions.

Load factor. Number of seats occupied by revenue passengers divided by available passenger seats[4].

Number of delivered aircraft. Number of aircraft delivered to the customer in the reporting time period.

Spare. Item or component that is kept in case to replace another item of the same type that is lost, broken, or worn out.

Revenue passenger[5]. A passenger carried for which the airline receives remuneration. It excludes, for example: persons travelling free; persons travelling at a fare or discount available only to employees of air carriers or their agents or only for travel on business for the carriers; infants who do not occupy a seat.

Revenue passenger kilometers[6] **(RPK)**. Also called passenger kilometers performed (PKP). An airline metric that is calculated by multiplying the number of revenue passenger carried by distance travelled in kilometers.

Revenue tonne. A tonne of payload carried for which the airline receives remuneration, either be the mass of cargo and/or mass of passengers and their luggage.

Revenue tonne kilometers[7] **(RTK)**. An airline metric that is calculated by multiplying the number of revenue tonnes carried by the distance travelled in kilometers. Tonne-kilometers performed (TKP) equals the sum of the products obtained by multiplying the total number of tonnes of each category of revenue load carried by the airport-to-airport distance.

Scope 1 emissions. A reporting organization's direct GHG emissions.

Scope 2 emissions. A reporting organization's indirection emissions associated with the generation of electricity, heating/cooling, steam, or other forms of embedded energy purchased for own consumption.

Scope 3 emissions. A reporting organization's indirect emissions other than those covered in scope 2. Scope 3 emissions are further divided into fifteen categories.

[3] See GHG Protocol *Technical Guidance for Calculating Scope 3 Emissions, Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard, Version 1.0 as updated (2022)*, available at: https://ghgprotocol.org/scope-3-calculation-guidance-2

[4] See for instance https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

[5] See slides 15 and 16 of following document: https://www.icao.int/mid/documents/2014/aviation%20data%20analyses%20seminar/4%20-%20introduction%20to%20air%20transport%20statistics.pptx

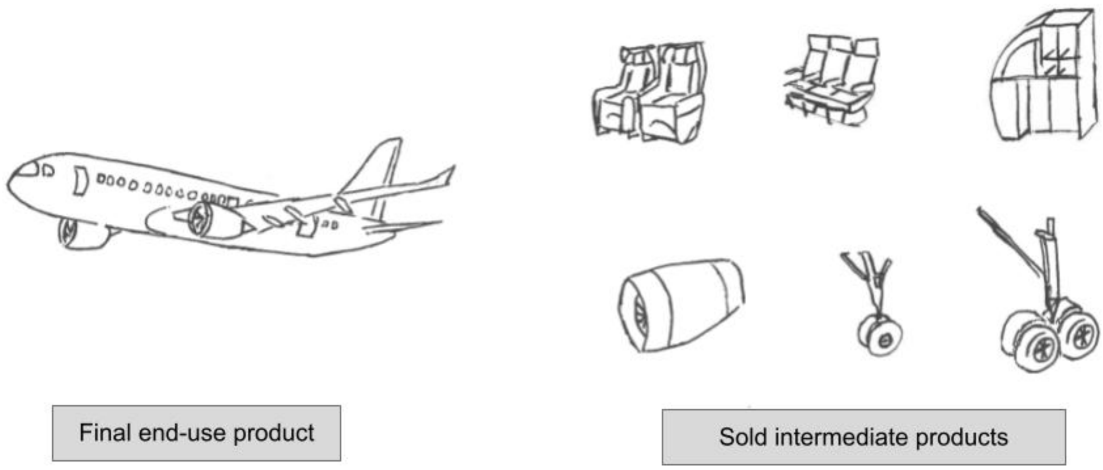
[6] See slides 17 to 19 in https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

[7] See slides 24 to 26 in https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

Scope 3 Category 11 emissions. A reporting organization's Scope 3 emissions associated with the use of sold products, as defined in the GHG Corporate Protocol Scope 3 standard[8] and supported by a technical guidance for calculating Scope 3 Emissions.[9]

Sustainable Aviation Fuel (SAF). Renewable or waste-derived aviation fuels that meets sustainability criteria. [10]

Sold Intermediate Products. Products that require further processing, transformation, or inclusion in another product before use, e.g., engines, cabin interiors, hydraulic and electrical systems, landing gears, bolts, as illustrated by the figure below:



Typical stage length. Typical distance flown by a flight from take-off to landing. For a given flight, the stage length depends on the origin and destination pair.

[8] See GHG Protocol *Corporate Value Chain (Scope 3) Accounting and Reporting Standard, as corrected (2013)*, available at: https://ghgprotocol.org/corporate-value-chain-scope-3-standard

[9] See GHG Protocol *Technical Guidance for Calculating Scope 3 Emissions, Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard, Version 1.0 as updated (2022)*, available at: https://ghgprotocol.org/scope-3-calculation-guidance-2

[10] See ICAO SAF definition, available at: https://www.icao.int/environmental-protection/pages/SAF.aspx

2 Context and purpose of this guidance

2.1 Introduction

IAEG identified that, among the various Scope 1, 2 and 3 greenhouse gas emission categories defined by the Greenhouse Gas (GHG) Corporate Protocol, Scope 3 Category 11 "Use of Sold Products" is generally one of the most relevant for aerospace companies.

IAEG therefore decided to develop industry-specific methodology and guidance materials to promote consistency of approaches within the aerospace industry. As a result of the significant attention currently focused on emissions from civil aviation and the expectation for continued growth in this industry, IAEG elected to focus initial guidance for calculating Scope 3 Use of Sold Products Emissions on the civil aviation sector.[11]

Calculation of Scope 3 Category 11 Use of Sold Products emissions requires a forecast of the emissions linked to future operation of civil aviation products over their projected lifetimes. The breadth of manufacturers in the civil aviation supply chain – including manufacturers of parts, components, engines, and aircraft – creates the potential for significant variation in Scope 3 reporting absent a recognized industry standard. This guidance was developed to provide civil aviation manufacturers with an industry-supported methodology and approaches for calculating their Scope 3 Category 11 emissions.

Although this guidance was developed for calculating Scope 3 Category 11 emissions, it may also be applicable to calculating the relevant portion of the ISO 14064-1[12] Category 5, indirect GHG emissions associated with the use of products, or ISO/TR 14069[13] Category 18, indirect GHG emissions associated with the use stage of the products.

2.2 Objectives

The guidance was developed with the following objectives:

- Be consistent with the GHG Protocol's *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*, and the GHG Protocol's *Technical Guidance for Calculating Scope 3 emissions*, Category 11 Use of Sold Products.
- Create a usable guide that is simple and reflects the fact that "use of sold products" emissions calculations are a forecast over a significant time frame.
- Provide guidance that can be used across the breadth of the civil aviation manufacturing sector.
- Promote use of reliable and internationally recognized emission factors and standards.

[11] As per Chapter 10 of IPCC Sixth Assessment Report (AR6) titled "Climate Change 2022, Mitigation of Climate Change", available at: https://www.ipcc.ch/report/ar6/wg3/, aviation was responsible for approximately 2.4% of total anthropogenic emissions of CO2 (including land-use change) in 2018.

[12] See ISO 14064-1:2018(E), Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

[13] See ISO/TR 14069:2013(E), Greenhouse gases — Quantification and reporting of greenhouse gas emissions for organizations — Guidance for the application of ISO 14064-1

- Provide a framework for inclusion of the impact of sustainable aviation fuel (SAF) as the global availability and adoption of SAF increases.
- Define a carbon intensity factor that can be used to reflect year over year progress reducing the carbon intensity of products delivered in the civil aviation sector.

3 Description of the methodology

3.1 Emissions description

GHG Corporate Protocol Scope 3, Category 11 emissions are the total expected lifetime emissions from use of the product(s) sold in the reporting year. These emissions are defined by the ISO 14064-1 as a portion of *Category 5, indirect GHG emissions associated with the use of products from the organization* and by the ISO/TR 14069 as a portion of *Category 18, indirect GHG emissions associated with the use stage of the products*.

These products can be either final products or intermediate products. In the current version of this document, civil aircraft delivered to the end use operators are considered final products; and systems and components integrated into the aircraft are considered intermediate products.

Scope 3, Category 11 calculation guidance provided by the GHG Corporate Protocol defines two types of emissions from the use of sold products:

- Direct use-phase emissions (Required)
    - Emissions from products that directly consume energy (fuels or electricity) during use.
      Examples: emissions from fuel or electricity consumed by aircraft & engines, and emissions from energy (via engine offtakes) directly consumed by systems on board of the aircraft

    - Emissions from products that contain or form GHG that are emitted during use.
      Examples: fugitive emissions from certain refrigeration and fire extinguishers (e.g., hydrofluorocarbons (HFCs).
      Given the small amount of fugitive emissions, if any, compared with emissions from energy consumption for civil aviation, and the fact that they are only relevant to a small number of aerospace manufacturers, specific guidance is not included in this document. Further details can be found in “Calculation formula [11.3]” in the *GHG Technical Guidance for Calculating Scope 3 emissions*.

- Indirect use-phase emissions (Optional)
    - Emissions from products that indirectly consume energy (fuels or electricity) during use.
      Examples include emissions associated with carrying the weight of aircraft interiors, landing gear and other systems during the flight. The weight of these products contributes to the overall fuel burn of the aircraft, and therefore results in indirect emissions for those systems.

Companies may optionally include emissions associated with maintenance of sold products during their lifetime if such emissions are not captured in other reporting categories. Specific guidance for emissions related to the maintenance of sold products during their lifetime is not included in this document.

Please note that due to important uncertainties remaining in quantifying some of the aviation non-GHG climate terms and in the underlying physical processes, only GHGs as identified by the UNFCCC/Kyoto Protocol are considered in the present guidance.

3.2 Calculation process

Calculating the expected lifetime emissions from sold products in accordance with the GHG Corporate Protocol requires a detailed understanding of how the products will be used, determination of emission factors applicable to the energy consumed by the product use, and detailed documentation of data sources and assumptions.

For civil aviation products, key data elements include:

Product Data

- Quantities of products sold
- Expected lifetimes of products sold
- Expected use of the products sold
- Fuel consumed per use of products
- Type of fuel consumed by products
- Electricity consumed per use of products

Emissions Factors

- Life cycle emission factors for fuels
- Life cycle emission factors for electricity

The overall approach to compute the Use of Sold Products emissions is illustrated in the figure below:

Determine organizational boundaries

For products or integrated systems at least partially attributable to activities within the organizational boundaries

Calculate whole aircraft lifetime emissions

Allocate whole aircraft lifetime emissions to products in question based on product lifetime and an allocation method

Report the portion of emissions defined by organizational boundaries

Defining the organizational boundary determines which operations are included in the company's organizational boundary and how emissions from each operation are consolidated by the reporting company. For Scope 3 Category 11 emissions, the organizational boundary defines the portion of product use phase emissions attributed to the reporting organization. The company has three options for defining its organizational boundaries: equity share, financial control, or operational control. A consistent consolidation approach should be used across the Scope 1, Scope 2, and Scope 3 emissions inventories.

3.3 Calculating direct use-phase emissions – final products

Calculation of the final products (whole aircraft) direct use-phase lifetime emissions from energy consumption can be accomplished using the following equations:

Direct use-phase emissions for the Final Products

$$\sum_{\substack{Aircraft\\Type}} \left\{ \begin{matrix} Number\ of \\ delivered \\ aircraft \end{matrix} \times \sum_{Year=1}^{\substack{Expected\\aircraft\ life}} \left[\begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} \right] \right\} \qquad \text{Equation (1)}$$

$$\begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} = \begin{matrix} Annual \\ fuel\ burn \\ per\ aircraft \end{matrix} \times \begin{matrix} Jet\ fuel \\ emission \\ factor \end{matrix} \times \left(\begin{matrix} \% \\ jet \\ fuel \end{matrix} + \begin{matrix} \% \\ alternative \\ fuels^{14} \end{matrix} \times \left(1 - \begin{matrix} Emission \\ reduction \\ factor \end{matrix} \right) \right) \qquad \text{Equation (2)}$$

$$\begin{matrix} Annual \\ fuel\ burn \\ per\ aircraft \end{matrix} = f \left(\begin{matrix} utilization, \\ mission\ profile, \\ air\ traffic\ efficiency, \\ load\ factor, \\ aicraft\ performance \end{matrix} \right) \qquad \text{Equation (3)}$$

Note that Equation (2) can also be written as:

$$\begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} = \begin{matrix} Annual \\ fuel\ burn \\ per\ aircraft \end{matrix} \times \begin{matrix} Jet\ fuel \\ emission \\ factor \end{matrix} \times \left(1 - \begin{matrix} \% \\ alternative \\ fuels \end{matrix} \times \begin{matrix} Emission \\ reduction \\ factor \end{matrix} \right) \qquad \text{Equation (2bis)}$$

Equation (1) may be simplified into $\sum_{\substack{Aircraft\\Type}} \left\{ \begin{matrix} Number\ of \\ delivered \\ aircraft \end{matrix} \times \left[\begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} \right] \times \begin{matrix} number\ of\ years \\ of\ the\ expected\ aircraft \\ life \end{matrix} \right\}$ if the *annual emissions per aircraft* are kept constant all along the aircraft lifetime.

[14] The % alternative fuels refers to the percent content of alternative fuels in the annual fuel burn, which is limited by the availability of alternative fuels, and in the case of SAF, is also limited by the maximum percentage of SAF blend certified for the aircraft.

Table summarizing data needed for calculating final products emissions:

Input	Potential data sources
Number of delivered aircraft	Delivery records in line with the company financial reporting.
Annual fuel burn per aircraft	Company internal information or statistics from external databases, or if not available based on generic aircraft utilization as provided in section 6.2. Several formulas may be applied to estimate the annual fuel burn, regardless the type of fuel, e.g. • Fuel burn per typical flight cycle x annual number of flight cycles • Average fuel burn per hour x annual number of flight hours • Average fuel burn per km x annual number of kilometers flown • … The fuel burn for each flight depends on the mission profile (range, speed, …), the payload, the mission rules (taxi duration, reserves, allowances…), as well as air traffic efficiency.
% jet fuel	From the alternative fuel projection scenario(s) selected by the company (see discussions below for further information and recommendations).
Jet fuel emission factor	See section 5.1
% alternative fuels	Same as above.
Emission reduction factor	See section 5.2 for SAF emission reduction factor
Expected aircraft life (years)	Derived from historical fleet database, provided by aircraft manufacturers, or see section 6.1 if this data is not readily available.

Alternative aviation fuels may include Sustainable Aviation Fuels (SAFs), hydrogen, ammonia, any other non-fossil-derived aviation fuels, or even electricity. The discussions below provide additional information and considerations for different types of fuels and some recommendations.

Presently, SAF blends up to 50% are the only liquid alternative fuels certified for operational use. SAF content accounted for 0.01% of global civil aviation jet fuel use in 2019,[15] but SAF production is growing, with an estimated increase of 200% in 2022[16], and the share of SAF in the fuel mix is expected

[15] See ATAG fact sheet #5 Aviation's Energy Transition/ May 2020, available at: https://www.caafi.org/resources/pdf/FACT_SHEET_5_Aviations_Energy_Transition.pdf

[16] See IATA press release titled 2022 SAF Production Increases 200% - More Incentives Needed to Reach Net Zero, available at: https://www.iata.org/en/pressroom/2022-releases/2022-12-07-01/

to become significant as the aviation industry decarbonization effort[17] accelerates. If a scale-up projection of SAF is assumed by the reporting company over the product lifetime, IAEG recommends to explicitly provide the SAF projection data and the data source cited (e.g., Waypoint 2050, IEA). When regulatory or incentive frameworks are definitively approved, such guidance will provide a reference to be followed for SAF incorporation over the expected lifetime of sold products. For aircraft powered by a mix of jet fuel and SAF, Equation (2bis) is the recommended formula as it is simpler to use.

Unlike SAF, there is no or minimal GHG emissions from the combustion of hydrogen or ammonia. In the case of future aircraft fueled by hydrogen or ammonia, the aircraft direct use-phase lifetime emissions are driven by the emissions associated with hydrogen or ammonia production. The following equation illustrates how Equation (2) may be reduced for the calculation of annual direct use-phase emissions for aircraft fueled by hydrogen or ammonia, or the portion of the emissions associated with hydrogen or ammonia fuel in a mixed fuel scenario:

Annual direct use-phase emissions for aircraft powered by hydrogen or ammonia

$$\begin{matrix} Annual \\ hydrogen\ or\ ammonia \\ emissions \\ per\ aircraft \end{matrix} = \begin{matrix} Annual \\ hydrogen\ or\ ammonia \\ consumption \\ per\ aircraft \end{matrix} \times \begin{matrix} Hydrogen \\ or\ ammonia \\ emission \\ factor \end{matrix} \qquad \text{Equation (4)}$$

Equation (4) can then be plugged into Equation (1) to calculate lifetime emissions. Hydrogen and ammonia emission factors are discussed in Section 5.3 of this document.

In the case of an electric aircraft, the following equation illustrates how Equation (2) may be reduced for the calculation of annual direct use-phase emissions from electricity consumption for charging batteries from the power grid, either for fully electric aircraft or hybrid electric aircraft:

Annual direct use-phase emissions for the Final Products with alternative energy (electricity)

$$\begin{matrix} Annual \\ electricity \\ emissions \\ per\ aircraft \end{matrix} = \begin{matrix} Annual \\ electricity \\ consumption \\ per\ aircraft \end{matrix} \times \begin{matrix} Electricity \\ emission \\ factor \end{matrix} \qquad \text{Equation (5)}$$

Equation (5) can then be plugged into Equation (1) to calculate lifetime emissions associated with electricity use. Electricity emission factors are discussed in Section 5.4 of this document.

[17] See ATAG Waypoint 2050 Second edition September 2021, available at: https://www.atag.org/component/attachments/attachments.html?id=967

3.4 Calculating direct & indirect use-phase emissions – sold intermediate products

Consistent with GHG Technical Guidance for Calculating Scope 3 Emissions, companies that sell intermediate products that directly consume energy – fuels or electricity – during use are required to include these direct use-phase emissions in their Category 11 calculations. However, the inclusion of indirect use-phase emissions is optional.

The calculation starts with determining the emissions of the final product (i.e., aircraft) over the expected lifetime of the sold intermediate product. Then, a second calculation is performed to define the percentage of the emissions that should be allocated to the sold intermediate product. **The allocation methodology is similar for both direct and indirect use-phase emissions**.

A reporting company may select a simple allocation method based on mass ratio or a hybrid allocation method. For example, the hybrid allocation method may be more suitable to systems/equipment that have significant direct use phase emissions that are only reasonably reflected by the simple mass ratio method (e.g., Environmental Control System).

Allocation method based on mass ratio:

Allocation method 1: based on mass ratio

$$\sum_{\substack{Intermediate \\ Product\ Types}} \left\{ \begin{matrix} Number\ of \\ delivered \\ products \end{matrix} \times \sum_{Year=1}^{\substack{Expected\ life\ of \\ intermediate\ product}} \left[\begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} \times \frac{Mass\ of\ intermediate\ product}{Mass\ of\ aircraft} \right] \right\} \quad \text{Equation (6)}$$

The choice of the “Mass of aircraft” shall be clearly stated in the reporting (e.g., Operating Empty Weight, average aircraft mass during the flight, …).

Hybrid allocation method for equipment that have both direct and indirect use-phase emissions (e.g., Environmental Control System, pneumatic systems, electrical systems, galleys):

Allocation method 2: Hybrid allocation method for equipment that have both direct and indirect use-phase emissions

$$\sum_{\substack{Intermediate\\Product\ Type}} \left\{ \begin{matrix} Number\ of \\ delivered \\ products \end{matrix} \times \sum_{Year=1}^{\substack{Expected\ life\ of\\intermediate\ product}} \left[\begin{matrix} Annual\ direct \\ emissions \\ of\ product \end{matrix} + \begin{matrix} Annual\ indirect \\ emissions \\ of\ product \end{matrix} \right] \right\} \quad \text{Equation (7)}$$

Where

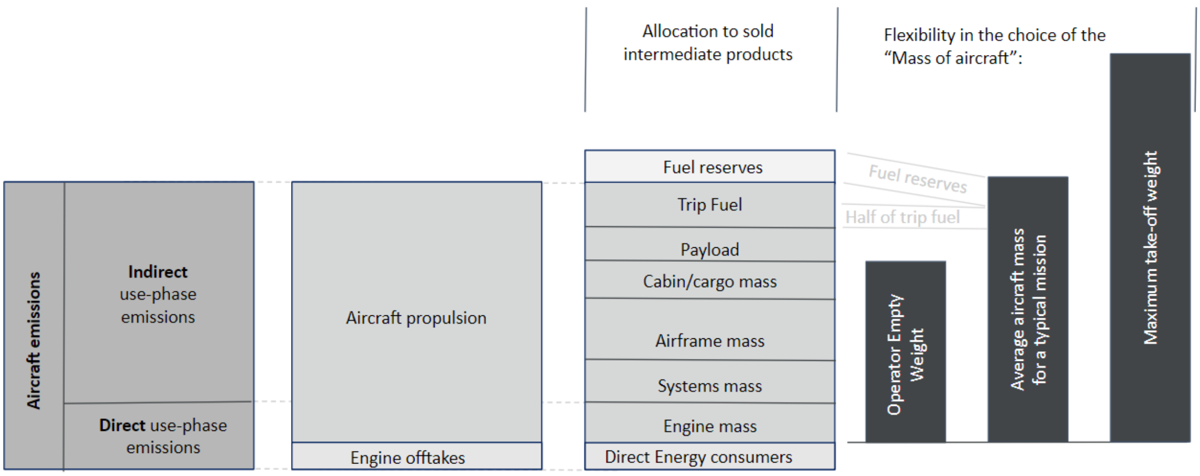
$$\begin{matrix} Annual\ direct \\ emissions \\ of\ product \end{matrix} = \begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} \times \left[\frac{Fuel\ offtake\ per\ intermediate\ product}{Total\ Fuel\ burn} \right] \quad \text{Equation (8)}$$

And

$$\begin{matrix} Annual\ indirect \\ emissions \\ of\ product \end{matrix} = \begin{matrix} Annual \\ emissions \\ per\ aircraft \end{matrix} \times \left[\frac{Fuel\ for\ propulsion}{Total\ fuel\ burn} \right] \times \left[\frac{Mass\ of\ intermediate\ product}{Mass\ of\ aircraft} \right] \quad \text{Equation (9)}$$

Indeed, some intermediate products have both direct emissions (related to the additional fuel burn due to pneumatic or mechanical offtakes on the engines for instance) and indirect emissions (related to the weight of the product). The proportion of offtakes may be difficult to obtain. The company may therefore contact the aircraft manufacturer to obtain emission figures, namely amounts of CO_2e per year of use on board of the aircraft per kVA operating for electrical consumers, or amounts of CO_2e per year of use on board of the aircraft per kg/s of bleed flow in the case of pneumatic consumers.

The figure below illustrates the hybrid allocation method:



Companies may adapt the allocation method presented above based on their specific situation. For example, for products that contribute to the aircraft drag and / or lift compared to their contribution to the aircraft mass, the allocation may quantify this drag and / or lift contribution.

In certain cases, the eventual end use of sold intermediate products may be unknown or the sold intermediate product may be further manufactured within the value chain (leading to potential mass decrease of the intermediate product once fitted on the final product). This is typically the case for suppliers that are several tiers away in the supply chain of the aircraft and it may be very difficult for them to obtain information on product use, to a point were calculation is not possible or at least extremely difficult. A similar situation may exist for intermediate products that have several end-use applications. In such instances, and consistent with the GHG Corporate Protocol Scope 3, Category 11 guidance, companies may disclose and justify the exclusion of all downstream emissions related to these sold intermediate products. For more information, see section 6.4 of the Scope 3 Standard (Accounting for downstream emissions).

If a company includes both direct and indirect use-phase emissions in its Category 11 calculations, it should disclose both emission numbers separately.

Table summarizing data needed for calculating sold intermediate product emissions:

Input	Potential data sources
Number of delivered products	Delivery records in line with the company financial reporting
Annual fuel burn per aircraft	See Section 3.3.
Expected lifetime of the sold intermediate product	Company internal information
Mass of sold intermediate product	Company internal data
Mass of aircraft	Depends on company's choice: Operator Empty Weight, Average Mass of aircraft (i.e., mass of the aircraft at the middle of the mission), MTOM, Mid mass from ICAO CO_2 standard. See also sections 8.6 and 8.7 for further information.
Fuel offtake per intermediate product / Total fuel burn	Portion of the fuel burn that is directly related to the energy consumption of the sold intermediate product (via mechanical or pneumatic offtakes). Total fuel offtakes usually represents less than a few percents of the *Total fuel burn*.
Fuel for propulsion / Total fuel burn	Portion of fuel burn that is related to propulsion, once removing the portion of the total fuel offtakes. The sum of (Fuel offtake per intermediate product / Total fuel burn) and (Fuel for propulsion / Total fuel burn) cannot exceed 1.

4 Emissions intensity metric

To address the concern that products with longer lifetimes can appear to have higher use-phase emissions than products with shorter lifetimes, the GHG Protocol recommends reporting relevant information such as product lifetimes and emissions intensity metrics to demonstrate improvements in product performance over time. Commonly used commercial aviation metrics are therefore suggested.

4.1 Intensity metric for commercial aircraft

To convert absolute emissions for commercial aircraft to an intensity metric, the following approach is recommended with two alternatives:

- Intensity metric for commercial aircraft carrying passengers
- Intensity metric for commercial aircraft carrying freight or passengers and belly freight.

Intensity metric for passenger aircraft

Emissions per revenue passenger kilometers (RPK), commonly used for passenger aircraft:

$$\frac{Sold\ Products\ Lifetime\ Emissions}{Sold\ Products\ Associated\ Lifetime\ RPK} \qquad \text{Equation (10)}$$

where

Sold Products Lifetime Emissions are the emissions estimated using Equation (1)

and

Sold Products Associated Lifetime RPK:

$$\sum_{\substack{Aircraft\\Type}} \left\{ \begin{matrix} Number\ of \\ delivered \\ aircraft \end{matrix} \times \sum_{Year=1}^{\substack{Expected\ aircraft\\life}} \left[\begin{matrix} Available \\ seats \end{matrix} \times \begin{matrix} Load \\ Factor \end{matrix} \times \begin{matrix} Typical \\ stage \\ length \end{matrix} \times \begin{matrix} Annual \\ flight \\ cycles \end{matrix} \right] \right\} \qquad \text{Equation (11)}$$

Intensity metric for freighter aircraft or aircraft carrying both passengers and belly freight

Emissions per revenue tonne kilometers (RTK):

$$\frac{Sold\ Products\ Lifetime\ Emissions}{Sold\ Products\ associated\ Lifetime\ RTK} \qquad \text{Equation (12)}$$

where

Sold Products Lifetime Emissions are the emissions estimated using Equation (1)

and

Sold Products associated Lifetime RTK:

$$\sum_{\substack{Aircraft\\Type}} \left\{ \begin{pmatrix} Number\ of \\ delivered \\ aircraft \end{pmatrix} \times \sum_{Year=1}^{\substack{Expected\ aircraft\\life}} \left[Payload(t) \times \begin{matrix} Typical \\ stage \\ length \end{matrix} \times \begin{matrix} Annual \\ flight \\ cycles \end{matrix} \right] \right\} \qquad \text{Equation (13)}$$

Where appropriate, passenger and luggage, belly freight, and main deck freight for dedicated freighters or combi aircraft should be included in the payload:

$$Payload(t) = \begin{matrix} Available \\ seats \end{matrix} \times \begin{matrix} Load \\ Factor \end{matrix} \times \begin{matrix} Weight\ of \\ passenger\ and \\ luggage\ (t)^{18} \end{matrix} + \begin{matrix} Belly \\ freight(t) \end{matrix} + \begin{matrix} Main\ deck \\ freight\ (t) \end{matrix} \qquad \text{Equation (14)}$$

Note that:

- The load factor assumption should be explicitly stated in the reporting as it is a key parameter used to track the efficiency of the sector.[19] The IATA source may be used as it represents global commercial aviation.[20] The load factor considered for the intensity metric shall be consistent with the load factor used for the product use emissions computation.
- The intensity metric may either be calculated as a single metric across all aircraft types, or as separate metrics for individual aircraft families, e.g., single aisle, widebody, etc.

[18] IATA Passenger CO2 Standard Methodology (https://www.iata.org/en/programs/environment/passenger-emissions-methodology) considers 100 kg per passenger (including their checked baggage)

[19] See ATAG fact sheet https://aviationbenefits.org/media/167475/fact-sheet_3_tracking-aviation-efficiency-v2.pdf

[20] See for instance IATA June 2020 report "Economic Performance of the Airline Industry", available at: https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

Table summarizing data needed for calculating an intensity metric for commercial aircraft:

Input	Potential data sources
Number of delivered products	Delivery records in line with the company financial reporting
Annual fuel burn per aircraft	See Section 3.3.
Typical stage length [km] x Annual flight cycles	Company's internal source that is in line with the way the annual fuel burn is computed. As described in section 3.3, several alternative formulas could be used, e.g. • Distance flown per hour x annual number of flight hours • Annual number of kilometers flown • …
Available seats	Typical cabin layout for each aircraft type
Load Factor	Data source at the discretion of the company (e.g., IATA)
Weight of passenger & luggage	IATA Passenger CO2 Standard Methodology considers 100 kg per passenger and their checked luggage, i.e., 0.1 tonne per passenger
Belly freight	Airlines statistics, Department of Transportation statistics
Main deck freight	Airlines statistics, Department of Transportation statistics

The intensity metric defined above may not be appropriate for business jets that have very specific operations and payload.

4.2 Intensity metric for sold intermediate products

In principle, the intensity metric for sold intermediate products may be calculated from their lifetime emissions and the RPK or RTK generated by their equipped aircraft over the lifetime of sold intermediate products.

Example of emissions Intensity Metric based on RPK

$$\left(\frac{Sold\ Intermediate\ Product\ Lifetime\ Emissions}{Sold\ Intermediate\ Products\ Associated\ Lifetime\ RPK}\right) \qquad \text{Equation (15)}$$

Where:

Sold Intermediate Products Lifetime Emissions are the emissions estimated in paragraph 3.4

And

Sold Intermediate Products associated lifetime RPK is the sum, over all aircraft types equipped with the sold intermediate products, of Lifetime Revenue Passenger Kilometers:

$$\sum_{\substack{Aircraft\ type \\ equipped\ with \\ sold\ products}} \left\{ \begin{matrix} Number\ of \\ delivered \\ aircraft \\ equipped \\ with\ sold \\ products \end{matrix} \times \sum_{Year=1}^{\substack{Expected \\ life}} \begin{bmatrix} Annual \\ revenue \\ passenger \\ kilometers\ of \\ aircraft\ type \end{bmatrix} \right\} \qquad \text{Equation (16)}$$

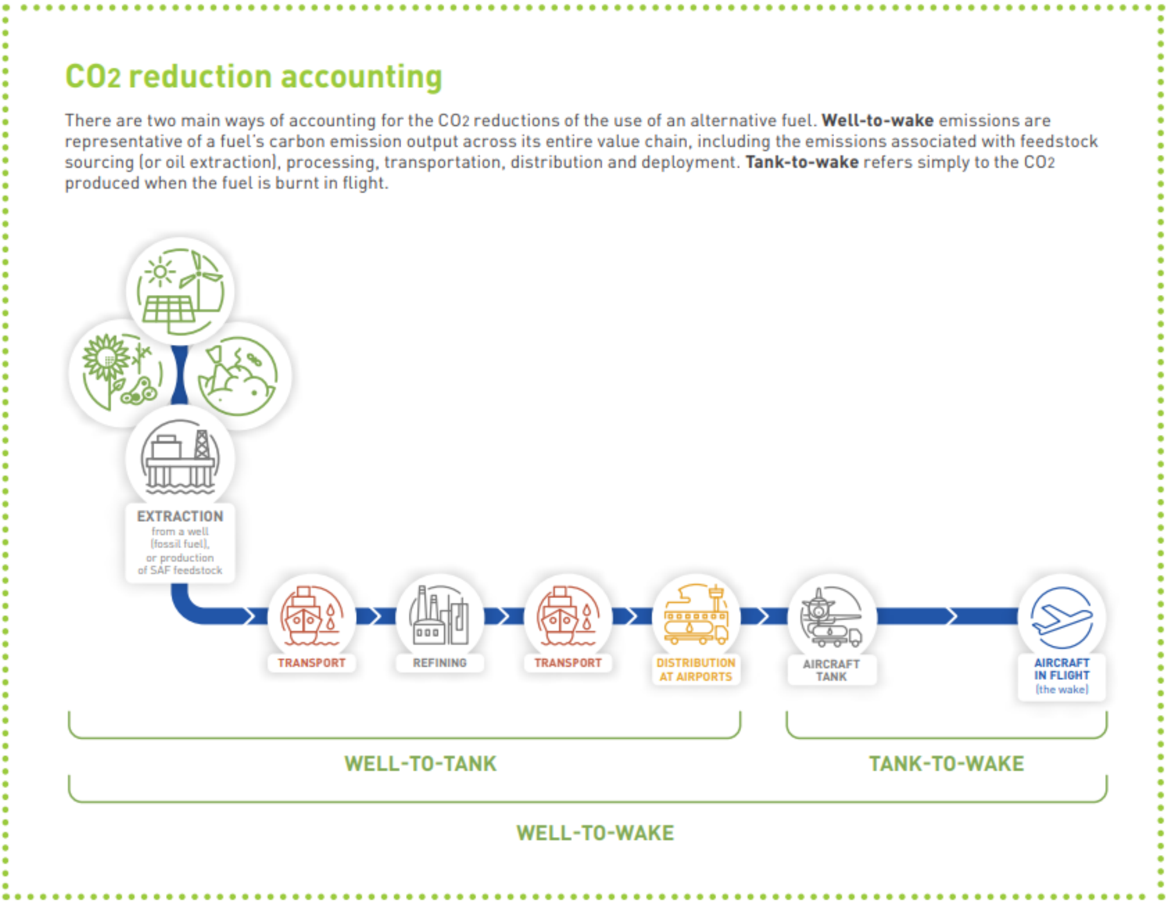
Where

$$\begin{matrix} Annual\ revenue \\ passenger\ kilometers\ of \\ aircraft\ type \end{matrix} = \begin{matrix} Available \\ seats \end{matrix} \times \begin{matrix} Load \\ Factor \end{matrix} \times \begin{matrix} Typical \\ stage \\ length \end{matrix} \times \begin{matrix} Annual \\ flight \\ cycles \end{matrix} \qquad \text{Equation (17)}$$

For companies selling different types of products, determining the volume of the associated revenue passenger or tonne kilometers generated over the life of the aircraft equipped with all products may be difficult given that different products have different useful lives. The intensity metric may either be calculated as a single metric across all products, or as separate metrics for individual product families or for individual aircraft families (e.g., single aisle, widebody, etc). Reporting of an intensity metric should be precise as to the definition of the metric, and the different factors driving its evolution.

5 Emission factors

As specified in the GHG Protocol Technical Guidance for Calculating Scope 3 Emissions, fuel lifecycle emission factors should be used for reporting Scope 3 Category 11 Use of Sold Products Emissions. The fuel lifecycle emission factor represents the well-to-wake emissions[21]. It varies based on the source feedstock, production process, and distribution as illustrated below[22]:



5.1 Fuel lifecycle emission factors – fossil fuel

International Civil Aviation Organization (ICAO) Annex 16, Volume IV, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), specifies lifecycle (well-to-wake) emission values for baseline fossil fuels in terms of lifecycle fuel emissions.[23]

[21] The lifecycle emissions factors presented here represent a "well to wake" lifecycle analysis to assess the overall or net GHG impacts of a fuel including each stage of its production and use.

[22] Chart excerpt from ATAG "Beginner's Guide to Sustainable Aviation Fuel", Edition 4, April 2023, available at: https://aviationbenefits.org/downloads/beginners-guide-to-sustainable-aviation-fuel/

[23] See Section 3.3.1 of *ICAO Annex 16, Volume IV, CORSIA, 1st edition, 2018*, which specifies baseline lifecycle emissions values for aviation fuel as 89 gCO2e/MJ for jet fuel and 95 gCO2e/MJ for AvGas, available at: https://www.icao.int/environmental-protection/CORSIA/Pages/SARPs-Annex-16-Volume-IV.aspx

ICAO Annex 16, Volume III, Aeroplane CO_2 Emissions, specifies that the lower heating value for fuel should be used for testing CO_2 emissions, as well as the reference value for jet fuel (43.217MJ/kg).[24] Both ASTM D910[25] and U.K. Def Stan 91-090[26] specify a minimum lower heating value of 43.50 MJ/kg for AvGas. Without an official reference value, this value may be used to calculate AvGas lifecycle emission factor.

The baseline fossil fuel lifecycle emission factors can then be obtained.

Table summarizing baseline fossil fuel lifecycle emission factors:

Fuel	Lifecycle Emission	Lower Heating Value	Lifecycle Emission Factor
Jet fuel	89 gCO2e/MJ	43.217 MJ/kg	3.846 kgCO2e/kg
AvGas	95 gCO2e/MJ	43.50 MJ/kg	4.132 kgCO2e/kg

5.2 Fuel lifecycle emission factors – Sustainable Aviation Fuel (SAF)

SAF lifecycle emission factors are significantly different than the lifecycle emission factors for fossil-based jet fuel because its production utilizes either CO_2 absorbed from the atmosphere (through bio-feeder stocks or direct carbon capture), or CO_2 recycled from wastes. SAF lifecycle emissions factors vary as a function of feedstock and process pathway. The ICAO CORSIA includes default lifecycle emission factors for CORSIA eligible SAF.[27]

The emission reduction factor (ERF) is defined such that:

$$ERF = 1 - LS_f/LC \qquad \text{Equation (18)}$$

with LS_f being the lifecycle emission of the selected SAF in gCO2e/MJ, and LC representing the baseline life cycle emission (e.g., 89 gCO_2e/MJ for fossil jet fuel).

5.3 Hydrogen and ammonia emission factors

Companies shall document the source of the emission factors used for hydrogen- or ammonia-powered aircraft as they depend on the production process, source of feedstock, and source of energy

[24] See Section 2.5.1 of *ICAO Annex 16, Volume III, Aeroplane CO2 Emissions, 1st edition as amended, 2020*, which specifies the reference lower heating value as 43.217 MJ/kg for jet fuel (due to the applicability of this standard to larger jet and propeller aircraft, emissions from AvGas is out of the scope), available at https://elibrary.icao.int

[25] See minimum net heat of combustion in Table 1 of *ASTM D910-21, Standard Specification for Leaded Aviation Gasolines*, available at: https://www.astm.org/d0910-21.html

[26] See Specific Energy in Table 1 of *U.K. Ministry of Defense, Defense Standard 91-090, Gasoline, Aviation, Grades UL91, 100/130 and 100/130 Low Lead. JSD: AVGAS UL91, AVGAS 100 and AVGAS 100LL*, available at: https://www.dstan.mod.uk

[27] See the latest version of *ICAO CORSIA Default Life Cycle Emissions Value for CORSIA Eligible Fuels*, available at: https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

(e.g., electrolysis, steam methane reforming with or without carbon capture and storage). Companies should use the most current emission factors as updates are provided from their emissions factor sources, with updates required no more frequently than annually.

5.4 Electricity emission factors

Companies shall document the source of emission factors that are used for electric charging of electric or hybrid electric aircraft. Companies should use the most current emission factors as updates are provided from their emissions factor sources, with updates required no more frequently than annually.

Regional average electric grid values, depending on delivered fleet location, may be used to estimate the electricity lifecycle emission factors.

It is recommended that the *IAEG GHG Reporting Guidance for the Aerospace Industry*[28] is followed for electricity emission factors.

[28] See Section D.7.b of the latest version of *the IAEG GHG Reporting Guidance for the Aerospace Industry*, available at: https://www.iaeg.com/ghg-guidance

6 Main assumptions for aircraft direct emissions estimation

Companies can use internal aircraft utilization data (such as yearly number of flight hours, average mission range, payload). If such internal data are not available, generic industry data may be used. The purpose of this chapter is to provide generic data to help companies that do not have access to aircraft-specific data. Freighters specificities shall be considered where appropriate.

Where possible, equipment manufacturers may contact their customers to obtain emissions value per aircraft family for mass and offtakes allocation. Companies are encouraged to make relevant information available, where possible, or to provide guidance on how to utilize their publicly reported information such as that in their sustainability report, to help their supply chain in calculating Scope 3 Category 11 emissions.

6.1 Aircraft lifetime

According to the 2019 ICAO Environmental Report,[29] the aircraft age at retirement is around 25 years for passenger aircraft and 32 years for freighters, computed over the 1980-2017 period.

6.2 Aircraft utilization

Some generic aircraft utilization data are provided below:

For passenger aircraft:

Aircraft category	Example of aircraft	Flight cycle duration (hours)	Annual flight hours per aircraft
Regional Turboprop	ATR42, ATR72, DASH-6, DASH-8, Beech1900, Fokker50, Jetstream 41, Saab 2000, Saab 340, King Air A100, Vazar Turbo Otter, ...	0.9	1550
Regional Turbojet	CRJ100, CRJ200, CRJ550, CRJ700, CRJ900, E170, E175, EMB-120, ERJ 135, ERJ-140, ERJ-145, F70, RJ85, ...	Not available yet	Not available yet

[29] See Chapter 8 of the *ICAO 2019 Environment Report*, available at: https://www.icao.int/environmental-protection/Pages/envrep2019.aspx

Aircraft category	**Example of aircraft**	**Flight cycle duration (hours)**	**Annual flight hours per aircraft**
Small	717, 737, 757, A318, A319, A320, A321, A320neo, A321neo, BAE146, MD-88, MD-90, RJ100, F100, CRJ1000, E190, E195, ...	2.0	2900
Medium	767, 787, A310, A330, A340, A350-900	6.1	4000
Large	747, 777, A350-1000, A380	7.0	4300

Data post-treated from Cirium / Fleet Analyzer for year 2019 for commercial aircraft.

For freighter aircraft:

Aircraft category	Example of aircraft	Flight cycle duration (hours)	Annual flight hours per aircraft
Regional freighter	An-26, An-28/M28, An-32, An-74, ATR42, ATR72, C-212, CRJ Regional Jet, DC-3, DHC-8, ...	1.3	550
Small freighter	727, 737, 757, An-12, An-72, BAE146, C-160, DC-9, MD-80, Tu204, ...	2.0	1350
Medium freighter	767, A300, A310, DC-10, DC-8, Il-62, Il-76, A330, ...	2.8	2050
Large freighter	747, 777, An-124, An-225, Il-96, MD-11, ...	5.8	3900

Data post-treated from Flight Radar 24 for year 2018 for freighters.

The reporting company may decide not to make the distinction between freighters and passenger aircraft, particularly if the number of sold freighter products is not representative versus the total number of sold passenger aircraft. In that case the reporting company may assimilate freighter aircraft to passenger aircraft for the sake of simplicity.

Due to very specific utilization of business jets, default generic data are not provided in this guidance.

6.3 Aircraft performance calculators

For companies that do not have internal aircraft performance tools required to compute amounts of fuel consumption for a given payload and range, the following tools may be relevant sources of fuel/emissions computations:

- FAA's Aviation Environmental Design Tool (AEDT)[30]
- Eurocontrol's Advanced Emission Model (AEM)[31]

[30] See FAA's Aviation Environmental Design Tool (AEDT) support website for technical details and information on how to obtain the AEDT tool: https://aedt.faa.gov/

[31] See Eurocontrol's advanced emission model (AEM) webpage for an overview of the tool and access conditions: https://www.eurocontrol.int/model/advanced-emission-model

7 Examples of application with fictive figures

Examples are provided in this section to illustrate the principle of the methodology presented in this guidance. Depending on the specific situation, a company may implement the methodology in different forms. Numeric values used in these examples are fictitious and do not refer to actual data of any particular aircraft, engines, or other equipment.

7.1 Example for an aircraft manufacturer

An aircraft manufacturer delivered 100 aircraft in the reported year:

Number of products sold	Aircraft type
70	single aisle
30	wide body

Based on the company's statistics, these types of aircraft have the following characteristics:

Aircraft type		Single Aisle	Wide Body
Typical flight duration	flight hours	2	6
Typical stage length	nm	800	2 500
Annual flight cycles	flight cycles	1 450	667
Aircraft lifetime	years	25	25
Revenue Payload		140 passengers	260 passengers & 4 tonnes of freight
Fuel burn	kg fuel per flight	4 000	30 000

Note that data are for illustrative purposes only, they do not refer to actual data.

Estimation of the lifetime GHG emissions of the delivered fleet:

- For the single aisle aircraft:

  70 aircraft x 25 years of operations x 1450 flights per year
  x 4000 kg fuel per flight x 3.846 kg CO_2e/kg jet-A
  = 39.0 Mt CO_2e

  The associated RPK are equal to:

  70 aircraft x 25 years of operations x 1450 flights per year
  x 800 nm x 140 passengers x 1.852 km/nm

= 526.3 billion RPK

This figure is equivalent to 52.63 billion RTK (assuming that one passenger and its luggage weighs 100kg)

- For the wide body aircraft:

  30 aircraft x 25 years of operations x 667 flights per year
  x 30000 kg fuel per flight x 3.846 kg CO_2e/kg jet-A
  = 57.7 Mt CO_2e

  The associated RTK are equal to:

  30 aircraft x 25 years of operations x 667 flights per year
  x 2500 nm x (260 passengers x 0.1 + 4) x 1.852 km/nm
  = 69.46 billion RTK

- In total the company will report 96.8 Mt CO_2e for its Scope 3 Category 11.

Intensity metric:

- For the single aisle aircraft:

  $$\text{intensity} = \frac{39}{52.63} = 742 \text{ gCO2e / RTK}$$

- For the long range aircraft:

  $$\text{intensity} = \frac{57.7}{69.46} = 831 \text{ gCO2e / RTK}$$

- For the delivered fleet:

  $$\text{intensity} = \frac{96.8}{52.63+69.46} = 792 \text{ gCO2e / RTK}$$

7.2 Example for engine manufacturers

An engine manufacturer delivered 200 engines in the reported year: 140 engines that will equip 70 single aisle aircraft and 60 engines that will equip 30 wide body aircraft.

The total lifetime emissions of the aircraft that are equipped with the engines will follow the same steps as described in section 1.1, leading to a total of 96.8Mt CO_2e. In that example, the engine's lifetime is the same as the aircraft.

As the engines are intermediate products, an allocation needs to be performed. The reporting company decides to follow the mass allocation method and to use average aircraft mass as reference mass for the allocation.

The average aircraft mass during the flight is estimated as follows:

Mass in kg	Single Aisle	Wide Body
Operator Empty Weight	42 000	140 000
Payload	14 000 (140 passengers x 100kg)	30 000 (260 passengers x 100kg + 4 000 kg of freight)
Fuel (= half of the fuel burn for the mission)	2 000	15 000
Fuel reserves	2 000	6 000
Total	**60 000**	**191 000**

Note that data are for illustrative purposes only, they do not refer to actual data.

The engines' unit masses are the following:

- 3000 kg for one single aisle engine
- 10 000 kg for one wide body engine

Therefore the allocation leads to:

- for the single aisle engine:

  140 engines x 25 years of operations x 1450 flights per year x 4000kg fuel per flight x 3.846 kg CO2e/kg jet-A x $\frac{3000}{60000}$
  = 3.90 Mt CO2e

- For the wide body aircraft:

  60 engines x 25 years of operations x 667 flights per year x 30000kg fuel per flight x 3.846 kg CO2e/kg jet-A x $\frac{10000}{191000}$
  = 6.04 Mt CO2e

- In total the company will report 9.94 Mt CO2e for its Scope 3 Category 11.

7.3 Example for equipment suppliers (for equipment without direct emissions)

In this example, the manufacturer sells equipment that does not directly consume energy. The manufacturer sold 1000 original equipment units during the reported year: 600 units will be fitted on single aisle aircraft and 400 units will be fitted on a wide body aircraft, assuming new aircraft installation only. As the equipment is an intermediate product, an allocation needs to be performed. The reporting company decides to follow the mass allocation method and to use the Operating Empty Weight as reference mass for the allocation.

The equipment weighs 30kg and has a lifetime of 10 years for the units installed on the single aisle aircraft and it weighs 50kg and has a lifetime of 15 years for the units installed on the wide body aircraft.

Equipment type	Number of products sold	Aircraft type	Mass of the equipment	Lifetime of the equipment (years)
Equipment A	600	single aisle	30 kg	10
Equipment B	400	wide body	50 kg	15

The allocated indirect emissions of the equipment units over their lifetime are the following:

For the equipment units installed on single aisle aircraft:

600 units x 10 years of operations x 1450 flights per year
x 4000 kg fuel per flight x 3.846 kg CO2e/kg jet-A
$\times \frac{30}{42000}$
= 95.6 kt CO2e

For the equipment units installed on wide body aircraft:

400 units x 15 years of operations x 667 flights per year
x 30000 kg fuel per flight x 3.846 kg CO2e/kg jet-A
$\times \frac{50}{140000}$
= 164.9 kt CO2e

The total indirect use phase emissions are therefore 260.5ktCO2e.

7.4 Example for suppliers of systems that have both direct and indirect emissions

In this example, the manufacturer sells equipment that has direct emissions (via engine offtakes) and indirect emissions (via the equipment mass). The equipment fuel consumption represents 2% of the fuel burn of the aircraft during its mission. Again, assume the equipment is for new aircraft installation only. The characteristics of the equipment are the following:

Equipment type	Number of products sold	Aircraft type	Mass of the equipment	lifetime of the equipment (years)
Equipment A	600	single aisle	300 kg	10
Equipment B	400	wide body	500 kg	15

The company decides to follow the hybrid allocation method (for indirect emissions the average aircraft mass is considered as reference) :

The direct emissions of the intermediate sold product are:

- for units installed on single aisle aircraft:

  600 units x 10 years of operations x 1450 flights per year
  x 4000 kg fuel per flight x 3.846 kg CO2e/kg jet-A
  x 2%
  = 2.7 Mt CO2e

- for units installed on wide body aircraft:

  400 units x 15 years of operations x 667 flights per year
  x 30000kg fuel per flight x 3.846 kg CO2e/kg jet-A
  x 2%
  = 9.2 Mt CO2e

The indirect emissions of the intermediate sold product are:

- for units installed on single aisle aircraft:

  600 units x 10 years of operations x 1450 flights per year
  x 4000kg fuel per flight x 3.846 kg CO2e/kg jet-A
  $\times \frac{300}{60000}$
  = 0.7 Mt CO2e

- for units installed on wide body aircraft:

400 units x 15 years of operations x 667 flights per year
x 30000kg fuel per flight x 3.846 kg CO_2e/kg jet-A
x $\frac{500}{191000}$

= 1.2 Mt CO_2e

The total emissions are therefore:

Equipment type	Number of products sold	Aircraft type	Direct emissions	Indirect emissions
Equipment A	600	single aisle	2.7 Mt CO2e	0.7Mt CO2e
Equipment B	400	wide body	9.2 Mt CO2e	1.2 Mt CO2e
Total	**1000**		**11.9 Mt CO2e**	**1.9 Mt CO2e**

7.5 Example for an aircraft manufacturer, with use of SAF

Same assumptions are considered as in Example 7.1 in terms of number and type of sold aircraft and aircraft utilization data.

Assumptions for SAF:

At this stage, IAEG does not recommend any reference to be used for SAF quantities projections as there is no consensus at IAEG level. The company is nevertheless encouraged to cite the reference that is used to do SAF projections. In this example, the company follows ATAG Waypoint 2050 [32] scenario 3 to project SAF availability and the associated Emission Reduction Factor. Two alternatives are proposed to do the computation.

Alternative 1:

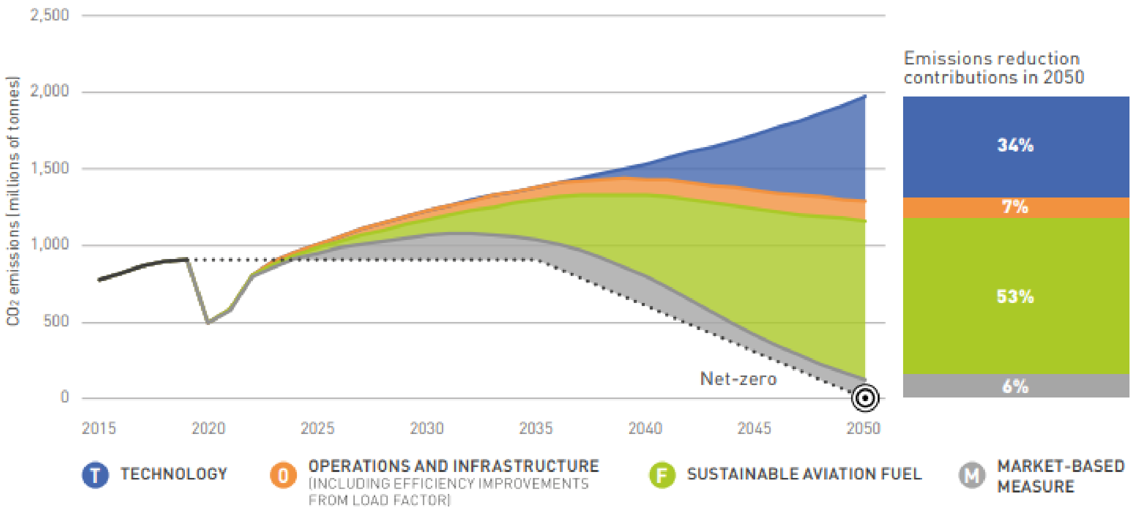


Image excerpt from ATAG Waypoint 2050, September 2021.

Dividing the CO2 emissions read on the grey line by the values read on the green line provides directly the factor $\left(\begin{matrix}\% \\ jet \\ fuel\end{matrix} + \begin{matrix}\% \\ alternative \\ fuels^{33}\end{matrix} \times \left(1 - \begin{matrix}Emission \\ reduction \\ factor\end{matrix}\right)\right)$ for every year until 2050.

[32] See https://aviationbenefits.org/media/167417/w2050_v2021_27sept_full.pdf

[33] In this case the % should not exceed the maximum percentage of SAF blend certified for the aircraft

Alternative 2: the company needs to consider:

- ERF variation along time: an ERF of 70% is considered in 2020, 80% in 2025 and 100% in 2050 in ATAG Waypoint 2050 Scenario 3. Linear variation will be considered between the different time points.
- SAF amount ratio computed as the amount of SAF divided by the total amount of fuel along time
- The inputs are summarized in the following table for aircraft deliveries in 2020:

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
SAF percentage	0%	3%	3%	3%	4%	4%	5%	7%	8%	10%
ERF	0.7	0.72	0.74	0.76	0.78	0.8	0.808	0.816	0.824	0.832
Year	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
SAF percentage	11%	13%	15%	18%	21%	24%	27%	31%	35%	39%
ERF	0.84	0.848	0.856	0.864	0.872	0.88	0.888	0.896	0.904	0.912
Year	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
SAF percentage	44%	48%	54%	59%	64%	69%	74%	79%	83%	87%
ERF	0.92	0.928	0.936	0.944	0.952	0.96	0.968	0.976	0.984	0.992

Warning, the values in the table above are computed from ATAG Waypoint 2050 scenario S3 and provided for example only. They may not reflect exact data from ATAG Waypoint 2050, nor actual values for historical years.

Then for both alternatives, the company needs to:

- Compute for each year along the aircraft lifetime the annual emissions per aircraft such that
$$\begin{matrix} Annual \\ emissions \\ per\ aircraft \\ in\ year\ i \end{matrix} = \begin{matrix} Annual \\ fuel\ burn \\ per\ aircraft \\ in\ year\ i \end{matrix} \times \begin{matrix} Jet\ fuel \\ emission \\ factor \end{matrix} \times \left(1 - \begin{matrix} \% \\ alternative \\ fuels \\ in\ year\ i \end{matrix} \times \begin{matrix} Emission \\ reduction \\ factor \\ in\ year\ i \end{matrix} \right)$$
- Do the sum : $\sum_{\substack{Aircraft \\ Type}} \left\{ \begin{matrix} Number\ of \\ delivered \\ aircraft \end{matrix} \times \sum_{Year=1}^{25} \begin{bmatrix} Annual \\ emissions \\ per\ aircraft \end{bmatrix} \right\}$

Estimation of the lifetime GHG emissions of the delivered fleet:

In this example we assume that the annual fuel burn per aircraft remains unchanged. The formula above is therefore simplified into:

- For the single aisle aircraft:
  70 aircraft x 1450 flights per year x 4000 kg fuel per flight x 3.846 kg CO2e/kg jet-A

  $$\times \sum_{year\ i=1}^{25} \left[1 - \begin{matrix} \% \\ alternative \\ fuels \\ in\ year\ i \end{matrix} \times \begin{matrix} Emission \\ reduction \\ factor \\ in\ year\ i \end{matrix} \right]$$

  = 31.3Mt CO2e

- For the wide body aircraft:
  30 aircraft x 667 flights per year x 30000 kg fuel per flight x 3.846 kg CO2e/kg jet-A

  $$\times \sum_{year\ i=1}^{25} \left[1 - \begin{matrix} \% \\ alternative \\ fuels \\ in\ year\ i \end{matrix} \times \begin{matrix} Emission \\ reduction \\ factor \\ in\ year\ i \end{matrix} \right]$$

  = 43.1 Mt CO2e

- In total the company will report 74.4 Mt CO2e for its Scope 3 Category 11, when assuming SAF penetration defined in ATAG Waypoint 2050 Scenario 3.
- The associated RPK are unchanged vs Section 7.1 (52.63 billion RTK for the delivered single aisle aircraft and 69.46 billion RTK), leading to an intensity metric for the delivered fleet:
  intensity = $\frac{74.4}{52.63+69.46}$ = 609 gCO2e / RTK

8 Frequently asked questions

8.1 Which scenario shall be used for incorporating SAF and which ERF shall be considered?

There are several scenarios existing for SAF projections (ATAG Waypoint 2050, IEA scenarios, ICAO LTAG scenarios, national scenarios) which leads to the difficulty of selecting an agreed scenario at IAEG level. At this stage, IAEG does not recommend any scenario in particular but recommends that the company shall transparently provide the reference that is considered for the computations. As for Emission Reduction Factors, there are different fuel pathways (HEFA, ATJ, Fischer-Tropsch …) and feedstocks providing different emissions reduction compared to fossil jet fuel. The company may use global average figures and report its choices in a transparent manner.

8.2 How to account for spares?

Spares shall not be accounted for, as they will replace another product that will be removed, therefore the overall aircraft emissions will remain the same.

8.3 How to account for retrofitted parts?

Retrofitted parts shall be accounted for but with adapted lifetime of the retrofitted parts.

8.4 If an intermediate product has a 10-year lifetime - the aircraft will need 2.5 intermediate products assuming 25 years of operations for the aircraft. Where the emissions related to the 1.5 missing equipments should be allocated?

Equation (6) for sold intermediate products allocation uses the sold intermediate product lifetime and not the one of the final end-use product (i.e., the aircraft). This is because Scope 3 Category 11 only considers lifetime emissions from products sold in the reporting year. Products to be sold in future years, in this case, products replacing end of life intermediate products, will be accounted for in the year when those replacement occur.

Note that for most of intermediate products (e.g. engines, landing gears, wings, …), their lifetime is the same as the aircraft lifetime. For those systems, the new products replacing older ones would then be considered as spares and should therefore not be accounted twice (see Section 8.2).

8.5 How should a company proceed when it does not have access to performance data?

Two performance tools are suggested in Section 6.3.

8.6 Where can we find aircraft mass data?

Certified mass values (MTOM, MZFM) are available in aircraft Type Certificate Data Sheets from EASA[34] and FAA[35].

Mass breakdown can be found in the *ICAO Independent Expert integrated technology goals assessment and review for engines and aircraft*[36] for

- A notional Gulfstream G650ER (business jet)
- A notional Embraer E190-E2 (regional aircraft)
- A notional Airbus A320neo (single aisle aircraft)
- A notional Airbus A350-900 (twin aisle).

Those mass breakdowns may be a good proxy for the different categories of commercial aircraft.

8.7 How to compute the average aircraft mass in flight or find a proxy?

The average mass in flight is computed in the following way:

Operator Empty Weight + Payload + 0.5 x Fuel consumption for the mission + Fuel reserves.

If the detailed masses above are not available (see also Section 8.6), the company may use as a proxy the *ICAO Annex 16 Volume III - Aeroplane CO2 Emissions*[37] mid gross mass that is computed the following way:

Mid gross mass = 0.5 x (high gross mass + low gross mass)

with

high gross mass = 0.92 x MTOM

low gross mass = 0.45 x MTOM + 0.63 x MTOM $^{0.924}$

Note: MTOM is expressed in kilograms.

[34] EASA aircraft Type Certificate Data Sheets can be accessed at: https://www.easa.europa.eu/en/document-library/type-certificates

[35] FAA aircraft Type Certificate Data Sheets can be accessed at: https://drs.faa.gov/browse /TCDSMODEL/doctypeDetails

[36] See Appendix K of the *ICAO Independent Expert integrated technology goals assessment and review for engines and aircraft* http://www.icscc.org.cn/upload/file/20200603/20200603140731_33885.pdf

[37] See Section 2.5.1 of *ICAO Annex 16, Volume III, Aeroplane CO2 Emissions, 1st edition as amended, 2020*, available at https://elibrary.icao.int

8.8 Which mass shall be considered to translate RPK into RTK?

Following IATA Passenger CO2 Standard Methodology[38], a mass of 100 kg per passenger (including their checked baggage) should be considered.

8.9 Engines are the aircraft system that consume most of fuel, why do we calculate their emissions using mass allocation, instead of the full amount?

Engines are consuming energy to assume a transportation function to provide propulsion and power for the whole aircraft, not like other systems that are end users of energy, e.g., environmental control system. If the full amount is allocated to engines, then there will be no emissions to allocate all other systems. Additionally, the *GHG Protocol Technical Guidance for Calculating Scope 3 Emissions* provided an explicit example showing mass allocation for engines as intermediate products.

[38] IATA Passenger CO2 Standard Methodology, available at: https://www.iata.org/en/programs/environment/passenger-emissions-methodology