

ENVIRONMENTAL FOOTPRINT AVIATION (EFA)

Delivery Drones Category Rules



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EXECUTIVE SUMMARY

The sustainability of drones and air mobility, including UAM, AAM, and IAS, depends on factors like energy source, emissions, noise pollution, infrastructure, safety, efficiency, public acceptance, technological advancements, and environmental impact assessment. Sustainable implementation, with a focus on clean energy, reduced emissions, and efficient infrastructure, can make these technologies more environmentally friendly, but careful planning and ongoing assessment are essential to ensure they align with sustainability goals and do not harm the environment or communities.

To ensure that all these factors are taken into account, a full life-cycle environmental assessment is needed. EASA is developing such a methodology, called **Environmental Footprint Aviation (EFA)** in a standardised manner which will ensure that the results can be trusted by European citizens and thus prevent greenwashing.

EFA will follow the format of a Product Environmental Footprint (PEF) Category Rule (PEFCR). This methodology is the European Commission's recommended methodology for assessing the environmental impacts of a product across its life cycle. This means it assesses the impacts of products while they are in use, the 'upstream' impacts associated with manufacturing and raw material extraction, and the 'downstream' impacts associated with their disposal at end-of-life.

The PEF method has been selected due to its comprehensive set of environmental indicators, but also due to its adoption by the European Commission and being referenced within important European policy such as the sustainable batteries regulations.

By establishing a standardised PEFCR for delivery drones and later electric aircraft (eVTOLs), EASA aims to enable eVTOL and delivery drone (hereby referred to as 'drone') manufacturers and operators to quantify and communicate information regarding their aircraft's environmental impact on a fair and consistent basis. This will enable investors and consumers to make informed decisions regarding the environmental impacts of their choices and uncertainties that can arise from different approaches to environmental assessments.

When benchmarked against other studies and (non-PEF) life cycle assessment results, the PEF-RP indicates the opportunity for drones to reduce the environmental impact of 'last-mile' delivery options.

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1. GENERAL INFORMATION ABOUT THE PEFCR

The Product Environmental Footprint (PEF) method provides detailed and comprehensive technical rules on how to conduct PEF studies that are more reproducible, consistent, robust, verifiable and comparable. Results of PEF studies are the basis for the provision of EF information and they may be used in a diverse number of potential fields of applications, including in-house management and participation in voluntary or mandatory programmes.

For all requirements not specified in this Product Environmental Footprint Category Rule (PEFCR) the user of the PEFCR shall refer to the documents this PEFCR is in conformance with

The compliance with the present PEFCR is optional for PEF in-house applications, whilst it is mandatory whenever the results of a PEF study or any of its content is intended to be communicated.

Terminology: shall, should and may

This PEFCR uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when a PEF study is conducted.

- *The term “shall” is used to indicate what is required in order for a PEF study to be in conformance with this PEFCR.*
- *The term “should” is used to indicate a recommendation rather than a requirement. Any deviation from a “should” requirement has to be justified when developing the PEF study and made transparent.*
- *The term “may” is used to indicate an option that is permissible. Whenever options are available, the PEF study shall include adequate argumentation to justify the chosen option.*

1.1 Technical Secretariat

The PEFCR is developed in the framework of the European Union Aviation Safety Agency (EASA)¹ IAM Hub, which stands for Innovation for Aviation and Mobility Hub, The IAM Hub focuses on fostering innovation within the aviation sector to address various challenges, including sustainability. The EASA IAM Hub's sustainability portion focuses on accelerating the adoption and development of sustainable technologies within the aviation industry. This initiative provides a collaborative platform where startups, industry leaders, and researchers can work together to innovate and implement solutions that reduce the environmental impact of aviation activities. Key components of this program include promoting advancements in technology that aim to lower emissions, aligning with regulatory standards to ensure safe and sustainable practices, and enhancing education and awareness about environmental issues in aviation. Through these efforts, the IAM Hub aims to contribute significantly to the industry's overall sustainability goals, although it faces challenges such as scalability, measurable impacts, and potential industry resistance.

EASA commissioned the PEFCR development and led the Technical Secretariat². During the development of the PEFCR, the Technical Secretariat were in collaboration with various industry representatives. The representatives listed in **Error! Reference source not found.** were involved.

¹ EASA is responsible for setting the rules, guidelines and standards for all safety and environmental aspects of civil aviation for 31 EASA member states (EU, Switzerland, Norway, Iceland, and Liechtenstein).

² EASA takes the role of the final decision maker on behalf of the Technical Secretariat. Industry involvement was ensured through regular consultations.

► **Table 1:** Technical secretariat

Name of the organisation	Type of organisation	Starting date of participation
EASA	Civil aviation safety agency	September 2023
Aviant	Drone manufacturer and operator	September 2023
Manna	Drone manufacturer and operator	September 2023
Matternet	Drone manufacturer and operator	April 2024
Rigi Tech	Drone manufacturer and operator	September 2023

1.2 Consultations and stakeholders

The first public stakeholder consultation for the first draft of the PEFCR will be open for consultation from 15 July 2024 until 26 August 2024 on the Comment Response Tool platform from EASA [EASA CRT application - Documents list \(europa.eu\)](#).

Stakeholder feedback will be reviewed. These comments will be implemented in the second version of the PEFCR, with consideration of relevance and feasibility.

► **Table 2:** The names of organisations providing comments on the PEFCR within consultation one

Names of organisations providing comments
TBC

The organisations who provide feedback/commentary, will be listed in this section after the conclusion of the public consultation.

1.3 Review panel and review requirements of the PEFCR

This PEFCR will be reviewed by a review panel of relevant experience and expertise. Their details will be added in **Error! Reference source not found.**

► **Table 3:** Members of the review panel (panel chair in bold)

Name of the member	Affiliation	Role
TBC		

The public review reports will be provided in Annex 3 of this PEFCR.

The reviewers will verify that the following requirements are fulfilled:

- The PEFCR has been developed in accordance with the requirements provided in Annex I and Annex II;
- The PEFCR supports the creation of credible, relevant and consistent PEF profiles;
- The PEFCR scope and the representative products are adequately defined;
- The functional unit, allocation and calculation rules are adequate for the product category under consideration;

- e) Datasets used in the PEF-RPs and the supporting studies are relevant, representative, reliable, and in compliance with data quality requirements;
- f) The selected additional environmental and technical information are appropriate for the product category under consideration and the selection is done in accordance with the requirements stated in Annex I,
- g) The model of the RP and corresponding benchmark (if applicable) represent correctly the product category or sub-category;
- h) The RP models, disaggregated in line with the PEFCR and aggregated in ILCD format, are EF compliant following the rules available at <http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml>;
- i) The RP model in its corresponding excel version is compliant with the rules outlined in section A.2.3 of Annex II;
- j) The Data Needs Matrix is correctly implemented;
- k) The classes of performance, if identified, are appropriate for the product category.

The public review reports will be provided in Annex 3 of the final version of the PEFCR.

1.4 Review statement

After review and satisfaction of the review panel that this PEFCR meets the requirements set by the European Commission, the panel with complete the review statement below.

This PEFCR was developed in compliance with the PEF Method adopted by the Commission on 15.12.2021.

The representative product(s) correctly describe the average product(s) sold in Europe (EU+EFTA+UK) for the product category/sub-category in scope of this PEFCR.

PEF studies carried out in compliance with this PEFCR would reasonably lead to reproducible results and the information included therein may be used to make comparisons and comparative assertions under the prescribed conditions (see section on limitations).

1.5 Geographic validity

This PEFCR is valid for commercial drones operating in the EU+ EFTA+UK. For a detailed explanation and further definition of 'commercial drones,' please refer to Section 3.1 of the document. This section provides comprehensive insights and specifications pertinent to commercial drone operations.

Each PEF study shall identify its geographical validity, within EU + EFTA + UK listing all the countries where the product object of the PEF study is consumed/sold with the relative market share. In case the information on the market for the specific product object of the study is not available, EU+EFTA+UK shall be considered as the default market, with an equal market share for each country.

1.6 Language

The PEFCR is written in English. The original in English supersedes translated versions in case of conflicts.

1.7 Conformance to other documents

This PEFCR has been prepared in conformance with the following documents (in prevailing order):

- Product Environmental Footprint (PEF) Guide; Annex I to the Recommendation (EU) 2021/2279 published in the Official Journal of the European Union, volume L 471 on 30 December 2021. This

document represents an update to the earlier guidelines provided in Annex II to Recommendation 2013/179/EU³, reflecting the latest methodologies and standards for assessing the environmental performance of products.

- Suggestions for updating the Product Environmental Footprint (PEF) method, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 00654-1, doi:10.2760/424613, JRC115959.

³ Product Environmental Footprint (PEF) Guide; Annex II to the Recommendation 2013/179/EU, 9 April 2013. Published in the official journal of the European Union Volume 56, 4 May 20137

2. PEFCR SCOPE

The main objective of the PEFCR is to simplify and harmonise the general practice for life cycle assessment of a drone, in order to create effective product category rules that can be used as a basis for environmental labelling. This PEFCR provides the rules for the assessment of the environmental performance of the product category. The PEFCR does not cover drones for personal use (retail drones), drones under the Military and Defence category, drones which do not provide a passenger or freight transportation service (e.g., commercial drones used for filmmaking or similar) or drones which are not powered through electricity.

The PEFCR is primarily intended for drone manufacturers.

- Scope of the PEFCR: All commercially operated cargo delivery drones.
- Sub-categories included in the PEFCR: None.
- Products in scope and technical performance: Unmanned drones for transporting a designated quantity of cargo.

2.1 Product classification

The Product Environmental Footprint Category Rules Guidance⁸ states, “the PEFCR shall clearly state the product category for which the PEFCRs apply by using descriptive language⁹. Once the scope has been finalised the corresponding relevant CPA codes shall be listed”. As of now, the latest CPA list version available does not contain a specific set of CPA codes for drones due to the immaturity of the relative regulatory landscape.

In the absence of a CPA list for drones, EASA has provided general categories under which drones can be specified. For unmanned aircraft systems (UAS, or drones), three categories are specified:

- Fixed wing
- Single rotor
- Multirotor

For a product to be included under this PEFCR, it must fall under one of the above three type categories given within EASA regulations and must not fall under a use case specified in section 2 above.

2.2 Representative product

In this document, the Representative Product will be referred to as the RP. The RP was set to one virtual (non-existing) product, the detailed description of the approach and justification is provided in Annex 4 “Representative product”. The RP has been derived in an attempt to reflect non-person based cargo carrying drones of fixed wing, single rotor, or multirotor types, which are used for non-recreational, non-military purposes.

The virtual product RP should be defined based on average European market sales-weighted characteristics of all drones covered in the PEFCR. However, this is not possible at this point in time due to the early-stage of the drone market. At the time of developing this PEFCR, the use of drones for non-recreational, non-military purposes is small. As such, the use of market share to weight a virtual (non-existent) product is not possible.

In the context of developing a PEFCR for delivery drones, the diversity of drones which could be identified under the product classification as defined by this PEFCR (and their respective environmental impacts) presents a significant challenge in defining a single RP. In the absence of being able to provide a sales-

weighted average of the different drone types (for reasons mentioned in the above paragraph), it is possible, if justified, to apply other weightings, such as the weighted averages based on the number of each drone type produced. However, for drones, this methodology encounters practical limitations primarily due to insufficient comprehensive data available across the various life cycle sub-modules for each drone type, again due to the relative immaturity of the market.

Given these constraints, it is recommended that this initial PEFCR does not attempt to aggregate disparate sub-modules of data into a single RP. Instead, we propose that the PEFCR for drones focuses on defining and categorizing environmental impacts based on whatever data is available while acknowledging the current data gaps. This approach allows for greater flexibility and relevance in the application of the PEFCR to the broad range of drone products available in the market.

The life cycle model of the virtual RP was based on the composition, with development of scaling factors to bring the reference flow to the accepted functional unit (Chapter 3.3). The data used within the virtual RP was provided by OEMs. Due to the early-stage of the industry, the granularity of data varied due to limited data collection processes and confidentiality or intellectual property issues. The data supplied was categorised into the life cycle stages, components and sub-components before being averaged per category.

The PEF study of the representative product (PEF-RP) is available upon request to the TS coordinator that has the responsibility of distributing it with an adequate disclaimer about its limitations. This includes with consideration of not sharing confidential information.

2.3 Functional unit and reference flow

The functional unit (FU) as defined by this PEFCR is the transportation of 1 kilogram of cargo over 1 kilometre by a drone meeting the minimum safety requirements during the reference lifetime of the drone. The defined FU aligns with the inclusions specified within section 3 and 3.1. No omissions to the functions of the product occur within the definition of the FU, other than the excluded applications previously defined.

Error! Reference source not found. defines the key aspects used to define the FU.

► **Table 4: Key aspects of the FU**

Requirement	Description
What?	Transportation of cargo by the drone
How much?	1 kilogram of freight over 1 kilometre
How well?	Meeting minimum safety standards outlined by EASA
How long?	During the reference lifetime of the drone

The “what” and “how well” aspects of the functional unit indicate the basic purpose of a drone and the minimum requirements for the product to be placed on the European market, defining the essence of the object of the study. The “how much” and “how long” aspects of the FU are reflecting the functional differences in the product and operate as scaling factors in the PEF study, being dependant on the vehicle design and use parameters. The correlations are found in defining the reference flow (fraction by mass of the drone required to perform the function), as well as the environmental impacts of the flight dependant on the flight profile and vehicle load.

In order for the model to output results in alignment with this functional unit, all quantitative input and output data collected for the drone(s) must be first scaled to a reference flow. The reference flow defines the amount of drone needed to fulfil the defined functional unit.

In order to model the impacts, the percentage of drone under the study reflected by the FU will vary from product to product. Drone operational use shall be characterised in terms of energy consumption, quantified as a flat rate of kilowatt-hours per kilometre travelled.

► **Equation 1: Reference flow for one drone**

$$Reference\ flow\ [drone] = \frac{1}{(RSL \times ANF \times RUC \times D)}$$

Where:

- RSL is the reference service life of the drone [years]. This is defined as the estimated number of years a drone is expected to be operational, adjusted for its projected use in urban air mobility.
- ANF is the average annual number of flights as defined by default [flight/year]. This is defined as the expected number of flights per year for a drone, considering high-frequency urban operations.
- RUC is revenue unit transportation [unit/flight]. This is defined as the cargo capacity (CC) of the drone as designed.
 - Note RUC is calculated as “cargo capacity × load factor”
 - The cargo capacity is defined as the maximum allowed weight of cargo transported by the drone.
 - The load factor is defined as the average percentage of the cargo load in the drone.
- JD is the average flight distance [km]. This is defined as the average distance covered by the drone per flight.

Error! Reference source not found. below defines the default values for these parameters to be applied within any subsequent PEF study.

► **Table 5: Key parameters in order to calculate the reference flow**

Parameter	Value	Unit	Parameter type
RSL	*	Years	Company specific
ANF	2,190	Flights per year	Fixed parameter
Cargo capacity (CC)	*	kg per flight	Company specific
Cargo load factor	40	%	Fixed parameter
RUC	CC * (40/100)	kg/flight	Calculated parameter
JD	24	km	Fixed parameter

*To be defined by the user

Calculation example

The calculation example in the following **Error! Reference source not found.** is based on default parameters (Annex 4) namely per 1kgkm of the RP.

► **Table 6: FU calculation example**

Parameter	Value
Reference service life of the drone	5 years
Average annual number of flights	2,190 flights/year
Cargo capacity (CC)	2 kg/flight
Cargo load factor	40%
Average flight distance	24 km

Final example reference flow calculation is given in Equation 2 below.

► **Equation 2:** Example calculation for the reference flow, based on data used within PEF-RP (Annex 4)

$$\text{Reference flow} = \frac{1}{(5 \times 2,190 \times (2 \times 0.40) \times 24)} = 4.76E - 06$$

The interim steps for Equation 2 are split out in Table 5:

► **Table 7:** Reference flow calculation example steps

Step	Description	Calculation example
1	Calculate number of flights during the lifetime	$5 [\text{years/life}] \times 2,190 [\text{flight/year}]$ $= 10,950 [\text{flight/life}]$
2	Calculate the revenue cargo capacity	$2 [\text{kg/flight}]$ $\times 0.40 [\text{average load factor}]$ $= 0.80 [\text{kg/flight}]$
3	Calculate the transportation service provided for an average flight	$0.8 [\text{kg/flight}] \times 24 [\text{km}]$ $= 19.2 [\text{kgkm/flight}]$
4	Calculate the total transportation services over the drone's lifetime	$10,950 [\text{flight/life}] \times 19.2 [\text{kgkm/flight}]$ $= 210,240 [\text{kgkm}]$
5	Calculate the fraction of the drone required to fulfil the functional unit	$\frac{1 [\text{drone}]}{210,240 [\text{kgkm}]}$ $= 4.76E - 06 [\text{drone per kgkm}]$

2.4 System boundary

The system boundary defines which parts of the product life cycle and which associated life cycle stages and processes shall be covered by the system under analysis in order to carry out the function as defined by the FU. This PEFCR shall include the cradle-to-grave environmental impacts of the life cycle of the drone.

Figure 2 shows the life cycle stages and processes that shall be included in the associated system boundary.

Stages '2a – Drone final assembly', '2b – Testing flights', '2c – Final assembly infrastructure', '4a – Operational Flights' and '4 – Use' represent the life cycle stages with within which processes are expected to be run by the

company conducting the PEF study. This means that the company conducting the PEF study should be both manufacturer and operator of the drones. They are therefore considered to be processes for which the company conducting the PEF study shall be able to provide primary data for. Such data would fall into Situation 1 as defined in the Data Needs Matrix (DNM) requirements and quality requirements in PEFCR Guidance document. Note that in some instances, it may be that the company does not run both the manufacturing and use stages and therefore, will need to obtain specific information from its data suppliers. In this case, the situation would be Situation 2 in regard to the DNM. In the process of implementing the PEFCR, the specific level of access that the company has over the various processes in the supply chain shall be assessed again by the company doing a PEF study, in order to determine the DNM situation that it would fall under and the data quality rating (DQR) requirements. Therefore, should the company only operate the drone, they must liaise with their supplier in order to obtain primary data for the necessary LC stages.

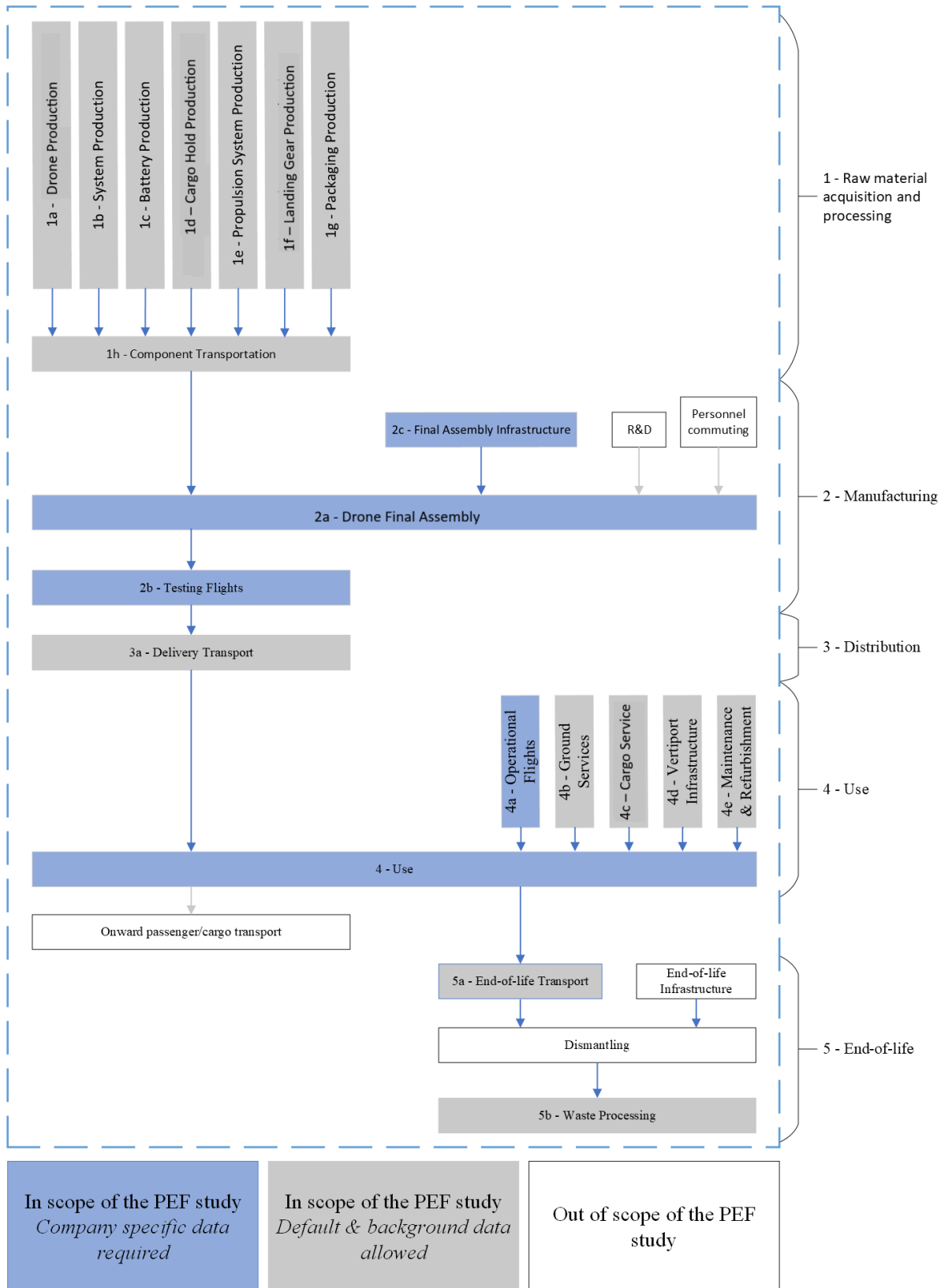
Each PEF study done in accordance with this PEFCR shall provide in the PEF study a diagram indicating the activities falling in situation 1, 2 or 3 of the data needs matrix, shown in Figure X below.

► **Table 8: DNM matrix copied from the PEF methodology**

		Most relevant processes	Other processes
Situation 1: Process run by the company using the PEFCR.	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).	
	Option 2	Calculate the DQR values (for each criterion + total)	Use default secondary dataset in PEFCR, in aggregated form (DQR≤3.0).
Situation 2: Process not run by the company using the PEFCR but with access to company-specific information	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).	
	Option 2	Calculate the DQR values (for each criterion + total) Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0).	
		Re-evaluate the DQR criteria within the product specific context	

Situation 3: process <u>not</u> run by the company using the PEFCR and without access to company-specific information	Option 3		Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0). Use the default DQR values.
	Option 1	Use default secondary data set in aggregated form (DQR≤3.0). Re-evaluate the DQR criteria within the product specific context	
	Option 2		Use default secondary data set in aggregated form (DQR≤4.0). Use the default DQR values

► **Figure 1: System boundary diagram**



The following life cycle stages and processes in **Error! Reference source not found.** shall be included in the system boundary:

Life cycle stage	Substage	Short description of the processes included
1. Raw materials acquisition and processing	1a. Drone frame production	- Extraction of raw materials required to produce the drone frame components - Processing of raw materials into drone frame materials components, including energy consumption and waste processing. - Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1b. System production	- Extraction of raw materials required to produce the drone system components - Processing of raw materials into system components, including energy consumption and waste processing. - Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1c. Battery production	- Extraction of raw materials required to produce the battery for the drone - Processing of raw materials into battery components, including energy consumption and waste processing. - Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1d. Cargo hold production	- Extraction of raw materials required to produce the drone's cargo hold - Processing of raw materials into cargo hold components, including

		energy consumption and waste processing. • Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1e. Propulsion System production	• Extraction of raw materials required to produce the drone's propulsion system(s) • Processing of raw materials into propulsion system components, including energy consumption and waste processing. • Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1f. Landing gear production	• Extraction of raw materials required to produce the drone's landing gear • Processing of raw materials into landing gear components, including energy consumption and waste processing. • Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1g. Raw materials and components packaging	• Extraction of raw materials required to package the components of the drone • Processing of raw materials into packaging elements, including energy consumption and waste processing. • Transport of the materials from the point of extraction to the site of processing, and any on-site or intermediate transport
	1h. Component transportation	• Transport of packaged drone components to the drone final assembly.
2. Manufacturing	2a. Drone final assembly	• Utility and material use (e.g., energy and water) for processing the drone components into a

		finished drone at the drone production site • Transport between sites of the final assembly. • Disposal of waste generated in the production process: transport and end of life treatment • Direct emissions during the production process
	2b. Testing flights	• Electricity consumed during test flights
	2c. Final assembly infrastructure	• Manufacturing infrastructure that is needed for manufacturing work including as a minimum land footprint and building structures.
3. Distribution	3. Delivery transport	• Transportation of the drone from the manufacturing site to the site of operation • OR • Electricity consumed during a delivery flight completed by the drone under study
4. Use stage	4a. Operational flights	• Electricity consumed during operational flights
	4b. Ground services	• Utility usage and waste generation associated in ground services required in the use stage • Disposal of waste generated from ground services: transport and end of life treatment • Direct emissions from ground services
	4c. Cargo services	• Extraction and upstream processing of any consumable products within the cargo servicing (e.g. active heating or cooling components) • Utility usage and waste generation associated in active heating or cooling for the cargo during the use stage

		• Transportation of such products from manufacturing locations to point of cargo service.
	4d. Vertiport infrastructure	• Extraction, transportation and processing of the raw materials necessary for the vertiport infrastructure construction (land transformation and occupation, buildings, vehicles, machinery) • Utility consumption in vertiport construction • Direct emissions in the vertiport construction • Utilities and material use in vertiport operations • Emissions originating in vertiport operations • Decommissioning of vertiport infrastructure
	4e. Maintenance and refurbishment	• Extraction and processing of raw materials into spare parts, materials and components, including energy consumption and waste processing • Transportation of such materials up to the point of maintenance/refurbishment. • Utilities consumption required for implementing maintenance and refurbishment • Disposal of waste generated from maintenance and refurbishment: transport and end of life treatment • Direct emissions from maintenance and refurbishment
5. End of Life	5a. End of life transport	• Transportation of the drone from the manufacturing site to the site of operation • OR • Electricity consumed during a delivery flight completed by the drone under study

	5b. Waste processing	• Transportation of disassembled components and materials to final waste processing (recycling, incineration, landfilling) • Material and component recycling • Treatment of generated waste not sent to recycling.
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It is assumed that for servicing, maintenance, and refurbishment no additional flights and infrastructure are required as these are all assumed to occur at the original vertiport.

The change of drone ownership is excluded from the scope of the PEFCR due to the high turnover of products currently in the industry due to the rapid advancement in technology. Therefore no flights or transport is assumed due to the change of ownership.

The following processes may be excluded from the system boundary based on the cut-off rule (see ANNEX 5. Cut-off processes):

- Research and development activities;
- Office working, home-working and commuting of employees;
- Capital goods and utilities required for dismantling of the aircraft in the end of life.

A full overview and justifications for these exclusions can be found in ANNEX 5. Cut-off processes. No additional cut-off is allowed.

2.4.1 List of EF impact categories

Each PEF study carried out in conformance with this PEFCR shall calculate the PEF-profile including all EF impact categories listed in Table 9, using the latest EF LCIA method.

► **Table 9: List of the impact categories to be used to calculate the PEF profile**

EF impact category	Impact category indicator	Unit	Characterization model	Robustness
Climate change, total ⁴	Global warming potential (GWP100)	kg CO ₂ eq	Bern model - Global warming potentials (GWP) over a 100-year time horizon (based on IPCC 2013)	I
Ozone depletion	Ozone depletion potential (ODP)	kg CFC-11 eq	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon (WMO 2014 + integrations)	I

⁴ The indicator "Climate Change, total" is a combination of three sub-indicators: Climate change – Change fossil; Climate change – Change biogenic; Climate change – land use and land use change. The sub-indicators are further described in section 4.4.10 of Annex I. The sub-categories 'Climate change – fossil', 'Climate change – biogenic' and 'Climate change - land use and land use change' shall be reported separately, if they show a contribution of more than 5% each to the total score of climate change.

Human toxicity, cancer	Comparative toxic unit for humans (CTUh)	CTUh	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al., 2018	III
Human toxicity, non-cancer	Comparative toxic unit for humans (CTUh)	CTUh	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al., 2018	III
Particulate matter	Impact on human health	Disease incidence	PM model (Fantke et al., 2016) in UNEP 2016	I
Ionising radiation, human health	Human exposure efficiency relative to U-235	kBq U-235 eq	Human health effect model as developed by Dreicer et al., 1995 (Frischknecht et al., 2000)	I
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (Van Zelm et al., 2008) as applied in ReCiPe	II
Acidification	Accumulated exceedance (AE)	mol H ⁺	Accumulated exceedance (Seppälä et al. 2006, Posch et al. 2008)	II
Eutrophication, terrestrial	Accumulated exceedance (AE)	mol N	Accumulated exceedance (Seppälä et al. 2006, Posch et al. 2008)	II
Eutrophication, freshwater	Fraction of nutrients reaching freshwater (P)	kg P eq	EUTREND model (Struijs et al., 2009) as applied in ReCiPe	III
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al., 2009) as applied in ReCiPe	III
Ecotoxicity, freshwater	Comparative toxic unit for ecosystems (CTUe)	CTUe	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al., 2018	III
Land use ⁵	Soil quality index	Dimensionless	Soil quality index based on LANCA model (Beck et al. 2010 and Bos et al. 2018) as per the LANCA CR version 2.5 (Amon and Maier, 2018)	III
Water use, human health	User deprivation potential weighted water deprivation	m ³ water eq of deprived water	Available Water Remaining (AWARE) model (Boulay et al., 2018) as per UNEP 2016	III
Resource use, minerals and metals	Abiotic resource depletion (ADP)	kg Sb eq	van Oers et al., 2002 as in CML 2002 method, v4.8	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	van Oers et al., 2002 as in CML 2002 method, v4.8	III

⁵ Refers to occupation and transformation

The full list of normalization factors and weighting factors are available in Annex 1 - List of EF normalisation factors and weighting factors.

The full list of characterization factors is available under “EF reference package” at the following link:
<http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml>.

2.5 Additional technical information

[Not Applicable]

2.6 Additional environmental information

The section below describes the additional environmental information which shall be reported.

2.6.1 Noise

In alignment with the PEF methodology, this section of the Drone PEFCR discusses the noise impacts of drone operations. Noise is a critical environmental aspect that affects human health and well-being, particularly in urban settings where drone use is anticipated to grow. Existing research underlines the importance of understanding and mitigating the noise produced by drones to ensure community acceptance and minimize public health impacts.

Drones are emerging as a significant source of noise, characterized by unique acoustic properties such as high-frequency broadband noise and pure tones. These noises are distinct from traditional road traffic or aircraft noise and are generally perceived as more annoying. The specific acoustic features of drone noise, including pitch and loudness, contribute to its potential to cause disturbance and annoyance among exposed populations.

Studies have highlighted that the noise from drones can vary significantly depending on the type of drone, its operation, and its proximity to the ground. This is especially relevant in densely populated areas where drones operate closer to residential settings⁶.

Research has led to the development of modelling frameworks to set recommendations for drone operations that minimise community noise impacts. These frameworks consider factors such as flight paths, operational altitudes, and drone design to reduce noise levels. Standards are beginning to emerge, guided by these studies, to inform regulations that could help manage drone noise in community settings⁷⁸.

⁶ Schäffer B, Pieren R, Heutschi K, Wunderli JM, Becker S. Drone Noise Emission Characteristics and Noise Effects on Humans—A Systematic Review. *International Journal of Environmental Research and Public Health*. 2021; 18(11):5940. <https://doi.org/10.3390/ijerph18115940>

⁷ Ramos-Romero C, Green N, Roberts S, Clark C, Torija AJ. Requirements for Drone Operations to Minimise Community Noise Impact. *International Journal of Environmental Research and Public Health*. 2022; 19(15):9299. <https://doi.org/10.3390/ijerph19159299>

⁸ Cranfield University. (2022, February 7). Drone noise: Trials help build data on sound impact. Retrieved from <https://www.cranfield.ac.uk/press/news-2022/drone-noise-trials-help-build-data-on-sound-impact>

The psychoacoustic properties of drone noise also play a significant role in how noise impacts are perceived by the public. Innovations in drone design and operational practices that consider these psychoacoustic factors are crucial for reducing the negative perception of drone noise⁹.

While substantial research has addressed the immediate impacts of drone noise, significant gaps remain, particularly regarding long-term health effects and the integration of drones into urban soundscapes. Future studies are needed to develop a more comprehensive understanding of how drone noise interacts with other urban noises and its cumulative effects on public health and well-being¹⁰.

Continued research and adaptive management practices will be essential to ensure that drone technology can be integrated sustainably into society, with minimal adverse effects on community noise levels and public health.

EASA has established guidelines for measuring and reporting the noise levels of drones under 600 kg to ensure a uniform approach to noise management and environmental protection¹¹. PEFCR users must adhere to the harmonized noise measurement procedures as outlined by EASA.

The EASA guidelines apply to drones used in low and medium-risk operations within the 'specific' category. This includes a wide range of activities such as:

- Package deliveries
- Powerline inspections
- Bird control
- Mapping services
- Aerial surveillance
- Roof inspections

The EASA procedures are designed to provide repeatable and accurate noise measurements, allowing for fair comparisons between various drone designs. The key steps include:

- conduct noise measurements in an open area free from reflective surfaces that could distort the results. Ensure the environment meets the conditions specified by EASA
- use calibrated noise measurement equipment, ensuring it meets the technical specifications and accuracy requirements set forth in the guidelines
- perform measurements under standardized flight conditions, including specific altitudes, speeds, and flight patterns as detailed in the EASA guidelines
- record noise levels continuously during the measurement period, ensuring data is collected over multiple flights to account for variability in reporting noise levels.

2.7 Limitations

A PEF study will have certain limitations even if carried out in accordance with this PEFCR. The distribution and end of life impact results reflect the average situation for a theoretical drone as captured in default parameters provided by the PEFCR, not necessarily the specific region, country, airline, and user intentions. The

⁹ Torija AJ, Nicholls RK. Investigation of Metrics for Assessing Human Response to Drone Noise. *International Journal of Environmental Research and Public Health*. 2022; 19(6):3152. <https://doi.org/10.3390/ijerph19063152>

¹⁰ RSG. (2021, December). Drone noise: Updated white paper. Retrieved from https://rsginc.com/wp-content/uploads/2021/12/RSG_White-Paper_Drone-Noise_Updated-12-2021.pdf

¹¹ <https://www.easa.europa.eu/en/newsroom-and-events/news/easa-finalises-guidelines-noise-measurements-drones-below-600-kg>

downstream scenario can vary significantly in reality, especially in the use stage: distances and geography of flights, scheduling of flights, years of operation before the decommissioning, needed maintenance etc. For drones, these cases are particularly volatile due to the rapid development of new technologies in the industry. While no drone has undergone full certification, the drones under development vary significantly and as new technologies advance, the scope for change within the technical conditions of the market will outpace those defined within this PEFCR.

As with all LCA studies, Life cycle impact assessment (LCIA) results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

When approaching the end of the development period for this PEFCR, a discussion was held as to whether this PEFCR should have sub-categories of drone based on maximum range, cargo or another parameter. Should this be implemented, the PEF-RP would require data from each sub-category of drone, however this is not possible given the currently development stage of the industry. To include multiple drone sub-categories in future versions of the PEFCR indicates a need for more detailed data collection and analysis. By developing more defined sub-categories, future assessments can provide a clearer and more accurate depiction of the environmental impacts specific to each variant of the product. By restricting comparative assertions to sub-categories of the same type, the assessments remain relevant and scientifically sound, avoiding misleading conclusions that could arise from comparing fundamentally different products. Since this PEFCR has not developed multiple sub-categories, a question arises regarding the comparability of two drone with significantly different characteristics. As such, this is recommended to be investigated further and for the next iteration of the PEFCR to consider defining and implementing specific sub-categories of drones based on key characteristic difference in models (e.g. single rotor, multirotor and fixed wing, or variations in maximum range or cargo capacity).

Specific limitations regarding the PEF-RP and the default datasets are outlined in more detail within section 7.6 of Annex 4. These have not been explicitly listed here as they will not be present within the final version of the PEFCR.

2.8 Comparisons and comparative assertions

It is allowed to make a comparison or a comparative assertion based on the results of a study generated under this PEFCR with those of another drone if both have been conducted and verified in accordance with this PEFCR. However, the comparison or comparative assertion would be valid only if the PEF study uses the exact suggested default datasets in DNM Situations where no company specific data is used. All information used in the comparison shall be based on verified PEF studies (see chapter **Error! Reference source not found.**). It is important that for any comparisons, that the equivalence of the systems being compared is evaluated before interpreting the results.

As mentioned in section 3.8, drawing comparisons between two drones with different characteristics may lead to inaccuracies in the comparison.

2.8.1 Data gaps and proxies

Within the first version of the PEFCR it has not been possible to meet the requirements of PEF for all datasets used within the study, leading to either data gaps or proxy data being applied to the first version of the PEFCR. This section details all data gaps and proxy datasets used within the PEFCR, and forms the starting point for future iterations. It is important to acknowledge the inherent uncertainties due to the emerging nature of the vehicles (drones) covered by this PEFCR, in particular, regarding data availability. The data required to completely assess the EF profile of these innovative products are not yet, fully comprehensive,

largely because these are nascent technologies, so the industry is still in the relatively early stages of development. Lack of extensive historical data, coupled with rapidly evolving technology and operational practices, may lead to less certainty in the PEFCR assessments for drones compared to more established industries. Consequently, the environmental impacts assessed by the current PEFCR should be viewed as best estimates based on available data. It is expected that these will be refined as the industry matures and more empirical data become available. Stakeholders should be aware that it is crucial that the PEFCR evolves over time to incorporate new findings and methodologies that reflect the most up to date and unique operational characteristics and technological advancements in the drone sector.

Due to the relatively young nature of the drone industry, comprehensive data on the processing of raw materials and the assembly of subcomponents are limited. Estimates for the processing of the raw materials and the assembly of subcomponents, relating to LC stages 1a to 1f have been derived based on consultations with industry stakeholders. These estimates are used to bridge data gaps and provide a preliminary understanding of the environmental impacts associated with these stages of drone production.

Due to the large number of raw materials and components used in drones, not all raw materials or components that are required to make and operate a drone may be represented in the EF compliant datasets available. While some of the data gaps may be possible to fill in with the ILCD datasets, some may only be able to be filled with the use of commercial databases. This was the case in the development of the RP. They have therefore been left as data gaps in the study. The processes left as data gaps are indicated in the Excel Annex II to the report. These processes excluded from the PEFCR due to missing datasets shall not be filled in by the user of the PEFCR.

Data on the drone final assembly infrastructure (LC stage 2c) is company-specific and shall be collected for the PEF study. Allocation of the infrastructure to one drone shall be done as specified in section 4.7 of this PEFCR.

2.8.1.1 Data gaps

Within the PEFCR Annex II and the PEF-RP, the following processes have been specified as data gaps:

- 3D Printing manufacturing process,
- Cutting, gluing and finishing manufacturing processes of fibreboard,
- Epoxy resin manufacturing process,
- Anodizing, machining, cutting and drilling for aluminium,
- Galvanising manufacturing process for steel,
- Machining manufacturing process for steel, stainless steel and zinc-plated steel,
- Propulsion system motor dataset,
- Charging infrastructure at the vertiport,
- Electricity used during final drone assembly,
- Industry-specific CFF parameters.

While it has been possible to identify ILCD-EL proxies for the propulsion system motor, charging infrastructure at the vertiport and manufacturing processes listed above, the datasets remain excluded from the first version of the PEFCR default datasets as no EF-compliant datasets exist.

Within the development of the PEFCR, it was necessary to form validated assumptions for the electricity used during final assembly due to no metering taking place at any of the OEM manufacturing facilities. This is a noted limitation as the final drone assembly requires company-specific data which cannot be supplied by the industry in the current form.

It is recommended that the next version of the PEFCR aims to develop the listed default datasets to implement within version 2.

3. MOST RELEVANT IMPACT CATEGORIES, LIFE CYCLE STAGES, PROCESSES AND ELEMENTARY FLOWS

PEF requires that the most relevant impact categories, life cycle stages, processes and elementary flows are established as areas of particular analysis. The following “most relevant” parameters have been established based on the final results of the PEF study of the drone RP (May 2024).

3.1 Most relevant EF impact categories

The most relevant impact categories for the product category in scope of this PEFCR are the following:

- Acidification (4th)
- Climate change – total (1st)
- Particulate matter (2nd)
- Resource use, fossils (3rd)
- Resource use, minerals and metals (5th)

3.2 Most relevant life cycle stages

The most relevant life cycle stages for the product category in scope of this PEFCR are the following:

- Stage 1, Raw material extraction (RM)
- Stage 4, Use including maintenance (Use)
- Stage 5, End of Life (EoL)

The most relevant life cycle stages, excluding the use phase, for the product category in scope of this PEFCR are the following:

- Stage 1, Raw material extraction

3.3 Most relevant processes

The most relevant processes for the product category in scope of this PEFCR are the following (as per Table 10). The most relevant processes of the life cycle excluding the use stage are also provided in Table 11) because the use stage contributes for more than 50% of the impact in the most relevant impact categories.

► **Table 10:** List of most relevant processes (for the full life cycle) per impact category, given in order of significance

Full life cycle	
Impact category	Most relevant processes
Climate change - total	Landfill MSW (from life cycle stage: EoL)
	Electricity (from life cycle stage: RM, Manufacturing and Use)
	CPT Battery (from life cycle stage: RM and Use)
	Aluminium Credit (from life cycle stage: EoL)
Particulate matter	Building (concrete) (from life cycle stage: Manufacturing and Use)
	Transistor (from life cycle stage: RM)
	Electricity (from life cycle stage: RM and Use)
Resource use, fossils	Electricity (from life cycle stage: RM and Use)
	Battery CPT (from life cycle stage: RM and Use)
	Aluminium Credit (from life cycle stage: EoL)
Acidification	Transistor (from life cycle stage: RM)
	CPT Battery (from life cycle stage: RM and Use)
	Electricity (from life cycle stage: RM and Use)
Resource use, minerals and metals	Transistor (from life cycle stage: RM)
	PWB (from life cycle stage: RM)
	Battery (from life cycle stage: RM and Use)

► **Table 11:** List of most relevant processes (excluding use stage) per impact category, given in order of significance

Life cycle without use stage	
Impact category	Most relevant processes
Resource use, minerals and metals	Transistor (from life cycle stage: RM)
	PWB (from life cycle stage: RM)
Particulate matter	Transistor (from life cycle stage: RM)
	Transoceanic ship (from life cycle stage: RM)
Climate change	Transistor (from life cycle stage: RM)
	Landfill MSW (from life cycle stage: EoL)
	PWB (from life cycle stage: RM)
	CFRP (from life cycle stage: RM)
Acidification	Transistor (from life cycle stage: RM)

3.4 Most relevant direct elementary flows

The most relevant direct elementary flows for the product category in scope of this PEFCR are the following (as per Table 12 to Table 16).

► **Table 12:** Most relevant elementary flows for the climate change – total impact category for the full life cycle

Full life cycle	
Climate change – total	
Process	Elementary flow
Electricity	Carbon dioxide, fossil (to air)
Landfill MSW	Methane, biogenic (to air)
Battery CPT	Carbon dioxide, fossil (to air)
Aluminium Credit	Carbon dioxide, fossil (to air)

► **Table 13:** Most relevant elementary flows for the particulate matter impact category for the full life cycle

Full life cycle	
Particulate matter	
Process	Elementary flow
Building (concrete)	Particulates, <2.5um (to air)
Transistor	Sulfur dioxide (to air)
	Particulates, <2.5um (to air)
Electricity	Particulates, <2.5um (to air)
	Sulfur dioxide (to air)

► **Table 14:** Most relevant elementary flows for the resource use – fossil impact category for the full life cycle

Full life cycle	
Resource use - fossils	
Process	Elementary flow
Electricity	Energy, from uranium (Raw)
	Energy, from coal (Raw)
	Energy, from gas, natural (Raw)
Aluminium Credit	Energy, from uranium (Raw)
	Energy, from gas, natural (Raw)
	Energy, from oil (Raw)
Battery CPT	Carbon dioxide, fossil (to air)
	Energy from uranium (Raw)
	Energy, from oil (Raw)

	Energy, from coal (Raw)
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► **Table 15:** Most relevant elementary flows for the acidification impact category for the full life cycle

Full life cycle	
Acidification	
Process	Elementary flow
Transistor	Sulfur dioxide (to air)
Battery CPT	Sulfur dioxide (to air)
Electricity	Sulfur dioxide (to air)
	Nitrogen oxides (to air)

► **Table 16:** Most relevant elementary flows for the resource use – minerals and metals impact category for the full life cycle

Full life cycle	
Resource use – minerals and metals	
Process	Elementary flow
Transistor	Gold (Raw)
	Platinum (Raw)
PWB	Gold (Raw)
	Copper (Raw)
Battery	Copper (Raw)
	Sulfur (Raw)
	Gold (Raw)
	Chromium (Raw)
	Cadmium (Raw)
	Lead (Raw)

The most relevant direct elementary flows excluding the use stage are also provided in Table 17 to Table 20) because the use stage contributes for more than 50% of the impact in the most relevant impact categories.

- **Table 17:** Most relevant elementary flows for the resource use – minerals and metals impact category for the full life cycle excluding use

Life cycle without use stage	
Resource use – minerals and metals	
Process	Elementary flow
Transistor	Gold (Raw)
	Platinum (Raw)
PWB	Gold (Raw)

- **Table 18:** Most relevant elementary flows for the particulate matter impact category for the full life cycle excluding use

Life cycle without use stage	
Particulate matter	
Process	Elementary flow
Transistor	Sulfur dioxide (to air)
	Particulates, <2.5um (to air)
Transoceanic ship	Nitrogen oxides (to air)
	Sulfur dioxide (to air)

- **Table 19:** Most relevant elementary flows for the climate change – total impact category for the full life cycle excluding use

Life cycle without use stage	
Climate change	
Process	Elementary flow
Transistor	Carbon dioxide, fossil (to air)
Landfill MSW	Methane, biogenic (to air)
Printed wiring board (PWB)	Carbon dioxide, fossil (to air)
Carbon fibre reinforced polymer (CFRP)	Carbon dioxide, fossil (to air)

- **Table 20:** Most relevant elementary flows for the acidification impact category for the full life cycle excluding use

Life cycle without use stage	
Acidification	
Process	Elementary flow
Transistor	Sulfur dioxide (to air)

4. LIFE CYCLE INVENTORY

All newly created datasets shall be EF or ILCD-EL compliant (see rules in section 4.5).

Sampling is not allowed.

4.1 List of mandatory company-specific data

The processes that require mandatory company-specific input data are within LC stages 2 and 4. The following processes shall be modelled specifically by the PEFCR user using company-specific data for the drone under study:

- Drone final assembly (LC stage 2a)
- Testing flights (LC stage 2b)
- Final assembly infrastructure (LC stage 2c)
- Operational flights (LC stage 4a)

These company specific data required are based on the design of the drone and the respective flight performance, and production processes input and outputs. In addition to the data required for each of the above stages, the following information on the drone design will also need to be known:

1. Drone model: specific model of the drone
2. Engine model: the model of the propulsion system (electric motors, battery specifications)
3. For delivery drones, the cargo capacity in the layout by the assigned cargo service.

2a – Drone final assembly:

The final assembly of the drone includes the final processing to combine components into the drone. The following points should be included within this stage:

1. Bill of components/bill of materials: number of processed materials (by material, in kg) for drone construction and amount of component for groups Systems, Cargo hold, Landing gear and Battery (by listed component groups, in kg)
2. The fraction of raw materials and components lost during production. The waste resulting from production loss shall be modelled with CFF (refer to section 4.10) using the material/component compositions.
3. Electricity (specific electricity mix used following the procedure from chapter 5.8), heating and cooling, process water, compressed air, welding gas, machinery etc required to assemble the components into a functional drone, e.g. unit for electricity used: kWh/drone assembled.
4. Transportation of the drone (semi-product) between the final assembly sites, excluding transport of pre-assembled components by or from suppliers. Unit: tkm/drone, by means of transportation.
5. Hazardous waste (unspecified): Hazardous waste according to the European waste directive 2008/98/EC Unit: kg/drone assembled.
6. Packaging waste (specified by fraction). Unit: kg/drone assembled.
7. Non-hazardous waste (specified by fraction). Unit: kg/drone assembled.
8. Non-hazardous waste (unspecified): other non-hazardous waste according to the European waste directive 2008/98/EC Unit: kg/ drone assembled.
9. Water emitted: Total water emitted to wastewater treatment systems Unit: kg/ drone assembled.

► **Table 21:** Data collection requirements for 2a - Drone final assembly

Requirements for data collection purposes			Requirements for modelling purposes
Activity data to be collected	Specific requirements (e.g., frequency, measurement standard, etc.)	Unit of measure	
Inputs:			
CFRP for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Polystyrene foam for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Fibreboard for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Paint for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Epoxy resin for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Aluminium for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Nylon 6 for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
LED for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Wiring for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Connectors for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Nuts and bolts for airframe	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
CFRP for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Aluminium for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PLA for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Nylon 6 for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PET for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PC for system casing	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Communication systems	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Aluminium	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PVC	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Electronics	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Siren	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Parachute	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Wiring	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Capacitors	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Transistors	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Steel	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Battery	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
CFRP for payload box	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Electronics for winch	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
ABS for winch	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Steel for securing payload box	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]

SBS for securing payload box	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Stainless steel for securing payload box	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Plywood for securing payload box	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Stainless steel in motor mount	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PLA in motor mount	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PWB in motor mount	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Aluminium in motor mount	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
CFRP in rotor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Epoxy resin in rotor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
PLA in rotor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Steel in rotor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Zinc plated steel in rotor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Motor	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
CFRP in landing gear	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
ABS in landing gear	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Zinc plated steel in landing gear	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Plastic packaging for components	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Paper packaging for components	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Wood packaging for components	amount in the ready drone	kg/drone	[see the PEFCR Excel annex II]
Production losses	year based average	kg/kg	[see the PEFCR Excel annex II]
Diesel	year based average	kg/drone	[see the PEFCR Excel annex II]
Electricity	year based average, specific electricity mix shall be used	kWh/drone	[see the PEFCR Excel annex II]
Light Fuel Oil	year based average	kg/drone	[see the PEFCR Excel annex II]
Liquefied Petroleum Gas	year based average	kg/drone	[see the PEFCR Excel annex II]
Natural gas	year based average	MJ/ drone	[see the PEFCR Excel annex II]
Petrol	year based average	kg/drone	[see the PEFCR Excel annex II]
Supplied heating	year based average	MJ/ drone	[see the PEFCR Excel annex II]
Supplied cooling	year based average	MJ/ drone	[see the PEFCR Excel annex II]
Compressed air	year based average	m3/ drone	[see the PEFCR Excel annex II]
Process water	year based average	kg/drone	[see the PEFCR Excel annex II]
Tooling Equipment	time in operation year-based average	kg/drone	[see the PEFCR Excel annex II]
Transport by truck, between the final assembly sites	primary logistics data	kgkm/drone	[see the PEFCR Excel annex II]
Transport by ship, between the final assembly sites	primary logistics data	kgkm/drone	[see the PEFCR Excel annex II]
Transport by air, between the final assembly sites	primary logistics data	kgkm/drone	[see the PEFCR Excel annex II]

Outputs:			
Wastewater generated	year based average	kg/drone	[see the PEFCR Excel annex II]
CFRP waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Polystyrene foam waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Wood waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Paint waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Epoxy resin waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Aluminium waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Nylon 6 waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Wiring/cable waste	year based average	kg/drone	[see the PEFCR Excel annex II]
PLA waste	year based average	kg/drone	[see the PEFCR Excel annex II]
PET waste	year based average	kg/drone	[see the PEFCR Excel annex II]
PC waste	year based average	kg/drone	[see the PEFCR Excel annex II]
PVC waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Electronics waste	year based average	kg/drone	[see the PEFCR Excel annex II]
ABS waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Stainless steel waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Zinc plated steel waste	year based average	kg/drone	[see the PEFCR Excel annex II]
packaging plastic waste	year based average	kg/drone	[see the PEFCR Excel annex II]
packaging wood waste	year based average	kg/drone	[see the PEFCR Excel annex II]
packaging paper waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Other non-hazardous waste	year based average	kg/drone	[see the PEFCR Excel annex II]
Other hazardous waste	year based average	kg/drone	[see the PEFCR Excel annex II]

For production of the same product in multiple sites, with differences in bills of components/materials and use of utilities and waste generation, a weighted average of the different sites shall be used. In case waste is treated on-site, impacts related to this treatment shall be included.

Utilities, consumables and other materials consumed in the operation of the manufacturing process shall be gathered. All data shall be collected and averaged with the total production of one calendar year to average seasonal variations. In the case of multiple drone products being produced on the same site, the data shall first be collected specifically for the drone product under study. If this is not possible, an allocation based on unit production shall be made (see section 4.7).

Utility use and waste, as well as infrastructure shall include that from offices, support and administrative functions related to the final assembly process.

Where the site is shared with another function (such as R&D, HR, sales, etc) and there is no separate metering of the utility use or waste generation no allocation to these other functions shall be applied. Utility use and waste generation shall be measured for the smallest division which includes still the entire manufacturing operation (e.g. if the water use for the manufacturing operations and the sales functions are metered together, but metered separately from the R&D operations, then the value for the manufacturing and sales operations shall be used). Each type of utility, consumable and waste types, can be considered separately (e.g. water use may be based on the manufacturing operations use, and electricity on total site use).

2b – Testing flights:

This stage includes any test flights required by the SAIL categories. The company shall state the SAIL category of their drone and use the associated number of flight hours (FH). From here the amount of energy required for the respective FH shall be used to calculate the emissions from this stage.

► **Table 22: Number of testing flight hours for each respective SAIL category**

SAIL Category	Flight hours (hours)
SAIL I	3
SAIL II	30
SAIL III	300
SAIL IV	3,000
SAIL V	30,000
SAIL VI	300,000

It is understood that for SAIL category drones which exceed category III or IV the number of flight hours become unrealistic for the duration it would take to demonstrate this. Should the drone under study be SAIL IV, SAIL V or SAIL VI, the company shall model the hours required to demonstrate the conformity and any subsequent flight hours (primary data) for the drone.

For details on how to collect the company-specific data for the energy use, please see section 5.2.2 and 5.4.1.

2c – Final assembly infrastructure:

The final assembly infrastructure includes any manufacturing infrastructure that is required for manufacturing work including as a minimum land footprint and building structures. These must include (as a minimum):

1. Multistorey buildings: buildings construction at the final assembly site, used for activities connected to final assembly. Unit: m³/drone.
2. Building, hall: Single-story structures and shelters (segmented areas within a larger hall) at the final assembly site used for the assembly process and related activities for drones. Unit: sqm/drone.
3. Road and paved field: concrete or paved areas at the final assembly site utilized for movement, assembly-related activities, and ground tests of drones. Unit: sqm/drone.
4. Industrial area: land allocated for industrial activity related to the final assembly of drones, calculated annually. Unit: m²*year/drone.
5. Land transformation: Land repurposed for industrial use to accommodate the construction of the final assembly site for drones, inclusive of any maintained green areas within the site. Unit: sqm/drone.

► **Table 23:** Data collection requirements for final assembly infrastructure

Requirements for data collection purposes			Requirements for modelling purposes
Activity data to be collected	Specific requirements (e.g. frequency, measurement standard, etc.)	Unit of measure	Default dataset to be used
Multistorey buildings	Total volume of buildings, construction and refurbishment, allocated to the FA, assumed 50 years planned operation	m3/drone	[see the PEFCR Excel annex II]
Building, hall	Total area of buildings, construction and refurbishment, allocated to the FA, assumed 50 years planned operation	sqm/drone	[see the PEFCR Excel annex II]
Road and paved field	Total area, construction and refurbishment, allocated to the FA, assumed 50 years planned operation	sqm/drone	[see the PEFCR Excel annex II]
Industrial area	Total area allocated to the FA	m2*year/drone	Elementary flow
Land transformation	Land area transformed for industrial use for FA site, including maintained green area	m2/drone	Elementary flows

4a – Operational flights:

The stage shall include all electricity consumed during operational flights. This shall be based on three flight phases: take-off, cruise, hover/landing (depending on the delivery method).

► **Table 24:** Data collection requirements for flight modelling

Flight phase	Take-off	Cruise	Landing
Energy use	E_{TO}	E_C	E_L
Unit of energy consumption	kWh	kWh	kWh
Consumption per distance / count	Per km travelled in take-off sequence	Per km travelled	Per km travelled in landing sequence

The energy data for this stage shall be calculated under neutral weather conditions. For details on how to calculate the energy used per flight and over the lifetime, please see section 5.2.2.

Depending on the product system and manufacturer, the above substages fall under DNM situation 1 or situation 2 (see section 4.4).

4.2 List of processes expected to be run by the company

In addition to the processes listed as mandatory company-specific data, the following stages could be run by the company:

- 1h. Raw materials (components) distribution to the final assembly
- 3a. Distribution (Delivery Transport)
- 4b. Ground Services
- 4c. Passenger Service
- 4d. Vertiport Infrastructure
- 4e. Maintenance and refurbishment

For 4b, 4c, 4d and 4e see sections 5.4.2 to 5.4.5 for details on how to model using company-specific data.

1h. Raw material component distribution to final assembly

The distribution of components to final assembly should be run using company specific data. In order to utilise company-specific data, the following data needs to be collected.

► **Table 25: Data requirements for component distribution to final assembly site**

Requirements for data collection purposes			Requirements for modelling purposes
Activity data to be collected	Specific requirements	Unit of measure	
Transport from component supplier to final assembly site	Primary logistics data	kgkm per drone	[see the PEFCR Excel annex II]
Mode of transport	Primary logistics data	n/a	[see the PEFCR Excel annex II]

Note that the data above should be collected for transport type. Should the components be supplied from more than one site, the weight of components per drone from each site shall be multiplied by the distance travelled to obtain the specific kgkm per drone for each route.

3a. Distribution (Delivery transport)

Similarly to the requirements for 1h, the same data shall be collected for the transport from final assembly site to the location of use. If more than one location of use exists, then a weighted average of the distances shall be conducted in order to obtain a representative average of the distance on drone would take.

► **Table 26: Data requirements for the distribution direct to customer**

Requirements for data collection purposes			Requirements for modelling purposes
Activity data to be collected	Specific requirements	Unit of measure	
Transport from final assembly site to location of use	Primary logistics data	kgkm per drone	[see the PEFCR Excel annex II]
Mode of transport	Primary logistics data	n/a	[see the PEFCR Excel annex II]

4.3 Data quality requirements

The data quality of each dataset and the total PEF study shall be calculated and reported. The calculation of the DQR shall be based on the following formula with four criteria:

► Equation 3: DQR calculation

$$DQR = \frac{TeR + GeR + TiR + P}{4}$$

where TeR is technological representativeness, GeR is geographical representativeness, TiR is time representativeness, and P is precision. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and related level of uncertainty.

The next sections provide tables with the criteria to be used for the semi-quantitative assessment of each criterion.

4.3.1 Company-specific datasets

The DQR shall be calculated at the level-1 disaggregation, before any aggregation of subprocesses or elementary flows is performed. The DQR of company-specific datasets shall be calculated as following:

(a) Select the most relevant activity data and direct elementary flows: most relevant activity data are the ones linked to sub-processes (i.e., secondary datasets) that account for at least 80% of the total environmental impact of the company-specific dataset, listing them from the most contributing to the least contributing one. Most relevant direct elementary flows are defined as those direct elementary flows contributing cumulatively at least with 80% to the total impact of the direct elementary flows.

(b) Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and each most relevant direct elementary flow.

- a. Each most relevant direct elementary flow consists of the amount and elementary flow naming (e.g., 40 g carbon dioxide). For each most relevant elementary flow, the user of the PEF CR shall evaluate the 4 DQR criteria named Te_{R-EF} , Ti_{R-EF} , Ge_{R-EF} , P_{EF} . For example, the user of the PEF CR shall evaluate the timing of the flow measured, for which technology the flow was measured and in which geographical area.
- b. For each most relevant activity data, the 4 DQR criteria shall be evaluated (named Ti_{R-AD} , P_{AD} , Ge_{R-AD} , Te_{R-AD}) by the user of the PEF CR.
- c. Considering that the data for the mandatory processes shall be company specific, the score of P cannot be higher than 3, while the score for TiR, TeR, and GR cannot be higher than 2 (The DQR score shall be ≤ 1.5).

(c) Calculate the environmental contribution of each most relevant activity data (through linking to the appropriate sub-process) and direct elementary flow to the total sum of the environmental impact of all most-relevant activity data and direct elementary flows, in % (weighted, using all EF impact categories). For example, the newly developed dataset has only two most relevant activity data, contributing in total to 80% of the total environmental impact of the dataset:

- a. Activity data 1 carries 30% of the total dataset environmental impact. The contribution of this process to the total of 80% is 37.5% (the latter is the weight to be used).

- b. Activity data 2 carries 50% of the total dataset environmental impact. The contribution of this process to the total of 80% is 62.5% (the latter is the weight to be used).

(d) Calculate the TeR , TiR , GeR and P criteria of the newly developed dataset as the weighted average of each criteria of the most relevant activity data and direct elementary flows. The weight is the relative contribution (in %) of each most relevant activity data and direct elementary flow calculated in step 3.

(e) The user of the PEFCR shall calculate the total DQR of the newly developed dataset using Equation 4, where $\overline{TeR}$, $\overline{GeR}$, $\overline{TiR}$, $\overline{R}$, $\overline{P}$ are the weighted average calculated as specified in point (d).

► **Equation 4: Total DQR calculation for newly developed datasets**

$$DQR = \frac{\overline{TeR} + \overline{GeR} + \overline{TiR} + \overline{P}}{4}$$

► **Table 27: How to assess the value of the DQR criteria for datasets with company-specific information**

Rating	P_{EF} and P_{AD}	Ti_{R-EF} and Ti_{R-AD}	Te_{R-EF} and Te_{R-AD}	G_{R-EF} and G_{R-AD}
1	Measured/calculated and externally verified	The data refers to the most recent annual administration period with respect to the EF report publication date	The elementary flows and the activity data exactly reflects the technology of the newly developed dataset	The activity data and elementary flows reflects the exact geography where the process modelled in the newly created dataset takes place
2	Measured/calculated and internally verified, plausibility checked by reviewer	The data refers to maximum 2 annual administration periods with respect to the EF report publication date	The elementary flows and the activity data is a proxy of the technology of the newly developed dataset	The activity data and elementary flows) partly reflects the geography where the process modelled in the newly created dataset takes place
3	Measured/calculated / literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data refers to maximum three annual administration periods with respect to the EF report publication date	Not applicable	Not applicable
4-5	Not applicable	Not applicable	Not applicable	Not applicable

P_{EF} : Precision for elementary flows; P_{AD} : Precision for activity data; Ti_{R-EF} : Time Representativeness for elementary flows; Ti_{R-AD} : Time representativeness for activity data;; Te_{R-EF} : Technology representativeness for elementary flows; Te_{R-AD} : Technology representativeness for activity data; G_{R-EF} : Geographical representativeness for elementary flows; G_{R-AD} : Geographical representativeness for activity data.

4.4 Data needs matrix (DNM)

All processes required to model the product and outside the list of mandatory company-specific data (listed in section 4.1) shall be evaluated using the Data Needs Matrix (see Table 28).

The user of the PEFCR shall apply the DNM to evaluate which data is needed and shall be used within the modelling of its PEF, depending on the level of influence the user of the PEFCR (company) has on the specific process. The following three cases are found in the DNM and are explained below:

1. Situation 1: the process is run by the company applying the PEFCR;
2. Situation 2: the process is not run by the company applying the PEFCR but the company has access to (company-)specific information;
3. Situation 3: the process is not run by the company applying the PEFCR and this company does not have access to (company-)specific information.

► **Table 28: Data Needs Matrix (DNM)**¹². *Disaggregated datasets shall be used

		Most relevant processes	Other processes
Situation 1: Process run by the company using the PEFCR.	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).	Calculate the DQR values (for each criterion + total)
	Option 2		Use default secondary dataset in PEFCR, in aggregated form (DQR≤3.0). Use the default DQR values
Situation 2: Process <u>not</u> run by the company using the PEFCR but with access to company-specific information	Option 1	Provide company-specific data (as requested in the PEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).	Calculate the DQR values (for each criterion + total)
	Option 2	Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0). Re-evaluate the DQR criteria within the product specific context	

¹² The options described in the DNM are not listed in order of preference.

Situation 3: process <u>not</u> run by the company using the PEFCR and without access to company-specific information	Option 3		Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0). Use the default DQR values.
	Option 1	Use default secondary data set in aggregated form (DQR≤3.0). Re-evaluate the DQR criteria within the product specific context	
	Option 2		Use default secondary data set in aggregated form (DQR≤4.0). Use the default DQR values

4.4.1 Processes in situation 1

For each process in situation 1 there are two possible options:

- The process is in the list of most relevant processes as specified in the PEFCR or is not in the list of most relevant process, but still the company wants to provide company specific data (option 1);
- The process is not in the list of most relevant processes and the company prefers to use a secondary dataset (option 2).

Situation 1/Option 1

For all processes run by the company and where the user of the PEFCR applies company-specific data. The DQR of the newly developed dataset shall be evaluated as described in section 4.3.1.

Situation 1/Option 2

For the non-most relevant processes only, if the user of the PEFCR decides to model the process without collecting company-specific data, then the user shall use the secondary dataset listed in the PEFCR together with its default DQR values listed here.

If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the metadata of the original dataset.

4.4.2 Processes in situation 2

When a process is not run by the user of the PEFCR, but there is access to company-specific data, then there are three possible options:

- The user of the PEFCR has access to extensive supplier-specific information and wants to create a new EF compliant dataset (Option 1);

- The company has some supplier-specific information and wants to make some minimum changes (Option 2);
- The process is not in the list of most relevant processes and the company wants to make some minimum changes (Option 3).

Situation 2/Option 1

For all processes not run by the company and where the user of the PEFCR applies company specific data, the DQR of the newly developed dataset shall be evaluated as described in section 4.3.1.

Situation 2/Option 2

The user of the PEFCR shall use company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets, starting from the default secondary dataset provided in the PEFCR.

Please note that the PEFCR lists all dataset names together with the UUID of their aggregated dataset. For this situation, the disaggregated version of the dataset is required.

The user of the PEFCR shall make the DQR context-specific by re-evaluating TeR and TiR using the **Table 27**. The criteria GeR shall be lowered by 30%¹³ and the criteria P shall keep the original value.

Situation 2/Option 3

The user of the PEFCR shall apply company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets, starting from the default secondary dataset provided in the PEFCR.

Please note that the PEFCR lists all dataset names together with the UUID of their aggregated dataset.

In this case, the user of the PEFCR shall use the default DQR values. If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the original dataset.

► **Table 29: How to assess the value of the DQR criteria when secondary datasets are used**

	<i>TiR</i>	<i>TeR</i>	<i>GeR</i>
1	<i>The EF report publication date happens within the time validity of the dataset</i>	<i>The technology used in the EF study is exactly the same as the one in scope of the dataset</i>	<i>The process modelled in the EF study takes place in the country the dataset is valid for</i>
2	<i>The EF report publication date happens not later than 2 years beyond the time validity of the dataset</i>	<i>The technologies used in the EF study is included in the mix of technologies in scope of the dataset</i>	<i>The process modelled in the EF study takes place in the geographical region (e.g., Europe) the dataset is valid for</i>
3	<i>The EF report publication date happens not later than 4 years beyond the time validity of the dataset</i>	<i>The technologies used in the EF study are only partly included in the scope of the dataset</i>	<i>The process modelled in the EF study takes place in one of the geographical regions the dataset is valid for</i>
4	<i>The EF report publication date happens not later than 6 years</i>	<i>The technologies used in the EF study are similar to those</i>	<i>The process modelled in the EF study takes place in a country</i>

¹³ In situation 2, option 2 it is proposed to lower the parameter GeR by 30% in order to incentivise the use of company-specific information and reward the efforts of the company in increasing the geographic representativeness of a secondary dataset through the substitution of the electricity mixes and of the distance and means of transportation.

	TiR	TeR	GeR
	<i>beyond the time validity of the dataset</i>	<i>included in the scope of the dataset</i>	<i>that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement.</i>
5	<i>The EF report publication date happens later than 6 years after the time validity of the dataset</i>	<i>The technologies used in the EF study are different from those included in the scope of the dataset</i>	<i>The process modelled in the EF study takes place in a different country than the one the dataset is valid for</i>

4.4.3 Processes in situation 3

If a process is not run by the company using the PEFCR and the company does not have access to company-specific data, there are two possible options:

- It is in the list of most relevant processes (situation 3, option 1);
- It is not in the list of most relevant processes (situation 3, option 2).

Situation 3/Option 1

In this case, the user of the PEFCR shall make the DQR values of the dataset used context-specific by re-evaluating TeR, TiR and GeR, using the table(s) provided. The criteria P shall keep the original value.

Situation 3/Option 2

For the non-most relevant processes, the user of the PEFCR shall apply the corresponding secondary dataset listed in the PEFCR together with its DQR values.

If the default dataset to be used for the process is not listed in the PEFCR, the user of the PEFCR shall take the DQR values from the original dataset.

4.5 Which datasets to use?

This PEFCR lists the secondary datasets to be applied by the user of the PEFCR. Whenever a dataset needed to calculate the PEF profile is not among those listed in this PEFCR, then the user shall choose between the following options (in hierarchical order):

- 1) Use an EF compliant dataset available on one of the nodes of the Life Cycle Data Network¹⁴;
- 2) Use an EF compliant dataset available in a free or commercial source;
- 3) Use another EF compliant dataset considered to be a good proxy. In such case this information shall be included in the “limitations” section of the PEF report;
- 4) Use an ILCD-EL compliant dataset as proxy. These datasets shall be included in the “limitations” section of the PEF report. A maximum of 10% of the single overall score may be derived from ILCD-EL compliant datasets (calculated cumulatively from lowest to largest contribution to the total EF profile).
- 5) If no EF compliant or ILCD-EL compliant proxy is available, it shall be excluded from the PEF study. This shall be clearly stated in the PEF report as a data gap and validated by the PEF study and PEF report verifiers.

¹⁴ <http://eplca.jrc.ec.europa.eu/LCDN/>

4.6 How to calculate the average DQR of the study

To calculate the average DQR of the PEF study, the user of the PEFCR shall calculate separately the TeR, TiR, GeR and P for the PEF study as the weighted average of all most relevant processes, based on their relative environmental contribution to the total single overall score. The calculation rules explained in section 5.8 of the PEF method shall be used¹⁵.

4.7 Allocation rules

Allocation is the process of assigning the environmental impacts of a system to its multiple products or functions. This is sometimes necessary in the LCA when a single process yields multiple outputs. The PEF methodology recommends avoiding allocation whenever possible by subdividing processes or using system expansion. When allocation cannot be avoided, it should be based on a physical relationship between the inputs and outputs, such as mass or energy content.

The allocation rules that apply to the PEFCR scope (manufacturing) are based on the physical relationship between the inputs and the outputs. Drone manufacturing processes commonly involve multiple output processes, including manufacturing of different types of drones. Allocation shall be avoided as much as possible, with division of the processes into smaller steps to identify inputs and outputs relevant for a particular vehicle product.

In case allocation is needed in a PEF study, unit allocation shall be used: the inputs and outputs of any ancillary materials are to be divided equally between the number of different unit drone manufactured since the environmental impact of manufacturing processes is often directly related to the number of units produced. Each drone requires a specific amount of resources and energy for its production. Therefore, distributing the total environmental impact based on the number of units manufactured ensures a fair and proportional allocation of impacts. In addition, using the number of units as the basis for allocation simplifies the data collection and calculation process. This method is straightforward and practical, especially when detailed data on mass or energy consumption for each type of drone is not readily available.

If unit allocation is deemed not appropriate method follow the guidance in the PEF guide. The allocation that was applied shall be explained and justified in the PEF report. For allocation related to raw materials the relevant hierarchy in the PEF methodology shall be followed. The allocation applied shall be explained and justified in the PEF report.

If the considered product is being assembled across multiple sites, the following applies:

- If final assembly of one drone is implemented at several sites with transportation of the semi-finished product between the sites: The quantities of inputs and outputs per site shall be allocated equally between the number of drones processed at each site.
- If several final assembly lines assemble the same type of drone under study: for each of the sites unit-based allocation shall be used. The resulting values for inputs and outputs then shall be modelled for the PEF study as weighted average, weighted on the number of vehicle assembled at each site. This procedure shall be done with respect to regionalisation when relevant.

¹⁵ https://environment.ec.europa.eu/document/download/680503dc-5a19-4f6a-bb92-84d9bfc8f312_en?filename=Annexes%201%20to%202.pdf

► **Table 30: Allocation rules**

Process	Allocation rule	Modelling instructions	Allocation factor ¹⁶
Manufacturing of different types of drones	Physical allocation	Divide the processes into smaller steps to identify inputs and outputs relevant for each drone type.	TBC
Allocation of ancillary inputs and outputs to drones	Unit allocation	Inputs and outputs are to be divided equally between the number of different unit drones manufactured.	TBC
Raw material allocation	Follow relevant PEFCRs; if unavailable, follow the PEF guide.	The allocation applied shall be explained and justified in the PEF report.	TBC
Final assembly across multiple sites	Unit-based allocation	Quantities of inputs and outputs per site shall be allocated equally between the number of drones processed at each site.	TBC
Multiple final assembly lines for the same drone type	Unit-based allocation	For each site, unit-based allocation shall be used, and values modelled as weighted average based on the number of drones assembled. This should respect regionalization when relevant.	TBC

4.8 Electricity modelling

The following electricity mix shall be used in hierarchical order:

- a) Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if :
 - (i) available, and
 - (ii) the set of minimum criteria to ensure the contractual instruments are reliable is met.
- b) The supplier-specific total electricity mix shall be used if:
 - (i) available, and
 - (ii) the set of minimum criteria to ensure the contractual instruments are reliable is met.
- c) The “country-specific residual grid mix, consumption mix” shall be used. Country-specific means the country in which the life cycle stage or activity occurs. This may be an EU country or non-EU country.

¹⁶ Note that the allocation factor is TBC. In the current PEF-RP, no allocation has taken place, it is unclear whether any multi-output processes will occur within the company-specific LC stages and allocation factors for these processes have not yet been investigated. This is something which is going to be further assessed within version two of the PEFCR.

The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in (a) and (b).

- d) As a last option, the average EU residual grid mix, consumption mix (EU+EFTA+UK), or region representative residual grid mix, consumption mix, shall be used.

Note: for the use stage, the consumption grid mix shall be used.

The environmental integrity of the use of supplier-specific electricity mix depends on ensuring that contractual instruments (for tracking) **reliably and uniquely convey claims to consumers**. Without this, the PEF lacks the accuracy and consistency necessary to drive product/ corporate electricity procurement decisions and accurate consumer (buyer of electricity) claims. Therefore, a set of **minimum criteria** that relate to the integrity of the contractual instruments as reliable conveyers of environmental footprint information has been identified. They represent the minimum features necessary to use supplier-specific mix within PEF studies.

Set of minimum criteria to ensure contractual instruments from suppliers

A supplier-specific electricity product/mix may only be used if the user of the PEF method ensures that the contractual instrument meets the criteria specified below. If contractual instruments do not meet the criteria, then country-specific residual electricity consumption-mix shall be used in the modelling.

The list of criteria below is based on the criteria of the GHG Protocol Scope 2 Guidance¹⁷. A contractual instrument used for electricity modelling shall:

Criterion 1 – Convey attributes

- 1) Convey the energy type mix associated with the unit of electricity produced.
- 2) The energy type mix shall be calculated based on delivered electricity, incorporating certificates sourced and retired (obtained or acquired or withdrawn) on behalf of its customers. Electricity from facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the environmental attributes of the country residual consumption mix where the facility is located.

Criterion 2 – Be a unique claim

- 1) Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.
- 2) Be tracked and redeemed, retired, or cancelled by or on behalf of the company (e.g., by an audit of contracts, third party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).

Criterion 3 – Be as close as possible to the period to which the contractual instrument is applied

Modelling “country-specific residual grid mix, consumption mix”:

Datasets for residual grid mix, consumption mix, per energy type, per country and per voltage are made available by data providers.

If no suitable dataset is available, the following approach should be used:

¹⁷ World Resources Institute (WRI) and World Business Council for Sustainable Development WBSD (2015): GHG Protocol Scope 2 Guidance. An amendment to the GHG Protocol. Corporate Standard.

Determine the country consumption mix (e.g., X% of MWh produced with hydro energy, Y% of MWh produced with coal power plant) and combine them with LCI datasets per energy type and country/region (e.g., LCI dataset for the production of 1MWh hydro energy in Switzerland):

Activity data related to non-EU country consumption mix per detailed energy type shall be determined based on:

- 1) Domestic production mix per production technologies;
- 2) Import quantity and from which neighbouring countries;
- 3) Transmission losses;
- 4) Distribution losses;
- 5) Type of fuel supply (share of resources used, by import and / or domestic supply).

These data may be found in the publications of the International Energy Agency (IEA (www.iea.org)).

Available LCI datasets per fuel technologies. The LCI datasets available are generally specific to a country or a region in terms of:

- 1) fuel supply (share of resources used, by import and/or domestic supply);
- 2) energy carrier properties (e.g., element and energy contents);
- 3) technology standards of power plants regarding efficiency, firing technology, flue-gas desulphurisation, NOx removal and de-dusting.

Allocation rules:

Allocation shall be avoided as much as possible, with division of the processes into smaller steps to identify inputs and outputs relevant for a particular drone. This PEFCR defines the following physical relationship in relation to electricity:

- i. In terms of subdividing electricity consumption for a site or process across multiple products, a unit based allocation shall be used, i.e., the total number of pieces assembled or manufactured should form the basis by which to apportion wider production electricity values by.
- ii. If no data is available to subdivide electricity consumption, the average EU+EFTA+UK mix, or relevant regional representative mix shall be used.

In case allocation is needed in a PEF study, unit based allocation shall be used: the inputs and outputs are to be divided equally between the number of drone manufactured during the reference period at the site with use of the reported amount of electricity. If the considered product is being assembled at multiple sites, the following applies:

- if final assembly of one drone is implemented at several sites with transportation of semi-ready product between the sites: amount of electricity per site shall be allocated equally between the number of drone processed at the given step(s) that each site specialises in, and all calculated electricity shall be included in the model with consideration of amounts, sources, and regionalisation.
- If several final assembly lines assemble the same type of drone under study: for each of the sites unit based allocation shall be used. The resulting electricity consumption then shall be modelled for the PEF study as weighted average, weighted on the number of drones assembled at each site. This procedure shall be done with respect to electricity sources and regionalisation.

Table 31: Allocation rules for electricity

Process	Physical relationship	Modelling instructions
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Supplier-specific electricity product	100% tracking system	Use if there is a 100% tracking system in place for the country, or if available and reliable contractual instruments are met.
Supplier-specific total electricity mix	Meets minimum criteria	Use if available and the set of minimum criteria to ensure the contractual instruments are reliable is met.
Country-specific residual grid mix	Consumption mix	Use country-specific residual grid mix, consumption mix for the country where the life cycle stage or activity occurs.
EU residual grid mix	EU+EFTA+UK	Use average EU residual grid mix or region representative residual grid mix as the last option.
Criteria for contractual instruments	Attributes, Uniqueness, Timeliness	A supplier-specific electricity product/mix may only be used if the contractual instrument meets the specified criteria: 1. Convey attributes (energy type mix). 2. Be a unique claim. 3. Be as close as possible to the period applied.
Country-specific data sources	Various factors	Determine country consumption mix, combine with LCI datasets per energy type and country/region. Use IEA publications and available LCI datasets per fuel technologies.
Allocation rules for electricity	Mass, Number of pieces	Avoid allocation by subdividing processes into smaller steps. Use unit-based allocation for subdividing electricity consumption across multiple products. If allocation is needed, inputs and outputs are divided equally between the number of drones manufactured. For multi-site assembly, allocate electricity equally between steps at each site and include all calculated electricity in the model. For multiple final assembly lines, use weighted average electricity consumption based on the number of drones assembled at each site.

If the consumed electricity comes from more than one electricity mix, each mix source shall be used in terms of its proportion in the total kWh consumed. For example, if a fraction of this total kWh consumed is coming from a specific supplier a supplier-specific electricity mix shall be used for this part. See below for on-site electricity use.

A specific electricity type may be allocated to one specific product in the following conditions:

- (a) If the production (and related electricity consumption) of a product occurs in a separate site (building), the energy type physical related to this separated site may be used.
- (b) If the production (and related electricity consumption) of a product occurs in a shared space with specific energy metering or purchase records or electricity bills, the product specific information (measure, record, bill) may be used.

- (c) If all the products produced in the specific plant are supplied with a publicly available PEF study, the company wanting to make the claim shall make all PEF studies available. The allocation rule applied shall be described in the PEF study, consistently applied in all PEF studies connected to the site and verified. An example is the 100% allocation of a greener electricity mix to a specific product.

On-site electricity generation:

If on-site electricity production is equal to the site's own consumption, two situations apply:

- 1) No contractual instruments have been sold to a third party: the own electricity mix (combined with LCI datasets) shall be modelled.
- 2) Contractual instruments have been sold to a third party: the 'country-specific residual grid mix, consumption mix' (combined with LCI datasets) shall be used.

If electricity is produced in excess of the amount consumed on-site within the defined system boundary and is sold to, for example, the electricity grid, this system may be seen as a multifunctional situation. The system will provide two functions (e.g., product + electricity) and the following rules shall be followed:

- 1) If possible, apply subdivision. Subdivision applies both to separate electricity productions or to a common electricity production where you may allocate based on electricity amounts the upstream and direct emissions to your own consumption and to the share you sell out of your company (e.g., if a company has a windmill on its production site and exports 30% of the produced electricity, emissions related to 70% of produced electricity should be accounted in the PEF study).
- 2) If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution¹⁸.

Subdivision is considered as not possible when upstream impacts or direct emissions are closely related to the product itself.

4.9 Climate change modelling

The impact category "climate change" shall be modelled considering three sub-categories:

1. **Climate change – fossil:** This sub-category includes emissions from peat and calcination/carbonation of limestone. The flows falling under this definition should be modelled consistently with the most updated EF list of elementary flows. The names ending with "(fossil)" (e.g., "carbon dioxide (fossil)" and "methane (fossil)") shall be used, if available.
2. **Climate change – biogenic:** This sub-category covers carbon emissions to air (CO₂, CO and CH₄) originating from the oxidation and/or reduction of biomass by means of its transformation or degradation (e.g., combustion, digestion, composting, landfilling) and CO₂ uptake from the atmosphere through photosynthesis during biomass growth – i.e., corresponding to the carbon content of products, biofuels or above ground plant residues such as litter and dead wood. Carbon exchanges from native forests¹⁹ shall be modelled under sub-category 3 (including connected soil emissions, derived products, residues). The emission flows ending with "(biogenic)" shall be used.

A simplified modelling approach shall be used when modelling foreground emissions.

Only the emission "methane (biogenic)" is modelled, while no further biogenic emissions and uptakes from atmosphere are included. If methane emissions can be both fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining fossil methane.

¹⁸ For some countries, this option is a best case rather than a worst case.

¹⁹ Native forests – represents native or long-term, non-degraded forests. Definition adapted from table 8 in Annex V C(2010)3751 to Directive 2009/28/EC.

- 3. Climate change – land use and land use change:** This sub-category accounts for carbon uptakes and emissions (CO₂, CO and CH₄) originating from carbon stock changes caused by land use change and land use. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions). For native forests, all related CO₂ emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forest²⁰ and residues), while their CO₂ uptake is excluded. The emission flows ending with “(land use change)” shall be used.

For land use change, all carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI 2011) and the supplementary document PAS2050-1:2012 (BSI 2012) for horticultural products. PAS 2050:2011 (BSI 2011): “Large emissions of GHGs can result as a consequence of land use change. Removals as a direct result of land use change (and not as a result of long-term management practices) do not usually occur, although it is recognized that this could happen in specific circumstances. Examples of direct land use change are the conversion of land used for growing crops to industrial use or conversion from forestland to cropland. All forms of land use change that result in emissions or removals are to be included. Indirect land use change refers to such conversions of land use as a consequence of changes in land use elsewhere. While GHG emissions also arise from indirect land use change, the methods and data requirements for calculating these emissions are not fully developed. Therefore, the assessment of emissions arising from indirect land use change is not included.

The GHG emissions and removals arising from direct land use change shall be assessed for any input to the life cycle of a product originating from that land and shall be included in the assessment of GHG emissions. The emissions arising from the product shall be assessed on the basis of the default land use change values provided in PAS 2050:2011 Annex C, unless better data is available. For countries and land use changes not included in this annex, the emissions arising from the product shall be assessed using the included GHG emissions and removals occurring as a result of direct land use change in accordance with the relevant sections of the IPCC (2006). The assessment of the impact of land use change shall include all direct land use change occurring not more than 20 years, or a single harvest period, prior to undertaking the assessment (whichever is the longer). The total GHG emissions and removals arising from direct land use change over the period shall be included in the quantification of GHG emissions of products arising from this land on the basis of equal allocation to each year of the period²¹.

- 1) Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out, no emissions from land use change should be included in the assessment.
- 2) Where the timing of land use change cannot be demonstrated to be more than 20 years, or a single harvest period, prior to making the assessment (whichever is the longer), it shall be assumed that the land use change occurred on 1 January of either:
 - a) the earliest year in which it can be demonstrated that the land use change had occurred; or
 - b) on 1 January of the year in which the assessment of GHG emissions and removals is being carried out.

“The following hierarchy shall apply when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvest period, prior to making the assessment (whichever is the longer):

²⁰ Following the instantaneous oxidation approach in IPCC 2013 (Chapter 2).

²¹ In case of variability of production over the years, a mass allocation should be applied

- 1) Where the country of production is known and the previous land use is known, the GHG emissions and removals arising from land use change shall be those resulting from the change in land use from the previous land use to the current land use in that country (additional guidelines on the calculations can be found in PAS 2050- 1:2012);
- 2) Where the country of production is known, but the former land use is not known, the GHG emissions arising from land use change shall be the estimate of average emissions from the land use change for that crop in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012);
- 3) Where neither the country of production nor the former land use is known, the GHG emissions arising from land use change shall be the weighted average of the average land use change emissions of that commodity in the countries in which it is grown.

Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used. Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied. Data sources, location and timing of land use change associated with inputs to products shall be reported.” [end of quote from PAS 2050:2011]

Soil carbon storage shall not be modelled, calculated, and reported as additional environmental information. However, if soil carbon storage contributes more than 5% to the total environmental impact score, it shall be reported separately.

The sum of the three sub-categories shall be reported.

The sub-category ‘Climate change-biogenic’ shall not be reported separately.

The sub-category ‘Climate change-land use and land transformation’ shall not be reported separately.

4.10 Modelling of end of life and recycled content

The end of life of products used during the manufacturing, distribution, retail, the use stage or after use shall be included in the overall modelling of the life cycle of the organisation. Overall, this should be modelled and reported at the life cycle stage where the waste occurs. This section provides rules on how to model the end of life of products as well as the recycled content.

The Circular Footprint Formula (CFF) is used to model the end of life of products as well as the recycled content and is a combination of "material + energy + disposal", i.e.,:

► Equation 5: CFF equation: Material

$$(1 - R_1)E_v + R_1 \times \left(AE_{recycled} + (1 - A) \times \frac{Q_{sin}}{Q_p} \right) + (1 - A)R_2 \times \left(AE_{recycledEoL} - E_v^* \times \frac{Q_{sout}}{Q_p} \right)$$

► Equation 6: CFF equation: Energy

$$(1 - B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

► **Equation 7: CFF equation: Disposal**

$$(1 - R_2 - R_3) \times E_D$$

With the following parameters:

- **A**: allocation factor of burdens and credits between supplier and user of recycled materials.
- **B**: allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.
- **Q_{sin}**: quality of the ingoing secondary material, i.e., the quality of the recycled material at the point of substitution.
- **Q_{sout}**: quality of the outgoing secondary material, i.e., the quality of the recyclable material at the point of substitution.
- **Q_p**: quality of the primary material, i.e., quality of the virgin material.
- **R₁**: it is the proportion of material in the input to the production that has been recycled from a previous system.
- **R₂**: it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R₂ shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R₂ shall be measured at the output of the recycling plant.
- **R₃**: it is the proportion of the material in the product that is used for energy recovery at EoL.
- **E_{recycled} (E_{rec})**: specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
- **E_{recyclingEoL} (E_{recEoL})**: specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.
- **E_v**: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.
- **E_v^{*}**: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
- **E_{ER}**: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g., incineration with energy recovery, landfill with energy recovery, etc.).
- **E_{SE,heat} and E_{SE,elec}**: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.
- **E_D**: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
- **X_{ER,heat} and X_{ER,elec}**: the efficiency of the energy recovery process for both heat and electricity.
- **LHV**: lower heating value of the material in the product that is used for energy recovery.

While the disposal might happen world-wide, the EoL treatment shall be modelled based on the European disposal parameters. Default circular footprint formula parameters that shall be used in modelling, are provided in Table 32.

A parameter

The following hierarchy shall be followed in respect to selecting a value to represent parameter A for each material:

1. The A value shall be taken from Table 32.
2. The default value of A = 0.5 shall be taken.

B parameter

The following hierarchy shall be followed in respect to selecting a value to represent parameter B for each material:

1. The default value of B = 0 shall be taken.

R₁ parameter

The following hierarchy shall be followed in respect to selecting a value to represent parameter R₁ for each material:

1. If the PEFCR user has access to a company specific applicable R₁ value, then this shall be used in line with the requirements of section 4.4.8.6 Recycled content (R₁) of the PEFCR guidance¹⁵ and with an explanation of the source.
2. If no company-specific value is available, then the R₁ value given in **Table 32** shall be used (this reflects the application-specific value as per part C of annex I of the PEFCR guidance¹⁵)
3. If there is no application-specific value in **Table 32**, then R₁ shall be set to 0. Note that material-specific values based on supply market statistics are not accepted as a proxy and therefore shall not be used).

R₂ parameter

The following hierarchy shall be followed in respect to selecting a value to represent parameter R₂ for each material:

1. The R₂ value shall be taken from Table 32.
2. The default value of R₂ = 0 shall be taken.

Q_s/Q_p parameter

The following hierarchy shall be followed in respect to selecting a value to represent parameter Q_s/Q_p for each material:

1. The Q_s/Q_{out} value shall be taken from Table 32.
2. The default value of Q_s/Q_p = 0 shall be taken.

If the CFF parameters for a specific material are not provided in Table 32, the user of the PEFCR shall refer to the PEF method and Annex C of the PEF method (JRC, 2021). In case the values are not provided there, the user shall set default values: A = 0.5, B = 0, R₁ = 0, R₂ = 0 and Q_s = 0. Deviation from the parameters is allowed only for the parameter R₁, when company specific data is available.

All datasets to be used for E_{rec}, E_{recEoL}, E_v, E_v^{*}, E_{ER}, E_{SE,heat} and E_{SE,elec}, E_D are provided in the Excel Annex II to the PEFCR (section 5b. waste processing), including DQRs.

► **Table 32: CFF parameters**

Material	A	B	Q _s /Q _p	R ₁	R ₂	R ₃ (share of the non-recycled material sent to energy recovery)
Drone						
Steel	0.2	0	1	0	0.85	0.06 (0.38)
Aluminium	0.2	0	1	0	0.85	0 (0)

Copper	0.2	0	1	0	0.95	0 (0)
Paper	0.2	0	0.85	0	0.62	0.37 (0.98)
Polymers	0.5	0	1*	0	0	0.77 (0.77)

* non-mechanical recycling

Modelling recycled content

The following part of the Circular Footprint Formula is used to model the recycled content:

► Equation 8: CFF recycled content – Manipulated version of Equation 5

$$(1 - R_1) \times E_v + R_1 \times (A \times E_{\text{recycled}} + (1 - A)E_v \times \frac{Q_{\text{Sin}}}{Q_p})$$

The R_1 values applied shall be supply-chain specific or default as provided in the table above (Table 32), in relation with the DNM. Material-specific values based on supply market statistics are not accepted as a proxy and therefore shall not be used. The applied R_1 values shall be subject to PEF study verification.

When using supply-chain specific R_1 values other than 0, traceability throughout the supply chain is necessary. The following guidelines shall be followed when using supply-chain specific R_1 values:

1. The supplier information (through e.g., statement of conformity or delivery note) shall be maintained during all stages of production and delivery at the converter;
2. Once the material is delivered to the converter for production of the end products, the converter shall handle information through their regular administrative procedures;
3. The converter for production of the end products claiming recycled content shall demonstrate through its management system the [%] of recycled input material into the respective end product(s).
4. The latter demonstration shall be transferred upon request to the user of the end product. In case a PEF profile is calculated and reported, this shall be stated as additional technical information of the PEF profile.
5. Company-owned traceability systems may be applied as long as they cover the general guidelines outlined above.

5. LIFE CYCLE STAGES

The following sub-sections describe the life cycle stages that shall be included in the scope of this PEFCR. These sections list (or make reference to) all technical requirements and assumptions to be applied by the user of the PEFCR, as well as the processes taking place in each life cycle stage (as applied in the modelling of the RP). Associated process tables can be found in the Excel Annex II of the PEFCR.

For all processes the DQR values shall be reported (for each criterion + total) for all the datasets used. For consistency across all European countries, all PEF studies shall use the generic European downstream scenarios (distribution, use & end of life) as defined in this PEFCR. It is not allowed to deviate from these default parameters.

5.1 LC stage 1. Raw material acquisition and pre-processing

This life cycle stage consists of raw material acquisition and processing required to produce the different component groups that are needed for drone manufacturing. This stage begins when the raw materials are extracted and ends when the components are transported to the final assembly site.

All listed substages are not expected to consist of company-specific data. There are seven component groups considered applicable for a drone in this PEFCR:

- 1a – Airframe
- 1b – Systems
- 1c - Battery
- 1d - Cargo hold
- 1e – Propulsion system
- 1f - Landing gear
- 1g – Packaging

Note that the transportation of the packaged component groups to the final assembly site is considered within the stage as well, as LC stage 1h. The waste generated in this LC stage shall be modelled in this LC stage, using the circular footprint formula (see the parameters in section 4.10, and the associated processes in Excel Annex II).

For the substages listed above, there exists a partial overlap in the technical requirements and assumptions. Technical requirements and assumptions which should be applied to all of the stages are given below:

- The raw material production processes are never expected to be run by the company.
- The raw materials list and quantities are based on the Bill of Materials/Bill of components. When modelling, the company-specific data from the Bill of Materials/Bill of Components on the amount of materials used shall be adjusted on the production losses rate.
- Amount of the raw material supplied to processing shall be modelled with the total production losses rate of 140%. Note for complete components (e.g. batteries or motors) it is not necessary to apply the scaling factor as it is assumed there are no losses during assembly.
- Processing steps shall be modelled based on the known significant characteristics of the material. The share of the material processed in each processing step shall be defined, and quantity of processing shall incorporate the production losses ratio.
- Recycled content of the material, and processing of the material waste shall be modelled with CFF (see parameters and requirements in section 4.10). Modelling of waste treatment shall follow the default process modelling (as provided in the EoL section of Excel annex II).

- If company specific transport data is not available, default transportation distances from the PEF method shall be used to model transport of the raw materials to processing: 1,000km by truck, 18,000km by sea (transoceanic containership).
- If company specific transport data is available and includes multiple supplier locations and/or transport modes, weighted average distances for each included transport mode shall be calculated.
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).

The following subsections provide all sub-stage specific technical information and assumptions to be applied and references to default datasets to be used where primary data is not available.

5.1.1 LC stage 1a. Airframe production

The stage considers the production of the required raw materials and components used for the structure of the drone. This shall include the materials used and materials processing (including utilities consumed, and production wastes and emissions generated).

The drone airframe is assumed to be manufactured with the use of a standard list of materials (already listed in Table 23), undergoing specific processing. The following materials are considered standard, with standard processing practices. These materials' processing shall therefore be modelled using the default processes composition provided in the Excel Annex II, including the percentage uplift for waste.

- CFRP for airframe
- Polystyrene foam for airframe
- Fibreboard for airframe
- Paint for airframe
- Epoxy resin for airframe
- Aluminium for airframe
- Nylon 6 for airframe
- LED for airframe
- Wiring for airframe
- Connectors for airframe
- Nuts and bolts for airframe

The deviation from this is possible based on company specific data. The deviation shall be justified in the report and the component manufacturing modelling adjusted proportionally.

Apart from the standard materials mentioned above (and in Excel Annex II), other materials might be relevant. If other materials are used in manufacturing of the drone component groups, with the mass and expected environmental impacts exceeding the 3% cut-off threshold, the modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

5.1.2 LC stage 1b. Systems production

The stage considers production of the drone systems, including the materials used and materials processing (including utilities consumed, and production wastes and emissions generated). The systems to be covered are listed as follows:

- System casing

- Communication systems
- Heat sinks
- PCBs (Electronics)
- Siren
- Parachute
- Wiring
- Capacitors
- Transistors
- Steel

When modelling, the default processes provided in the Excel Annex II shall be used.

Apart from the standard components mentioned above (and in Annex II), other components might be used. If other components are used in the systems, and it is not logically possible to allocate the component to one of the groups above, and the mass and expected environmental impacts are exceeding the 3% cut-off threshold, the modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

5.1.3 LC stage 1c. Battery production

The stage considers production of the battery of the drone, including the materials used and materials processing (including utilities consumed, and production wastes and emissions generated). The systems to be covered are listed as follows:

- Drone battery

At this stage, there is a lack of specific data about battery production for drone vehicles.

The battery model will either need to be completed using the Battery PEF LCI²² (CPT Li-ion battery) or be based on a PEF battery study specific to that which is used for the specific drone under study.

The modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

When modelling, the default processes provided in the Excel Annex II shall be used.

5.1.4 LC stage 1d. Cargo hold production

The stage considers production of the drone cargo hold, including the materials used and materials processing (including utilities consumed, and production wastes and emissions generated). The components of the cargo hold system to be covered are listed as follows:

- Payload box
- Payload box securing
- Winch

²² Note that an update to this is current under development – This version has used to out-dated PEFCR LCI found in the following link: wayback.archive-it.org/org-1495/20221004164603mp/https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm

It should be noted that of the drones included within the data collection, one third of drones studied utilised a winch to deliver the package during a hover phase. As such, the default dataset aligns with this observation (requiring one third of a winch).

When modelling, the default processes provided in the Excel Annex II shall be used.

Apart from the standard components mentioned above (and in Annex II), other components might be used. If other components are used in the systems, it is not logically possible to allocate the component to one of the groups above, and the mass and expected environmental impacts are exceeding the 3% cut-off threshold, the modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

5.1.5 LC stage 1e. Propulsion system production

The stage considers production of the drone's propulsion system, including the materials used and materials processing (including utilities consumed, and production wastes and emissions generated). The components of the propulsion system to be covered are listed as follows:

- Motor mount
- Motor
- Rotors

When modelling, the default processes provided in the Excel Annex II shall be used.

Apart from the standard components mentioned above (and in Annex II), other components might be used. If other components are used in the systems, it is not logically possible to allocate the component to one of the groups above, and the mass and expected environmental impacts are exceeding the 3% cut-off threshold, the modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

5.1.6 LC stage 1f. Landing gear production

The stage considers production of the that make up the landing gear of the drone. This includes the materials used and materials processing (including utilities consumed, and production wastes and emissions generated).

The landing gear for drones are assumed to be composed of several standard groups of components. The following components are considered:

- Landing gear

When modelling, the default processes provided in the Excel Annex II shall be used.

Apart from the standard components mentioned above (and in Annex II), other components might be used. If other components are used in the systems, it is not logically possible to allocate the component to one of the groups above, and the mass and expected environmental impacts are exceeding the 3% cut-off threshold, the modelling of the processed material shall be implemented by the practitioner following the technical requirements and assumptions listed in section 5.1 above.

5.1.7 LC stage 1g. Packaging production

The stage considers production of the packaging materials need to package all of the aforementioned component groups, prior to them being transported to the final assembly site. This includes the materials used and materials processing (including utilities consumed, and production wastes and emissions generated).

The some aspects of the technical requirements and assumptions to be applied to packaging are different to those listed at the start of section 6.1. The full list is listed as follows in order to provide clarity, and where different to those listed in section 6.1, shall be considered to override those at the start of section 6.1.

Technical requirements and assumptions:

- The packaging material production processes are never expected to be run by the company.
- Default amount and composition of packaging shall be used: 0.195 kg/kg of component, including 25% of plastic packaging, 25% of paper packaging, and 50% of wooden packaging.
- Recycled content of the material, and processing of the packaging material waste shall be modelled with CFF (see parameters and requirements in section 5.10). Modelling of waste treatment shall be done on a material composition basis and using the default process modelling (as provided in the EoL section of Excel Annex II).
- If company specific transport data is not available, default transportation distances from the PEF method shall be used to model transport of the packaging materials to the components manufacturing: 230km by truck, 280km by train, and 360km by inland waterways.
- If company specific transport data is available and includes multiple supplier locations and/or transport modes, weighted average distances for each included transport mode shall be calculated.
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).

When modelling, the default processes provided in the Excel Annex II shall be used.

5.1.8 LC stage 1h. Component transportation

The result of the raw material acquisition and pre-processing in the substages 1a-1f are components ready to be supplied to final assembly.

Stage 1h includes transport of the packaged components to the final assembly site.

Technical requirements and assumptions:

- Total mass of the supplied component with accounted production losses and packaging shall be used for transportation modelling.
- If company specific transport data is not available, default transportation distances to model transport of the components to the final assembly are: 2,400km by truck, 50,000km by sea (transoceanic containership), and 1,200km by air. These defaults are based on input from industry representatives.
- If company specific transport data is available and includes multiple supplier locations and/or transport modes, weighted average distances for each included transport mode shall be calculated.
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).

Default processes for modelling transport of the components to the final assembly site are provided in the Excel Annex II.

5.2 LCS 2. Manufacturing

This life cycle stage consists of the manufacturing required to produce the final drone. This includes the following sub-stages:

- 2a - Drone final assembly
- 2b – Testing flights
- 2c – Final assembly infrastructure

5.2.1 LC stage 2a. Drone final assembly

This stage begins when the product components enter the final production site and ends when the finished drone is ready to leave the final assembly site. It includes all the manufacturing processes and utilities required for the final assembly of the drone. Final assembly refers to the point where the separate component groups of the vehicle (as laid out in section 5.1) are put together into a functional flight-ready product prepared for delivery.

For this stage, company-specific data is required to model the final assembly of the drone. This should be conducted in-line with the requirements and assumptions listed below and contain all information provided in section 5.1 above.

Technical requirements and assumptions:

- The waste of products used during manufacturing shall be included in the modelling.
- Data on waste generation at the final assembly site shall be collected as activity data as a minimum on the level of four categories: hazardous waste, non-hazardous metal waste, other non-hazardous waste, and wastewater.
- The processes shall include the quantities of drone specific component and packaging material inputs, the use of supplies and energy, and the production of waste.
- In the absence of manufacture and site specific data on waste generation, a default loss rate of 8% shall be applied for all component groups.
- Further waste processing shall be modelled with the CFF, according to the EoL process modelling (as provided in the EoL section of Excel Annex II)

Transportation of one drone (semi-product) between the final assembly sites can be introduced if a phase of the final assembly (e.g., seat fitting) is carried out on another site. The transportation processes within the assembly shall be modelled if relevant. If transport is implemented by the mean of the drone flight itself, the guidance in section 6.2.2 and 6.4.1 shall be used with activity data for journey distances applied. For transportation between such sites, the modelling shall be based on the activity data in tkm per mean of transportation, using primary data. A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data) unless site-specific data is available.

The related processes provided in the Excel Annex II shall be used.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.2.2 LC stage 2b. Testing flights

This stage covers the energy needed for a set quantity of test flights. Before delivery to the customer, each assembled drone must undergo testing to ensure its reliability and safety. This testing includes flights necessary for certification but excludes any flights conducted for research and development purposes.

Company-specific data is required for this stage, specifically for the SAIL category and certain parameters for the energy use calculation.

Technical requirements and assumptions:

- The required flight hours shall be taken from Table 22 and be based on the SAIL category of the drone.
- The energy consumption of the drone associated with the respective flight hours for the relevant SAIL category shall be calculated.
- The energy consumption calculations shall be based on the activity data for one flight under the specified parameters (see Table 33).
- The number and distance of the test flights required for each drone shall be determined as an average, based on the typical number of test flights conducted for products in this category.

In Table 25, default parameters of the test flight are declared, based on a drone within SAIL category II.

- FH: Total Flight Hours required for testing (hours), which is fixed to 30 hours.
- JD: Regular Journey Distance (km)²³.
- JT_{min}: Regular Journey Time (minutes).
- EC: Energy Consumption rate (kWh per km).
- TF: number of test flights.

► **Table 33: Default number and distance of test flights, given 30 FH (Example of SAIL II)**

	Default Parameters	Parameter type
Number of journeys	90	Company-specific
JD	24km	Fixed parameter
JT	20 minutes	Company-specific
Journey distance during take-off sequence (JD _{TO})	2km	Company-specific
Journey distance during landing sequence (JD _L)	2km	Company-specific
Journey distance during cruise (JD _C)	20km	Company-specific

The following equations shall be used by the PEFCR user in order to calculate the necessary number of test flights (TF) of its drone needed to reach 30 FH. The equation can account for different flight durations and distances, as well as the energy consumption rates, which are relevant for electrically powered vehicles like drones.

► Equation 9: Number of flights to meet testing requirements

$$\text{Number of flights} = \frac{FH}{JT} = \frac{30 \text{ hours}}{20 \text{ minutes}} = \frac{30}{\frac{1}{3}} = 90 \text{ flights}$$

Note that the above formula works assuming that the speed is not changing between flights, namely every journey uses the same speed.

²³ not affecting the total flight hours (FH) but is relevant for energy consumption calculations

In addition, to compute also the total energy consumption linked to TF, the above formula can be extended as follows:

► **Equation 10:** Energy used per flight, based on parameters given in Table 33 and Table 34

$$\text{Energy per Flight} = (E_{TO} \times JD_{TO}) + (E_C \times JD_C) + (E_L \times JD_L)$$

► **Equation 11:** Energy used for full lifetime of test flights

$$TF \text{ Total Energy} = \text{Number of flights} \times \text{Energy per Flight}$$

► **Table 34:** Phases of flight for drones

Flight phase	Take-off	Cruise	Landing
Energy use	E_{TO}	E_C	E_L
Unit of energy consumption	kWh	kWh	kWh
Consumption per distance / count	Per km travelled in take-off sequence	Per km travelled	Per km travelled in landing sequence

The above equations assume that the energy consumption rate (E_i) per kilometre (JD) is constant for each phase of the flight.

The related processes provided in the Excel Annex II shall be used.

5.2.3 LC stage 2c. Final assembly infrastructure

Within this stage, the necessary data to collect includes all manufacturing infrastructure that is needed for manufacturing work including as a minimum land footprint and building structure. As discussed in section 4.1, company-specific data shall be used for this stage and shall include the total volume of the manufacturing facility which is required to produce one drone. This only includes areas where manufacturing takes place, any administrative or non-manufacturing areas are not included within this stage.

If the manufacturing facility only conducts the final assembly of the drone (and no other products), the total volume of building required to produce one drone can be calculated as follows. The total building volume may be scaled based on the number of drones produced at the facility.

► **Equation 12:** Calculation for the volume of one drone.

$$\text{Volume for one drone} = \frac{\text{Total building volume for manufacturing the final drone}}{\text{Number of drones produced during the building's lifetime}}$$

If the manufacturing facility produces more products than exclusively the drone under study then the following hierarchy shall be followed:

1. If the products are produced in a distinct location within the facility, then the volume of the drone production shall be used.
2. If the products are produced in shared locations within the facility, then the total manufacturing area shall be scaled based on the percentage of drones produced. E.g., if 1,000 drones are produced and

9,000 of another product are produced, then 10% ($1,000/(9,000+1,000)$) of the total manufacturing area shall be assigned to the drone under study.

The total volume required for one drone shall then be modelled using the default processes specified within Excel Annex II.

All other infrastructure required to assemble the final drone shall also be included with this stage.

5.3 LC stage 3. Distribution

5.3.1 LC stage 3a. Delivery transport

This stage begins when the product is ready to leave the final assembly site and ends when the product arrives at the location of operation.

Transport from factory (final assembly) to the final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as the organisation that operates the drone during the use stage. This stage shall be modelled based on the following requirements.

Technical requirements and assumptions:

- The total mass of the supplied drone with packaging shall be used for transportation modelling.
- If company specific transport data is not available, default transportation distances to model transport of the components to the final assembly are: 1,000km by truck, 18,000km by sea (transoceanic containership). These defaults are based on the international supply chain values given by PEF.
- If company specific transport data is available and includes multiple supplier locations and/or transport modes, weighted average distances for each included transport mode shall be calculated.
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data). The user of the PEFCR shall always check the utilisation ratio applied in the default dataset and adapt it accordingly.

In the case supply-chain-specific information is available for one or several transport parameters, they may be applied following the Data Needs Matrix (DNM).

The user of the PEFCR shall report the DQR values (for each criterion + total) for all datasets used.

The related processes provided in the Excel Annex II shall be used.

5.4 LC stage 4. Use

The use stage shall cover the operational flights of the drone (electricity), respective cargo services, ground services, and vertiport infrastructure requirements during the drone's useful lifetime. Maintenance and refurbishment activities are also covered.

This stage begins when the product arrives at the location of operation and ends when the product reaches the end of its service life and is ready for the decommissioning process.

5.4.1 LC stage 4a. Operational flights

This life cycle stage considers the operational flights during the useful lifetime of the drone, in particular energy used in flights during each phase of the flight. Specific data in relation to the drone under study from the user of the PEFCR shall be used.

Technical requirements and assumptions:

- The average annual number of flight and the distance one flight shall be taken as default. These parameters are given in Table 35 below.
- The company undertaking the PEF study shall provide activity data for the energy use per kilometre (kWh/km) during each phase of flight. Based on this version of the PEFCR, this should cover a minimum of take-off, cruise and landing. This data shall match the testing data described within Section 5.2.2.
- The company undertaking the PEF study shall provide product-specific data for the reference service life of the drone.
- For the use stage the consumption grid mix shall be used. The electricity mix shall reflect the ratios of sales between EU countries/regions. To determine the ratio a physical unit shall be used (e.g., number of products). Where such data are not available, the average EU consumption mix (EU+EFTA+UK), or region-representative consumption mix, shall be used.

► **Table 35:** List of relevant parameters to calculate the total amount of electricity used during the lifetime of the drone

Parameter	Value	Unit	Parameter type
Average annual number of flights	2,190	Flights per year	Fixed parameter
Distance per flight	24	km	Fixed parameter

► **Table 36:** Flight data for one flight (partial copy of Table 33 from Section 6.2.2)

	Default Parameters	Parameter type
Journey distance during take-off sequence (JD_{TO})	2km	Company-specific
Journey distance during landing sequence (JD_L)	2km	Company-specific
Journey distance during cruise (JD_C)	20km	Company-specific

The total energy use per flight shall be calculated as follows:

► **Equation 13:** Energy used per flight, based on parameters given in Table 35 and Table 36

$$\text{Energy per Flight} = (E_{TO} \times JD_{TO}) + (E_C \times JD_C) + (E_L \times JD_L)$$

► **Equation 14:** Energy used for full lifetime of operational flights

$$OF \text{ Total Energy} = RSL \times ANF \times \text{Energy per Flight}$$

Default processes for modelling the energy use for the average drone flight are provided in the Excel Annex II.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.4.2 LC stage 4b. Ground services

This life cycle stage considers ground services provided to the vehicle during its useful lifetime. This stage includes any consumables or utilities (excluding charging) which take place in-between regular flight operations. This does not include maintenance (see Section 5.4.5). Based on discussions with industry representatives, current ground servicing is entirely manual, consisting of visual checks. Therefore, ground servicing is assumed to include no material, energy or process flows.

However, automation of ground servicing is possible and would lead to material, energy and process flows. Therefore, this stage remains within the system boundary for the PEFCR, but it is empty by default in this version, with company-specific data being required to model automated ground servicing. The requirements of this are described below.

Technical requirements and assumptions:

- The amount of materials (kg) or energy (kWh) inputs shall be measured per flight. This shall be scaled using the lifetime number of flights (RSL x ANF) to reflect the total inputs during the lifetime.
- Amount of the material supplied to ground servicing shall be modelled with the total losses rate of 110% (1.1kg per 1kg used).
- If company specific transport data is not available, default transportation distances from the PEF method shall be used to model transport of the materials to final client: 1,000km by truck, 18,000km by sea (transoceanic containership).
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).
- Processing of waste generated in the passenger services shall be modelled with CFF see parameters and requirement in section 5.10.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.4.3 LC stage 4c. Cargo services

This life cycle stage considers cargo servicing provided over the useful lifetime of the drone. This includes any active heating or cooling used during flight and any other necessary storage services for the cargo. Similarly to ground services, based on discussions with industry representatives, not active heating or cooling currently exists for cargo. Therefore, the cargo services stage is assumed to include no material, energy, or process flows, when used.

While there does not currently exist a drone with active heating or cooling, it was not ruled out as an option for future development by some industry representatives. Therefore, this stage remains within the system boundary for the PEFCR, but it contains no material, energy or process flows in this version, with company-specific data being required to model any cargo services. The requirements for this are described below.

Technical requirements and assumptions:

- The amount of materials (kg) or energy (kWh) inputs shall be measured per flight. This shall be scaled using the lifetime number of flights (RSL x ANF) to reflect the total inputs during the lifetime.
- Amount of the material supplied to ground servicing shall be modelled with the total losses rate of 110% (1.1kg per 1kg used).

- If company specific transport data is not available, default transportation distances from the PEF method shall be used to model transport of the materials to final client: 1,000km by truck, 18,000km by sea (transoceanic containership).
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.4.4 LC stage 4d. Vertiport infrastructure

A drone hub is an area of infrastructure to facilitate secure take-offs and landings of a drone. Establishing a drone hub requires a flat plot of land and the landing pad is a crucial element of the drone hub. This also contains any charging infrastructure required for each drone during its lifetime. PEFCR users are directed to Excel Annex II for the default values. Adjustments based on company-specific data or local operational needs are advised.

Initially, the landing pad is to be constructed with minimal technological enhancements to maintain simplicity and manage costs. As industry standards evolve and market stability is achieved, these specifications may be adapted to include more advanced technological integrations.

As the drone industry develops, the design and specifications of the drone hub infrastructure are anticipated to be refined.

5.4.5 LC stage 4e. Maintenance and refurbishment

This life cycle stage considers scheduled maintenance and refurbishment of the drone during its useful lifetime. Due to the infancy of the drone industry, insufficient data was identified to accurately model unscheduled maintenance during the lifetime of a drone, therefore it is not considered within the default datasets for this version of the PEFCR.

5.4.5.1 Maintenance

This substage considers scheduled and unscheduled maintenance of a drone during its lifetime. For the first iteration of the PEFCR, the maintenance data is not complete. A summary of what has been included within the default datasets is described below. For the RP in this PEFCR, only the battery and motor maintenance has been defined. It is strongly advised that any company conducting a PEF study utilise company-specific data for this sub-stage, specifically for the battery replacement rate.

Technical requirements and assumptions:

- Drone default maintenance inputs are provided in the following Table 37.
- Maintenance inputs and outputs shall be modelled based on company-specific data of the drone under study, in line with the certification requirements, when available.
- Auxiliary material delivery to the maintenance shall be modelled as supplied locally with the following distances: 130km by truck, 240 km by train, and 270km by inner waterways. A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).
- For the use stage the consumption grid mix shall be used. The electricity mix shall reflect the ratios of sales between EU countries/regions. To determine the ratio a physical unit shall be used (e.g., number of products). Where such data are not available, the average EU consumption mix (EU+EFTA+UK), or region-representative consumption mix, shall be used.

- If company-specific data is to be used to update the replacement battery rate, this shall be based on the number of cycles before the battery no longer charges beyond 80%²⁴ capacity.

► **Table 37: Maintenance default values for drones**

Vehicle type	Parameter	Replacement rate	Maintenance type
Drone	Battery	Batteries are replaced every 600 flights. (1 cycle = 1 flight)	Replacement Parts
Drone	Motor	Motors are replaced every 500 flights. (1 cycle = 1 flight)	Replacement Parts

Default processes for modelling the drone maintenance are provided in the Excel Annex II.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.4.5.2 Refurbishment

This substage considers the necessary refurbishments for drone systems and bodies in order for them to continue to be operational. It should be noted that at this stage of the industry, very few drones have reached the end of their serviceable life and where this has occurred, technological advancements have removed the need for refurbishment. The PEFCR acknowledges that there will exist a need for refurbishment and the related technical requirements and assumptions are listed below. However, for the current default datasets and the current version of the PEF-RP do not include any flows relating to the refurbishment of drones.

If a company were to plan to refurbish the model of drone to allow for a longer service life, the necessary material, energy and process flows to be included within the model must meet the technical requirements discussed below.

Technical requirements and assumptions

- The reference service life of the drone shall be prescribed by the company. Refurbishment frequencies must be defined for every component group or sub-component and shall not exceed the reference service life of the drone.
- Modelling of the component groups input for refurbishment shall be identical to those assumed for modelling in the drone final assembly. The necessary materials and manufacturing processes shall be included for each component group.
- Default transportation distances to model transport of the components to the final assembly are: 2,400km by truck, 50,000km by sea (transoceanic containership), and 1,200km by air.
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).
- Waste generated in refurbishment, discarded parts and components, shall be modelled with CFF (see requirements and parameters in section 4.10). Modelling of waste treatment shall be done on a material composition basis and using the default process modelling (as provided in the EoL section of Excel annex II).

²⁴ Note that the 80% value is a value chosen based on discussions with industry representatives. The PEFCR notes that the industry representatives suggested that this value be based on safety requirements defined by EASA.

- For the use stage the consumption grid mix shall be used. The electricity mix shall reflect the ratios of sales between EU countries/regions. To determine the ratio a physical unit shall be used (e.g., number of products). Where such data are not available, the average EU consumption mix (EU+EFTA+UK), or region-representative consumption mix, shall be used.

Default processes for modelling of aircraft refurbishment are not provided in the Excel Annex II.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

5.5 LC stage 5. End of life

The end of life stage begins when the product in scope and its packaging is discarded by the user and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e., as a recycled input). In general, it includes the waste of the product in scope, such as the food waste, and primary packaging.

Other waste (different from the product in scope) generated during the manufacturing, distribution, retail, use stage or after use shall be included in the life cycle of the product and modelled at the life cycle stage where it occurs.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used. The end of life shall be modelled using the circular footprint formula and rules provided in section 'End of life modelling' of this PEFCR and in the PEF method, together with the default parameters listed in Table 32.

Before selecting the appropriate R_2 value, the user of the PEFCR shall carry out an evaluation for recyclability of the material. The PEF study shall include a statement on the recyclability of the materials/ products. The statement on recyclability shall be provided together with an evaluation for recyclability that includes evidence for the following three criteria (as described by ISO 14021:1999, section 7.7.4 'Evaluation methodology'):

1. The collection, sorting and delivery systems to transfer the materials from the source to the recycling facility are conveniently available to a reasonable proportion of the purchasers, potential purchasers and users of the product;
2. The recycling facilities are available to accommodate the collected materials;
3. Evidence is available that the product for which recyclability is claimed is being collected and recycled.

Point 1 and 3 can be proven by recycling statistics (country specific) derived from industry associations or national bodies. Approximation to evidence at point 3 can be provided by applying for example the design for recyclability evaluation outlined in EN 13430 Material recycling (Annexes A and B) or other sector-specific recyclability guidelines if available.

Following the evaluation for recyclability, the appropriate R_2 values (supply-chain specific or default) shall be used. If one criterion is not fulfilled or the sector-specific recyclability guidelines indicate limited recyclability, an R_2 value of 0% shall be applied. Company-specific R_2 values (measured at the output of the recycling plant) shall be used, if available. If no company-specific values are available and the criteria for the evaluation of recyclability are fulfilled (see below), application-specific R_2 values shall be used as listed in the table below.

- a) If an R_2 value is not available for a specific country, the European average shall be used.

- b) If an R_2 value is not available for a specific application, the R_2 values of the material shall be used (e.g. materials average).
- c) In case no R_2 values are available, R_2 shall be set equal to 0 or new statistics may be generated in order to assign an R_2 value in the specific situation.

The applied R_2 values shall be subject to the PEF study verification.

5.5.1 LC stage 5a. End of life transport

This stage considers the transport of the drone upon its decommissioning to the final disassembly site.

Technical requirements and assumptions:

- If company specific transport data is available and includes multiple supplier locations and/or transport modes, weighted average distances for each included transport mode shall be calculated.
- If company specific transport data is not available, default transportation distances to model transport of the components to the final assembly are: 1,000km by truck, 18,000km by sea (transoceanic containership).
- A total utilization rate of the truck is 64% (Utilization & empty return is applied in line with the PEF default data).
- In case a company wants to deviate from the default EoL transport values above and use company specific EoL flight data a global average company specific delivery journey scenario shall be developed. This shall be a weighted average of the actual flight distances for the full global operations of the products the company is analysing. This analysis shall be added to the PEF Study background report.

End of life transport distances used within the PEF-RP are provided within Excel Annex II.

5.5.2 LCS 5b. Waste processing

In the end of life the decommissioned drone is disassembled, and the parts and waste materials generated in the disassembly are sent for further treatment, including recycling, incineration, or landfilling. The scenario of processing is defined per material fraction.

Technical requirements and assumptions:

- Amount of waste material or component generated in disassembly is as defined by the bill of material/bill of component, by mass.
- Material composition of the materials from disassembly shall be modelled based on the BoM. The table shows coefficients to translate the mass of a component/material in the discarded drone (rows) into specific waste flows (columns) that allow CFF modelling of waste treatment.
- Waste treatment per material shall be modelled with the use of CFF (see requirement and parameters in section 4.10).
- For the materials and component groups added in previous life cycles, the material composition in disassembly shall be described and justified in the PEF study, and waste treatment of the waste materials shall also be modelled with the use of CFF.

Default processes for modelling the waste processing by fraction are provided in the Excel Annex II.

The user of the PEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

6. EFA RESULTS

6.1 Benchmark values

► **Table 38:** Characterised benchmark values for RP drone

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	Mole of H ⁺ eq.	1.02E-04	1.95E-04
Climate Change	kg CO ₂ eq	4.21E-03	2.38E-02
Climate change (fossil)	kg CO ₂ eq	3.69E-04	7.16E-03
Climate change (biogenic)	kg CO ₂ eq	3.84E-03	1.66E-02
Climate change (land use and land use change)	kg CO ₂ eq	2.51E-06	1.27E-05
Ecotoxicity, freshwater	CTUe	1.70E-02	1.76E-01
Particulate matter	Disease incidences	9.52E-10	3.11E-09
Eutrophication, marine	kg P eq.	6.29E-06	1.90E-05
Eutrophication, freshwater	kg N eq.	6.37E-08	8.13E-07
Eutrophication, terrestrial	Mole of N eq.	6.57E-05	1.89E-04
Human toxicity, cancer	CTUh	2.69E-12	7.10E-12
Human toxicity, non-cancer	CTUh	3.53E-11	1.66E-10
Ionising radiation	kBq U235 eq.	1.43E-04	3.10E-03
Land Use	Pt	9.21E-03	6.75E-02
Ozone depletion	kg CFC-11 eq.	1.14E-11	1.09E-10
Photochemical ozone formation, human health	kg NMVOC eq.	2.15E-05	5.87E-05
Resource use, fossils	MJ	4.82E-02	2.04E-01
Resource use, mineral and metals	kg Sb eq.	1.57E-07	1.90E-07
Water use	m ³ world equiv.	9.17E-04	5.90E-03

► **Table 39:** Normalised benchmark values for RP drone

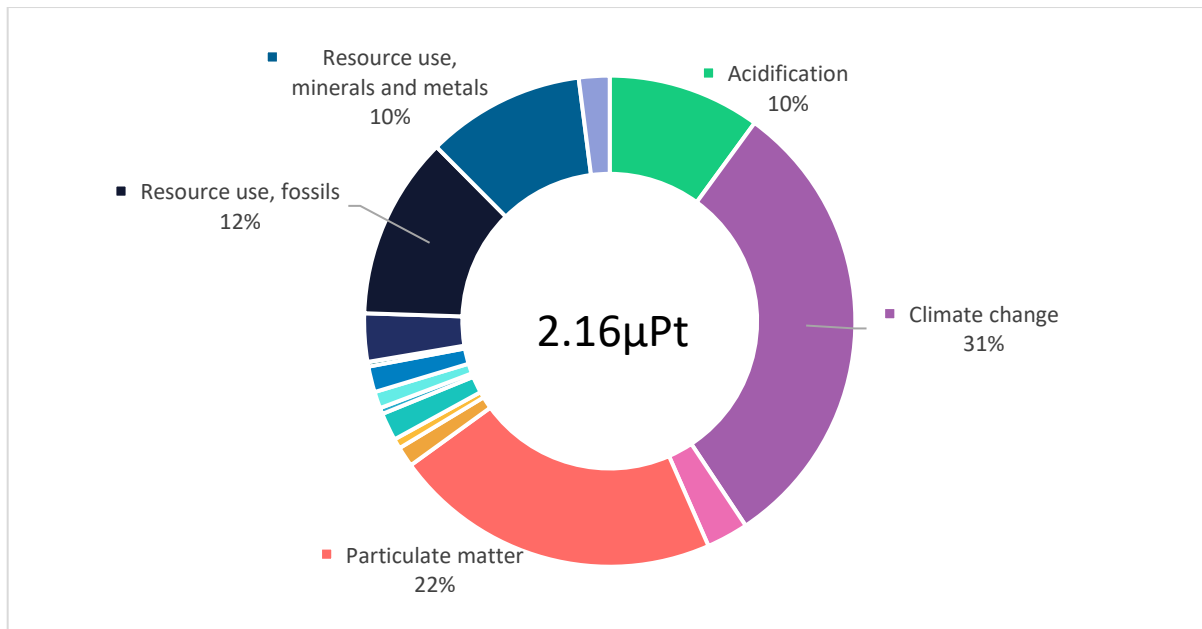
Impact category	Life cycle excl. use stage	Total life cycle
Acidification	1.84E-06	3.51E-06
Climate Change - total	5.57E-07	3.15E-06
Climate change (fossil)		
Climate change (biogenic)		
Climate change (land use and land use change)		
Ecotoxicity, freshwater	3.00E-07	3.10E-06
Particulate matter	1.60E-06	5.22E-06
Eutrophication, marine	3.22E-07	9.72E-07
Eutrophication, freshwater	3.97E-08	5.06E-07
Eutrophication, terrestrial	3.71E-07	1.07E-06
Human toxicity, cancer	1.56E-07	4.12E-07
Human toxicity, non-cancer	2.74E-07	1.29E-06
Ionising radiation, human health	3.40E-08	7.34E-07
Land Use	1.12E-08	8.23E-08

Ozone depletion	2.17E-10	2.09E-09
Photochemical ozone formation, human health	5.26E-07	1.44E-06
Resource use, fossils	7.42E-07	3.13E-06
Resource use, mineral and metals	2.46E-06	2.99E-06
Water use	7.99E-08	5.15E-07

► **Table 40: Weighted benchmark values for RP drone (pt)**

Impact category	Life cycle excl. use stage	Total life cycle
Acidification	1.14E-07	2.17E-07
Climate Change – total	1.17E-07	6.63E-07
Climate change (fossil)		
Climate change (biogenic)		
Climate change (land use and land use change)		
Ecotoxicity, freshwater - total	5.75E-09	5.95E-08
Particulate matter	1.43E-07	4.68E-07
Eutrophication, marine	9.53E-09	2.88E-08
Eutrophication, freshwater	1.11E-09	1.42E-0
Eutrophication, terrestrial	1.38E-08	3.96E-08
Human toxicity, cancer - total	3.33E-09	8.77E-09
Human toxicity, non-cancer - total	5.04E-09	2.38E-08
Ionising radiation, human health	1.70E-09	3.68E-08
Land Use	8.93E-10	6.54E-09
Ozone depletion	1.37E-11	1.32E-10
Photochemical ozone formation, human health	2.51E-08	6.86E-08
Resource use, fossils	6.18E-08	2.61E-07
Resource use, mineral and metals	1.86E-07	2.26E-07
Water use	6.80E-09	4.38E-08
Single Score	6.96E-07	2.16E-06

► **Figure 2: EFA Single score benchmark results, with the most relevant impact categories labelled.**



6.2 EFA profile

The user of the PEFCR shall calculate the PEF profile of its product in compliance with all requirements included in this PEFCR. The following information shall be included in the PEF report:

- full life cycle inventory;
- characterised results in absolute values, for all impact categories (as a table);
- normalised results in absolute values, for all impact categories (as a table);
- weighted result in absolute values, for all impact categories (as a table);
- the aggregated single overall score in absolute values.

Together with the PEF report, the user of the PEFCR shall develop an aggregated EF compliant dataset of its product in scope. This dataset shall be made available to the European Commission and may be made public. The disaggregated version may remain confidential.

7. VERIFICATION

The verification of an EF study/report carried out in compliance with this PEFCR shall be done according to all the general requirements included in Section 8 of the PEF method, including Annex A and the requirements listed below.

The verifier(s) shall verify that the PEF study is conducted in compliance with this PEFCR.

In case policies implementing the PEF method define specific requirements regarding verification and validation of PEF studies, reports and communication vehicles, the requirements in said policies shall prevail.

The verifier(s) shall validate the accuracy and reliability of the quantitative information used in the calculation of the study. As this can be highly resource intensive, the following requirements shall be followed:

- 1) The verifier(s) shall check if the correct version of all impact assessment methods was used. For each of the most relevant impact categories, at least 50% of the characterisation factors (for each of the most relevant EF impact categories) shall be verified, while all normalisation and weighting factors of all impact categories shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with²⁵. This may also be done indirectly, for example:
 - a) Export the EF-compliant datasets from the LCA software used to do the PEF study and run them in Look@LCI²⁶ to obtain LCIA results. If Look@LCI results are within a deviation of 1% from the results in the LCA software, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.
 - b) Compare the LCIA results of the most relevant processes calculated with the software used to do the PEF study with the ones available in the metadata of the original dataset. If the compared results are within a deviation of 1%, the verifier(s) may assume that the implementation of characterisation factors in the software used to do the PEF study was correct.
- 2) The cut-off applied (if any) fulfils the requirements of this PEFCR and the PEF method;
- 3) All the newly created datasets shall be checked on their EF compliance (for the meaning of EF compliant datasets refer <http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml>). All their underlying data (elementary flows, activity data and sub processes) shall be validated;
- 4) The aggregated EF compliant dataset of the product in scope (meaning, the EF study) is made available to the European Commission.
- 5) For at least 70% of the most relevant processes (by number) in situation 2 option 2 of the DNM, 70% of the underlying data shall be validated. The 70% of data shall include all energy and transport sub-processes for processes in situation 2 option 2;
- 6) For at least 60% of the most relevant processes (by number) in situation 3 of the DNM, 60% of the underlying data shall be validated;
- 7) For at least 50% of the other processes (by number) in situation 1, 2 and 3 of the DNM, 50% of the underlying data shall be validated.

In particular, verifier(s) shall verify if the DQR of the process satisfies the minimum DQR as specified in the DNM for the selected processes.

²⁵ Available at: <http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml>

²⁶ <https://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml>

These data checks shall include, but should not be limited to, the activity data used, the selection of secondary sub-processes, the selection of the direct elementary flows and the CFF parameters. For example, if there are 5 processes and each one of them includes 5 activity data, 5 secondary datasets and 10 CFF parameters, then the verifier(s) has to check at least 4 out of 5 processes (70%) and, for each process, (s)he shall check at least 4 activity data (70% of the total amount of activity data), 4 secondary datasets (70% of the total amount of secondary datasets), and 7 CFF parameters (70% of the total amount of CFF parameters), i.e. the 70% of each of data that could be subject to a check.

The verification of the PEF report shall be carried out by randomly checking enough information to provide reasonable assurance that the PEF report fulfils all the conditions listed in section 8 of Annex I, including part A of this Annex.

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Definitions

Activity data – This term refers to information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains, which represent the activities of a process, are each multiplied by the corresponding activity data²⁷ and then combined to derive the environmental footprint associated with that process.

Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g., waste), number of hours equipment is operated, distance travelled, floor area of a building, etc.

Synonym of “non-elementary flow”.

Acidification – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NO_x, NH₃ and SO_x lead to releases of hydrogen ions (H⁺) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Additional environmental information – Environmental information outside the EF impact categories that is calculated and communicated alongside PEF results.

Additional technical information – Non-environmental information that is calculated and communicated alongside PEF results.

Attributional – Process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

Average data – Production-weighted average of specific data.

Background processes – Refers to those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes.

Belly freight – Transportation of goods via aircraft designated for passenger transport, typically carried in the belly hold. Excludes passenger baggage.

Benchmark – A standard or point of reference against which any comparison may be made. In the context of PEF, the term ‘benchmark’ refers to the average environmental performance of the representative product sold in the EU market.

²⁷ Based on GHG protocol scope 3 [definition from the Corporate Accounting and Reporting Standard \(World resources institute, 2011\)](#).

Bill of materials – A bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in scope of the PEF study. In some sectors it is equivalent to the bill of components.

Business to Business (B2B) – Describes transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

Business to Consumers (B2C) – Describes transactions between business and consumers, such as between retailers and consumers. According to ISO 14025:2006, a consumer is defined as “an individual member of the general public purchasing or using goods, property or services for private purposes”.

CAPA – Centre for Aviation, a commercial data provider specialising in commercial aviation news, fleet data and company profiles.

Characterisation – Calculation of the magnitude of the contribution of each classified input/output to their respective EF impact categories, and aggregation of contributions within each category.

This requires a linear multiplication of the inventory data with characterisation factors for each substance and EF impact category of concern. For example, with respect to the EF impact category “climate change”, the reference substance is CO₂ and the reference unit is kg CO₂-equivalents.

Characterisation factor – Factor derived from a characterisation model which is applied to convert an assigned life cycle inventory result to the common unit of the EF impact category indicator (based on ISO 14040:2006).

Civil aviation authority (CAA) - national or international regulator for civil aviation, such as EASA, with responsibilities which may include aircraft and air operator certification for airworthiness, aircraft design and manufacture, airports, aircraft registry, air traffic control and environmental standards.

Classification – Assigning the material/energy inputs and outputs tabulated in the life cycle inventory to EF impact categories according to each substance’s potential to contribute to each of the EF impact categories considered.

Climate change – EF impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change is an impact affecting the environment on a global scale.

Co-function - Any of two or more functions resulting from the same unit process or product system.

Commissioner of the EF study – Organisation (or group of organisations), such as a commercial company or non-profit organisation, that finances the EF study in accordance with the PEF method and the relevant PEFCR, if available (definition adapted from ISO 14071/2014, point 3.4).

Company-specific data – Refers to directly measured or collected data from one or more facilities (site-specific data) that are representative for the activities of the company (company is used as a synonym for organisation). It is synonymous to “primary data”. To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset – Refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases.

Comparative assertion – An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category) (adapted from ISO 14044:2006).

Comparison – A comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs.

Consumer – An individual member of the general public purchasing or using goods, property or services for private purposes.

Co-product – Any of two or more products resulting from the same unit process or product system (ISO 14040:2006).

CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation; an international market based carbon reduction measure for airlines managed by ICAO.

Cradle-to-gate – A partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer’s “gate”. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle-to-grave – A product’s life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Critical review – Process intended to ensure consistency between a PEFCR and the principles and requirements of the PEF method.

Data quality – Characteristics of data that relate to their ability to satisfy stated requirements (ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data quality rating (DQR) - Semi-quantitative assessment of the quality criteria of a dataset, based on technological representativeness, geographical representativeness, time-related representativeness, and precision. The data quality shall be considered as the quality of the dataset as documented.

Delayed emissions – Emissions that are released over time, e.g., through long use or final disposal stages, versus a single emission at time t.

Direct elementary flows (also named elementary flows) – All output emissions and input resource uses that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) – The transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Directly attributable – Refers to a process, activity or impact occurring within the defined system boundary.

Disaggregation – The process that breaks down an aggregated dataset into smaller unit process datasets (horizontal or vertical). The disaggregation may help make data more specific. The process of disaggregation should never compromise or threaten to compromise the quality and consistency of the original aggregated dataset.

Downstream – Occurring along a product supply chain after the point of referral.

EASA IAM Hub – The European Union Aviation Safety Agency (EASA) Innovative Air Mobility (IAM) Hub is a digital platform developed by the EASA that serves as a centralised point of collaboration and information exchange for all stakeholders involved in innovative air mobility within Europe. This includes cities, regions, national authorities, the EU itself, as well as operators and manufacturers. The IAM Hub aims to support the safe, secure, efficient, and sustainable implementation of innovative air mobility practices, aligning with the objectives outlined in the EU's Drones Strategy 2.0. This platform facilitates interaction among various stakeholders, helping to create transparency and fostering advancements in the field of air mobility, particularly concerning drones and electric aircraft.

Ecotoxicity, freshwater – EF impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

EF communication vehicles – All the possible ways that may be used to communicate the results of the EF study to the stakeholders (e.g., labels, environmental product declarations, green claims, websites, infographics, etc.).

EF compliant dataset – Dataset developed in compliance with the EF requirements, regularly updated by DG JRC provided at <https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html>

Electricity tracking²⁸ – The process of assigning electricity generation attributes to electricity consumption.

Elementary flows – In the life cycle inventory, elementary flows include “material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation” (ISO 14040, 3.12).

Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the EF impact categories.

Environmental aspect – Element of an organisation’s activities or products or services that interacts or can interact with the environment (ISO 14001:2015).

Environmental footprint (EF) impact assessment – Phase of the PEF analysis aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (based on ISO 14044:2006). The impact assessment methods provide impact characterisation factors for elementary flows, to aggregate the impact so as to obtain a limited number of midpoint indicators.

Environmental footprint (EF) impact assessment method – Protocol for converting life cycle inventory data into quantitative contributions to an environmental impact of concern.

Environmental footprint (EF) impact category – Class of resource use or environmental impact to which the life cycle inventory data are related.

²⁸ <https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii>

Environmental footprint (EF) impact category indicator – Quantifiable representation of an EF impact category (based on ISO 14000:2006).

Environmental impact – Any change to the environment, whether adverse or beneficial, that wholly or partially results from an organisation’s activities, products or services

Environmental mechanism – System of physical, chemical and biological processes for a given EF impact category linking the life cycle inventory results to EF category indicators (based on ISO 14040:2006).

Eutrophication – EF impact category related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland that accelerate the growth of algae and other vegetation in water.

The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass. Three EF impact categories are used to assess the impacts due to eutrophication: eutrophication, terrestrial; eutrophication, freshwater; eutrophication, marine.

External communication – Communication to any interested party other than the commissioner or the practitioner of the study.

Extrapolated data – Data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.

Flight cycle – The completed process of an aircraft taking off and landing. Synonymous with the term flight meaning one aircraft trip movement, however also including the process of “Touch and go”.

Flight Time or Flight Hours The period of time that elapses between the drone leaving the ground and the next time it touches down

Flow diagram – Schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Foreground elementary flows – Direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground Processes – Those processes in the product life cycle for which direct access to information is available. For example, the producer’s site and other processes operated by the producer or its contractors (e.g., goods transport, head-office services, etc.).

Functional unit – Defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions “what?”, “how much?”, “how well?”, and “for how long?”.

Gate-to-gate – A partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate-to-grave – A partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Global warming potential (GWP) – An index measuring the radiative forcing of a unit mass of a given substance accumulated over a chosen time horizon. It is expressed in terms of a reference substance (for example, CO₂-equivalent units) and specified time horizon (e.g., GWP 20, GWP 100, GWP 500, for 20, 100, and 500 years respectively).

GWP relates to a substance’s capacity to influence changes in the global average surface air temperature and subsequent change in various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

Horizontal averaging – The action of aggregating multiple unit process datasets or aggregated process datasets in which each provides the same reference flow in order to create a new process dataset (UN Environment, 2011).

Human toxicity – cancer – EF impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to cancer.

Human toxicity - non cancer – EF impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.

Independent external expert – Competent person, not employed in a full-time or part-time role by the commissioner of the EF study or the user of the EF method, and not involved in defining the scope or conducting the EF study (adapted from ISO 14071/2014, point 3.2).

Indirect land use change (iLUC) – This occurs when a demand for a certain land use leads to changes, outside the system boundary, i.e., in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

Input flows – Product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products (ISO 14040:2006).

Intermediate product – Output from a unit process that in turn is input to other unit processes that require further transformation within the system (ISO 14040:2006). An intermediate product is a product that requires further processing before it is saleable to the final consumer.

The International Civil Aviation Organization (ICAO) – A UN agency with the core function to maintain an administrative and expert bureaucracy (the ICAO Secretariat) supporting aviation diplomatic interactions, and to research new air transport policy and standardization innovations as directed and endorsed by governments through the ICAO Assembly, or by the ICAO Council which the assembly elects.

Ionising radiation, human health – EF impact category that accounts for the adverse health effects on human health caused by radioactive releases.

Land use – EF impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc.

Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in soil quality multiplied by the area).

Lead verifier – Person taking part in a verification team with additional responsibilities compared to the other verifiers in the team.

Life cycle – Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 14040:2006).

Life cycle approach – Takes into consideration the spectrum of resource flows and environmental interventions associated with a product from a supply-chain perspective, including all stages from raw material acquisition through processing, distribution, use, and end of life processes, and all relevant related environmental impacts (instead of focusing on a single issue).

Life cycle assessment (LCA) – Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040:2006).

Life cycle impact assessment (LCIA) – Phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts for a system throughout the life cycle (ISO 14040:2006).

The LCIA methods used provide impact characterisation factors for elementary flows in order to aggregate the impact to obtain a limited number of midpoint and/or damage indicators.

Life cycle inventory (LCI) – The combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle inventory (LCI) dataset – A document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. A LCI dataset could be a unit process dataset, partially aggregated, or an aggregated dataset.

Load factor – Ratio of actual load to the full load or capacity (e.g., mass or volume) that a vehicle carries per trip.

Material-specific – A generic aspect of a material. For example, the recycling rate of polyethylene terephthalate (PET).

Maximum take-off weight (MTOW) or maximum take-off mass (MTOM) – The highest weight or mass an aircraft can fly due to regulatory, structural, aerodynamic and/or thrust limitations, combining both the inherent weight of the aircraft and the maximum load it can carry

Multi-functionality – If a process or facility provides more than one function, i.e., it delivers several goods and/or services ("co-products"), then it is "multifunctional". In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products, according to clearly stated procedures.

Non-elementary (or complex) flows – In the life cycle inventory, non-elementary flows include all the inputs (e.g., electricity, materials, transport processes) and outputs (e.g., waste, by-products) in a system that need further modelling efforts to be transformed into elementary flows. Synonym of "activity data".

Normalisation – After the characterisation step, normalisation is the step in which the life cycle impact assessment results are multiplied by normalisation factors that represent the overall inventory of a reference unit (e.g., a whole country or an average citizen).

Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system in terms of the total contributions to each impact category per reference unit.

Displaying the normalised life cycle impact assessment results for the different impact topics next to each other indicates which impact categories are affected most and least by the analysed system.

Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

OAG – A commercial data provider specialising in the aviation and travel industry, most notably flight information including airline schedules.

Operating empty weight (OEW) – The sum of the manufacturer empty weight (MEW), plus any manufacturer delivery standard items, plus any items required for the operation. For an aircraft completing commercial operations, it is the total weight less the passengers and their baggage, freight, and usable fuel.

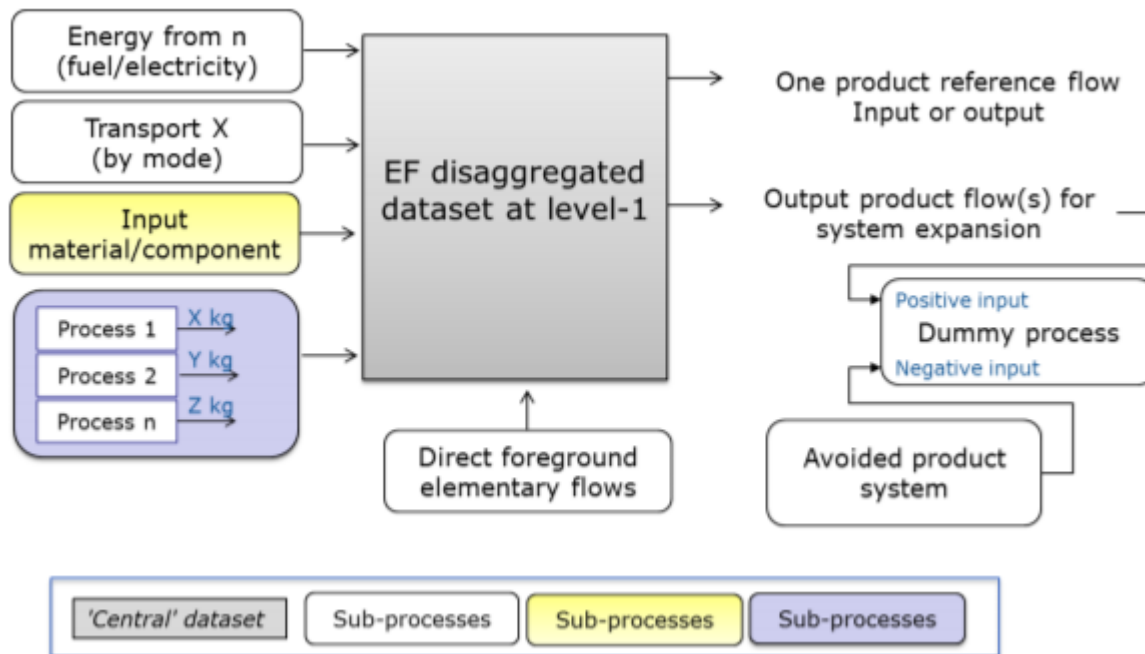
Output flows – Product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases (ISO 14040:2006).

Ozone depletion – EF impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g., chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons).

Partially disaggregated dataset – A dataset with a LCI that contains elementary flows and activity data, and that yields a complete aggregated LCI data set when combined with its complementing underlying datasets yield.

Partially disaggregated dataset at level-1 – A partially disaggregated dataset at level 1 contains elementary flows and activity data of one level down in the supply chain, while all complementing underlying datasets are in their aggregated form.

Figure 3: Example of dataset partially disaggregated at level-1



Particulate Matter – EF impact category that accounts for the adverse health effects on human health caused by emissions of particulate matter (PM) and its precursors (NO_x , SO_x , NH_3).

Payload – The weight of an aircraft excluding what is necessary for operation, equivalent to the operating empty weight. Equivalent to the combined weight of the passengers and freight.

PEFCR supporting study (SS) – PEF study based on a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

PEF profile – The quantified results of a PEF study. It includes the quantification of the impacts for the various impact categories and the additional environmental information considered necessary to report.

PEF report – Document that summarises the results of the PEF study.

PEF study of the representative product (PEF-RP) – PEF study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and any other major requirements needed to define the benchmark for the product category/sub-categories in scope of the PEFCR.

PEF study – Term used to identify the totality of actions needed to calculate the PEF results. It includes the modelling, data collection, and analysis of the results. PEF study results are the basis for drafting PEF reports.

Photochemical ozone formation – EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NO_x) and sunlight.

High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.

Population – Any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study.

Primary data²⁹ - Data from specific processes within the supply chain of the user of the PEF method or user of the PEFCR.

Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the user of the PEF method or user of the PEFCR.

In this method, primary data is synonym of "company-specific data" or "supply-chain specific data".

Product – Any goods or service (ISO 14040:2006).

Product category – Group of products (or services) that can fulfil equivalent functions (ISO 14025:2006).

Product category rules (PCRs) – Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories (ISO 14025:2006).

Product environmental footprint category rules (PEFCRs) – Product category specific, life cycle based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category.

²⁹ Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011)

PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the PEF method.

Only the PEFCRs listed on the European Commission website (http://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.html) are recognised as in line with this method.. Only PEFCRs developed by or in cooperation with the European Commission, or adopted by the Commission or as EU acts, are recognised as being in line with this method.

Product flow – Products entering from or leaving to another product system (ISO 14040:2006).

Product system – Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product (ISO 14040:2006).

Raw material – Primary or secondary material used to produce a product (ISO 14040:2006).

Reference flow – Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit (based on ISO 14040:2006).

Refurbishment – The process of restoring components to a functional and/or satisfactory state to the original specification (providing the same function), using methods such as resurfacing, repainting, etc. Refurbished products may have been tested and verified to function properly.

Releases – Emissions to air and discharges to water and soil (ISO 14040:2006).

Representative product (model) – The RP may be a real or a virtual (non-existing) product. The virtual product should be calculated based on average European market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category.

Other weighting sets may be used, if justified, for example weighted average based on mass (ton of material) or weighted average based on product units (pieces).

Representative sample – A representative sample with respect to one or more variables is a sample in which the distribution of these variables is exactly the same (or similar) as in the population from which the sample is a subset.

Resource use, fossil – EF impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

Resource use, minerals and metals – EF impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

Revenue unit - one passenger transported by the aircraft with revenue, including luggage and allocated additional weight not accounted for into OEW or passenger services (standard 100kg), or unit of cargo conducted in belly freight with revenue, equal to 100kg.

Review – Procedure intended to ensure that the process of developing or revising a PEFCR has been carried out in accordance with the requirements provided in the PEF method and part A of Annex II.

Review report – A documentation of the review process that includes the review statement, all relevant information about the review process, the detailed comments from the reviewer(s) and the corresponding responses, and the outcome. The document shall carry the electronic or handwritten signature of the reviewer (or the lead reviewer, if a reviewer panel is involved).

Review panel – Team of experts (reviewers) who will review the PEFCR

Reviewer – Independent external expert conducting the review of the PEFCR and possibly taking part in a reviewer panel.

Sample – A sample is a subset containing the characteristics of a larger population. Samples are used in statistical testing when population sizes are too large for the test to include all possible members or observations. A sample should represent the whole population and not reflect bias toward a specific attribute.

Secondary data³⁰ - Data that are not from a specific process within the supply-chain of the company performing a PEF study.

This refers to data that are not directly collected, measured, or estimated by the company, but sourced from a third party LCI database or other sources.

Secondary data include industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data.

Primary data that go through a horizontal aggregation step are considered as secondary data.

Sensitivity analysis – Systematic procedures for estimating the effects of the choices made regarding methods and data on the results of a PEF study (based on ISO 14040: 2006).

³⁰ Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011)

Site-specific data – Directly measured or collected data from one facility (production site). It is synonymous to “primary data”.

Specific data – Directly measured or collected data representative of activities at a specific facility or set of facilities. Synonymous with “primary data.”

Subdivision – Subdivision refers to disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The process is investigated to see whether it may be subdivided. Where subdivision is possible, inventory data should be collected only for those unit processes directly attributable to the products/services of concern.

Sub-population – Any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes a homogenous sub-set of the whole population. Synonymous with “stratum”.

Sub-processes – Those processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form (see Figure 3).

Sub-sample – A sample of a sub-population.

Supply chain – All of the upstream and downstream activities associated with the operations of the user of the PEF method, including the use of sold products by consumers and the End of Life treatment of sold products after consumer use.

Supply chain specific – Refers to a specific aspect of the specific supply chain of a company. For example the recycled content value of an aluminium produced by a specific company.

System boundary – Definition of aspects included or excluded from the study. For example, for a “cradle-to-grave” EF analysis, the system boundary includes all activities from the extraction of raw materials through processing, distribution, storage, use, and to the disposal or recycling stages.

System boundary diagram – Graphic representation of the system boundary defined for the PEF study.

Temporary carbon storage – This happens when a product reduces the GHGs in the atmosphere or creates negative emissions, by removing and storing carbon for a limited amount of time.

Type III environmental declaration – An environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental

information (ISO 14025:2006). The predetermined parameters are based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044.

Uncertainty analysis – Procedure to assess the uncertainty in the results of a PEF study due to data variability and choice-related uncertainty.

Unit process – Smallest element considered in the LCI for which input and output data are quantified (based on ISO 14040:2006).

Unit process, black box – Process chain or plant level unit process. This covers horizontally averaged unit processes across different sites. It covers also those multi-functional unit processes, where the different co-products undergo different processing steps within the black box, hence causing allocation problems for this dataset.³¹

Unit process, single operation - Unit operation type unit process that cannot be further subdivided. Covers multi-functional processes of unit operation type³².

Upstream – Occurring along the supply chain of purchased goods/services prior to entering the system boundary.

User of the PEFCR – Stakeholder producing a PEF study based on a PEFCR.

User of the PEF method – Stakeholder producing a PEF study based on the PEF method.

Validation – Confirmation, by the environmental footprint verifier, that the information and data included in the PEF study, PEF report and the communication vehicles are reliable, credible and correct.

Validation statement – Conclusive document aggregating the conclusions from the verifiers or the verification team regarding the EF study. This document is mandatory and shall carry the electronic or handwritten signature of the verifier or, in case of a verification panel, of the lead verifier.

Verification report – Documentation of the verification process and findings, including detailed comments from the verifier(s), as well as the corresponding responses. This document is mandatory,

³¹ More details can be found in the Guide for EF-compliant datasets at https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf

³² More details can be found in the Guide for EF-compliant datasets at https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf

but it may be confidential. The document shall carry the electronic or handwritten signature of the verifier, or in case of a verification panel, of the lead verifier.

Verification team – Team of verifiers who will perform the verification of the EF study, of the EF report and the of EF communication vehicles.

Verifier – Independent external expert performing a verification of the EF study and possibly taking part in a verification team.

Vertical aggregation – Technical- or engineering-based aggregation refers to vertical aggregation of unit processes that are directly linked within a single facility or process train. Vertical aggregation involves combining unit process datasets (or aggregated process datasets) together, linked by a flow (UN Environment, 2011).

Waste – Substances or objects which the holder intends (or is required) to dispose of (ISO 14040:2006).

Water use – EF impact category that represents the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, based on the assumption that the less water remaining available per area, the more likely another user will be deprived (see also <http://www.wulca-waterlca.org/aware.html>).

Weighting – A step that supports the interpretation and communication of the results of the analysis. PEF results are multiplied by a set of weighting factors, which reflect the perceived relative importance of the impact categories considered. Weighted EF results may be directly compared across impact categories, and also summed across impact categories to obtain a single overall score.

Acronyms

AF	allocation factor
ABS	Acrylonitrile butadiene styrene
B2B	business to business
B2C	business to consumer
BoM	bill of materials
BSI	British Standards Institution
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
CFRP	Carbon fibre reinforced plastics
CPA	Classification of Products by Activity
DNM	Data Needs Matrix
DQR	Data Quality Rating
EASA	European Union Aviation Safety Agency
E _{TO}	Energy use during take-off
E _L	Energy use during landing
E _C	Energy use during cruise
EC	European Commission
EF	environmental footprint
EoL	End of Life
FU	functional unit
FH	Flight hours
GHG	greenhouse gas
GPS	Global Positioning System
GR	geographical representativeness
GWP	global warming potential
ILCD	International Reference Life Cycle Data System
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
LCA	life cycle assessment
LCDN	Life Cycle Data Network
LCI	life cycle inventory
LCIA	life cycle impact assessment
LC	life cycle
LED	Light emitting diode
MTOM	Maximum take-off mass
MTOW	Maximum take-off weight
NMVOC	non-methane volatile compounds
OEW	Operating Empty Weight
P	precision
PAS	Publicly Available Specification
PC	Polycarbonate
PCR	Product category rules

PET	Polyethylene Terephthalate
PEF	product environmental footprint
PEFCR	product environmental footprint category rules
PEF-RP	PEF study of the representative product
PLA	Polylctic acid
PMMA	Polymethyl Methacrylate
PVC	Polyvinyl chloride
RF	reference flow
RM	Raw material and extraction stage (LC Stage 1)
RP	representative product
SB	system boundary
SS	supporting study
TeR	technological representativeness
TiR	time representativeness
TS	Technical Secretariat
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
WWF	World Wildlife Fund

Annexes

ANNEX 1. List of EF normalisation and weighting factors

Global normalisation factors are applied within the EF. The normalisation factors as the global impact per person are used in the EF calculations.

► **Table 41:** Normalisation and weighting factors used in EF3.1

Impact category	Normalisation factors (NFs)	Weighting factor [%]
Acidification	5.56E+01	6.20%
Climate change	7.55E+03	21.06%
Ecotoxicity, freshwater	5.67E+04	21.06%
EF-particulate Matter	5.95E-04	1.92%
Eutrophication marine	1.95E+01	2.96%
Eutrophication, freshwater	1.61E+00	2.80%
Eutrophication, terrestrial	1.77E+02	3.71%
Human toxicity, cancer	1.29E-04	2.13%
Human toxicity, non-cancer	1.29E-04	1.84%
Ionising radiation, human health	4.22E+03	5.01%
Land use	8.19E+05	7.94%
Ozone depletion	5.23E-02	6.31%
Photochemical ozone formation - human health	4.09E+01	4.78%
Resource use, fossils	6.50E+04	8.32%
Resource use, minerals and metals	6.36E-02	7.55%
Water use	1.15E+04	8.51%

Normalisation and weighting factors are available at: <http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml>

ANNEX 2. PEF study template

Annex E of the PEF method (JRC, 2019) presents the PEF report template that shall be applied for all types of PEF studies (e.g., including PEF-RPs or supporting studies of PEFCRs). The template presents the mandatory report structure to be followed and the information to be reported as a non-exhaustive list. All items required to be reported by the PEF method shall be included, even if they are not explicitly mentioned in the template.

Each PEF study shall include a checklist annex (below), completed with all the requested information.

ITEM: This column lists all the items that shall be included in a PEF report or PEF Supporting study (SS) (The PEF report can stay confidential)	Included in the study: Indicate if the item is included or not in the study (Y/N)	Section: Indicate in which section # the item is included	Page: Indicate in which page the item is included
Summary			
General information about the product			
General information about the company			
Diagram with system boundary and indication of the situation according to DNM			
List and description of processes included in the system boundaries			
List of co-products, by-products and waste			
Life cycle inventory analysis			
Additional information			
Impact assessment results: categorised, normalised, weighted, and single score			
Identification of most relevant impact categories (only SS)			
Identification of most relevant life cycle stages (only SS)			
Identification of most relevant processes (only SS)			
Identification of most relevant direct elementary flows (only SS)			
Feedback to the draft PEFCR (only SS)			
List of activity data used			
List of secondary datasets used			
Data gaps			
Assumption			
Scope of the study			
Category to which the product belongs			
DQR calculation of each dataset used for the most relevant processes, the new ones created, and other processes in situation 1.			
Average DQR of the study			
The full test report(s) used to determine the Additional information: Noise			

ANNEX 3. Review reports of the PEFCR and PEF-RP(s)

[to be added upon finalization of the review]

ANNEX 4. Representative product

See document titled: Annex 4 – EFA Delivery Drone PEF-RP Report v1

ANNEX 5. Cut-off processes

In accordance with the guidelines set forth by the Product Environmental Footprint (PEF) methodology, certain processes are considered out of scope for the environmental footprint assessment of drones. These exclusions are justified based on the criteria that these processes do not significantly alter the overall environmental impact assessment results when compared to the total life cycle of the product. The following processes are excluded from the scope of this PEFCR:

- Activities related to the research and development of drone technology are excluded. The PEF methodology considers the environmental impacts of R&D as negligible in the context of the total life cycle of the product, as these activities do not recur with each unit produced.
- The environmental impact of personnel commuting is excluded from this assessment. This exclusion is based on the PEF methodology, which acknowledges that the commuting habits of personnel vary widely and are not directly attributable to the production or operational processes of drones.
- The dismantling, recycling, or disposal infrastructure related to drones at the end of their life cycle is also excluded. The PEF methodology recommends this exclusion due to the complexity and variability of end of life processes, which may significantly differ based on geographic and regulatory environments, and thus are not consistently applicable across all assessments.

These exclusions are made to ensure the focus remains on the most significant environmental impacts directly attributable to the core operations of drones. By adhering to the PEF methodology's guidelines, this PEFCR ensures that the assessment is both manageable and relevant, while still providing a comprehensive view of the environmental impacts that are most pertinent to the lifecycle of drones.



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