MRV non-CO_2 data collection Guidance for Aircraft Operators

This document provides an initial guidance to Aircraft Operators relating to the collection of data for the Monitoring, Reporting, and Verification (MRV) of Non-CO_2 aviation effects, <u>before NEATS[1] is made available</u>

February 2025

[1] Commission IT tool: Non-CO_2 Aviation Effects Tracking System (NEATS)

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1 Introduction

This guidance document aims to support aircraft operators in aligning and complying with the non-CO_2 MRV requirements. It is part of a series of documents provided by the Commission services for supporting the implementation of the MRV. These are listed below.

In addition, in December 2024, number of events took place (workshop and trainings) related directly to how stakeholders can undertake the MRV (the presentations and recordings are available on the Commission's website[2]).

This guidance takes into account discussions within meetings with multiple stakeholders and experts, as well as comments received through the open public consultation on the amending act (Implementing Regulation (EU) 2024/2493) of the "Monitoring and Reporting Regulation" (Implementing Regulation (EU) 2018/2066). The amending act is referred hereinafter as **"the Regulation"**. It was published on 23 September 2024, and it contains the key elements and definitions for the operationalisation of the monitoring and reporting of non-CO_2**.**

	Document name	Date
1	Initial MRV explainer: A system for airlines to monitor, report and verify non-CO_2 effects of aviation A step-by-step guide for airlines	June 2024
2	Commission Implementing Regulation (EU) 2024/2493 of 23 September 2024 amending Implementing Regulation (EU) 2018/2066 (consolidated act here)	September 2024
3	Non-CO_2 monitoring plan template (as part of the overall monitoring plan covering both CO_2 and non-CO_2)[3]	February 2025
4	Responses to Frequently Asked Questions (FAQs)	February 2025
5	**MRV guidance document**	**February 2025**
6	Reference set of technical specifications (RSTS)	to come (February-March 2025)

[2] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-aviation_en#events

[3] under Documentation > Monitoring and Reporting Regulation (MRR): Guidance and templates.

1.1 Aim of the guidance document

The guidance provides information for aircraft operators on how to undertake the MRV. It describes what data aircraft operators can collect, how they can collect it and in what format it can be stored and uploaded to the Commission IT tool - **Non-CO_2 Aviation Effects Tracking System** (hereinafter, **"NEATS"**).

The guidance builds on the monitoring plan shared by the Commission, which aircraft operators fill in to inform Competent Authorities on how they plan to monitor the emissions.

1.2 Context

The MRV begins on 1st January 2025. It will make use of NEATS, to be provided by the Commission in due course of 2025 to aircraft operators, accredited verifiers and Competent Authorities for the purpose of facilitating the MRV. This IT tool connects all the data and models required to calculate the non-CO_2 impact. It also aims to facilitate the upload of *Primary data* (see definition here under), but it does not seek to be incorporated in flight management systems (FMS) or to create protocols, or equivalent, to allow for the collection of monitored in-flight data in the first place.

Once NEATS is made available by the Commission, the current guidance will be completed and refined to account for the specific functionalities in NEATS.

The current unavailability of NEATS does not prevent the MRV to start. In absence of NEATS, and in line with requirements in Article 56b(6) of the Regulation, the aircraft operators must monitor, at the minimum (*Primary data*), their flight information, as well as the aircraft properties on a per flight basis.

Once NEATS is available, the non-CO_2 impact can be fully computed retroactively by the tool without input from aircraft operators, using **"*Secondary data*"** sourced from external sources (e.g. EUROCONTROL) by NEATS. In this case, only the flight information (e.g. call sign) provided by NEATS should be checked by the aircraft operator to ensure consistency between actual flights that took place and sourced call signs by NEATS. The *Secondary data* in NEATS includes also 4D flight trajectory data, weather data from external sources, and conservative default values on specific data sets such as fuel, engine, and aircraft properties. An aircraft operator may want to provide own data and replace the default values with more precise values on fuel flow, aircraft properties, and engine identification derived from their own tracking systems monitored throughout the year, or from other sources. Hereafter, we call the aircraft operator provided data "***Primary data***".

There are two types of data of relevance for the MRV.

- ***Primary data*** is data that is measured and/or monitored and/or defined and recorded data directly by the aircraft operator (e.g. actual flight trajectory, engine identifiers, aircraft mass along the trajectory, fuel flow, fuel properties). *Primary data* is reputed more precise from what can be provided through NEATS (Secondary data),
- ***Secondary data*** is the data provided by NEATS, without input of the aircraft operator.

The MRV is developed to allow aircraft operators to fully monitor, through NEATS, their non-CO_2 impacts based on the *Secondary data* which reduces the burden to deliver *Primary data*. This means an operator can comply with the MRV without needing to provide any *Primary data* as such, once NEATS is made available.

The Regulation allows to make use of third-party IT tools in place of NEATS. Any such tool must first be approved by the Commission. In the course of 2025, the Commission will provide a description of the process through which such tools can be approved so that it can be used by aircraft operators to compute their non-CO_2 impact.

The legislation also refers to an update on the Accreditation and Verification Regulation (AVR) to ensure non-CO_2 emissions reporting can be verified. More information on the provisions of the AVR (update of the AVR is underway, to be finalised in Q2 2025, as planned) with details on verification will be provided in the updated MRV guidance document, once NEATS is made available, and where needed in specific guidance on the verification.

2 MRV guidance

2.1 Overview of MRV cycle

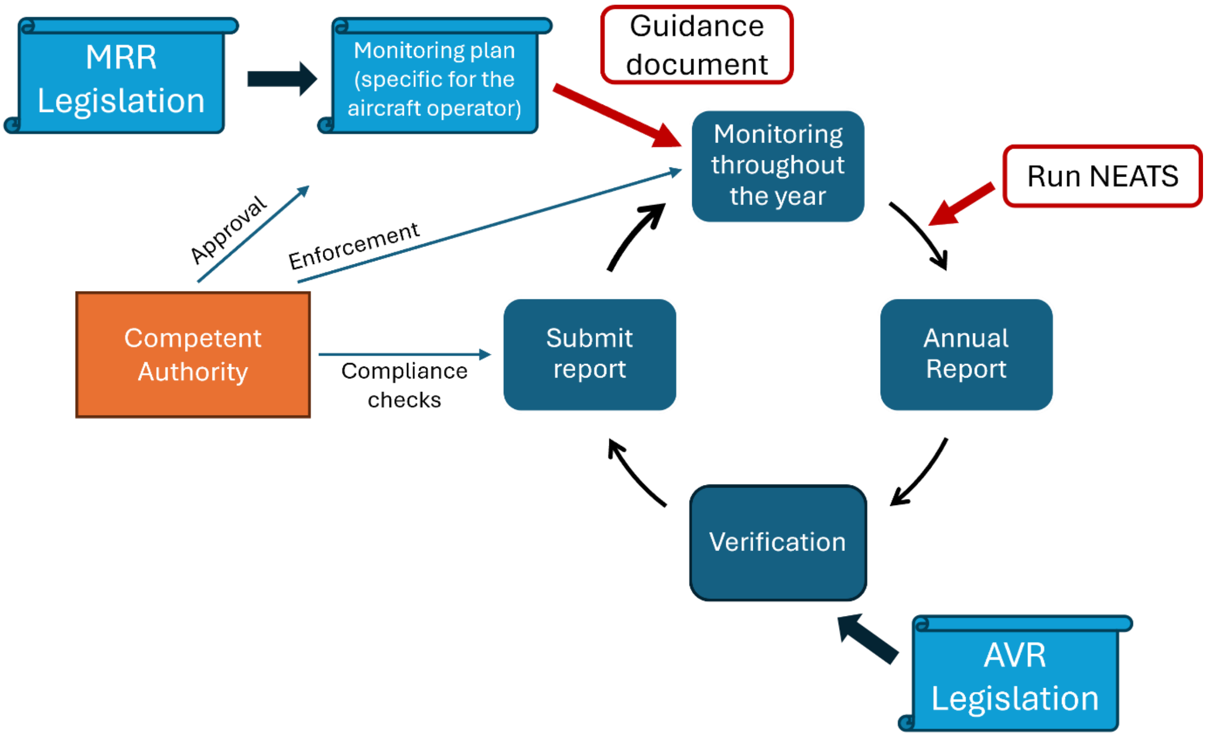

Figure 1:*Principle of the MRV compliance cycle, adapted from the MRR Guidance document*

Starting January 1st, 2025, aircraft operators are obliged to monitor and report the non-CO_2 climate impacts of their flights, reporting them to the Competent Authority by March 31st of the following year. The procedural steps and deadlines of the non-CO_2 MRV align with the existing EU ETS obligations for CO_2. As part of the MRV, aircraft operators need to fill in a monitoring plan and to submit it for approval to the Competent Authority. Monitoring plans for non-CO_2 effects are integrated with the CO_2 into the same monitoring plan, where non-CO_2 is additional sheet, thus simplifying the administrative processes.

The monitoring plan serves as a support document for aircraft operators to plan the data they intend to monitor and how to monitor it throughout the year. Within the monitoring plan, aircraft operators have to decide whether they gather *Primary data* and if so, how they do so.

With the monitored data, NEATS streamlines the reporting exercise referred to in Article 68(5) of the Regulation. The tool automatically generates the XML table referred to in Annex X, Section 2a(9) of the Regulation at the end of each reporting year, minimising administrative burden associated with reporting. Once the report is complete, as for CO_2, verifiers will review and validate the annual CO_2(e) per aircraft operator. After submission of the verification report, the Competent Authority will conduct a compliance check.

2.2 Scope of the MRV

Aircraft operators must monitor the non-CO_2 aviation effects occurring from 1 January 2025, from the activities performed by aircrafts equipped with jet engines (e.g. turboprops are excluded from the MRV), enabling the calculation of a CO_2 equivalent (CO_2(e)) per flight. The aircraft operators should report those non-CO_2 aviation effects once a year. However, to facilitate the start of the MRV for non-CO_2 effects, in 2025 and 2026, while the reporting may cover all routes, such reporting shall only be required in respect of routes involving two aerodromes located in the European Economic Area (EEA) (this covers also flights to and from outermost regions), and routes from an aerodrome located in the EEA departing to Switzerland or to the United Kingdom. In respect of 2025 and 2026, the reporting of non-CO_2 aviation effects taking place from other flights is possible.

Firstly, the monitoring plan requires a decision on the geographic scope of the operations conducted by the aircraft operator.:

- Reduced scope: limited to intra-EEA flights and to Switzerland and United Kingdom.
- In-between geographical scope: includes the reduced scope and a selection of extra-EEA flights. The aircraft operators should select the routes they wish to monitor on top of the intra-EEA scope and describe this in the monitoring plan.
- Full geographical scope: covers the reduced scope as well as flights outbound from and inbound to the EEA.

Secondly, the monitoring plan requires aircraft operators to specify the IT tool they wish to use to determine the non-CO_2 effects. For the emissions of the year 2025, only NEATS will be made available. For reporting emissions of subsequent years, the aircraft operators will have the choice between:

- NEATS,
- Commission-approved other IT tools, if such are available,
- combination of NEATS and a Commission-approved other IT tools, if such are available.

As subsequent step in the monitoring plan, the aircraft operator must select the method they will use to calculate their non-CO_2 emissions. Only aircraft operators classified as small emitters as defined in Article 55(1) of the Regulation may choose Method D.

Aircraft operators must then decide whether they would like to provide any *Primary data* within the tool.

NEATS can provide all required data for the MRV automatically, using *Secondary data* sources, including default values, though this may lead to an overestimation of overall non-CO_2 impacts of the monitored flights. Aircraft operators are therefore encouraged to actively monitor and make use of as much relevant *Primary data* as possible.

2.3 NEATS *Primary data* requirement

This section provides instructions for operators on the *Primary data* required for Methods C and D of the NEATS tool. The process flowcharts and explanations below outline the *Primary data* that aircraft operators can collect throughout the year and provide to NEATS. Once NEATS is in place, an updated guidance document will be provided.

Calculation methods

Depending on whether the aircraft operator is a small emitter or not, Methods C and D are used to determine the non-CO_2 emissions. Methods A and B, which are not described here, apply to the monitoring of CO_2 emissions.

- **Method C: Weather-based approach** (MRV Default)
  Mandatory for non-small emitters, as defined in Article 55(1) of the Regulation, this method utilizes flight information, trajectory data, aircraft properties, fuel properties and enhanced weather data. The key feature of Method C is that the climate impact at a specific time and location is calculated based on the actual weather information for that time and location.
- **Method D: Simplified climatological location-based approach**
  Developed for small emitters, as defined in Article 55(1) of the Regulation, this method relies primarily on in-flight location-related data such as flight information and trajectory data. It also incorporates basic weather data and aircraft properties. Small emitters may opt to use Method D, or alternatively, apply different methods for different aircraft types.

These methods require different datasets and engage distinct climate modules within the NEATS tool. More information on the models applied within each method will be provided within the *Reference set of technical specifications* (RSTS) document.

Flight information, flight trajectories, aircraft properties and weather data are always needed (*Secondary* or *Primary data*) in Method C and Method D (in Method D, weather data is not explicitly included for climate effect calculation). For Method D, data on fuel properties is optional, while aircraft performance (monitored fuel flow, etc.) is optional for both methods. While some data items are easier to gather, others require more elaborated approach, and this guidance aims to support this process.

2.4 Method C

Flowchart

Figure 2. illustrates the flowchart showing Method C of the NEATS modelling process for aircraft operators. The options for providing fuel flow are described in more detail in Figure 3. The flowchart structure is divided per type of data.

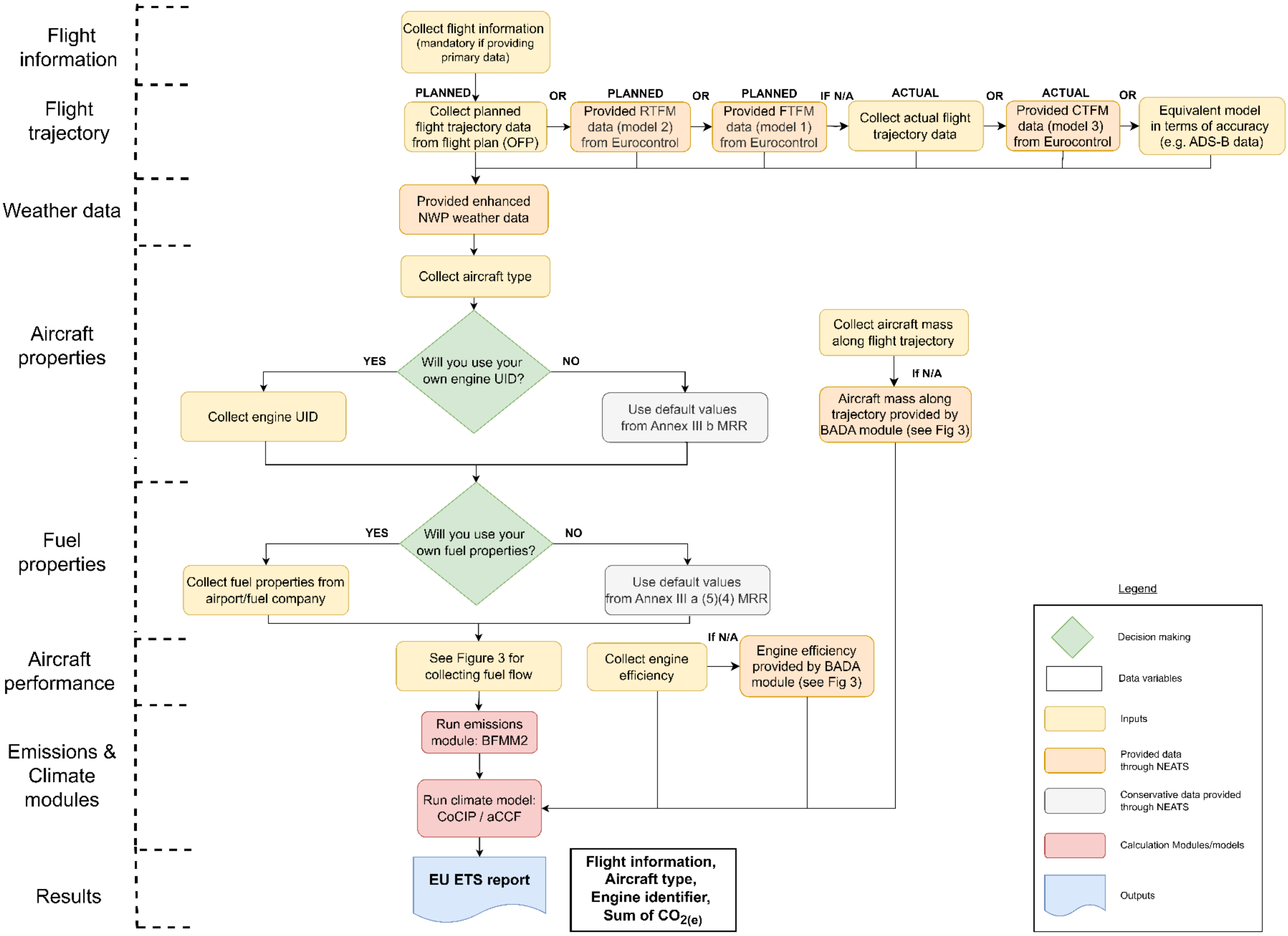

***Figure 2**: Flowchart for Method C*

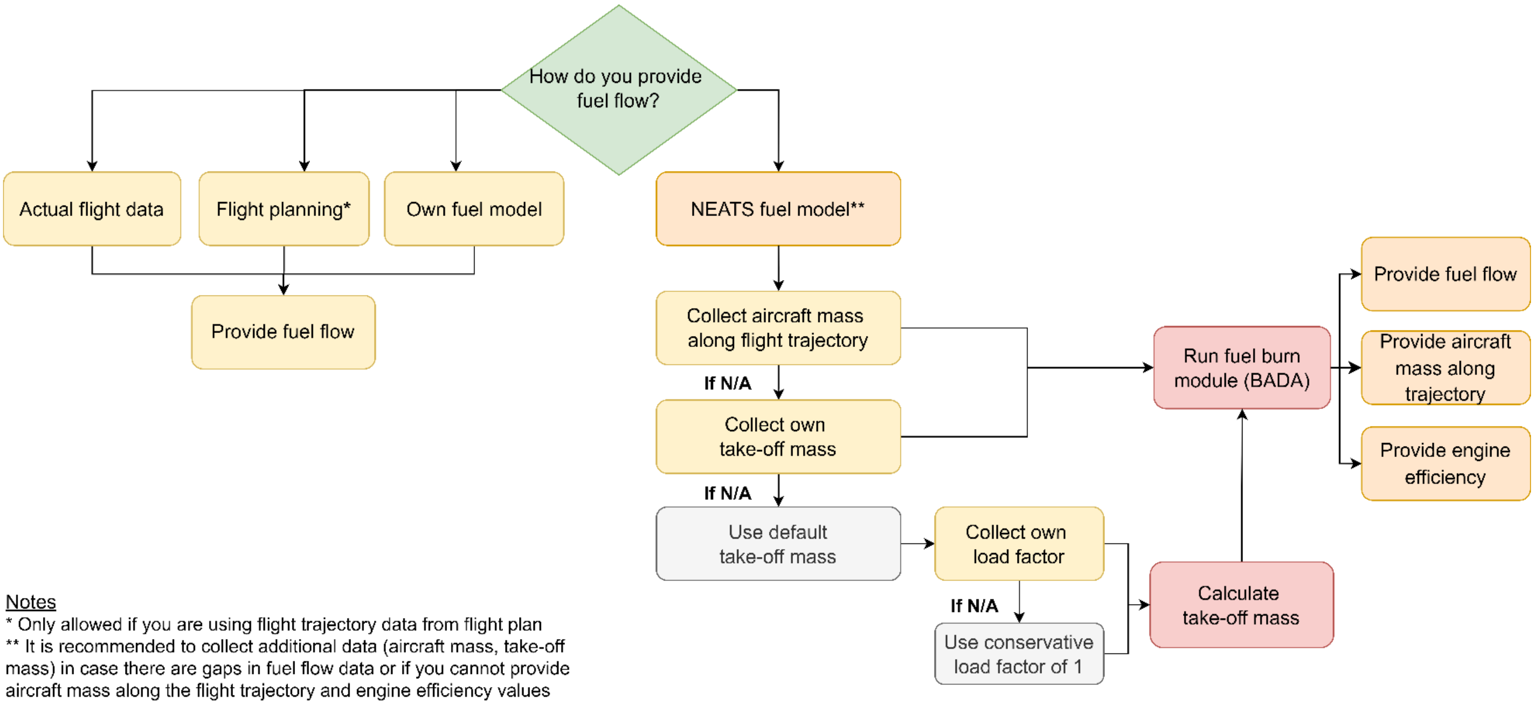

***Figure 3**: Fuel flow options*

Explanation on inputs

For Method C, aircraft operators are recommended to record and monitor the following sets of *Primary data* (if they don't monitor *Primary data*, *Secondary data* is provided by NEATS, once the tool is made available):

Data sets	Data variables	Primary data possible source	*Secondary data*, including default values
Flight information (Mandatory if providing *Primary data*)	Flight number	Flight plan (OFP)	N/A
	Day and time (Departure and Arrival)		N/A
	Departure airport		N/A
	Arrival airport		N/A
Flight Trajectory	4D flight trajectories	Flight plan (OFP)	From EUROCONTROL: RTFM[4], or equivalent. If not available the FTFM[5], or model of equivalent accuracy (e.g. ADSB), shall be used as default.

[4] Regulated Tactical Flight Model
[5] Filed Tactical Flight Model

Weather data	Numerical Weather Prediction (NWP) model weather data	NEATS only	N/A
Aircraft properties	Aircraft type	Flight plan (OFP)	N/A
	Engine UID	Aircraft registration	See Annex IIIb of the Regulation
	Aircraft mass (along the trajectory)	Performance	Base for Aircraft Data (BADA) model output
	Aircraft take-off mass (as alternative to aircraft mass along the trajectory)	Flight plan (OFP)	BADA Maximum take-off mass
	Load factor (as alternative to take-off mass)	Flight plan (OFP)	1
Fuel properties	Hydrogen per carbon ratio	Airport services/fuel provider	See Annex III a (5)(4)
	Aromatic content		
	Net calorific value		
	Sulphur and Naphthalenes		
Aircraft performance	Fuel Flow	Actual fuel flow, Flight plan or own fuel burn model	BADA model output

Flight information data

To avoid discrepancies in the completeness of flights as provided by NEATS, all aircraft operators applying the MRV need to always check the correctness of the flight information provided in NEATS, once it is made available and once, they have access to it and to the flight information in NEATS. *Primary data* provided by aircraft operators must be correlated to the correct flights. **Therefore, it is required to provide flight information, as *Primary data* when providing other *Primary data*.** The flight information to monitor includes the ICAO call sign, date and time of departure and arrival, as well as the ICAO/IATA codes of the departure and arrival airports (see definition in Annex IIIa, section 1 of the Regulation).

Flight trajectory data

Operators can provide 4D flight trajectory data, defined by the aircraft latitude, longitude, and pressure altitude (flight level) at time stamps between the start and end of the flight. The interval between two-time stamps must not exceed 60 seconds. If this is not possible, linear interpolation can be used in homogenous flight phases, typically for the cruise phase.

The aircraft operators must always start considering if they can use *Primary data* (e.g. collected planned flight trajectory data from the flight plan (OFP)) and if not, make use of the *Secondary data* provided in NEATS: the EUROCONTROL planned flight trajectory data (Regulated Tactical Flight Model (RTFM), or alternatively, if RTFM is not available, the Filed Tactical Flight Model (FTFM) from EUROCONTROL, or an equivalent model with comparable data accuracy). The ex-ante (to the flight) calculation allows to avoid regulatory route adjustments during flight as well as inaccuracies in the weather forecast have no consequences on calculated CO_2e values.

While in Method C, the flight trajectory is defined at the minimum by the latest flight plan (at the minimum, RTFM or FTFM), in theory the aircraft operator can decide to complement the latest flight plan by collected actual flight trajectory data (*Primary data*) or by flight flown data as *Secondary data* (represented by the EUROCONTROL Current Tactical Flight Model (CTFM), more generally referred to as model 3 document). In such case, it is assumed that the most up-to-date data (the post-operational one) is the one to be used for the CO_2(e) calculation, where this is possible (as this would also entail use of weather reanalysis data). The aircraft operator should expressly justify the choice of different set of flight trajectory data (including in relation to *Secondary data*) in the monitoring plan, under section 21(a).

In all cases, when providing *Primary data* or deviating from the RTFM or FTFM, the aircraft operator needs to be vigilant about maintaining the consistency between the 4D trajectory data and the aircraft performance data (e.g. planned fuel flow should be used when planned flight trajectory is being used, while in principle, monitored in-flight fuel flow should be used when CTFM or collected actual flight trajectory data is being used). This ensures consistency between the flight trajectory and fuel flow data points. Accordingly, section 23 of the monitoring plan is always to be filled in.

Weather data

For Method C, NEATS provides the necessary Numerical Weather Prediction (NWP) model forecast data. In order to run the climate response models (e.g. CoCiP and aCCF), enhanced weather input data is necessary (15 weather parameters, see Appendix 3 of this guidance). While under NEATS only the NWP-provided weather data is accepted, with other IT tools approved this data can be further improved upon, meaning additional weather data to the one provided through the NWP can be accepted, as long the NWP is the same as the one used in NEATS. For Method D, the simplified weather data used includes air temperature, specific humidity, and pressure altitude along the flight trajectory.

Aircraft properties

The aircraft operator can provide aircraft properties – aircraft type, engine UID, and aircraft mass along the trajectory. The aircraft type can be collected from the flight plan, while the engine UID can be provided based on the aircraft’s registration (flowchart option: YES). Alternatively, if this information is not available, a default engine for the aircraft type is used (see Annex IIIb of the Regulation) (flowchart option: NO).

For missing engines (not listed in the ICAO EDB), a suitable proxy (precursor/successor) could be selected from the ICAO EDB, e.g., based on similarities in engine design. Moreover, in case of aircraft equipped with different engines, NEATS calculates emissions per aircraft rather than per engine, making it currently impossible to set engine specific UIDs. If engine performance and emissions are similar, differences may be negligible. Alternatively, NEATS can be run separately for each engine type, and the average output from the calculations used.

Aircraft mass along trajectory is required for the calculation of the fuel flow as described in Figure 3. See further details in the section on aircraft performance.

Fuel properties

In NEATS, aircraft operators can input fuel properties on a per flight basis (aromatics content, sulphur, naphthalene content, hydrogen-to-carbon ratio, and the net calorific value). Since aircraft operators typically do not monitor this information, it could be provided by fuel companies to aircraft operators, provided such arrangements exist between aircraft operators and fuel companies. Fuel companies routinely monitor fuel content and may be able to transmit fuel information to aircraft operators. Even then, monitoring specific fuel properties for individual flights is challenging, at the current time. The legal reference in the Regulation is the actual value or the use of ASTM maximum values as a default.

Provided the current challenge to measure the actual fuel properties value per flight and in order to reduce the administrative burden for the initial period of the MRV, it is recommended to temporarily accept for the years 2025 and 2026, as actual values (*Primary data*), the maximum values for each of the above mentioned (aromatics content, sulphur, naphthalene content, hydrogen-to-carbon ratio, and the net calorific value), as observed on a yearly basis in all the batches provided to a given EEA airport, as obtained by the aircraft operators from fuel suppliers, and assume these are the values for the flights taking off from the given airport for the given year. Average/mean values cannot be accepted as they may lead to underestimation of actual values.

Example for aromatics: In the year 2025, airport X received number of batches where the highest observed aromatics level is 20%, all flights taking off from airport X in 2025 are considered to contain 20% of aromatics. The same approach is applied for the other parameters.

If no fuel property data is available, NEATS will use the upper limits of Jet-A1 fuel for estimations (flowchart option: NO)

Aircraft performance

Operators can input aircraft performance data along the trajectory as *Primary data* (monitored values). This is optional for both Method C and Method D. This information is also available through the NEATS model as *Secondary data* (default values). Aircraft performance includes fuel flow and aircraft engine efficiency (known as aircraft overall propulsion efficiency).

These can be supplied by the aircraft operator or be provided through the EUROCONTROL's Base for Aircraft Data (BADA) model for fuel flow calculation that is part of NEATS. If the aircraft operator chooses not to provide monitored data, NEATS uses the aircraft properties information to derive fuel flow, overall propulsion, and aircraft mass along the trajectory. In all cases the provided values have to align with the type of trajectory (see section on flight trajectory data). This implies that when actual flight data is used the values are monitored from the actual flight or calculated using a fuel flow model based on the actual flight's trajectory. When planned flight data is used, the data should similarly be sourced from the flight planning process or calculated based on the planned trajectory. With regards to the discrepancies between the calculated and actual fuel used, the aircraft operators are encouraged to monitor the differences in fuel calculations. If NEATS provides higher fuel estimates, than actual usage, operators may want to submit their own verified fuel flow data (*Primary data*).

When considering the possibility of interpolating 4D-trajectory data in cases where on-board fuel data is recorded at intervals exceeding 60 seconds, it is important to remind that based on the assumptions for typical aircraft speeds and the extent of areas of ice supersaturation, a recommended effective time resolution is at least 60s. However, flight trajectories can be reported at a lower frequency (e.g. for straight cruise flight on same flight level) and subsequently be interpolated if the flight trajectory and aircraft performance are sufficiently homogeneous. Thus, an up-sampling to 60s resolution is only critical if flight level changes are not resolved by the original trajectory data.

The aircraft overall propulsion efficiency means the percentage of useful thrust generated by an aircraft engine relative to the energy input from fuel. Aircraft operators should calculate the aircraft engine efficiency based on the thrust over the duration of the flight and the energy input from the fuel. These data inputs are calculated along the flight trajectory based on weather data input fields and aircraft performance data. In NEATS, BADA is used for these calculations, or aircraft operators can use own calculations based on an own performance model. More details and references to the equations are provided in the FAQs and/or in the *Reference set of technical specifications* document to come. The ways in which fuel flow and aircraft mass can be collected is described in Figure 3. If the aircraft operator opted for using the flown flight trajectory (CTFM) for flight trajectory data in the monitoring plan (see flight trajectory data section), then also monitored in-flight fuel flow must be used.

Aircraft operators have the option to obtain fuel flow, mass, and aircraft engine efficiency through BADA from NEATS as Secondary data. The BADA fuel model can be run with Primary data inputs, selected, and monitored by the aircraft operators, increasing the accuracy of the resulting fuel flow output, as opposed to the result from default values provided by NEATS. For more accurate results, the BADA model can be executed with aircraft mass along the trajectory. If this data is not available, alternatively monitored take-off mass can be used. In cases where take-off mass is not recorded, an approximate value can be calculated by applying a load factor to the default maximum mass of the aircraft type. The load factor is either collected by aircraft operators or set to 1 as a default value.

Explanation on emission & climate models

Method C uses the following emission & climate models:

- Boeing Fuel Flow Method 2 (BFFM2): calculates engine emissions (NO_x, HC, CO),
- Contrail Cirrus Prediction Model (CoCiP): models contrail formation,
- algorithmic Climate Change Functions (aCCF): quantifies climate impacts of emissions.

Within NEATS, The BFFM2 emissions module uses the collected and/or provided data to calculate engine emissions during different flight phases. The outputs, along with other collected and/or provided data, are fed into the CoCiP and aCCF open-source models. The models are further explained in the *Reference set of technical specification document* and the FAQ.

Outputs from NEATS

Once CoCiP and aCCF models are run, NEATS generates the results in CO_2(e). At the end of each reporting year, NEATS produces an XML table for each flight of each aircraft operator applying the MRV. This table includes details such as flight information, aircraft type, engine identifier, and CO_2(e) values for all three efficacy-weighted global warming potential (EGWP) time horizons (20, 50, and 100 years). This streamlined process reduces the administrative burden on operators while ensuring accurate and consistent reporting of emissions data.

2.5 Method D

The following section presents the guidance document for small emitters following Method D. Since Method D is a simplified version of Method C, this section highlights the key differences between the two methods to help aircraft operators in implementing NEATS. A flowchart illustrating the NEATS modelling process for Method D is provided in Figure 4.

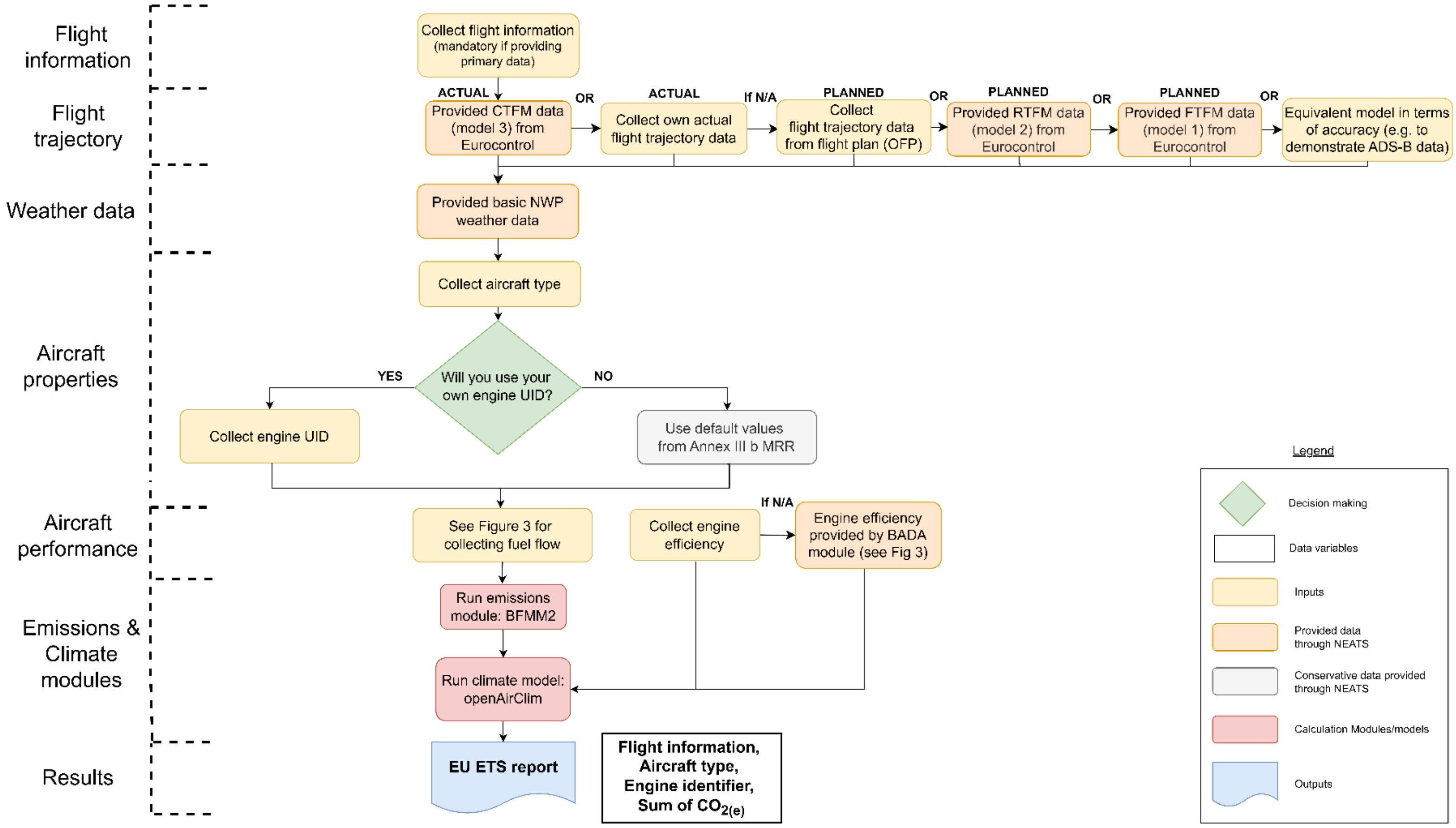

Figure 4: Flowchart for Method D

Explanation on inputs

Small emitters using Method D are required to monitor similar sets of data to those using Method C. The inputs provided in the flowchart in Figure 4 are described, with a reference to the explanations provided for Method C where there is overlap.

Flight information & Flight trajectory data

For Method D it is recommended to collect the actual flown flight trajectory data (*Primary data*). If this cannot be provided the Current Tactical Flight Model (CTFM or model 3) from EUROCONTROL should be used or a model of equivalent accuracy, or finally the previously mentioned RTFM (model 2) or FTFM (model 1) can be used in the form of *Secondary data* (if no CTFM available). The flight information and flight trajectory data are monitored and collected under the same format and requirements as for Method C.

Weather data
Method D only requires basic weather data provided by weather sources through NEATS. This data includes air temperature, specific humidity, and pressure altitude along the flight trajectory.

Aircraft properties

See Method C.

Fuel properties
Fuel properties do not need to be specified in Method D as they are not used in the calculation.

Aircraft performance
Aircraft performance data is optional within Method D. See Method C.

Explanation of emissions & climate models

Method D uses the following emission & climate models:

- Boeing Fuel Flow Method 2 (BFFM2),
- openAirClim model.

Similarly to Method C, the Boeing Fuel Flow Method 2 (BFFM2) emissions module is executed. The module calculates aircraft engine emissions of NO_x, HC, and CO by correlating fuel flow rates with emissions generated during various flight phases.

The collected monitored data within NEATS is subsequently fed into the open-source climate model of AirClim (openAirClim). This model also requires the final input of engine efficiency from aircraft operators (if available and desired to improve accuracy of results). The models and their chosen parameters are further described in the *Reference set of technical specification* document.

Method D requires less data (in comparison with Method C), and it is better plannable (use of post-operational flight data), which can be helpful particularly for small emitters. As weather data is not explicitly included for the climate effect calculations, the calculated CO_2(e) will be similar for each flight on the same route. If only few flights are flown on a particular route, Method D could, in contrast to Method C, lead to large year-to-year variability in CO_2(e).

NEATS Outputs

When openAirClim is executed, it provides $CO_{2(}$e) values for three EGWP time horizons (20, 50, and 100 years). To facilitate the reporting exercise, once per year NEATS does an extract as XML table for each flight, including details such as flight information, aircraft type, engine identifier, and CO_2(e) values for the given aircraft operator and year. The EGWP results takes into account efficacy which is mandatory for the CO_2(e) calculation in the MRV. More detail will be provided in the reference set of technical specification document, expected in Q1 2025.

Appendix 1 NEATS input descriptions

The additional formatting and technical specifications of the data variables required by NEATS are described based on the system architecture specification that NEATS will be developed on. The precision of the data variables is included and should be treated as approximate. Further operational validation is necessary to confirm their suitability.

Flight information, Aircraft properties and fuel properties data

Data type	Type	Format / Unit	Desired precision
flight_identification	String	ICAO Callsign	N/A
departure_date_time	String	ISO 8601	N/A
arrival_date_time	String	ISO 8601	N/A
departure_airport	String	ICAO location indicator/aerodrome name/IATA indicator	N/A
arrival_airport	String	ICAO location indicator/aerodrome name/IATA indicator	N/A
aircraft_type	String	[A-Z0-9]{2,4} for ICAO aircraft type designator, no pattern for other aircraft type	N/A
engine_uid	String	See ICAO Engine Emissions Database, **example below**	N/A
takeoff_mass	Decimal	Kg, **example below**	One decimal place
load_factor	Decimal	unitless	Three decimal places
hydrogen_content	Decimal	unitless	Two decimal places
hydrogen_per_carbon_ratio	Decimal	unitless	N/A
aromatic_content	Decimal	unitless	Three decimal places
calorific_value	Decimal	MJ kg_{fuel}^{-1}	Two decimal places

Flight trajectory and aircraft performance data

Data type	Type	Format / Unit	Requirements
flight_identification	String	ICAO Callsign	N/A
departure_date_time	String	ISO 8601	N/A
timestamp	String	See ISO 8601	Interval < 60s
latitude	Decimal	See WGS 84 / EPSG:4326	For each timestamp, 2 decimal places
longitude	Decimal	See WGS84 / EPSG:4326	For each timestamp, 2 decimal places
flight_level	Integer	flight level number	For each timestamp
fuel_flow	Decimal	kg s^{-1}	For each timestamp
engine_efficiency	Decimal	unitless	For each timestamp
aircraft_mass	Decimal	kg	For each timestamp

Appendix 2 Examples of *Primary data* files collected

This section provides a description and corresponding examples of the data file for a number of use cases in which aircraft operators provide *Primary data* in line with the above guidance. These examples only apply when an aircraft operator decides to provide *Primary data*, or are required to do so. All values in the data are fictional and only meant to indicate formatting.

Engine UID and basic trajectory

In this case the operator provides the engine UID and own basic trajectory data as *Primary data*.

Flights file:

```
flight_identification,departure_date_time,arrival_date_time,departure_airport,arrival_airport,aircraft_type,engine_uid
ABC123A,2024-12-23T13:06:23,2024-12-23T12:46:23,EHAM,LPPT,A320,1IA001
ABC123B,2024-08-26T16:37:30,2024-08-26T14:51:30,Amsterdam Airport Schiphol,LPPT,A320,1IA001
ABC123C,2024-09-11T03:31:08,2024-09-11T04:50:08,AMS,LPPT,A320,1IA001
```

Trajectory file:

```
flight_identification,departure_date_time,timestamp,latitude,longitude,flight_level
ABC123A,2024-12-23T13:06:23,2024-09-11T03:31:08,50.84,4.38,370
ABC123B,2024-08-26T16:37:30,2024-09-11T03:31:38,-50.91,4.45,370
ABC123C,2024-09-11T03:31:08,2024-09-11T03:32:08,-50.98,-4.52,245
```

Basic flight data with take-off mass

In this case the operator provides the aircraft take-off mass.

Flights file:

```
flight_identification,departure_date_time,arrival_date_time,departure_airport,arrival_airport,aircraft_type,takeoff_mass
ABC123A,2024-12-23T13:06:23,2024-12-23T12:46:23,EHAM,LPPT,A320,57462.7
ABC123B,2024-08-26T16:37:30,2024-08-26T14:51:30,EHAM,LPPT,A320,58850.1
ABC123C,2024-09-11T03:31:08,2024-09-11T04:50:08,EHAM,LPPT,A320,59066.4
```

Providing all *Primary data* parameters

The below examples provide the columns of all optional parameters. For clarity, the basic parameters are excluded in the flights file.

Flights file:

```
…,engine_uid,takeoff_mass,load_factor,hydrogen_content,hydrogen_per_carbon_ratio,aromatic_content,calorific_value
…,1IA001,57462.7,0.832,0.12,1,0.152,41.15
…,1IA001,58850.1,0.782,0.42,1,0.174,41.15
…,1IA001,59066.4,0.912,0.71,1,0.265,41.15
```

Trajectory file:

```
flight_identification,departure_date_time,timestamp,latitude,longitude,flight_level,fuel_flow,engine_efficiency,aircraft_mass
ABC123A,2024-12-23T13:06:23,2024-09-11T03:31:08,50.84,4.38,370,0.45,0.91,64015.1
ABC123B,2024-08-26T16:37:30,2024-09-11T03:31:38,-50.91,4.45,370,0.48,0.81,63998.6
ABC123C,2024-09-11T03:31:08,2024-09-11T03:32:08,-50.98,-4.52,245,0.47,0.71,63983.2
```

Appendix 3 Weather data

Weather data

Though currently not possible to input as *Primary data*, weather data detail is provided below. En-route weather is required for MRV in the format of a gridded weather standard (NetCDF4) and is provided in an automatic way. Based on sample data provided by the data stakeholder group, it is expected that NEATS will receive 4 predictions per day with a size of around 100GB (uncompressed) respectively about 60 GB (compressed) per prediction. Each one of these prediction files has an hourly forecast for relevant meteorological conditions for the whole world up to 60 hours ahead. The weather data parameters for the enhanced NWP model (Method C) are listed below. The first three parameters are required by the basic NWP model (Method D).

1. Air pressure
2. Air temperature
3. Specific humidity
4. Relative humidity over ice
5. Eastward wind
6. Northward wind
7. Vertical velocity (Omega)
8. Specific ice content
9. Geopotential
10. Outgoing longwave radiation
11. Total net solar radiation
12. Solar direct radiation
13. Air density
14. Potential Vorticity
15. Cloud cover