



**ICAO CORSIA CO₂ Estimation and Reporting Tool
(CERT): 2021 Version**

— Design, Development and Validation —

C  **RSIA**

November 2021

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1. INTRODUCTION

In order to facilitate the implementation of the Standards and Recommended Practices relating to the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) was developed. The ICAO document entitled “ICAO CORSIA CO₂ Estimation and Reporting Tool” is referenced in Annex 16, Volume IV, Appendix 3, and is referred to as an ICAO CORSIA Implementation Element.

The ICAO CORSIA CERT tool supports aeroplane operators in:

- a) assessing whether or not an aeroplane operator is within the applicability scope of the Monitoring, Reporting and Verification (MRV) requirements (Annex 16, Volume IV, Part II, Chapter 2, 2.1);
- b) assessing their eligibility to use fuel use monitoring methods in support of their Emissions Monitoring Plan (Annex 16, Volume IV, Part II, Chapter 2, 2.2);
- c) filling any CO₂ emissions data gaps (Annex 16, Volume IV, Part II, Chapter 2, 2.5); and
- d) fulfilling their monitoring and reporting requirements by supporting the development of the standardized Emissions Monitoring Plan and Emissions Report templates (Appendix 1 of the *Environmental Technical Manual* (Doc 9501), Volume IV – *Procedures for demonstrating compliance with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)*).

ICAO’s Committee on Aviation Environmental Protection (CAEP) will develop and recommend updates to the ICAO CORSIA CERT information that will be captured in some form of ICAO document and, following approval by the ICAO Council, the ICAO CORSIA Implementation Element will be published on the ICAO CORSIA website (www.icao.int/corsia).

2. HIGH LEVEL ARCHITECTURE AND EVOLUTION OF THE ICAO CORSIA CERT

2.1 General Overview

The ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) is expected to be updated and enhanced over time to reflect: (1) evolving requirements from the implementation of CORSIA (i.e., Annex 16, Volume IV) such as the phased implementation of CORSIA reflected in the ICAO document entitled “CORSIA States for Chapter 3 State Pairs” that will be available on the ICAO CORSIA website from 2020, (2) increasing data coverage in terms of aeroplane types and geographic distribution; and (3) improvements in fuel efficiency observable from input data and resulting from technology and operations. A version/release of the tool is expected to be only valid for a given reporting year.

With the 2018 version of the ICAO CORSIA CERT, an aeroplane operator, that uses the CO₂ estimation functionality of the ICAO CORSIA CERT, was able to estimate for each year if its annual CO₂ emissions are above the thresholds as described in Annex 16, Volume IV¹.

¹ The Standards and Recommended Practices of Annex 16, Volume IV, Part II, Chapter 2 shall be applicable to an aeroplane operator that produces annual CO₂ emissions greater than 10 000 tonnes from the use of an aeroplane(s) with a maximum certificated take-off mass greater than 5 700 kg conducting international flights, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, on or after 1 January 2019, with the exception of humanitarian, medical and firefighting flights.

The Standards and Recommended Practices of Annex 16, Volume IV, Part II, Chapter 2 shall not be applicable to international flights, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, preceding or following a humanitarian, medical or firefighting flight provided such flights were conducted with the same aeroplane, and were required to accomplish the related humanitarian, medical or firefighting activities or to reposition thereafter the aeroplane for its next activity. The aeroplane operator shall provide supporting evidence of such activities to the verification body or, upon request, to the State.

An aeroplane operator was also able to determine its eligibility to use simplified compliance procedures (as per Annex 16, Volume IV, Part II, Chapter 2, 2.2)². The ICAO CORSIA CERT was based on the ICAO CO₂ Estimation Models (CEMs) that capture the set of equations that allow to estimate for a given aeroplane type the CO₂ emissions as a function of Great Circle Distance.

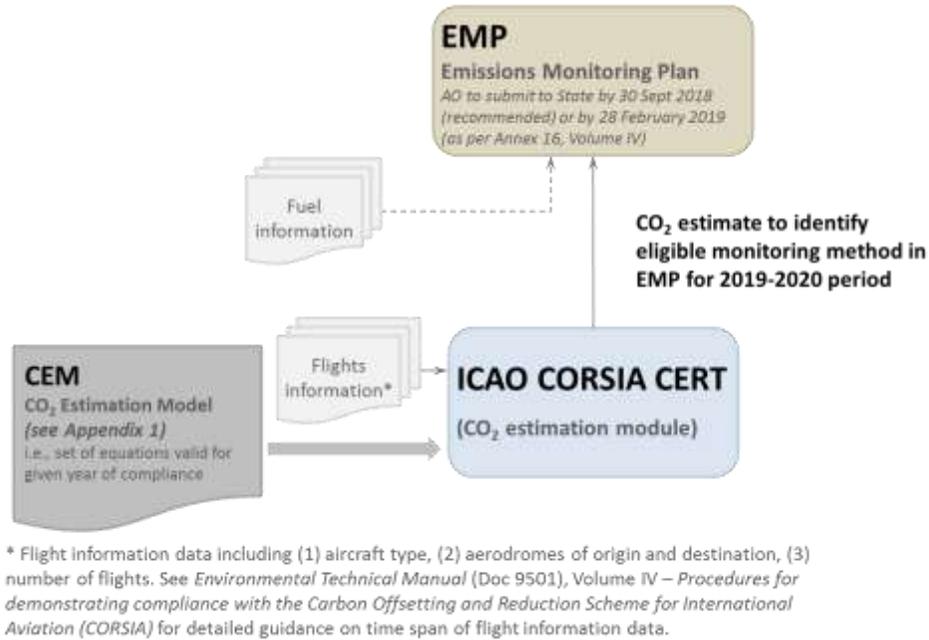


Figure 1: Architecture of CORSIA Emissions Monitoring Plan and reporting system (2018 or aeroplane operator year of entry into CORSIA)

Starting with the 2019 version of the ICAO CORSIA CERT, aeroplane operators are able to comply with simplified monitoring and reporting requirements from Annex 16, Volume IV, Part II, Chapter 2. The ICAO CORSIA CERT will allow aeroplane operators to import or manually input the required information: (1) individual or aggregated information at the individual flight, or aerodrome-pair level, (2) flights for which there are data gaps in order to generate emissions estimations.

Aeroplane operators eligible to use simplified compliance procedures (as per Annex 16, Volume IV, Chapter 2, 2.2) will be able to manually and/or automatically input information at individual flight level to estimate their CO₂ emissions for the compliance year and generate the Emissions Report.

Figure 3 summarizes the evolution of the functionalities of the ICAO CORSIA CERT, where the 2018 version only included the CO₂ estimation functionality to determine the applicability of CORSIA and

² For the 2019-2020 period: the aeroplane operator with annual CO₂ emissions from international flights, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, and Chapter 2, 2.1, greater than or equal to 500 000 tonnes shall use a Fuel Use Monitoring Method as described in Appendix 2. The aeroplane operator with annual CO₂ emissions from international flights, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, and Chapter 2, 2.1 of less than 500 000 tonnes shall use either a Fuel Use Monitoring Method or the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT), as described in Annex 16, Volume IV, Appendices 2 and 3 respectively.

For the 2021-2035 period: the aeroplane operator, with annual CO₂ emissions from international flights subject to offsetting requirements, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, and Chapter 3, 3.1, of greater than or equal to 50 000 tonnes, shall use a Fuel Use Monitoring Method as described in Annex 16, Volume IV, Appendix 2 for these flights. For international flights, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, and Chapter 2, 2.1, not subject to offsetting requirements, as defined in Annex 16, Volume IV, Part II, Chapter 3, 3.1, the aeroplane operator shall use either a Fuel Use Monitoring Method, as described in Annex 16, Volume IV, Appendix 2, or the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT), as described in Annex 16, Volume IV, Appendix 3. The aeroplane operator, with annual CO₂ emissions from international flights subject to offsetting requirements, as defined in Annex 16, Volume IV, Part II, Chapter 1, 1.1.2, and Chapter 3, 3.1, of less than 50 000 tonnes, shall use either a Fuel Use Monitoring Method or the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) as described in Annex 16, Volume IV, Appendices 2 and 3 respectively.

eligibility to the use of the ICAO CORSIA CERT. The 2019 and 2020 include the monitoring and report generation functionality. The 2021-2035 versions will then include splitting of the emissions between those subject to offsetting requirements, as they belong to routes between pairs of participating States, and those that have only to be reported but that are not subject to offsetting requirements.

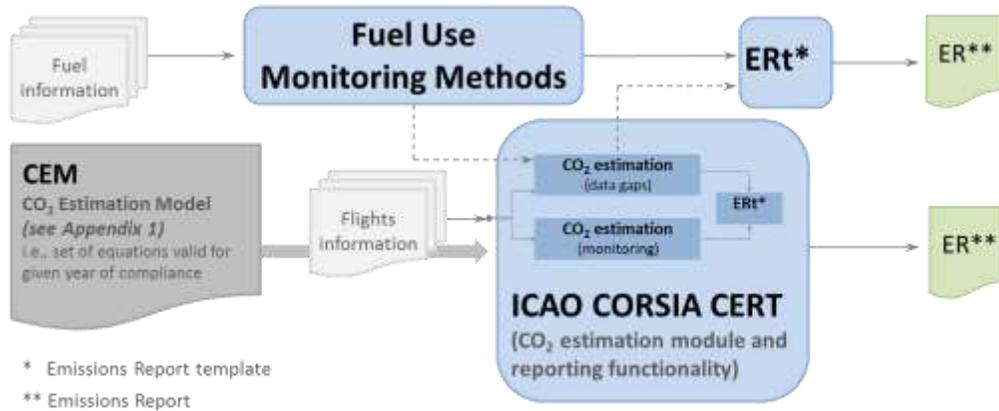


Figure 2: Architecture of CORSIA reporting system (2019 onward for compliance purposes)

	CERT CO ₂ Estimation and Reporting Tool		
	2018	2019-2020	2021-2035
Year of validity	2018	2019-2020	2021-2035
Estimation of CO ₂ for determination of simplified compliance procedures eligibility	Yes	Yes	Yes
Monitoring (estimating CO ₂)	No	Yes	Yes
Report generation functionality	No	Yes	Yes
States for Chapter 3 State pairs	No	No	Yes

Figure 3: Phased development and implementation of the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT)

2.2 Architecture of the 2021 Version of the ICAO CORSIA CERT

Based on requirements from Annex 16 Volume IV, a more detailed architecture of the 2021 version of the ICAO CORSIA CERT was developed. First, potential and expected users of the CERT were identified. Through an iterative process of mapping processes/tasks by different users required functionalities were identified.

2.2.1 Potential Users of the ICAO CORSIA CERT 2021

Figure 4 shows the list of potential users of the ICAO CORSIA CERT along with whether they have a submitted/approved EMP, their primary monitoring method, description of the use of the CERT and needed functionalities.

Users	Submitted/Approved EMP	Primary Monitoring Method (PMM)	Description of Use of the CERT	Needed Functionalities
Aeroplane Operators	Yes	Eligible to use the CERT as PMM	Estimating emissions and filling ER using the CERT (only)	- CO ₂ Estimation - ER generation
Aeroplane Operators	Yes	Required to use a Fuel Use Monitoring Method as PMM	Using the CERT to fill data gaps and generate ER	- CO ₂ Estimation - ER generation
Aeroplane Operators	Yes	Required to use a Fuel Use Monitoring Method as PMM	Using the CERT to fill data gaps	- CO ₂ Estimation - Summary Assessment
Aeroplane Operators	No	n/a	Evaluating applicability of CORSIA and eligibility to use the CERT	- CO ₂ Estimation - Summary Assessment
States	n/a	n/a	Order of Magnitude checks and Data gap filling	- CO ₂ Estimation - Summary Assessment
ICAO	n/a	n/a	Data gap filling	- CO ₂ Estimation - Summary Assessment
Verifiers	n/a	n/a	Order of Magnitude checks	- CO ₂ Estimation - Summary Assessment

Figure 4: Potential Users of the ICAO CORSIA CERT 2019+ versions

2.2.2 ICAO CORSIA CERT 2019+ High-Level Architecture

The ICAO CORSIA CERT 2021 version was built on the 2020 version with regard to the input of aeroplane operator information, the CO₂ estimation and the generation of a summary assessment functionalities. To meet the additional requirements from monitoring of emissions according to Annex 16 Volume IV, additional functionalities will be added in the 2019+ version, including;

- ICAO CEMs: The 2021 version of the ICAO CORSIA CERT contains the same ICAO CEMs as in the 2020 version that were based on the 2020 version of the COFdb.

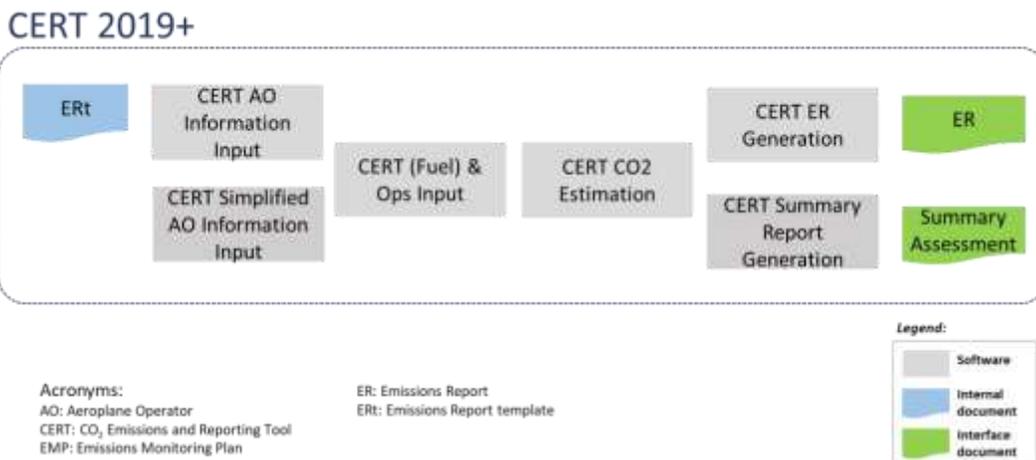


Figure 5: High Level Architecture of the 2019+ versions of the ICAO CORSIA CERT

In accordance with the requirements from Annex 16 Volume IV and the ETM Volume IV, the 2018 version of the ICAO CORSIA CERT only requires the CO₂ estimation functionality and no reporting capabilities. The reporting functionality was added to the 2019 version which will be used by aeroplane operators to monitor (via estimation) and report their 2019 CO₂ emissions as well as to fill data gaps if needed. The template of the Emissions Report based on the Second Edition of the Environmental Technical Manual (ICAO Doc 9501) was integrated into. The ICAO CORSIA CERT allows operators to automatically fill and export the Emissions Report.

2.2.3 Detailed Use Cases for the ICAO CORSIA CERT 2019+

Figure 6 shows the processes expected to be followed by an aeroplane operator for which the State has approved the submitted EMP and the right to use the ICAO CORSIA CERT as a primary monitoring method. This (aeroplane operator) user would also use the ICAO CORSIA CERT to generate its Emissions Report.

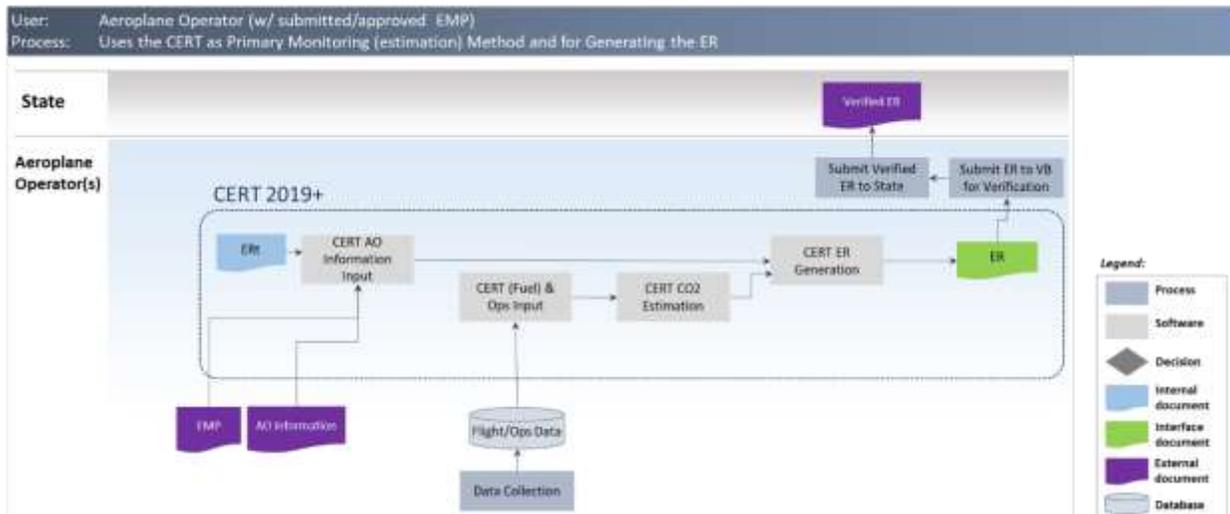


Figure 6: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for an aeroplane operator with an approved EMP and using the ICAO CORSIA CERT as primary monitoring method and to generate its ER.

Figure 7 shows the processes expected to be followed by an aeroplane operator for which the State has approved the submitted EMP and that uses the ICAO CORSIA CERT to fill data gaps (i.e., flights with no data from the approved Fuel Use Monitoring Method). This (aeroplane operator) user would also use the ICAO CORSIA CERT to generate its Emissions Report.

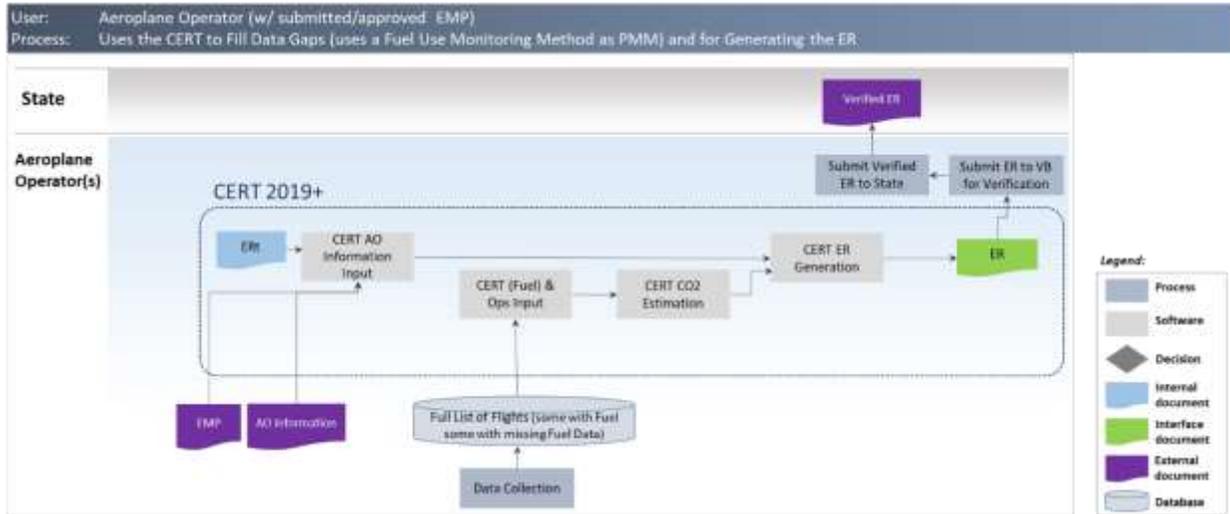


Figure 7: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for an aeroplane operator with an approved EMP and using the ICAO CORSIA CERT to fill data gaps and generate its ER.

Figure 8 shows the processes expected to be followed by an aeroplane operator that uses the ICAO CORSIA CERT only to estimate the fuel and emissions for data gaps (i.e., flights with no data from the approved Fuel Use Monitoring Method). This (aeroplane operator) user would not use the ICAO CORSIA CERT to generate its Emissions Report.

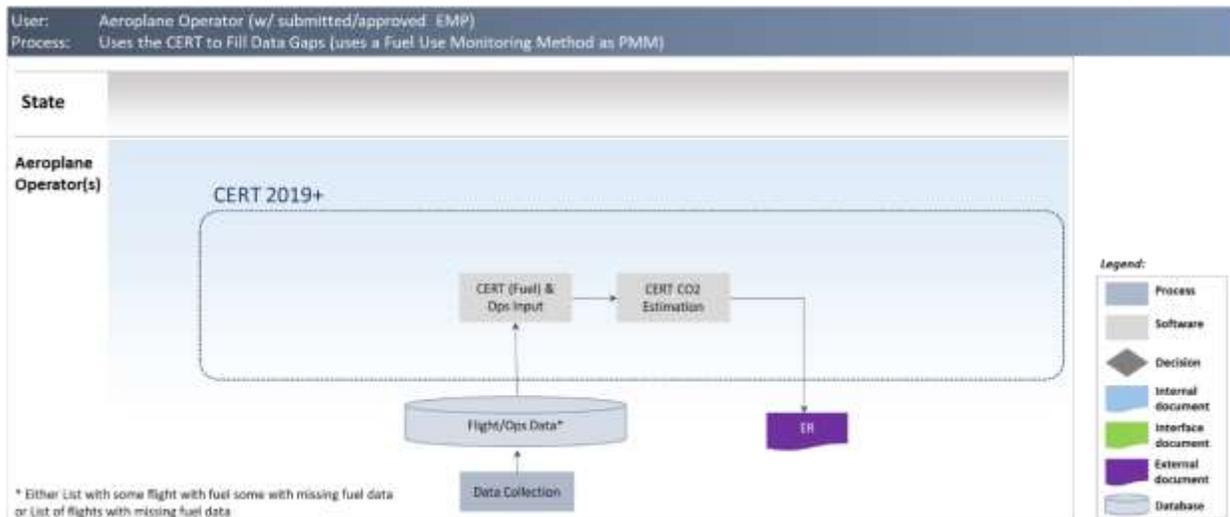


Figure 8: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for an aeroplane operator using the ICAO CORSIA CERT only to fill data gaps.

Figure 9 shows the processes expected to be followed by an aeroplane operator to determine the applicability of CORSIA and eligibility to use the ICAO CORSIA CERT. Note: this process is similar to the use of the 2018 version of the ICAO CORSIA CERT.

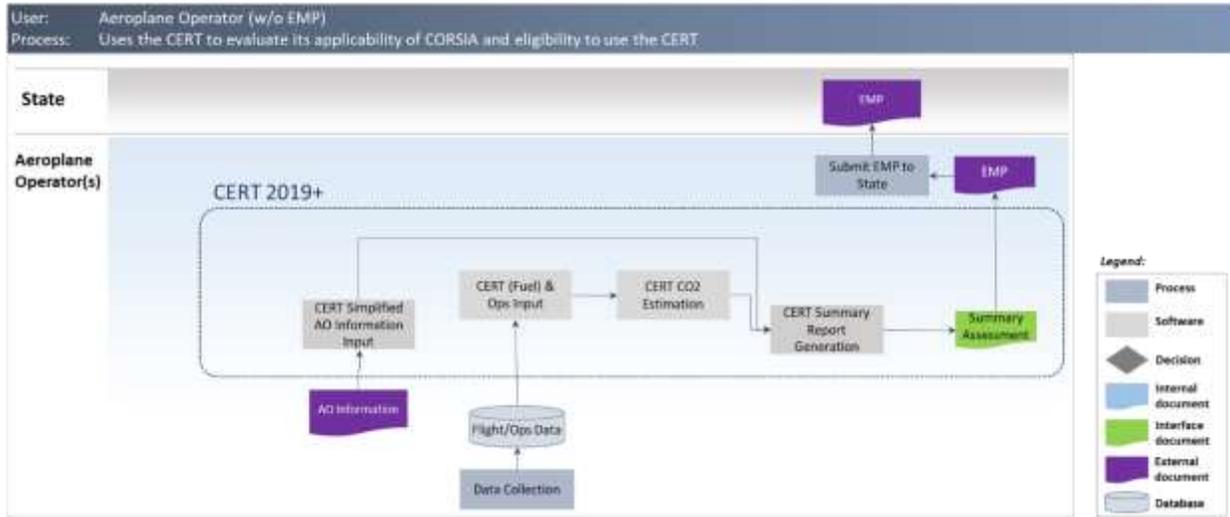


Figure 9: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for an aeroplane operator to determine the applicability of CORSIA and eligibility to use the ICAO CORSIA CERT.

Figure 10 shows the processes expected to be followed by a State to fill data gaps.

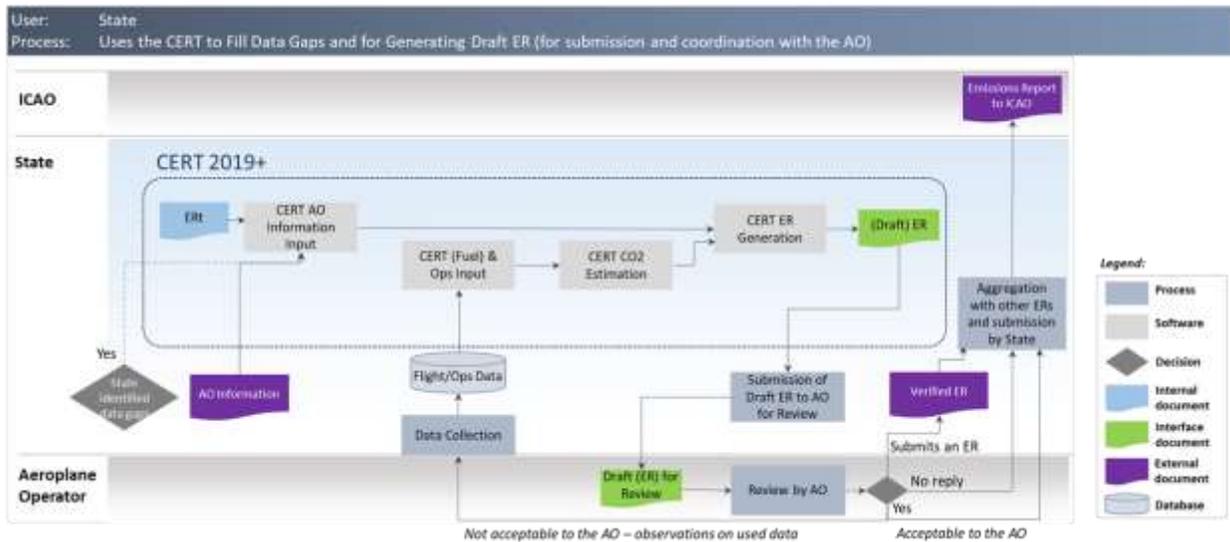


Figure 10: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for a State to fill data gaps.

Figure 11 shows the processes expected to be followed by ICAO to fill data gaps.

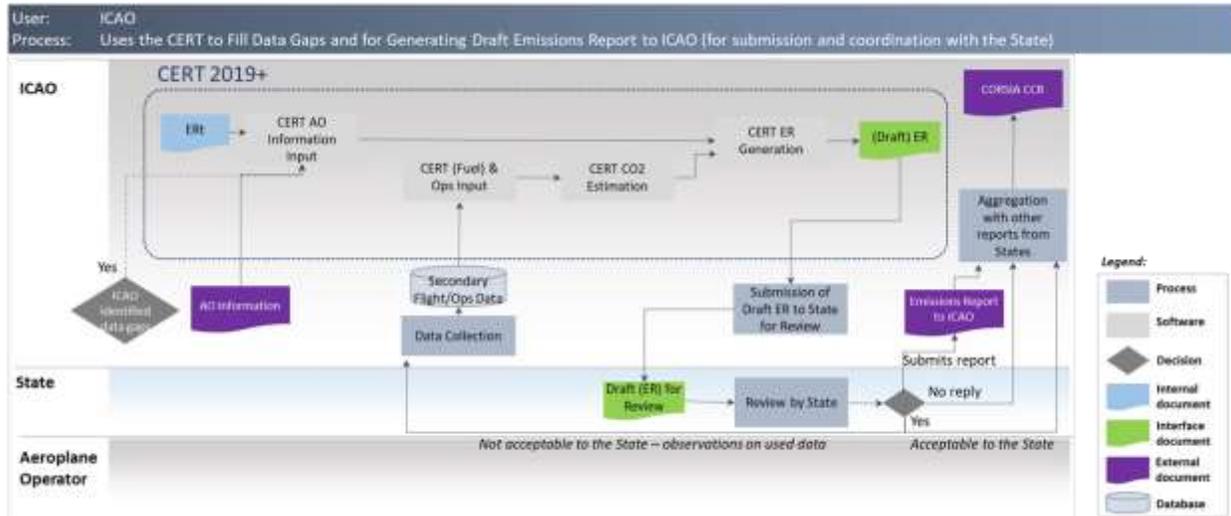


Figure 11: Mapping of processes supported by the 2019+ versions of the ICAO CORSIA CERT for ICAO to fill data gaps.

3. DESIGN AND DEVELOPMENT OF THE ICAO CORSIA CERT

Based on assessment conducted by the ICAO-CAEP of the potential candidate methods that could be used as a basis for a CO₂ estimation tool, it was recommended that a modeling approach and tool based on a statistical method was most appropriate and fit for purpose for developing the ICAO CEMs underlying the ICAO CORSIA CERT. The statistical method is based on actual historic fuel burn data, provided by aeroplane operators, that are used to establish statistical models to estimate fuel burn for a particular distance or time and aircraft type. Similar to the Fuel Use Monitoring Methods as described in Annex 16, Volume IV, Appendix 2, a menu of ICAO CEMs based on Great Circle Distance input or Block Time input could provide flexibility to aeroplane operators to meet the monitoring and reporting requirements from the CORSIA.

3.1 Functionality of the ICAO CORSIA CERT

The ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) comprises a three-step process as described in Figure 12. This includes:

- (1) Entering aeroplane operator’s information (to meet the requirements of the Emissions Report template per the *Environmental Technical Manual* (Doc 9501), Volume IV);
- (2) Entering flight data either manually or using a file upload, to estimate CO₂ emissions using either the Block Time or Great Circle Distance (GCD). The user enters a) Aircraft type and b) aerodrome designator for origin-destination based on Doc 7910 — *Location Indicators* (i.e., Great Circle Distance GCD) or flight operating time (i.e., Block Time) as input to estimate an aeroplane operator’s CO₂ emissions; and
- (3) Generating the Emissions Report, reviewing and submitting it.

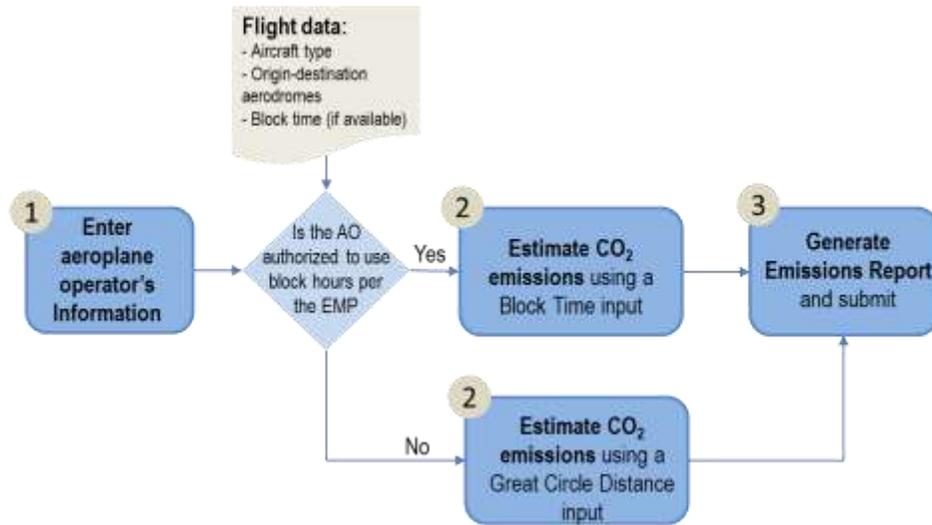


Figure 12: Overview of the high-level functions of the potential CORSIA CO₂ Estimation and Reporting Tool

3.2 Development of the ICAO CO₂ Estimation Models (CEMs)

Underlying the ICAO CORSIA CERT CO₂ estimation functionality (i.e., step 2 in Figure 12), the ICAO CEMs allow to convert the users input (i.e., aircraft types, aerodromes of origin and destination, Block Time if available) into estimated CO₂ emissions.

3.2.1 Overview of the Process for Developing ICAO CEMs

Figure 13 shows an overview of the process for developing the ICAO CEMs. First, the list of aircraft types, by ICAO Type Designator, for which an ICAO CEM needs to be established were scoped and identified. Doc 8643 — *Aircraft Type Designators*³ was analyzed to identify those aircraft types that are within the scope of applicability of Annex 16, Volume IV, i.e., Maximum Take Off Mass (MTOM) greater than 5 700 kg. Because Doc 8643 does not include MTOM information, several information sources, including: the EASA Certification Database, the ICAO Noise Certification database, and complementary information such as the US FAA Type Certificate Data Sheets (TCDS) were used and mapped to each aircraft type designators in Doc 8643. The identified aircraft types form the basis for the ICAO CORSIA CERT aeroplane database. Section 3.2.2 provides additional information about the process for scoping the ICAO CORSIA CERT aeroplane database.

For each of the aircraft types identified in the scoping process described above, an ICAO CEM was developed. As shown in Figure 13, a four-tier approach was developed and implemented:

- (1) First, if the aircraft type can be mapped to an aircraft type available in the validated CCG Operations and Fuel database (COFdb), an ICAO CEM is developed using the methodology described in section 3.2.3;
- (2) Second, if the aircraft type is not available in the COFdb but there is an equivalent aircraft type which is modeled using (1) within the same family (and same manufacturer), an ICAO CEM

³ ICAO Document Aircraft Type Designators (*Doc 8643*), available for query at: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

is developed through scaling of the ICAO CEM of the equivalent aircraft type, using the method described in 3.2.4;

- (3) Third, if the aircraft type is not mapped to the COFdb via steps 1 or 2, then the ICAO Fuel Formula is used, (see section 3.2.5 for background on the ICAO Fuel Formula); and
- (4) Finally, if an aircraft type is missing an ICAO CEM after steps 1 to 3, a generic equation can be developed using the methodology described in section 3.2.6. This approach is used for aircraft types identified in Appendix A-1 (Table A-1.2.d) as well as aircraft types that can be entered into the ICAO CORSIA CERT as Custom Aeroplane.

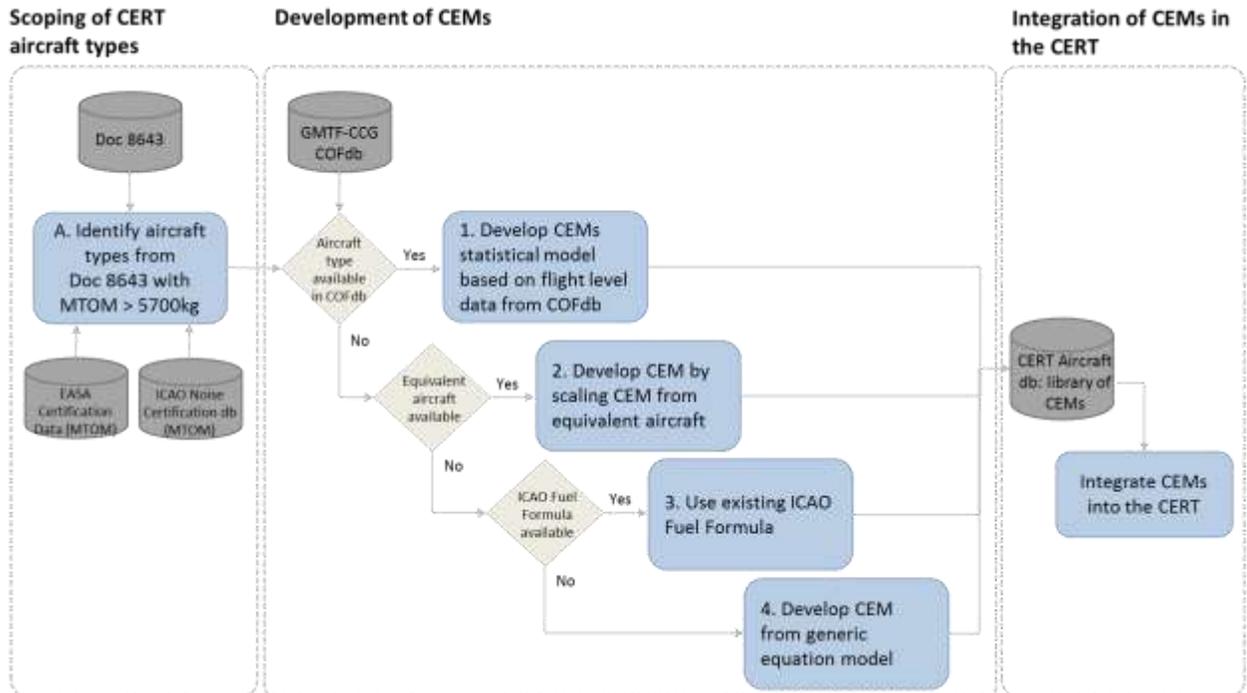


Figure 13: Summary of process for developing ICAO CO₂ Emissions Estimation Models (CEMs)

3.2.2 Scoping of ICAO CORSIA CERT aeroplane database

Users of the ICAO CORSIA CERT can enter aircraft type by ICAO Type Designator (e.g., B738 for a Boeing B737-800 or A321 for an Airbus A321). The Type Designators are consistent with Doc 8643 — *Aircraft Type Designators which is filtered to only include aircraft types that are under the scope of applicability of Annex 16, Volume IV (i.e., Maximum Take Off Mass (MTOM) greater than 5 700 kg).*

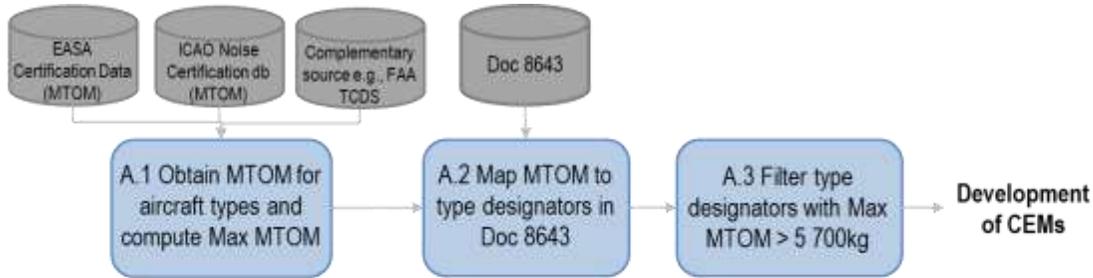
Data sources

- Doc 8643:
 - o The 2021 version of the ICAO CORSIA CERT is based on the version of Doc 8643 that was last updated on 17 December 2019.
- Maximum Take Off Mass (MTOM):
 - o The following version of the EASA Noise Certification Databases (www.easa.europa.eu/document-library/noise-type-certificates-approved-noise-levels) were used to obtain MTOM data by aircraft type.
 - EASA approved noise levels (Heavy propeller driven aeroplanes), Issue 29, last updated: 6 August 2019
 - EASA approved noise levels (Jet aeroplanes), Issue 31, last updated: 6 August 2019
 - EASA approved noise levels (Light propeller driven aeroplanes), Issue 28, last updated: 6 August 2019
 - o In addition, the ICAO Noise Certification Database, version 2.24 that was validated by the CAEP Working Group 1 (WG1) on the 8th November 2017 was used. The Noise Certification database is available at: <http://noisedb.stac.aviation-civile.gouv.fr>
 - o Complementary data sources were also used when needed, including the U.S. Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS), available at: http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/Frameset?OpenPage

Methodology

In order to ensure that aircraft types (by Type Designator) with a variant greater than 5 700 kg Maximum Take-Off Mass (MTOM) is available in the ICAO CORSIA CERT, the Maximum MTOM was derived from across aeroplane variants and the multiple available MTOM databases.

Figure 14 illustrates the process for filtering aircraft types with MTOM greater than 5 700 kg. Aircraft types from the MTOM databases were mapped to Doc 8643 — Aircraft Type Designators. The Maximum MTOMs were then used to filter and identify Type Designators with MTOM greater than 5700 kg.



Doc 8643 has total of 10 020 aircraft types categorized as Amphibian, Helicopter, Landplane, SeaPlane or Tilt-wing. Further, each aircraft type has the manufacturer's name, ICAO Designator, engine type, engine count and wake turbulence category (WTC).

Doc 8643 has wake turbulence category (WTC) designated for each aircraft type. The WTCs are as follows:

- **H** (Heavy) aircraft types of 136 000 kg (300 000 lb) or more;
- **M** (Medium) aircraft types less than 136 000 kg (300 000 lb) and more than 7 000 kg (15 500 lb); and
- **L** (Light) aircraft types of 7 000 kg (15 500 lb) or less.
- *Note: Super Heavy* for Airbus A380-800 with a maximum take-off mass in the order of 560 000 kg.

Figure 14: Development of list of aircraft types with MTOM>5 700kg for CORSIA CO₂ emissions estimation tool development process

3.2.3 Development of ICAO CEMs based on aeroplane operator data (COFdb)

As described in the first step of the four-tier approach in Figure 13, if the aircraft type can be mapped to an aircraft type available from the CCG Operations and Fuel database (COFdb), an ICAO CEM is developed using statistical models.

Overview of the CCG Operations and Fuel database (COFdb)

The CAEP Working Group 4 (WG4) CCG Operations and Fuel database (COFdb) is a database of actual flights that includes: aircraft type, great circle distance (based on aerodrome of origin and destination), fuel burn, block time, and operation year for each flight.

Data contained in the COFdb comes from aeroplane operators who have voluntarily agreed to provide data for the development of the ICAO CORSIA CERT as per recommendation from Annex 16, Volume IV, Appendix 3. Given the commercial sensitivity of flight level fuel burn information, the COFdb is the result of a multi-step process used to ensure that data in the COFdb is anonymized i.e., that neither the aeroplane operator nor the individual flight can be identified from the COFdb data. Aeroplane operators provide relevant flight level data to DPO Data Providing Organizations (DPOs) who process the flight level data anonymizing it to remove references to the actual aeroplane operators and flight, assigning to it a unique code to allow traceability if needed, and provide it to the WG4-CCG co-leads for it to be integrated in the COFdb replacing the DPO unique code with a COFdb specific unique code. Once validated by the CCG co-leads, the resulting COFdb is shared only with WG4 CCG members and governed by a Use Agreement and for the sole purpose of supporting and facilitating the work of developing, validating and maintaining the ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) and the underlying ICAO CO₂ Estimation Models (CEMs).

Data collection and validation processes

When providing data to CAEP, DPOs are responsible for:

- validating, to the extent possible to the Organization, the correctness of the departure and arrival aerodrome as well as of the correct use of the ICAO aircraft type designator as per Doc 8643 for each flight having indeed been operated between those aerodromes, coordinating with the aeroplane operator as necessary;
- computing the Great Circle Distance, rounded to the kilometer, between the departure and arrival aerodrome, using the latitude and longitude of the aerodromes as provided in the applicable version of Doc 7910 (applicability determined on the basis of the date of flight and the date of issue of the ICAO Document) or applicable AIP information and with the Earth modelled according to the WGS84 reference system and geodetic datum; the Great Circle Distance field is to be left empty if either the departure or the arrival aerodrome is not available in Doc 7910;
- computing whether the flight is international or domestic on the basis of the departure and arrival aerodrome and in accordance with the prescriptions of Annex 16, Volume IV, Part II, Chapter 1, 1.1.2;
- including for each flight record a unique identifier per aircraft type, identifier which allows the DPO to identify the related flight data supplier in order to coordinate with the latter as and if required;
- ensuring that, when available, the block time is provided in minutes without decimals, leaving the field empty if not available;
- excluding from the provided data records for which:
 - o the validation of the first point is unsuccessful; or
 - o the aircraft type is not in the applicable version of Doc 8643 (applicability determined on the basis of the date of the flight and the date of issue of the ICAO Document); or
 - o both the Great Circle Distance and the block time are unknown.

Integration of data into the COFdb (pre-verification)

Prior to integrating data received from a DPO into the COFdb, CAEP conducts a parallel and redundant process that includes (1) pre-verification of the COFdb in order to ensure the quality of the data as well as (2) accurate and appropriate data integration in the COFdb.

Verification and distribution of the COFdb

CAEP also conducts verification of the integrated COFdb, including checks that the data available in the received version of the COFdb is complete. The COFdb is then made available to each CAEP expert contributing to the development of the ICAO CORSIA CERT and that have executed a Use Agreement at the time of the distribution of the COFdb.

Version of the COFdb used for the 2021 version of the ICAO CORSIA CERT

For the 2021 version of the ICAO CORSIA CERT, the COFdb version 2021_1.1 as of January 17, 2020 was used. This 2020 version 1.1 of the COFdb includes data from approximately 4.5 million flights (after removal of older data) for 104 aircraft types by ICAO Type Designator. Data ranged from 2006 to 2018 with about 66% of the data coming from 2015 to 2019.

Identifying and removing outliers from aeroplane operator's raw data

Before final regression models were developed for each of the aircraft type, outliers were identified and removed. To identify outliers, a first regression on the entire dataset is developed. This allows the calculation of the standardized residual absolute value for all data points. As an initial step, data points with a standardized residual absolute value greater than 3σ were identified as outliers and were examined. For each aircraft type and regressions, CCG evaluated the fitness of the 3σ criterion for the given dataset. If deemed appropriate, the default 3σ criterion was used. For a few aircraft types, 4σ or 5σ were used to better capture the distribution of flights across the dataset. Once outliers were removed, single or multi-segment regressions were developed.

Regression model selection and development

The ICAO CEMs are based on piece-wise linear fuel burn vs. GCD or block time functions. The dependent variable is fuel burn. There are two potential explanatory variables in the model: (1) Block Time or (2) Great Circle Distance (GCD) of the flight. The 2019 version of the ICAO CORSIA CERT and subsequent versions include both Great Circle Distance and Block Time input.

Figure 15 shows an illustration for a sample aircraft type with the COFdb data split into data retained for the development of the regression i.e., ICAO CEM (in green) and outliers (in red).

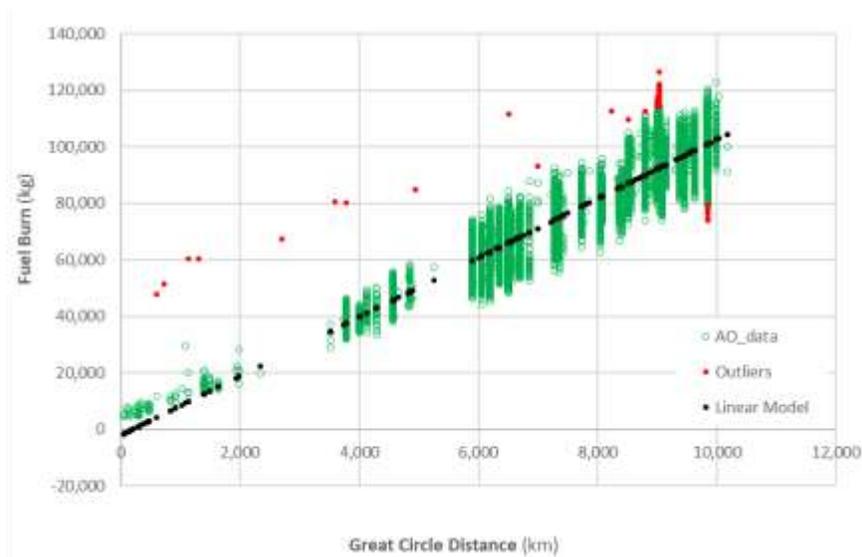


Figure 15: Illustration of sample data used to generate ICAO CEMs, including outlier data removed from the process of generating the ICAO CEM

To generate an ICAO CEM, the CCG followed the following steps:

- Import an aircraft type database;
- Generate a regression on entire dataset (i.e., linear OLS model);
- Identify outliers and remove them; and
- Run a second single-segment regression or a piece-wise regression (up to three segments with breakpoints).

If breakpoints are not used on some aircraft types, uncorrected linear regression ICAO CEMs may result in negative intercept. Piecewise linear equations are used to address this and better represent the dataset. The need for breakpoints was determined using the following rules:

- If there is a negative intercept -> introduce a breakpoint;
- If there is a cluster consistently above or below -> introduce a breakpoint; and
- If there is a Great Circle Distance (GCD) gap -> potentially introduce breakpoints.

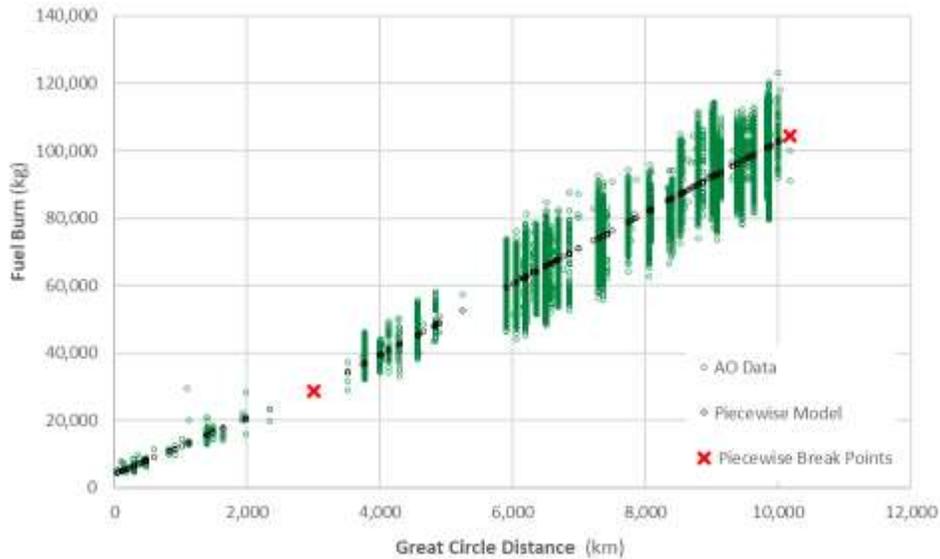


Figure 16: Illustration of fuel burn statistical method model formulation (GCD Model)

3.2.4 Development of ICAO CEMs based on equivalent aircraft types

If the aircraft type is not available in the COFdb but can be mapped to an equivalent aircraft type within the same family (and same manufacturer), an ICAO CEM is developed through scaling of the ICAO CEM of the equivalent aircraft type.

The development of equivalent aircraft type model was only allowed for aircraft within the same family (and same aeroplane manufacturer) if deemed appropriate. For example, an Airbus A342 was deemed equivalent to an Airbus A343 for which an ICAO CEM based on data from the COFdb was available.

Once equivalent aeroplane are identified, the ICAO CEM was adjusted by scaling (multiplying) it using a Mass ratio of the Average Operating MTOM of both aircraft types:

$$\text{MTOM ratio factor} = \frac{\text{Avg. MTOM}_{\text{aeroplane not in COFdb}}}{\text{Avg. MTOM}_{\text{equivalent aeroplane in the COFdb}}}$$

Data from a global registration database was used to develop Average MTOM values for each aircraft types in the ICAO CORSIA CERT aeroplane database.

3.2.5 ICAO CEMs based on ICAO Fuel Formula

If the aircraft type is not mapped to the COFdb or equivalent aircraft type, then the ICAO Fuel Formula is re-used.

Additional information on the ICAO Fuel Formula used in the ICAO Carbon Calculator is available at ICAO Carbon Emissions Calculator Methodology Version 10, https://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v10-2017.pdf

3.2.6 Development of ICAO CEMs based on generic equation model

Finally, to allow the estimation of fuel burn and CO₂ emissions for an aircraft type that is missing an ICAO CEM after applying the steps in 3.2.3 to 3.2.5, a set of generic equation models are developed from which an ICAO CEM for such aircraft type can then be derived. This step forms the basis for the ICAO CORSIA CERT functionality of entering custom aeroplane that can either be (1) one of the aircraft types identified in Appendix A-1, Table A-1.2.d or (2) an aircraft type not included in Doc 8643 that a user may need to enter and use towards the estimation of its emissions. For each linear regression-based model the fuel is calculated on specific distances. Those are determined to ensure a sufficient level of granularity and account for the possible variation of the piecewise breakpoints.

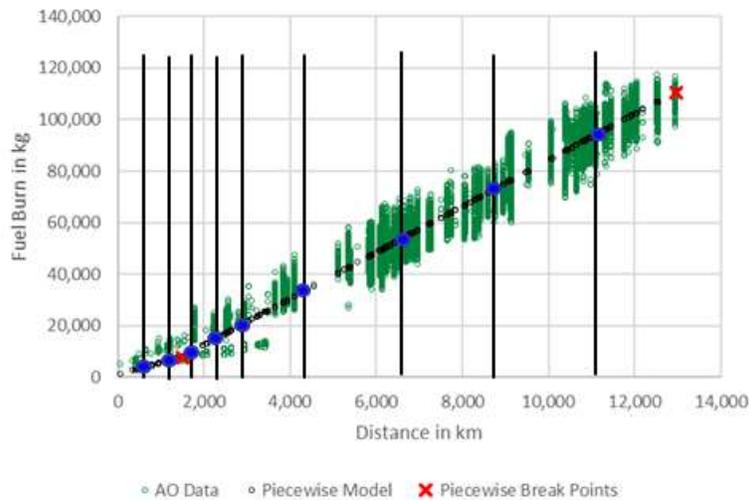


Figure 17: Illustration of process for binning data for developing generic equation

For each distance band value the calculated fuel are reported versus the aeroplane average Maximum Take-off Mass (MTOM). To develop generic equation models most representative, aircraft types are grouped by category including:

- Heavy Jets⁴;
- Medium Jets with Certified MTOM greater than 60 000 kg⁵;
- Medium Jets with Certified MTOM lower or equal to 60 000 kg; and
- Turboprops and Turboshaft aeroplane.

Figure 18 illustrates the development of generic aeroplane (fuel burn) values (in orange) for a given distance within the category of Medium Jets with Certified MTOM greater than 60 000 kg based on

⁴ Heavy Jets, Medium Jets, Turboprops and Turboshaft powered aircraft based on categorization included in Doc 8643.

⁵ The Medium Jets category was split into two subcategories to capture different trends across the broad MTOM range from approximately 10 tonnes to approximately 120 tonnes. A breakpoint at 60 tonnes was established as it captures trends appropriately. In addition, the 60 tonnes thresholds leverages and is consistent with the ICAO CO₂ emissions standard (governed by Annex 16, Volume III) that includes a breakpoint at 60 tonnes certified MTOM.

values from the ICAO CEMs (in blue) for aeroplane in the same category. Distances of 0 km and 1 000 km are shown for illustration.

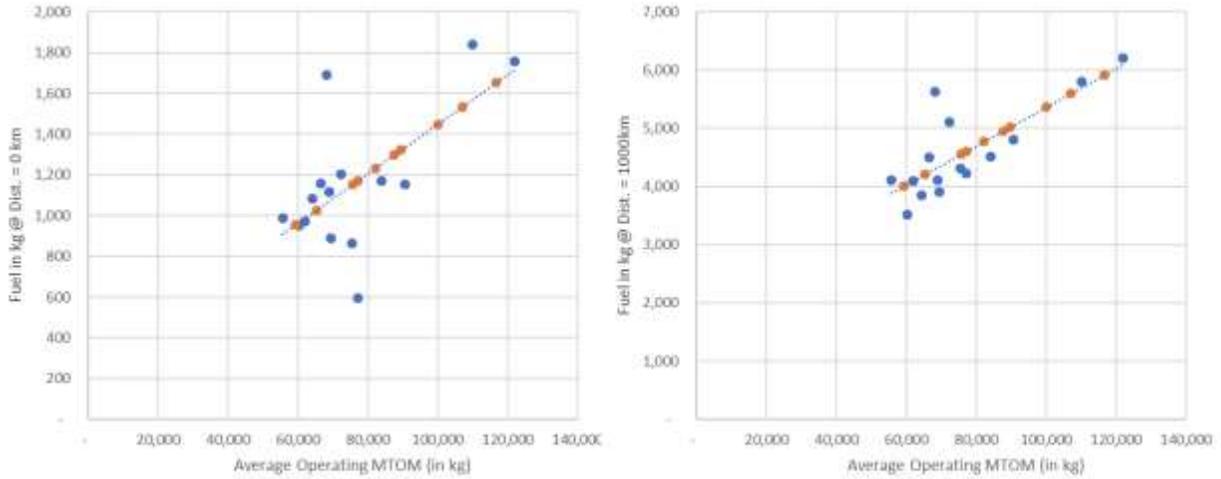


Figure 4: Illustration of generic aeroplane fuel burn-MTOM based regressions for a given distance

Similarly to aeroplane operator fuel burn data, a linear regression is then calculated. The result is a set of equations (per aeroplane category and distance band) returning a fuel as a function of the aeroplane maximum take-off mass. As based on that set of equations, a fuel estimation model (equation) can be derived for any aircraft type (Figure 11).

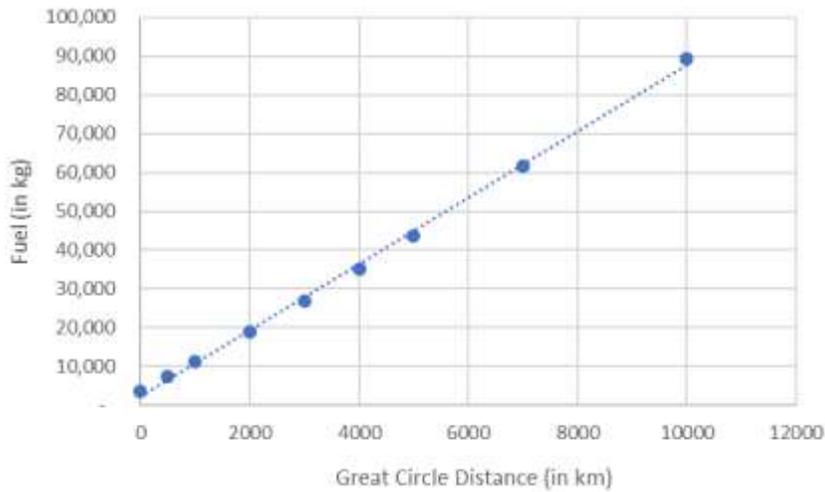


Figure 5: Illustration of generic aeroplane ICAO CEM

4. IMPLEMENTATION OF THE ICAO CORSIA CERT: VERSION 2021

ICAO CORSIA CERT has been developed, tested and validated on Microsoft Excel 2013 and Windows 7 as Operating System. This should not be considered the minimum possible configuration. However, due to possible compatibility issues with older Excel versions and/or operating systems other than those tested, it is recommended to use Windows 7 or higher and Excel version 2010 or later. ICAO CORSIA CERT has not been tested on any MAC OS.

The ICAO CORSIA CERT version 2021 was developed to include two key functionalities;

- a) Summary of assessment of applicability of CORSIA and eligibility to use the ICAO CORSIA CERT in 2021
- b) CO₂ Estimation and Reporting for 2021

4.1 Summary of assessment of applicability of CORSIA and eligibility to use the ICAO CORSIA CERT in 2021

The ICAO CORSIA CERT version 2021 was developed to take the user through a simple three steps process where the user:

- (1) Enters aeroplane operator information relevant for assessing the applicability of CORSIA and eligibility to use the ICAO CORSIA CERT for monitoring and reporting of CO₂ emissions;
- (2) Estimates its CO₂ emissions from international flights; and
- (3) Generates a summary assessment of applicability of CORSIA and eligibility of the aeroplane operator to use the ICAO CORSIA CERT, with the possibility to generate documents to save them for record keeping.

4.1.1 Aeroplane operator identification

To allow for the identification of the aeroplane operator on the summary documents, the user can enter key information on the aeroplane operator. The format of the required information is consistent with the identification page of the Emissions Monitoring Plan. This information is then used in the summary assessment and saved documents.

4.1.2 Calculation of CO₂ emissions

The core functionality of the ICAO CORSIA CERT is the estimation of CO₂ emissions based on user input data.

4.1.3 Loading and entering data into the ICAO CORSIA CERT

The user can enter aircraft type and flight information data into the ICAO CORSIA CERT using two key paths:

- a) Manual entry by selecting an aircraft type designator from the list of types available in the ICAO CORSIA CERT aeroplane database. If needed, the user can also enter codes that are not included in the ICAO CORSIA CERT aeroplane database which become 'custom aeroplane code'. See below for details on the custom aeroplane and aerodrome functionality in the ICAO CORSIA CERT; and
- b) Direct upload into the ICAO CORSIA CERT by loading a file containing aircraft types, origin and destination aerodromes as well as number of flights. This file in csv format can be used as the interface between an aeroplane operator's Operations and Flight Management System and the ICAO CORSIA CERT.

4.1.4 Comparison of the operations input data against the ICAO CORSIA CERT aeroplane and aerodrome databases

When loading operations data into the ICAO CORSIA CERT or calculating CO₂ emissions, the user can choose to compare the input aircraft type and aerodromes entries against the internal ICAO CORSIA CERT aeroplane and aerodromes databases. This comparison checks for consistency and returns any aircraft type code and aerodrome code that does not match the internal ICAO CORSIA CERT aeroplane and aerodromes databases. The user can then choose to enter custom aeroplane and aerodromes information for these codes or return to the input data and correct the codes if an error was made in the data entry.

Entering custom aeroplane codes

If the user chooses to use custom aeroplane codes, he/she is prompted to select an aircraft category from the following list:

- a) Jet (Heavy) with certified MTOM $\geq 136\ 000$ kg;
- b) Jet with certified MTOM $\geq 60\ 000$ kg and $< 136\ 000$ kg;
- c) Jet with certified MTOM $< 60\ 000$ kg; and
- d) Turboprop.

The user is also prompted to enter the Average Maximum Take Off Mass (MTOM) in the aeroplane operator fleet. The Average MTOM is calculated using the arithmetical average of individual MTOMs of aeroplane in the fleet of a given aircraft type code. The individual MTOMs are the individual maximum permissible take-off mass of each individual aeroplane according to the certificate of airworthiness, the flight manual or other official documents as defined by ICAO Annex 16, Volume IV.

Based on the aeroplane category selected and the Average Maximum Take Off Mass (MTOM) in the aeroplane operator fleet, the ICAO CORSIA CERT derives a tailored ICAO CEM from the relevant generic equation model according to the approach described in section 3.2.6. The custom aeroplane functionality displays information on the fuel burn rate (kg/km) and intercept value (fuel at great circle distance of 0 km) depending on the underlying regression model associated with a manually selected aeroplane category and average MTOM. The indicated fuel burn rate and interception value are used within ICAO CORSIA CERT to calculate the estimated fuel and emissions for all flights with this Custom Aeroplane Code.

The following coefficients are used in the 2021 version of the ICAO CORSIA CERT to generate generic equations (as a function of entered Average MTOM) for aircraft types entered as custom aeroplane, by aircraft type category.

Aircraft Type Category	Coefficients for Linear Function to Derive the <u>Intercept</u> of the Generic Equation		Coefficients for Linear Function to Derive the <u>Slope</u> of the Generic Equation	
	Intercept	Slope	Intercept	Slope
Coefficients for Generic Equation based on Great Circle Distance (i.e., Fuel = slope * GCD + intercept)				
Jet (Heavy) with certified MTOM $\geq 136\ 000$ kg	-113.7137664	0.009291852	0.951365126	2.57593E-05
Jet with certified MTOM $\geq 60\ 000$ kg and $< 136\ 000$ kg	137.7074107	0.011128137	1.747754615	2.21315E-05
Jet (Heavy) with certified MTOM $< 60\ 000$ kg	199.515606	0.013327825	0.081018763	5.61413E-05
Turboprop	-4.19723143	0.01234964	0.324835791	4.96388E-05

Figure 20: Coefficients used in the 2021 version of the ICAO CORSIA CERT to generate generic equations (as a function of entered Average MTOM) for aircraft types entered as custom aeroplane

Note. - If custom aircraft types are entered but already exist in the ICAO CORSIA CERT aeroplane database, the information in the ICAO CORSIA CERT aeroplane database will anyhow be used as default for calculating CO₂ emissions.

Entering custom aerodrome codes

If needed, the user can enter custom aerodrome codes in order to allow for the calculation of CO₂ emissions for each flight entered. The user is prompted to enter aerodrome latitude using WGS84 coordinates. In the 2021 version of the ICAO CORSIA CERT, the user has greater flexibility for entering aerodrome coordinates. The separation symbols can be defined by the user.

Latitude and longitude pairs for aerodromes or Aerodrome Reference Points (ARP) within the ICAO CORSIA CERT shall be used with the following Latitude & Longitude sign convention.

A negative latitude (-) means South of the Equator. A negative longitude (-) means West of the Prime Meridian.

In addition, the user is prompted to enter an ICAO Member State attributed to the aerodrome by selecting from the list of 193 ICAO Member States as of April 2020. In order to help with the attribution of aerodromes to ICAO Member States, the ICAO CORSIA CERT provide a suggestion on a potential ICAO Member State based on the first two letters of the Custom Aerodrome Code (for codes with four letters only).

Note. - If custom aerodromes are entered but already exist in the ICAO CORSIA CERT aeroplane database, the information for the custom aerodromes will be used as default for the purpose of calculating CO₂ emissions.

Note. – In order to help the user search the ICAO CORSIA CERT aeroplane and aerodrome databases, a search functionality was developed. Additional information on the underlying Doc 8643 can be found at: <https://www.icao.int/publications/DOC8643/Pages/default.aspx>. In addition, additional information on Doc 7910 can be found at <https://gis.icao.int/7910FLEX/>.

4.1.5 Computation of Great Circle Distance

For each aerodrome pair entered as input into the tool, the ICAO CORSIA CERT calculates a Great Circle Distance (GCD).

Doc 7910 was used as the basis for the aerodrome latitudes and longitudes. The input latitude and longitude is based on WGS84. In order to compute Great Circle Distance used as input to the ICAO CORSIA CERT underlying ICAO CEMs, the Vincenty's Method was used and implemented in the ICAO CORSIA CERT. The Vincenty's method is an iterative process used in geodesy to calculate the distance between two points on the surface of a spheroid, developed by Thaddeus Vincenty (1975a). It is based on the assumption that the figure of the Earth is an oblate spheroid, and hence is more accurate than methods that assume a spherical Earth, such as Great Circle Distance. The method is widely used in geodesy because they are accurate to within 0.5 mm (0.020") on the Earth ellipsoid.

4.1.6 Generation of a summary assessment of CO₂ emissions

After ensuring that the entered information is complete and calculating CO₂ emissions, the user can generate a summary assessment of applicability of Annex 16, Volume IV, Chapter 2 and eligibility to use the ICAO CORSIA CERT in 2022.

The summary assessment includes:

- a) Aeroplane operator information** based on input from the user;
- b) Estimated CO₂ emissions and status of aeroplane operator.** This comprises:
 - Total annual estimated CO₂ emissions (international). It should be noted that emissions are for all international State pairs. For the 2021 version of the ICAO CORSIA CERT, this total splits between State pairs with offsetting requirements and State pairs not subject to offsetting requirements (see Annex 16, Volume IV, Chapter 3 for details).
 - Total annual estimated CO₂ emissions (domestic). Domestic aviation is outside the scope of applicability of Annex 16, Volume IV. Information is provided for awareness of tool user in the event domestic flights are entered in the input tables.
 - Status of aeroplane operator as to whether the aeroplane operator falls under the scope of applicability of CORSIA as per Annex 16, Volume IV, Chapter 2 and whether the aeroplane operator is eligible to use the ICAO CORSIA CERT or required to use one of the five Fuel Use Monitoring Methods. For details on Fuel Use Monitoring Methods refer to Annex 16, Volume IV, Chapter 2 and Appendix 2 and the Environmental Technical Manual (Doc 9501), Volume IV.
- c) Detailed estimated CO₂ emissions by State pairs.**

4.1.7 Generation of report on summary assessment

To support the Emissions Monitoring Plan (EMP) in 2021, the aeroplane operator can use the ICAO CORSIA CERT to estimate its emissions. The ICAO CORSIA CERT can produce a copy summary assessment along with a copy of the Appendix to the summary assessment containing the custom aeroplane and aerodromes information (if entered in the tool).

The user can save a copy for its records. In accordance with Annex 16, Volume IV, Appendix 4, 2.3.1.1 a) on the supporting information on methods and means for calculating emissions from international flights, the aeroplane operator can submit a copy of the summary assessment to its State along with the Emissions Monitoring Plan.

4.2 CO₂ Estimation and Reporting for 2021

The CO₂ Estimation and Reporting functionality of the ICAO CORSIA CERT version 2021 was developed to take the user through each step of the Emissions Report generation process where the user:

- a. Enters aeroplane operator identification and description of activities,
- b. Enters underlying basic information of the Emissions Report,
- c. Enters aeroplane fleet and fuel types
- d. Select Fuel density
- e. Selected the level of aggregation of the information reported,
- f. Load its operations (and fuel) data to estimation CO₂ emissions,
- g. Completes the prefilled “Reporting - State pairs” report, or
- h. Completes the prefilled “Reporting - Aerodrome pairs”, and

- i. Completes the prefilled “Data gaps” information.
- j. Review the Emissions Report and Export the Emissions Report in various formats to meet the need of the aeroplane operator.

The following section provides additional information on each of the steps and the associated underlying methodologies and assumptions.

4.2.1 Starting to Fill the Emissions Report

If the ICAO CORSIA CERT is used to fill an Emissions Report, the user will be prompted to enter information on (1) Aeroplane operator identification and description of activities, (2) Underlying basic information of the Emissions Report, (3) Aeroplane fleet and fuel types, (4) Fuel density and (5) Level of aggregation of the information reported.

The ICAO CORSIA CERT replicates the same process and format as the ICAO Emissions Report template.

4.2.2 Loading and entering data into the ICAO CORSIA CERT

In order to estimate fill the relevant portions of the Emission Report, the ICAO CORSIA CERT will estimate CO₂ emissions and fill data gaps (as needed). The first step is to load or enter data into the ICAO CORSIA CERT. An aeroplane operator can enter aircraft type and flight information data into the ICAO CORSIA CERT using two key paths:

- a) Manual entry by selecting an aircraft type designator from the list of types available in the ICAO CORSIA CERT aeroplane database. If needed, the user can also enter codes that are not included in the ICAO CORSIA CERT aeroplane database which become ‘custom aeroplane code’. See section 4.2.3 for details on the custom aeroplane and aerodrome functionality in the ICAO CORSIA CERT; and
- b) Direct upload into the ICAO CORSIA CERT by loading a file containing aircraft types, origin and destination aerodromes as well as number of flights. This file in .csv format can be used as the interface between an aeroplane operator’s Operations and Flight Management System and the ICAO CORSIA CERT.

4.2.3 Comparison of the operations input data against the ICAO CORSIA CERT aeroplane and aerodrome databases

When loading operations data into the ICAO CORSIA CERT or calculating CO₂ emissions, the user can choose to compare the input aircraft type and aerodromes entries against the internal ICAO CORSIA CERT aeroplane and aerodromes databases. This comparison checks for consistency and returns any aircraft type code and aerodrome code that does not match the internal ICAO CORSIA CERT aeroplane and aerodromes databases. The user can then choose to enter custom aeroplane and aerodromes information for these codes or return to the input data and correct the codes if an error was made in the data entry.

Entering custom aeroplane codes

If the user chooses to use custom aircraft type codes, he/she is prompted to select an aeroplane category from the following list:

- e) Jet (Heavy) with certified MTOM \geq 136 000 kg;

- f) Jet with certified MTOM $\geq 60\,000$ kg and $< 136\,000$ kg;
- g) Jet with certified MTOM $< 60\,000$ kg; and
- h) Turboprop.

The user is also prompted to enter the Average Maximum Take Off Mass (MTOM) in the aeroplane operator fleet. The Average MTOM is calculated using the arithmetical average of individual MTOMs of aeroplane in the fleet of a given aeroplane code. The individual MTOMs are the individual maximum permissible take-off mass of each individual aeroplane according to the certificate of airworthiness, the flight manual or other official documents as defined by ICAO Annex 16, Volume IV.

Based on the aeroplane category selected and the Average Maximum Take Off Mass (MTOM) in the aeroplane operator fleet, the ICAO CORSIA CERT derives a tailored ICAO CEM from the relevant generic equation model according to the approach described in section 3.2.6. The custom aeroplane functionality displays information on the fuel burn rate (kg/km) and intercept value (fuel at great circle distance of 0 km) depending on the underlying regression model associated with a manually selected aeroplane category and average MTOM. The indicated fuel burn rate and interception value are used within ICAO CORSIA CERT to calculate the estimated fuel and emissions for all flights with this Custom Aeroplane Code.

The following coefficients are used in the 2021 version of the ICAO CORSIA CERT to generate generic equations (as a function of entered Average MTOM) for aircraft types entered as custom aeroplane, by aircraft type category.

Aircraft Type Category	Coefficients for Linear Function to Derive the Intercept of the Generic Equation		Coefficients for Linear Function to Derive the Slope of the Generic Equation	
Coefficients for Generic Equation based on Great Circle Distance (i.e., Fuel = slope * GCD + intercept)				
	Intercept	Slope	Intercept	Slope
Jet (Heavy) with certified MTOM $\geq 136\,000$ kg	-113.7137664	0.009291852	0.951365126	2.57593E-05
Jet with certified MTOM $\geq 60\,000$ kg and $< 136\,000$ kg	137.7074107	0.011128137	1.747754615	2.21315E-05
Jet (Heavy) with certified MTOM $< 60\,000$ kg	199.515606	0.013327825	0.081018763	5.61413E-05
Turboprop	-4.19723143	0.01234964	0.324835791	4.96388E-05
Coefficients for Generic Equation based on Block Time (i.e., Fuel = slope * Block_Time + intercept)				
	Intercept	Slope	Intercept	Slope
Jet (Heavy) with certified MTOM $\geq 136\,000$ kg	3242.96057	-0.025916812	0.289704965	0.000431018
Jet with certified MTOM $\geq 60\,000$ kg and $< 136\,000$ kg	784.8502339	-0.012637172	11.03636464	0.000425351
Jet (Heavy) with certified MTOM $< 60\,000$ kg	119.6022853	0.000242613	3.006234178	0.000583241
Turboprop	-18.57018159	0.006084983	0.858892757	0.000423119

Figure 21: Coefficients used in the 2021 version of the ICAO CORSIA CERT to generate generic equations (as a function of entered Average MTOM) for aircraft types entered as custom aeroplane

Note. - If custom aircraft types are entered but already exist in the ICAO CORSIA CERT aeroplane database, the information in the ICAO CORSIA CERT aeroplane database will anyhow be used as default for calculating CO₂ emissions.

Entering custom aerodrome codes

Note. – The Custom Aerodrome functionality for the “CO₂ Estimation and Reporting for 2019” functionality is identical to the Custom Aerodrome functionality for the “Summary of assessment of applicability of CORSIA and eligibility to use the ICAO CORSIA CERT in 2021”. See section 4.1.4 for details.

4.3 Data entry error and plausibility of input data

The ICAO CORSIA CERT 2021 version also includes a number of new functionality that allows the user to identify potential data entry errors and confirm the accuracy of the input data, including;

- **Date;** Date is an Optional Field. When importing an Input File and/or Calculating CO₂ Emissions, the ICAO CORSIA CERT checks that the year of the entered date matches the Reporting Year (as described in "2 Underlying basic information of the Emissions Report" section a) of the Emissions Report). Warning messages are displayed as "Date" in the last column (i.e., "Warnings") of the input/output table.
- **ICAO Aircraft Type Designator availability;** The tool will prompt the user to check the aircraft type designator against the underlying ICAO CORSIA CERT Aeroplane database and the Custom Aeroplane entered by the user. If any discrepancies are found, the user will be prompted to update/edit existing Custom Aircraft Types or enter new ones,
- **Origin Aerodrome and Destination Aerodrome availability;** Similar to the aircraft type input, the tool will prompt the user to check the origin and destination aerodromes against the underlying ICAO CORSIA CERT Aerodrome database and the Custom Aerodromes entered by the user. If any discrepancies are found, the user will be prompted to update/edit existing Custom Aerodromes or enter new ones.
- **“Total Number of Flights” valid input checks;** The tool will check that input values of total number of flights for flight entries are; (1) greater or equal to 0, (2) integer values (i.e., not fractions of flights). If errors are identified, a pop up message will appear and flight entries will be highlighted.
- **Type of Fuel valid input checks;** The tool will check that a correct Type of Fuels (i.e., Jet-A, Jet-A1, Jet-B, AvGas) are entered. It should be noted that the Type of Fuel selected can include equivalent fuels. If discrepancies between input data and acceptable Type of Fuels are identified, the tool will return an error message and the flight entries with errors will be highlighted.
- **Great Circle Distance comparison with Aeroplane Type’s Potential Max Range;** For each of the flight entries for which Great Circle Distance (GCD) was computed, the tool will also compare the GCD to a Maximum Range for the associated aircraft type. If the GCD exceeds this maximum range, a warning will be return. It should be noted that this comparison and possible warning are for information only. The intent is to identify potential input errors (e.g., order of magnitude error such as 0 added to input data). The warning can also result from normal operations if longer range versions of the aeroplane are operated.
- **Estimated and/or Reported Fuel comparison with Aeroplanes Maximum Fuel Tank Capacity;** For each of the flight entries, the tool will identify cases where average reported and/or estimated fuel (and resulting CO₂ emissions) per flight exceed the ICAO CORSIA CERT default maximum fuel tank capacity value for that ICAO Aircraft Type and/or Custom aeroplane code. In order to avoid a possible overestimation of CO₂ emissions, the user is prompted to check the following flight entries flagged with “Fuel Cap”. It should be noted that this warning message may be ignored since individual maximum fuel tank capacity and fuel tank configuration can differ from the ICAO CORSIA CERT default values (e.g., some aeroplanes can have additional fuel tanks which could be one explanation). It should be noted that this comparison and possible warning are for information only. The intent is to identify potential input errors (e.g., order of magnitude error such as 0 added to input data).

4.4 Calculation of CO₂ emissions

1.1.1 The ICAO CORSIA CERT 2021 version builds on the 2020 version with regard to the input of aeroplane operator information, the CO₂ estimation and the generation of a summary assessment functionalities. To meet requirements from Annex 16 Volume IV Chapters 2 and 3, the CERT 2021 embeds the CORSIA Implementation Element titled as “CORSIA States for Chapter 3 State Pairs” that will be used to determine the CO₂ emissions subject to offsetting requirements in 2021. The first version (July 2020) of CORSIA Implementation Element titled as “CORSIA States for Chapter 3 State Pairs” is available on the CORSIA website⁶. This document includes the list of 88 States that participate in CORSIA from 1 January 2021. The CCG developed functionality to embed this list in the CERT 2021 and scripts to calculate and report CO₂ emissions subject to offsetting requirements into the Emissions Report (ER) template.

4.4.1 Generation of Emissions Report (5.1 Reporting - State Pairs and 5.2 Reporting - Aerodrome Pairs, 6 Data Gaps)

After ensuring that the entered information is complete and calculating CO₂ emissions and based on the selection in “5 Reporting” (i.e., reporting on a State pair level or reporting on an aerodrome pair level), the user can fill the portion of the Emissions Report template with statistics on number of flights, emissions, data gaps, etc..

The sections of the Emissions Report automatically and partially filled by the ICAO CORSIA CERT include:

d) 5.1 Reporting at State Pair Level. This comprises:

- Total annual measured and/or estimated CO₂ emissions (international). It should be noted that emissions are for all international State pairs. For the 2021 version of the ICAO CORSIA CERT, this total splits between State pairs with offsetting requirements and State pairs not subject to offsetting requirements (see Annex 16, Volume IV, Chapter 3 for details).
- Total annual number of flights during the reporting period (international). It should be noted that flights are for all international State pairs. For the 2021 version of the ICAO CORSIA CERT, this total splits between State pairs with offsetting requirements and State pairs not subject to offsetting requirements (see Annex 16, Volume IV, Chapter 3 for details).
- The user can manually enter the Total emissions reductions claimed from the use of CORSIA eligible fuels.
- If the ICAO CORSIA CERT is used for data gap filling and actual fuel quantities (based on one of the five Fuel Use Monitoring Methods) are used, the break down will be automatically calculated by the ICAO CORSIA CERT and presented in section b).
- The user can manually enter the details of emissions reductions claimed from the use of CORSIA eligible fuels.
- Based on input and calculations in the “CO₂ Emissions Estimation & Data Gap Filling” section, the ICAO CORSIA CERT automatically generated the list of State Pairs including; State of departure, State of arrival, whether the CO₂ emissions were estimated by the ICAO CORSIA CERT, total number of flights, fuel type, total mass of fuel, fuel conversion factors, total CO₂ emissions. In the 2021 version, the ICAO CORSIA CERT indicates whether the State Pair is subject to offsetting requirements.

⁶ Reference: ICAO document, “CORSIA States for Chapter 3 State Pairs”, Version July 2020, available at: https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_States_for_Chapter3_State_Pairs_Jul2020.pdf, last retrieved on August 4th 2020.

e) 5.2 Reporting at Aerodrome Pair Level. This comprises:

- Total annual measured and/or estimated CO₂ emissions (international). It should be noted that emissions are for all international State pairs. For the 2021 version of the ICAO CORSIA CERT, this total splits between State pairs with offsetting requirements and State pairs not subject to offsetting requirements (see Annex 16, Volume IV, Chapter 3 for details).
- Total annual number of flights during the reporting period (international). It should be noted that flights are for all international State pairs. For the 2021 version of the ICAO CORSIA CERT, this total splits between State pairs with offsetting requirements and State pairs not subject to offsetting requirements (see Annex 16, Volume IV, Chapter 3 for details).
- The user can manually enter the Total emissions reductions claimed from the use of CORSIA eligible fuels.
- If the ICAO CORSIA CERT is used for data gap filling and actual fuel quantities (based on one of the five Fuel Use Monitoring Methods) are used, the break down will be automatically calculated by the ICAO CORSIA CERT and presented in section b).
- The user can manually enter the details of emissions reductions claimed from the use of CORSIA eligible fuels.
- Based on input and calculations in the “CO₂ Emissions Estimation & Data Gap Filling” section, the ICAO CORSIA CERT automatically generates the list of Aerodrome Pairs including; ICAO aerodrome code and State for the Departure, ICAO aerodrome code and State for the Arrival, whether the CO₂ emissions were estimated by the ICAO CORSIA CERT, total number of flights, fuel type, total mass of fuel, fuel conversion factors, total CO₂ emissions. In the 2021 version, the ICAO CORSIA CERT indicates whether the Aerodrome Pair is subject to offsetting requirements.

f) 6 Data Gaps. This comprises:

- Based on input and calculations in the “CO₂ Emissions Estimation & Data Gap Filling” section, the ICAO CORSIA CERT automatically assesses whether data gaps occurred during the reporting year and whether the threshold of 5 per cent for data gaps was exceeded and reports the percent of data gaps. The 2021 version of the ICAO CORSIA CERT follows the requirements from Annex 16 Volume IV, where starting in 2021, the percentage of data gaps are calculated by dividing the total number of flights with data gaps by total number of international flights subject to offsetting requirements.

Note. – In the 2019 and 2020 versions of the ICAO CORSIA CERT, the percentage of data gaps were calculated by dividing total number of flights with data gaps by total number of international flights.

- The user can manually enter the details on the data gaps if the 5 per cent threshold has been exceeded in the reporting year.

4.5 Exporting copies of the Emissions Report and Generation of Log of Assumptions

To support the Emissions Reporting (ER) in 2021, the aeroplane operator can use the ICAO CORSIA CERT to estimate its emissions and generate a filled version of the Emissions Report.

The ICAO CORSIA CERT can export and produce a copy of the Emissions Report in Excel Format (i.e., as a stand-alone version of the Emissions Report).

The ICAO CORSIA CERT can also generate (if needed and/or for purposes of record keeping) a time stamp pdf version of the Emissions Report. The user can save a copy for its records.

In addition, the ICAO CORSIA CERT returns a Log of Assumptions containing general information as well as the Custom aeroplane and Custom aerodrome information (if entered in the tool).

In accordance with Annex 16, Volume IV, Appendix 4, 2.3.1.1 a) on the supporting information on methods and means for calculating emissions from international flights, the aeroplane operator can submit a copy of the Log of Assumptions to its State along with the Emissions Report.

For purpose of tools interfaces (if needed), the user can export a .csv file of the data contained in "CO₂ Emissions Estimation & Data Gap Filling". Similarly, the user can export a .csv file of the data contained in "Custom aeroplane information" and "Custom aerodrome information".

5. VALIDATION AND REVIEW OF THE ICAO CO₂ ESTIMATION MODELS (CEMS)

The work on the ICAO CO₂ Estimation Models (CEMs), ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) and the associated development/maintenance documentation was led by the CAEP Working Group 4 (WG4). The CAEP Modeling and Database Group (MDG) subsequently conducted a validation exercise to ensure the ICAO CORSIA CERT was fit for purpose in terms of its use within CORSIA.

6. PHASED DEVELOPMENT OF THE ICAO CORSIA CERT AND FEEDBACK

The ICAO CORSIA CO₂ Estimation and Reporting Tool (CERT) can be used by an aeroplane operator to support the monitoring and reporting of their CO₂ emissions, in accordance with the requirements from ICAO Annex 16, Volume IV, Part II, Chapter 2, 2.2 and Appendix 3.

The ICAO CORSIA CERT supports aeroplane operators in fulfilling their monitoring and reporting requirements by populating the standardized Emissions Monitoring Plan and Emissions Report templates in Appendix 1 of the Environmental Technical Manual (Doc 9501), Volume IV – Procedures for demonstrating compliance with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). This support includes:

- (i) assessing its eligibility to use Fuel Use Monitoring Methods in support of their Emissions Monitoring Plan (e.g. CO₂ emissions threshold requirements);
- (ii) assessing whether or not it is within the applicability scope of Annex 16, Volume IV, Chapter 2 (MRV requirements); and
- (iii) filling any CO₂ emissions data gaps.

6.1 Phased development of the ICAO CORSIA CERT and expected 2022 version

As described in section 2, the ICAO CORSIA CERT is expected to be valid for a given year to address the evolution of the required functionality of the ICAO CORSIA CERT in accordance with Annex 16, Volume IV.

In support of the recommendations from Annex 16, Volume IV, Appendix 3 on the collection of data to further develop and maintain the ICAO CO₂ Estimation Models (CEMs) used within the ICAO CORSIA CERT, Appendix A-2 shows the list of aeroplane that will be the focus of further and targeted data collection towards the 2022 version of the ICAO CORSIA CERT. Any operator and/or State willing to contribute to the development of the ICAO CORSIA CERT and provide data is encouraged to contact ICAO-CAEP.

6.2 Process for providing feedback and input towards the future versions of the ICAO CORSIA CERT

Feedback on the ICAO CORSIA CERT functionalities or questions can be directed to CERT@icao.int

**APPENDIX A-1: ICAO CO₂ Estimation Model (CEM) based on Great Circle Distance (GCD)
Input in version 2021 of the ICAO CORSIA CERT**

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-1.1.a (cont.). Aircraft types (by ICAO type designator) modelled with ICAO CEM based on aeroplane operator data from the COFdb

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
E145	ERJ-145EP	Yes				
E170	ERJ-170-100	Yes				
E190	ERJ-190 Lineage 1000	Yes				
E195	ERJ-190-200	Yes				
E35L	EMB-135BJ Legacy	Yes				
E45X	EMB-145XR	Yes				
E55P	EMB-505 Phenom 300	Yes				
F100	100	Yes				
F2TH	Falcon 2000	Yes				
F70	70	Yes				
F900	Falcon 900	Yes				
FA50	Falcon 50	Yes				
FA7X	Falcon 7X	Yes				
FA8X	Falcon 8X	Yes				
G280	Gulfstream G280	Yes				
GL5T	Global 5000	Yes				
GLEX	Global Express	Yes				
GLF4	Gulfstream 4	Yes				
GLF5	Gulfstream 5	Yes				
GLF6	Gulfstream G650	Yes				
H25B	Hawker 800	Yes				
LJ31	31	Yes				
LJ40	40	Yes				
LJ45	45	Yes				
LJ60	60	Yes				
RJ85	RJ-85 Avroliner	Yes				
AN26	An-26	Yes				
AT43	ATR-42-300	Yes				
AT45	ATR-42-500	Yes				
AT46	ATR-42-600	Yes				
AT72	ATR-72-201	Yes				
AT75	ATR-72-500	Yes				
AT76	ATR-72-600	Yes				
B190	1900	Yes				
BE30	300 Super King Air	Yes				
D328	328	Yes				
DH8A	Dash 8 (100)	Yes				
DH8D	Dash 8 (400)	Yes				
F50	50 Maritime Enforcer	Yes				
SF34	SF-340	Yes				

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-1.1.b. Aircraft types (by ICAO type designator) modelled with equivalent aircraft types

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
A30B	A-300B2		Yes	A306		
A338	A-330-800		Yes	A339		
A342	A-340-200		Yes	A343		
A345	A-340-500		Yes	A346		
A35K	A-350-1000 XWB		Yes	A359		
B741	747-100		Yes	B744		
B742	747-200		Yes	B744		
B743	747-300		Yes	B744		
B74R	747SR		Yes	B744		
B74S	747SP		Yes	B744		
B78X	787-10 Dreamliner		Yes	B789		
A19N	A-319neo		Yes	A20N		
B37M	737 MAX 7		Yes	B38M		
B39M	737 MAX 9		Yes	B38M		
B3XM	737 MAX 10		Yes	B38M		
BCS1	BD-500 CSeries CS100		Yes	BCS3		
MD81	MD-81		Yes	MD82		
MD83	MD-83		Yes	MD82		
MD87	MD-87		Yes	MD88		
B461	BAe-146-100		Yes	B462		
B732	737-200		Yes	B733		
C25C	525C Citation CJ4		Yes	C550		
C525	525 Citation CJ1		Yes	C550		
C55B	550B Citation Bravo		Yes	C550		
C560	560 Citation 5		Yes	C550		
E75L	ERJ-170-200 (long wing)		Yes	E170		
E75S	ERJ-170-200 (short wing)		Yes	E170		
GA5C	Gulfstream G500 (G-7)		Yes	GLF5		
GA6C	G-7 Gulfstream G600		Yes	GLF5		
GA7C	Gulfstream G700		Yes	GLF6		
H25A	HS-125-1		Yes	H25B		
H25C	Hawker 1000		Yes	H25B		
LJ25	25		Yes	LJ40		
LJ35	35		Yes	LJ40		
LJ55	55		Yes	LJ45		
LJ70	70		Yes	LJ45		
LJ75	75		Yes	LJ45		
RJ1H	RJ-100 Avroliner		Yes	B463		
RJ70	RJ-70 Avroliner		Yes	RJ85		
AN30	An-30		Yes	AN26		
AN32	An-32		Yes	AN26		
AT73	ATR-72-211		Yes	AT72		
DH8B	Dash 8 (200)		Yes	DH8D		
DH8C	Dash 8 (300)		Yes	DH8D		
DHC7	DHC-7 Dash 7		Yes	DH8D		
E290	E190-E2		EF2 Method	E190		
E295	E195-E2		EF2 Method	E195		

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-1.1.c. Aircraft types (by ICAO type designator) modelled with ICAO Fuel Formula

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
DC10	DC-10					D10
DC85	DC-8-50					D8T
DC86	DC-8-60					D8L
DC87	DC-8-70					D8Q
IL62	IL-62					IL6
IL76	IL-76					IL7
IL86	IL-86					ILW
IL96	IL-96					IL9
L101	L-1011 TriStar					L10
B701	707-100					70M
B721	727-100					
T134	Tu-134					TU3
T154	Tu-154					TU5
T204	Tu-204					T20
A148	An-148					A81
AN72	An-72					AN7
BA11	BAC-111 One-Eleven					B11
DC91	DC-9-10					D91
DC92	DC-9-20					D92
DC93	DC-9-30					D93
DC94	DC-9-40					D94
F28	F-28 Fellowship					F28
FA10	Falcon 10					DF2
J328	Dornier 328JET					FRJ
S601	SN-601 Corvette					NDC
WW24	1124 Westwind					WWP
YK40	Yak-40					YK4
YK42	Yak-42					YK2
A140	IRAN-140 Faraz					A40
A748	748					HS7
AN12	An-12					ANF
AN24	An-24					AN4
AN28	An-28					A28
ATP	ATP					ATP
BE20	Super King Air (200)					BE2
BELF	SC-5 Belfast					SHB
C130	L-100 Hercules					LOH
C212	C-212 Aviocar					CS2
CN35	CN-235					CSS
CVLP	Convairliner					CVR
CVLT	Cosmopolitan					CV5
D228	Dornier 228					D28
DC3	DC-3					DC3
DC6	DC-6					DC6
DHC6	DHC-6 Twin Otter					DHT
E110	EMB-110 Bandeirante					EMB
E120	EMB-120 Brasilia					EM2
F27	F-27					F27
G159	G-159 Gulfstream 1					GR5
IL14	IL-114					IL4
IL18	IL-18					IL8
J531	BAe-3100 Jetstream 31					J31
J532	BAe-3200 Jetstream Super 31					J32
J541	BAe-4100 Jetstream 41					J41
L188	Electra (L-188)					LOE
L410	L-410 Turbolet					L4T
N262	N-262 Frigate					ND2
S820	2000					S20
SC7	SC-7 Skyliner					SH5
SH33	SD3-30					SH3

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Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
SH36	360					SH6
SW2	SA-26 Merlin 2					SWM
YS11	YS-11					YS1

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-1.2.b. Aircraft types (by ICAO type designator) modelled with equivalent aircraft types

Type Designator	Fuel (in kg) for given Great Circle Distance (in km)																
	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	7000	8000	9000	10000
A30B	2,696	5,541	8,386	11,230	14,075	16,919	19,764	22,608	25,453	28,297	31,142	33,987	36,831	42,520	48,209		
A338	1,801	4,844	7,888	10,932	13,976	17,020	20,064	23,108	26,151	29,195	32,239	35,283	38,327	44,415	50,502	56,590	62,678
A342	1,802	6,614	10,293	13,971	17,650	21,328	25,006	28,685	32,363	36,042	39,720	43,398	47,077	55,022	63,823	72,625	81,426
A345	3,997	8,074	12,150	16,226	20,302	24,379	28,455	32,531	36,607	40,683	44,759	48,835	52,911	60,880	71,516	82,152	92,787
A35K	3,896	7,497	11,098	14,700	18,301	21,902	25,503	29,104	32,705	36,306	39,907	43,508	47,109	55,562	65,866	74,171	82,475
B741	5,112	9,728	14,344	18,961	23,577	28,194	33,125	38,153	43,181	48,209	53,237	58,265	63,293	73,349	84,732		
B742	5,640	10,733	15,827	20,920	26,014	31,107	36,548	42,095	47,643	53,190	58,738	64,285	69,833	80,928	93,488	108,319	123,149
B743	5,565	10,591	15,616	20,642	25,668	30,694	36,062	41,536	47,010	52,483	57,957	63,431	68,905	79,852	92,245	106,879	121,512
B74R	4,881	9,289	13,698	18,106	22,514	26,923	31,631	36,433	41,234	46,035	50,836	55,638	60,439	70,041	80,912	93,747	106,583
B74S	4,762	9,063	13,364	17,665	21,966	26,267	30,861	35,545	40,230	44,914	49,598	54,283	58,967	68,335	78,941	91,464	103,987
B78X	2,377	5,204	8,031	10,858	13,685	16,512	19,339	22,166	24,993	28,079	31,472	34,865	38,258	45,044	51,830	58,616	65,402
A19N	779	2,073	3,350	4,601	5,852	7,159	8,480	9,801	11,121	12,442	13,763	15,084	16,405				
B37M	707	1,992	3,276	4,541	5,775	7,010	8,248	9,489	10,729	11,970	13,210	14,451	15,691	18,172			
B39M	809	2,279	3,748	5,195	6,607	8,020	9,437	10,856	12,275	13,694	15,114	16,533	17,952				
B3XM	790	2,227	3,663	5,077	6,457	7,837	9,222	10,609	11,996	13,383	14,770	16,157	17,544				
BCS1	496	1,831	3,166	4,502	5,837	7,172	8,508										
MD81	790	2,761	4,733	6,705	8,676	10,648	12,620	14,591	16,563	18,535	20,506						
MD83	900	3,148	5,396	7,644	9,892	12,140	14,388	16,636	18,884	21,132	23,380	25,628	27,876	32,372			
MD87	1,618	3,424	5,231	7,038	9,125	11,352	13,580	15,807	18,034	20,261	22,488	24,715	26,943				
B461	675	2,158	3,642	5,125													
B732	944	2,245	3,620	5,051	6,483	7,914	9,346	10,777	12,208	13,640	15,071						
C25C	234	764	1,169	1,568	1,966	2,365	2,764	3,163	3,562								
C525	148	485	741	994	1,247	1,500											
C55B	204	668	1,021	1,369	1,717	2,066	2,414	2,762									
C560	222	728	1,113	1,493	1,872	2,252	2,632	3,012									
E75L	522	1,870	2,884	4,156	5,429	6,701	7,973										
E75S	506	1,813	2,796	4,029	5,262	6,496	7,729										
GA5C	620	1,462	2,165	2,868	3,571	4,274	4,977	5,681	6,384	7,087	7,790	8,493	9,196	10,524	11,815	13,105	
GA6C	745	1,758	2,603	3,448	4,294	5,139	5,984	6,830	7,675	8,520	9,366	10,211	11,056	12,652	14,204	15,757	17,309
GA7C	580	1,825	2,674	3,522	4,371	5,219	6,068	6,917	7,765	8,614	9,463	10,311	11,160	12,857	14,555	16,252	17,949
H25A	219	742	1,142	1,541	1,940	2,340	2,739	3,138	3,537	3,937	4,336						
H25C	263	894	1,375	1,856	2,337	2,818											
LJ25	92	432	713	994	1,276	1,557	1,838										
LJ35	113	527	870	1,213	1,556	1,899	2,242	2,585	2,928	3,271							
LJ55	71	638	961	1,284	1,607	1,930	2,253										
LJ70	72	652	983	1,313	1,644	1,974	2,305	2,635									
LJ75	74	668	1,006	1,344	1,683	2,021	2,359	2,698									
RJ1H	688	2,625	4,561	6,497	8,433	10,369	12,305	14,242	16,178								
RJ70	538	2,355	4,173	5,990	7,807												
AN30	439	1,625	2,802	3,545	4,288	5,031											
AN32	515	1,908	3,289	4,161	5,034	5,906	6,778										
AT73	48	868	1,492	2,116	2,740												
DH8B	169	632	1,095	1,559													
DH8C	199	744	1,289	1,835	2,380												
DHC7	207	774	1,341														
E290	492	1,718	2,696	3,699	4,806	5,914	7,021	8,128	9,236	10,343	11,451						
E295	397	1,826	2,959	4,092	5,225	6,357	7,490	8,623	9,756	10,888							

APPENDIX A-2: ICAO CO₂ Estimation Model (CEM) based on Block Time (BT) Input in version 2021 of the ICAO CORSIA CERT

Table A-2.1.a. Aircraft types (by ICAO type designator) modelled with ICAO CEM based on aeroplane operator data from the COFdb

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
A124	An-124 Ruslan	Yes				
A306	A-300B4-600	Yes				
A310	A-310	Yes				
A332	A-330-200	Yes				
A333	A-330-300	Yes				
A339	A-330-900	Yes				
A343	A-340-300	Yes				
A346	A-340-600	Yes				
A359	A-350-900 XWB	Yes				
A388	A-380-800	Yes				
B744	747-400 (international, winglets)	Yes				
B748	747-8	Yes				
B762	767-200	Yes				
B763	767-300	Yes				
B764	767-400	Yes				
B772	777-200	Yes				
B773	777-300	Yes				
B77L	777-200LR	Yes				
B77W	777-300ER	Yes				
B788	787-8 Dreamliner	Yes				
B789	787-9 Dreamliner	Yes				
MD11	MD-11	Yes				
A20N	A-320neo	Yes				
A21N	A-321neo	Yes				
A318	A-318	Yes				
A319	A-319	Yes				
A320	A-320	Yes				
A321	A-321	Yes				
B38M	737 MAX 8	Yes				
B722	727-200	Yes				
B733	737-300	Yes				
B734	737-400	Yes				
B735	737-500	Yes				
B736	737-600	Yes				
B737	737-700	Yes				
B738	737-800	Yes				
B739	737-900	Yes				
B752	757-200	Yes				
B753	757-300	Yes				
MD82	MD-82	Yes				
MD88	MD-88	Yes				
MD90	MD-90	Yes				
B462	BAe-146-200	Yes				
B463	BAe-146-300	Yes				
B712	717-200	Yes				
C25B	525B Citation CJ3	Yes				
C550	550 Citation 2	Yes				
C56X	560XL Citation Excel	Yes				
C68A	680A Citation Latitude	Yes				
CL30	BD-100 Challenger 300	Yes				
CL35	BD-100 Challenger 350	Yes				
CL60	CL-600 Challenger 650	Yes				
CRJ1	Regional Jet CRJ-100	Yes				
CRJ2	Challenger 800	Yes				
CRJ7	Challenger 870	Yes				
CRJ9	Challenger 890	Yes				
CRJX	Regional Jet CRJ-1000	Yes				
DC95	DC-9-50	Yes				
E135	ERJ-135	Yes				
E145	ERJ-145EP	Yes				

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-2.1.a (cont.). Aircraft types (by ICAO type designator) modelled with ICAO CEM based on aeroplane operator data from the COFdb

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
E170	ERJ-170-100	Yes				
E190	ERJ-190 Lineage 1000	Yes				
E195	ERJ-190-200	Yes				
E35L	EMB-135BJ Legacy	Yes				
E45X	EMB-145XR	Yes				
E55P	EMB-505 Phenom 300	Yes				
F100	100	Yes				
F2TH	Falcon 2000	Yes				
F70	70	Yes				
F900	Falcon 900	Yes				
FA50	Falcon 50	Yes				
FA7X	Falcon 7X	Yes				
FA8X	Falcon 8X	Yes				
G280	Gulfstream G280	Yes				
GL5T	Global 5000	Yes				
GLEX	Global Express	Yes				
GLF4	Gulfstream 4	Yes				
GLF5	Gulfstream 5	Yes				
GLF6	Gulfstream G650	Yes				
H25B	Hawker 800	Yes				
LJ31	31	Yes				
LJ40	40	Yes				
LJ45	45	Yes				
LJ60	60	Yes				
RJ85	RJ-85 Avroliner	Yes				
AN26	An-26	Yes				
AT43	ATR-42-300	Yes				
AT45	ATR-42-500	Yes				
AT46	ATR-42-600	Yes				
AT72	ATR-72-201	Yes				
AT75	ATR-72-500	Yes				
AT76	ATR-72-600	Yes				
B190	1900	Yes				
BE30	300 Super King Air	Yes				
D328	328	Yes				
DH8A	Dash 8 (100)	Yes				
DH8D	Dash 8 (400)	Yes				
F50	50 Maritime Enforcer	Yes				
SF34	SF-340	Yes				

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-2.1.b. Aircraft types (by ICAO type designator) modelled with equivalent aircraft types

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
A30B	A-300B2		Yes	A306		
A338	A-330-800		Yes	A339		
A342	A-340-200		Yes	A343		
A345	A-340-500		Yes	A346		
A35K	A-350-1000 XWB		Yes	A359		
B741	747-100		Yes	B744		
B742	747-200		Yes	B744		
B743	747-300		Yes	B744		
B74R	747SR		Yes	B744		
B74S	747SP		Yes	B744		
B78X	787-10 Dreamliner		Yes	B789		
A19N	A-319neo		Yes	A20N		
B37M	737 MAX 7		Yes	B38M		
B39M	737 MAX 9		Yes	B38M		
B3XM	737 MAX 10		Yes	B38M		
MD81	MD-81		Yes	MD82		
MD83	MD-83		Yes	MD82		
MD87	MD-87		Yes	MD88		
B461	BAe-146-100		Yes	B462		
B732	737-200		Yes	B733		
C25C	525C Citation CJ4		Yes	C550		
C525	525 Citation CJ1		Yes	C550		
C55B	550B Citation Bravo		Yes	C550		
C560	560 Citation 5		Yes	C550		
E75L	ERJ-170-200 (long wing)		Yes	E170		
E75S	ERJ-170-200 (short wing)		Yes	E170		
GA5C	Gulfstream G500 (G-7)		Yes	GLF5		
GA6C	G-7 Gulfstream G600		Yes	GLF5		
GA7C	Gulfstream G700		Yes	GLF6		
H25A	HS-125-1		Yes	H25B		
H25C	Hawker 1000		Yes	H25B		
LJ25	25		Yes	LJ40		
LJ35	35		Yes	LJ40		
LJ55	55		Yes	LJ45		
LJ70	70		Yes	LJ45		
LJ75	75		Yes	LJ45		
RJ1H	RJ-100 Avroliner		Yes	B463		
RJ70	RJ-70 Avroliner		Yes	RJ85		
AN30	An-30		Yes	AN26		
AN32	An-32		Yes	AN26		
AT73	ATR-72-211		Yes	AT72		
DH8B	Dash 8 (200)		Yes	DH8D		
DH8C	Dash 8 (300)		Yes	DH8D		
DHC7	DHC-7 Dash 7		Yes	DH8D		
E290	E190-E2		EF2 Method	E190		
E295	E195-E2		EF2 Method	E195		

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

Table A-2.1.c. Aircraft types (by ICAO type designator) modelled with ICAO Fuel Formula

Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
DC10	DC-10					D10
DC85	DC-8-50					D8T
DC86	DC-8-60					D8L
DC87	DC-8-70					D8Q
IL62	IL-62					IL6
IL76	IL-76					IL7
IL86	IL-86					ILW
IL96	IL-96					IL9
L101	L-1011 TriStar					L10
B701	707-100					70M
B721	727-100					
T134	Tu-134					TU3
T154	Tu-154					TU5
T204	Tu-204					T20
A148	An-148					A81
AN72	An-72					AN7
BA11	BAC-111 One-Eleven					B11
DC91	DC-9-10					D91
DC92	DC-9-20					D92
DC93	DC-9-30					D93
DC94	DC-9-40					D94
F28	F-28 Fellowship					F28
FA10	Falcon 10					DF2
J328	Dornier 328JET					FRJ
S601	SN-601 Corvette					NDC
WW24	1124 Westwind					WWP
YK40	Yak-40					YK4
YK42	Yak-42					YK2
A140	IRAN-140 Faraz					A40
A748	748					HS7
AN12	An-12					ANF
AN24	An-24					AN4
AN28	An-28					A28
ATP	ATP					ATP
BE20	Super King Air (200)					BE2
BELF	SC-5 Belfast					SHB
C130	L-100 Hercules					LOH
C212	C-212 Aviocar					CS2
CN35	CN-235					CS5
CVLP	Convairliner					CVR
CVLT	Cosmopolitan					CV5
D228	Dornier 228					D28
DC3	DC-3					DC3
DC6	DC-6					DC6
DHC6	DHC-6 Twin Otter					DHT
E110	EMB-110 Bandeirante					EMB
E120	EMB-120 Brasilia					EM2
F27	F-27					F27
G159	G-159 Gulfstream 1					GRS
I114	IL-114					I14
IL18	IL-18					IL8
JS31	BAe-3100 Jetstream 31					J31
JS32	BAe-3200 Jetstream Super 31					J32
JS41	BAe-4100 Jetstream 41					J41
L188	Electra (L-188)					LOE
L410	L-410 Turbolet					L4T
N262	N-262 Frégate					ND2
SB20	2000					S20
SC7	SC-7 Skyliner					SHS
SH33	SD3-30					SH3

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Type Designator	Example of Model*	CEM based on AO data (from COFdb)	CEM based on Equivalent Aircraft Type		CEM based on ICAO Fuel Formula	
		Source of CEM	Source of CEM	Type Designator of Equivalent Aircraft	Source of CEM	ICAO Aircraft Code
SH36	360					SH6
SW2	SA-26 Merlin 2					SWM
YS11	YS-11					YS1

* Example of model: Doc 8643 includes one or more model for a given type designator. Sample/example of model is provided in this table. For additional details of other applicable models for a given type designator see: <https://www.icao.int/publications/DOC8643/Pages/Search.aspx>

APPENDIX A-3: Aircraft types (by type designator) that will be the focus of further and targeted data collection towards the 2022 version of the ICAO CORSIA CERT

Note. - List based on estimated CO₂ emissions from international emissions in 2018. Sorted by decreasing CO₂ emissions. Some aircraft types that entered service in or shortly prior to 2018 for which CO₂ emissions were limited due to limited fleet size would be of special interest towards the data collection process for the 2022 CERT.

Type Designator	Manufacturer	Example of Model*	Type Designator	Manufacturer	Example of Model*
E75L	EMBRAER	ERJ-170-200 (long wing)	... continued from previous column		
B39M	BOEING	737 MAX 9	C25A	CESSNA	525A
MD83	BOEING	MD-83	SW2	SWEARINGEN	SA-26 Merlin 2
B78X	BOEING	787-10 Dreamliner	C560	CESSNA	560 Citation 5
A35K	AIRBUS	A-350-1000 XWB	C25C	CESSNA	525C Citation CJ4
DC10	BOEING	DC-10	LJ75	LEARJET	75
F28	FOKKER	F-28 Fellowship	FA20	DASSAULT	Falcon 200
A30B	AIRBUS	A-300B2	H25C	BRITISH AEROSPACE	Hawker 1000
IL76	ILYUSHIN	Il-76	HA4T	HAWKER BEECHCRAFT	4000 Hawker 4000
SU95	SUKHOI	Superjet 100-95	FA10	DASSAULT	Falcon 10
IL96	ILYUSHIN	Il-96	C650	CESSNA	650
AN12	ANTONOV	An-12	ATP	BRITISH AEROSPACE	ATP
A345	AIRBUS	A-340-500	T154	TUPOLEV	Tu-154
B742	BOEING	747-200	B721	BOEING	727-100
T204	TUPOLEV	Tu-204	G150	GULFSTREAM AEROSPACE	Gulfstream G150
A148	ANTONOV	An-148	MD81	BOEING	MD-81
RJ1H	AI(R)	RJ-100 Avroliner	DHC6	DE HAVILLAND CANADA	DHC-6 Twin Otter
C750	CESSNA	750	JS31	BRITISH AEROSPACE	BAe-3100 Jetstream 31
C680	CESSNA	680	BCS1	AIRBUS	BD-500 CSeries CS100
B732	BOEING	737-200	DC87	DOUGLAS	DC-8-70
SB20	SAAB	2000	GALX	GULFSTREAM AEROSPACE	Gulfstream G200
BE40	BEECH	400	C551	CESSNA	551
A342	AIRBUS	A-340-200	D228	DORNIER	Dornier 228
C525	CESSNA	525 Citation CJ1	CN35	AIRBUS	CN-235
MD87	BOEING	MD-87	JS41	AI(R)	BAe-4100 Jetstream 41
DH8C	DE HAVILLAND CANADA	Dash 8 (300)	E110	EMBRAER	EMB-110 Bandeirante
DC93	DOUGLAS	DC-9-30	BE20	BEECH	Super King Air (200)
GLF2	GRUMMAN	G-1159	GLF3	GULFSTREAM AEROSPACE	G-1159A
F27	CONAIR	F-27	T134	TUPOLEV	Tu-134
CVLT	CANADAIR	Cosmopolitan	B461	BRITISH AEROSPACE	BAe-146-100
LJ35	GATES LEARJET	35	SH36	SHORT	360
E545	EMBRAER	EMB-545 Legacy 450	AJ27	COMAC	ARJ-21-700 Xiangfeng
AN24	ANTONOV	An-24	C212	AIRBUS	C-212 Aviocar
ASTR	GULFSTREAM AEROSPACE	Gulfstream G100	LJ55	GATES LEARJET	55
E120	EMBRAER	EMB-120 Brasilia	G159	GRUMMAN	G-159 Gulfstream 1
DC91	DOUGLAS	DC-9-10	YK40	YAKOVLEV	Yak-40
YK42	YAKOVLEV	Yak-42	B37M	BOEING	737 MAX 7
B745	BOEING	747SP	L101	LOCKHEED	L-1011 TriStar
B743	BOEING	747-300	SC7	SHORT	SC-7 Skyliner
A158	ANTONOV	An-158	A748	AIL	748
DH8B	DE HAVILLAND CANADA	Dash 8 (200)	I114	ILYUSHIN	Il-114
...	LJ70	LEARJET	70

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