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COMMITTEE DRAFT (CD)

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IEC SC 21A : SECONDARY CELLS AND BATTERIES CONTAINING ALKALINE OR OTHER NON-ACID ELECTROLYTES	
SECRETARIAT: France	SECRETARY: Mr Pierre Bourg
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 21	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☒ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

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TITLE:

Methodology for the Carbon Footprint calculation applicable to Lithium-ion batteries

NOTE FROM TC/SC OFFICERS:

The new CD will be discussed during the next IEC SC 21A/WG 6 meeting to be held on October 26th 2022 in San Francisco.

As it is a second CD and it has been widely discussed during the series of meeting held in 2022 by the group of experts working on this standard a commenting period of 8 weeks seems to be acceptable

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODOLOGY FOR THE CARBON FOOTPRINT CALCULATION APPLICABLE TO INDUSTRIAL LITHIUM-ION BATTERIES – Part 1: General requirements and global methodology

FOREWORD

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IEC 63369 has been prepared by subcommittee SC21A/WG6, of IEC technical committee SC21A. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at http://www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

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METHODOLOGY FOR THE CARBON FOOTPRINT CALCULATION APPLICABLE TO INDUSTRIAL LITHIUM-ION BATTERIES
Part 1: General requirements and global methodology

1 Scope

This document is part of a series. The first part addresses general requirements and global methodology whereas the second part addresses application of the methodology.

This document provides a comprehensive methodology for the calculation of carbon footprint of industrial type Li-ion battery systems from cradle to grave. (Second life or usage that was not intended when the battery is put on the market are not taken into account).

The definition of the parameters used for the calculation allows for an improved comparability of results for all rechargeable Li-ion chemistries. Classes of representative products are defined in this document to allow comparison inside each class.

This methodology is mainly intended for use by the battery purchaser or the battery end-user, based on the data provided by the battery manufacturer, in order to compare the carbon footprint to select between battery systems being considered for their use over their Reference Service Life.

The methodology can also be used for a variety of purposes such as for battery system development, eco-design and participation in voluntary or mandatory programmes

An intermediate calculation step can be performed at the “gate of the battery factory” (post-manufacturing). Primary data are to be collected by cell/components manufacturers.

This document with the other parts of the standard offers also general guidance for the specific application of ISO 14067 to such a calculation.

This document with the other parts of the standard does not pertain to Li-ion batteries of portable type or for use in road electric vehicle.

The carbon footprint calculation of charging and power conversion equipment is not covered in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62619:2022 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications

IEC TS 62933-2-2:2022 Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing methods - Application and performance testing

IEC TS 62933-3-1:2018 Electrical energy storage (EES) systems 212 - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification

IEC 62973-1:2018 Railway applications - Rolling stock - Batteries for auxiliary power supply systems - Part 1: General requirements

IEC 60896-21:2004 Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test

ISO/IEC 17020:2012 Conformity assessment -- Requirements for the operation of various types of bodies performing inspection

ISO 15686-8:2008 Buildings and constructed assets — Service-life planning — Part 8: Reference service life and service-life estimation

ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework

ISO 14025:2006 Environmental labels and declarations — Type III environmental declarations — Principles and procedures

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/

ISO Online browsing platform: available at http://www.iso.org/obp

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3.1.1

Company-specific data
Primary data
Foreground data

Directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company.

Note 1 to entry: In case the component is manufactured in several facilities, to determine the level of representativeness of the primary data collected, a sampling procedure may be applied.

3.1.2

Secondary data
Background data

Data not directly collected, measured, or estimated by the company, but sourced from a third party LCI database or other sources.

Note 1 to entry: data not from a specific process within the supply-chain of the company performing the carbon footprint study.

Note 2 to entry: Secondary data includes 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 other generic data.

Note 3 to entry: Primary data that go through a horizontal aggregation step are considered as secondary data.

Note 4 to entry: more details on secondary data selection is provided in IEC63369- 2

3.1.3

Battery manufacturer

The entity which is supplying the battery system(s) to meet the Reference Service Life of the application as expressed in the technical specifications from the user.

Note 1 to entry: The component manufacturer that does not know the sizing of the battery is NOT defined as the battery manufacturer in the case of this standard.

3.1.4

Battery system sizing

Activity that takes into account the final usage of the battery system and selects the most optimized solution including all its technical parameters.

Note 1 to entry: It includes for example efficiencies, life expectations, selection of sub-systems, safety, etc.

3.1.5

Component manufacturer

The entity which is supplying a component of the battery system.

Note 1 to entry: The component manufacturer does not perform the battery system sizing.

3.1.6

Functionality class

< of batteries>

Grouping where the battery system presents similarities in their functioning

Note 1 to entry: Batteries in the same functionality class can be compared in terms of carbon footprint

3.1.7

Representative virtual product

Market weighted-average modelling of existing batteries in a given functionality class.

Note 1 to entry: There is a minimum number of representative virtual products per functionality class except when the bill of materials is significantly different.

3.1.8

Battery System

Battery

<for Li-ion>

System which comprises one or more cells, modules or battery packs and has a battery management system intended to provide the Reference Service Life as expressed by the user.

Note 1 to entry: The battery system may have cooling or heating units. More than one battery system may constitute a larger battery system.

[SOURCE: IEC 62619:2022, 3.11, modified – “capable of controlling current in case of overcharge, overcurrent, overdischarge, and overheating” has been replaced by " intended to provide the Reference Service Life as expressed by the user” and note1 to entry deleted.]

3.1.9

Functional unit
defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the battery being evaluated.

Note 1 to entry: The functional unit definition answers the questions “what?”, “how much?”, “how well?”, and “for how long?”. See examples in the document.

3.1.10

Reference flow

Amount of product needed to fulfil the defined function, measured in kg of battery system per kWh of the total energy required by the application over its Reference Service Life.

Note 1 to entry: All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.

3.1.11

Reference Service Life
RSL
<of a battery system>

Service life that may be expected for a battery system according to a particular set, i.e., a reference set, of ambient and operating conditions during use stage and that may be used to estimate the service life under other conditions during the use stage

Note 1 to entry: The reference service life is a theoretical period used for calculation purposes. It is not to be compared to the minimum, average or actual service life of the product.

Note 2 to entry: The reference set is provided by the end-user when procuring the battery system to compare all potential solutions on the same basis.

[SOURCE : ISO 15686-8, modified]

3.1.12

Set
a group or collection of conditions during use stage that are usually found together

3.1.13

compliant dataset
A dataset which complies with all the requirements in this document, with a DQR lower than 3

Note 1 to entry: a *compliant dataset* can be a company-specific dataset or a secondary dataset

3.1.14

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

3.1.15

Life cycle inventory 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.

Note 1 to entry: A LCI dataset could be a unit process dataset, partially aggregated or an aggregated dataset.

3.1.16

Partially disagreggated dataset
A dataset with a Life Cycle Inventory that contains elementary flows and activity data, and that only in combination with its complementing underlying datasets yield a complete aggregated LCI data set.

3.1.17

communication vehicles
includes all the possible ways that can be used to communicate the results of the CF study to the stakeholders. The list of CF communication vehicles includes, but it is not limited to, labels, environmental product declarations, green claims, websites, infographics, etc

3.1.18

point of substitution
point in the value chain where secondary materials substitute primary materials

3.2 Abbreviated terms

BCF	Battery Carbon Footprint
BTMS	Battery Thermal Management System
CAM	Cathode Active Material
CCF	Component Carbon Footprint
CF	CO2 Footprint
CFF	Circular Footprint Formula
DQR	Data Quality Rating
EF	Elementary Flow
EmF	Emission Factor
EPA	Environmental Protection Agency
FSS	Fire Suppression System
FU	Functional Unit
GHG	Green House Gas
GoO	Guarantee of Origin
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LCI	Life Cycle Inventory
LFP	Lithium Iron Phosphate cathode material
LTO	Lithium Titanium Oxide anode material
MOB	Mobile applications
NMC	Nickel Manganese Cobalt cathode material
OEM	Original Equipment Manufacturer

OND On-demand Cycling
PCB Printed Circuit Board
PCF Product Carbon Footprint
PCS Power Conversion System
PPA Power Purchase Agreement
PV Photovoltaic
REC Renewable Energy Certificate
REP Repetitive Cycling
STA Stationary applications

4 General information

This document with the other parts provides the necessary guidance and structure to ensure that all Battery Carbon Footprint (BCF) calculations for industrial Li-ion batteries and their components are derived, verified and presented in a consistent and comparable way.

The methodology is used to assess the carbon footprint of single, multiple or all stages of the life of a battery. In all cases, the reference service life has to be known for the calculation.

This document with the other parts can be applied to provide the Battery Carbon Footprint calculations for one or for several stages of the battery life.

As the charge and discharge energy flows transmitted by the battery to the application are already taken into account at the application level, the energy consumption attributed to the use stage of the battery in this standard is limited to the energy losses linked to the battery and related component efficiency during charge, discharge and storage (e.g. powering BTMS).

5 Classification of industrial Li-ion batteries

Industrial Li-ion batteries are used in a large variety of applications and for proper Battery Carbon Footprint calculations, their main functionality has to be identified.

The following functionality classes are covered in this document and the other parts:

- Applications with frequent and repetitive charge and discharge cycles (REP), and
- Applications with sporadic on-demand energy delivery (OND)

In order to compare the BCF of batteries with similar functionalities, each classification is divided in two sub-classes to reflect significant difference in the Bill-of-Materials, eg Fire Suppression System in ESS applications and not in mobility.

The specific uses of industrial Li-ion cells and batteries are classified as follows:

5.1 Repetitive energy supply

5.1.1 Repetitive energy supply in mobile equipment (“REP-MOB”)

The battery is storing and very frequently supplying energy in mobile equipment over its service life.

The metrics for this duty is the total energy dischargeable in kWh over the Reference Service Life.

In such an application, the specific volumetric and gravimetric energy density is of key importance.

5.1.2 Repetitive energy supply in stationary equipment (“REP-STA”)

The battery is storing and very frequently supplying energy in stationary equipment over its service life.

The metrics for this duty is the total energy dischargeable in kWh over the Reference Service Life.

In such an application, the gravimetric energy density is less important than for mobile applications.

5.2 On-demand energy supply

5.2.1 On-demand energy supply in mobile equipment (“OND-MOB”)

The battery is sporadically supplying auxiliary energy in mobile equipment, when main power is lost and as required over its service life.

The metrics for this duty are specific power capability (W/Wh) and Reference Service Life in calendar years of operation.

In such an application, the specific volumetric and gravimetric energy density is of key importance.

5.2.2 On-demand energy supply in stationary equipment (“OND-STA”)

The battery is sporadically supplying auxiliary energy in stationary equipment, when main power is lost and as required over its service life.

The metrics for this duty are specific power capability (W/Wh) and Reference Service Life in calendar years of operation.

In such an application, the specific gravimetric energy density is less important than for mobile applications.

5.3 Potential combination of functionality classes

In principle, the battery system should be attributed to a single functionality class.

For very specific cases, where it is unclear if the battery usage is “repetitive-cycling” or “on-demand”, three cases are possible (cases 1 and 2 are strongly recommended):

- Case 1: Attribute the battery system to the “repetitive-cycling” functionality class
- Case 2: Attribute the battery system to the “On-demand” functionality class
- Case 3: The end-user shall establish the ratio between the cycling part and the on-demand part of the usage of the battery, eg x% REP + (100-x)% OND and in this case, the comparison of carbon footprints with other batteries is ONLY valid for the same weighed shares x% REP + (100-x)% OND.

6 Functional unit

6.1 Functional Unit: generalities

The function of the rechargeable batteries used in mobile or stationary applications is to supply energy (electrical current at a desired voltage range) over the Reference Service Life of the application as described in the technical specifications of the battery system purchaser. Identification of the end-user's detailed energy requirement needs is key for the definition of the functional unit for industrial batteries.

The end-user is specifying the usage and Reference Service Life for the battery(ies) inside the application. The battery system manufacturer is sizing the battery(ies) to meet the end-user specifications and will rely on the information from the sub-component manufacturers to perform the calculations.

To ensure the same functional unit, it is possible to size the battery system in different ways. Table 1 provides an example with dummy figures for comparing either a large battery for the entire service life or several smaller batteries to be replaced over time.

Details of the calculation are given in the following sections starting with an overview for the global calculation in Table 1.

	unit	unit precision	who ?	remark	REP-MOB case 1	REP-MOB case 2
identify the need	kWh_needed (over life)	Total needed by the application over the complete life (in years or cycles)	end-user request (technical specification)		5000 cycles of 2 kWh (under conditions in the application specification) = **10 000 kWh needed over life (*)**	5000 cycles of 2 kWh (under conditions in the application specification) = **10 000 kWh needed over life (*)**
identify the "physical unit"	kWh_produced	IEC kWh =rated energy at production including the whole system	battery system manufacturer (sizing)	the sizing can be a big battery for all life, or several small ones being replaced over life	10 kWh (selected at sizing as capable of 1000 cycles)	2,5 kWh (selected at sizing as capable of 500 cycles)
define the functionnal unit (as per the IEC 63369 definition)	normalized_kWh by kWh_installed	system boundaries as per clause 7.4	used to allow comparison of 2 batteries	1 kWh of all kWh_needed over reference service life	1kWh (from 10 MWh)	1kWh (from 10 MWh)
reference flow (as per the IEC 63369 definition)	total number of batteries to provide the kWh_needed multiplied by the weight of each battery	can be one big battery with high endurance cycling properties, or several smaller ones with less endurance	battery system manufacturer (sizing)	total number_of batteries over service life (***)	1 battery	8 batteries
intermediate calculation	"physical unit" CO2 footprint	(for 1 battery produced)	battery system manufacturer (with real production lines values and accepted	full system scope as per figure 1	900 kg CO2 eq for 1 battery system of 10 kWh	375 kg CO2 eq for 1 battery system of 2.5 kWh

			secondary data as per IEC 63369)			
CO2 footprint calculation (intermediate calculation, not normalized)	kg CO2 eq for reference flow		battery system manufacturer (production & use & recycling)	=CO2_production_per_battery_system (cradle to grave) *Nb_ref_flow (***)	=900 kg CO2 eg * 1 battery over life ==> **900 kg CO2 eq (**)**	=375 kg CO2 eg * 8 batteries over life ==> **3000 kg CO2 eq (**)**
CO2 footprint calculation (final, to compare the 2 possible solutions)	kg CO2 eq (as result of IEC 63369)				= 900 (**) / 10 000 (*) ===> **0,09 kg CO2 eq IEC 63369**	= 3000 (**) / 10 000 (*) ===> **0,3 kg CO2 eq IEC 63369**

Table 1: Example with dummy figures of a repetitive-cycling functional unit and resulting carbon footprint

Some examples of load profiles as expected by the end-user are provided in the specific sections to illustrate the end-user's expression of needs. The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

Depending on the application constraints, the size and/or the durability of the battery may not be capable of delivering its service over the application service life. In this case, the number of batteries per application will be increased (and hence the number of units required for analysis) to deliver the total Wh over the service life required by the application.

6.2 Functional Unit and Reference Flow for repetitive energy supply (REP-MOB & REP-STA)

The function of the rechargeable batteries used in mobile or stationary applications is to supply electrical current at a desired voltage range. The rechargeable battery is the main energy storage unit for mobile and stationary applications. Therefore, the functional unit (FU) for rechargeable batteries is defined as **1 kWh** (kilowatt-hour) **of the total energy provided by the battery system over the Reference Service Life** (measured in kWh).

The energy consumption during the use stage of the battery is defined **by the energy losses** linked to the battery including BTMS during charge, discharge and storage. The total energy received and released by the battery to the application has to be taken into account by the end-user for the use phase of its Product Carbon Footprint profile to avoid double counting.

For the REP use cases, the charging requirement is part of the load cycle provided by the end-user, as the battery is in regular cycling mode in usual operating conditions.

Some examples of load profiles are provided to illustrate the type of usage of the battery in the application and to size the battery according to the application need. . The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

6.2.1 Example of REP-MOB load profile – Forklift

Example of load Cycle for forklift is found in IEC 60 254-1 clause 3.1 and 3.3 :

Constant current discharge in 5 hours equivalent to a constant power discharge obtained by multiplying the 5 h constant current with 1.85 V (medium voltage during discharge)

The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

What?	Electrical energy, measured in Wh or kWh delivered (current and voltage during a unit of time).
How much?	1 kWh of the total energy delivered over Reference Service Life (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle).
How well?	Maximum specific energy (measured in Wh delivered /kg of reference flow) delivering the load profile
How long?	The amount of cumulative energy delivered over Reference Service Life of the batteries (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle). The time required to deliver this total energy is not a significant parameter of the service.

Table 2 - Key aspects of the Functional Unit defining the key aspects used to define the FU. REP-MOB

6.2.2 Example of REP-STA load profile – ESS container

Examples of Load profiles for ESS are found in technical specifications 62 933-3.2, 62 933 -3.3, 61 427-2). The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

What?	Electrical energy, measured in Wh or kWh delivered (current and voltage during a unit of time).
How much?	1 kWh of the total energy delivered over Reference Service Life (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle).
How well?	Maximum energy per surface area (measured in Wh/m2 footprint) delivering the load profile
How long?	The amount of cumulative energy delivered over Reference Service Life of the batteries (quantity of Wh, obtained from the number of cycles multiplied by the amount of delivered energy over each cycle). The time required to deliver this total energy is not a significant parameter of the service.

Table 3 - Key aspects of the Functional Unit defining the key aspects used to define the FU. REP-STA

The reference flow is the amount of battery(ies) needed to fulfil the defined function and shall be measured in kg of battery(ies) per kWh of the total energy required by the application over its

Reference Service Life. All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.

Depending on the application constraints, the size and/or the durability of the battery may not be capable of delivering the total energy required over the application service life. In this case, the number of batteries per application will be increased (and hence the number of units required for analysis) to deliver the total Wh over the Reference Service Life required by the application.

6.3 Functional Unit and Reference Flow for On-demand energy supply (OND-MOB & OND-STA)

The function of the on-demand batteries used in mobile or stationary applications is to supply specific power capability for a duty cycle (W over time) for an expected service life expressed in calendar years of operation.

The rechargeable battery provides on-demand energy over the designed Reference Service Life (back up batteries).

The functional unit (FU) is defined as the capability to provide the on-demand energy according to the load profile over the defined service life in months/years.

Definition of a back-up cycle: performing a discharge (Watts over a specified time) when demanded and recharging the battery to bring it back to its initial energy level

Example of a back-up cycle for Stationary: 500 kW during 20 minutes in an hospital in case of failure of the main grid energy supply then recharging according to the end-user request (see examples of values in the virtual representative product). Typically, one or two cycles per month with the battery(ies) lasting around 20 years in these conditions.

The Functional Unit for “on-demand use is normalized to **1 kWh “of back-up cycle”** (kilowatt-hour) **of the energy requested by the application in case of a duty cycle discharge, once a year, over the Reference Service Life by the battery** system (measured in years).

What?	Specific power capability (W for full discharge of the application at the end of battery service life /Wh) when demanded during the Reference Service Life of the application in calendar years of operation. eg example of FU for railways: 18 kWh spread over a period of three hours **once a year** during 30 years of train operation according to the profile on figure 1
How much?	1 kWh of the total energy delivered over service life **per year**
How well?	Maximum specific energy delivering the load profile, measured in Wh/kg for mobile application
How long?	The amount of energy delivered on-demand over service life as specified by the end-user in years

Table 4 - Key aspects of the Functional Unit defining the key aspects used to define the FU OND-MOB

What?	Specific power capability (W for full discharge of the application at the end of battery service life /Wh) when demanded during the Reference Service Life of the application in calendar years of operation. eg example of FU for a virtual UPS:

	400kWh spread over a period of 0.2 hours **three times per year** during eight years of UPS operation according to the profile on figure 88
How much?	1 kWh of the total energy delivered over service life per year
How well?	Maximum specific energy delivering the load profile, measured in Wh/m3 for stationary applications
How long?	The amount of energy delivered on-demand over Reference Service Life as specified by the end-user in years

Table 5 - Key aspects of the Functional Unit defining the key aspects used to define the OND-STA

Note: In this case, the use is three times per year, but the end-user still qualifies this battery as "on-demand" battery.

The reference flow is the amount of product needed to fulfil the defined function and shall be measured in kg of battery system per kWh of the "back-up cycle" that can be performed once a year by the application over its service life (calendar years is key). All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.

Depending on the application constraints, the size and/or the durability of the battery may not be capable of delivering "back-up cycle" that can be performed once a year over the application service life. In this case, the number of batteries per application will be increased (and hence the number of units required for analysis) to deliver the total Wh over the Reference Service Life required by the application.

	unit	unit precision	who ?	remark	OND-MOB case 1	OND-MOB case 2
identify the need	kWh_needed (over life)	Total needed by the application over the complete life (in years or cycles)	end-user request (technical specification)		10 MWh (under conditions in the application specification) = **10 000 kWh needed once a year over a life of 20 yr (*)**	10 MWh (under conditions in the application specification) = **10 000 kWh needed once a year over a life of 20 yr (*)**
identify the "physical unit"	kWh_produced	IEC kWh =rated energy at production including the whole system	battery system manufacturer (sizing)	the sizing can be a big battery for all life, or several small ones with replacement over life	14 MWh (selected at sizing as **capable of 20** yr)	11 MWh (selected at sizing as **capable of 5** yr)
define the **functionnal unit** (as per the IEC 63369 definition)	normalized_kWh by kWh_installed	system boundaries as per clauses 6.3 and 6.4	used to allow comparison of 2 batteries	1 kWh of all kWh_needed once	10 MWh (once a year over 20 yr)	10 MWh (once a year over 20 yr)

reference flow (as per the IEC 63369 definition)	total number of batteries multiplied by the weight of each battery needed to provide the kWh_needed	can be one big battery with high calendar life, or several smaller ones with lower calendar life	battery system manufacturer (sizing)	Nb_ref_flow	1 battery	4 batteries
intermediate calculation	"physical unit" CO2 footprint	(for 1 battery produced)	battery system manufacturer (with real production lines values and accepted secondary data as per IEC 63369)	full system scope as per figure 1	1 650 000 kg CO2 eq for 1 battery system of 14 MWh (produced)	1 350 000 kg CO2 eq for 1 battery system of 11 MWh (produced)
CO2 footprint calculation (intermediate calculation, not normalized)	kg CO2 eq for reference flow		battery system manufacturer (production & use & recycling)	=CO2_production_per_battery_system (cradle to grave) *Nb_ref_flow	=1650 t CO2 eg * 1 battery over life ==> **1650 t CO2 eq (**)**	=1350 t CO2 eg * 4 batteries over life ==> **5400 t CO2 eq (**)**
CO2 footprint calculation (final, to compare the 2 possible solutions)	kg CO2 eq (as result if IEC 63369)				= 1650 000 (**) / 10 000 (*) / 20 (*) **===> 165/20 kg = 8,25 kg CO2 eq IEC 63369**	= 6 600 000 (**) / 10 000 (*) / 20 (*) **===> 540/20 kg = 27 kg CO2 eq IEC 63369**

Table 6 – Example with dummy figures of the on-demand functional unit and resulting carbon footprint

The recharge condition is not part of the load cycle for OND use cases, as the battery is in permanent charge mode in usual operating conditions.

Some examples of load profiles are provided to illustrate the type of usage of the battery in the application and to size the battery according to the application need. The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

6.3.1 Example of OND-MOB load profile –IEC 62973-1 Regional train / EMU

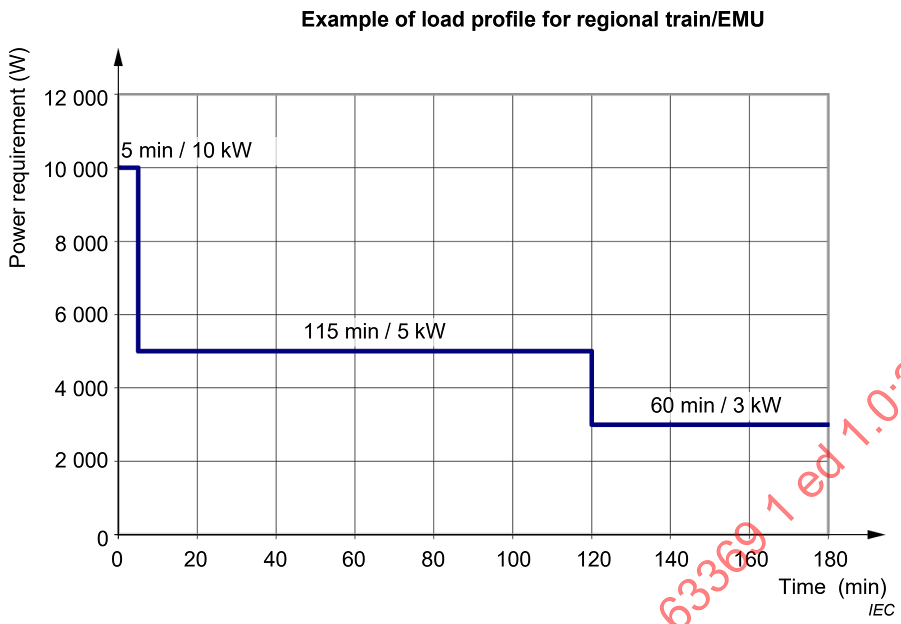


Figure 1 – Example of OND-MOB: load profile for regional train / EMU (without starting up segment)

The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

As stated inTable 4, the discharge load occurrence is considered to happen once a year, and the expected life duration is of 30 years for the considered application.

6.3.2 Example of OND-STA load profile: IEC 60896-21

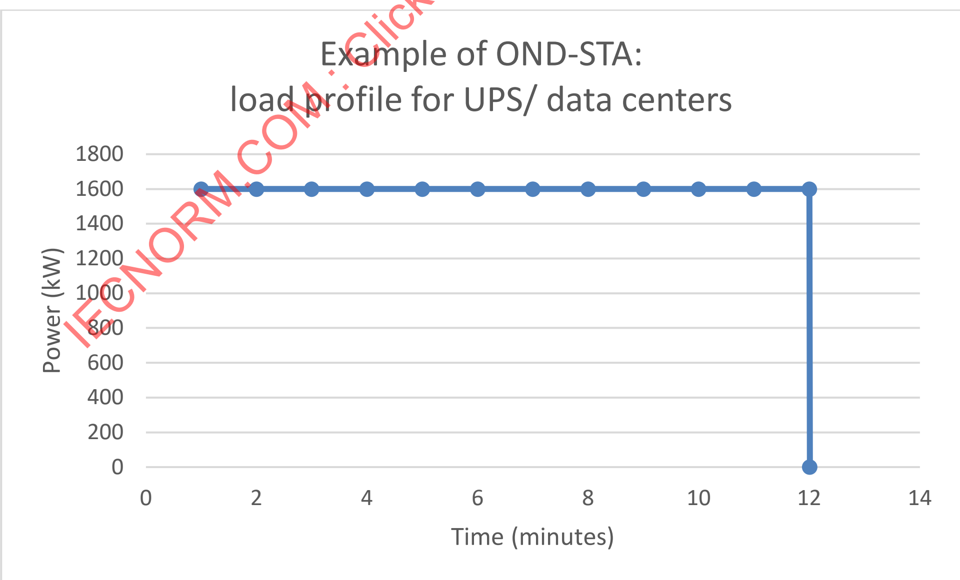


Figure 2 – Example of OND-STA: load profile for UPS/ data centers

The real Reference Service Life including load profiles, operating conditions, … shall be stated by the battery purchaser as the base of all the calculations.

As stated in Table 5, the discharge load occurrence is considered to happen few times a year, and the expected life duration is of 8 years for the considered application.

The energy consumption during the use stage of the battery is defined by the energy used to maintain the battery at its operational ability to provide the back-up cycle linked to the battery including BTMS and BMS during floating charge. The total duration of service availability provided by the battery to the application has to be taken into account by the end-user provider, for the use phase of its Product Carbon Footprint profile.

The metrics for this duty are specific power capability expressed in W and Wh and expected service life in calendar years of operation.

7 Calculation methodology

This part describes the global methodology consisting of 2 main steps:

- **Step 1) Derivation of a virtual representative product**
  - The components and processes having a significant carbon footprint ("hot spots") shall be identified.
  - These items shall receive particular attention during the calculation of the Battery Carbon Footprint.
  - For this purpose, a virtual product is defined (see 7.3) to identify the hotspots.
- **Step 2) Derivation of carbon footprint data of actual products**
  - The components and process steps with a significant carbon footprint (="hotspots") shall be investigated and documented with company specific data.
  - For other components and production processes of the Bill Of Materials (BOM) ("cold spots"), secondary data are acceptable.
  - In part 2, the carbon footprint calculation of actual products will be performed using primary data for "hotspots" and agreed common secondary data for "cold spots". Global Data platforms to access the data needed for the BCF calculations will be defined in part 2.

7.1 Concept of virtual representative product

The virtual representative product is a market weighted-average modelling of existing batteries in a given functionality class. The virtual product is not intended to be an actual battery (eg for the case of a road vehicle with 75% of 4 wheelers and 25% of 2 wheelers, a virtual representative product could be a 3,5 wheeler).

Virtual representative products are used to describe a large variety of active materials and other components that are existing in different technologies. They include a little amount of every potential actual product, so we are able to have them identified in the virtual product; then parts of the virtual products which are not part of the Bill of Materials of the actual product should be removed in the part 2 when the carbon footprint of the actual product will be calculated.

It will be used as the basis for calculations in part 2. Actual products should only be compared within their own functionality classes.

Based on the results of these virtual calculations, the major contributor values will be identified as hotspots. Those hotspots will be used to focus on what matters the most in the calculations of the Battery Carbon Footprint of actual batteries.

At the end of the calculation where primary data are requested for hotspots, it is possible that the hotspots of the actual battery are different from the hotspots of the representative product of the same functionality class.

7.2 Composition of the virtual representative product

The main components of the virtual representative products are identified as follows:

- The cell and its safety essential components (Safety Management Unit -SMU) incorporated during the battery assembly stage and, if present, the modules and their structures.
- The system component parts necessary for ensuring proper battery function as required for the application:
    - The BMS (Battery Management System):
        - The BCU (Battery Control Unit) consisting of electronic components like switches and contactors
        - The BMU (Battery Management Unit) consisting of the electronic part for battery management (Note: A SMU may be incorporated in a BMS for the presentation of the BCF results)
    - The BTMS (Battery Thermal Management System) consisting of components directly associated to the battery for its thermal management. It can consist in various components allowing for static or dynamic heat exchanges such as thermal conductive parts, tubes for circulating fluids, etc..

- - The final outer casing of the battery if applicable
- In some configurations part of the BMS might be positioned in the charger or application (for example: contactors or switches). In this case, these components are considered to be part of the BMS.

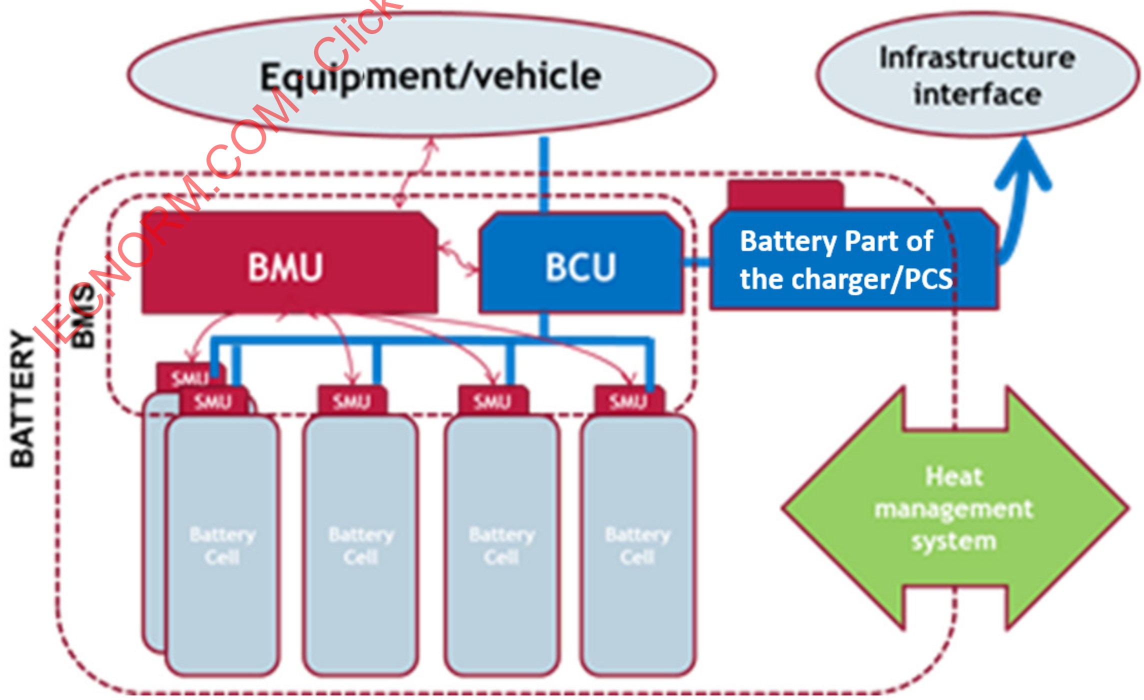


Figure 3 – representative products components

Battery part of the charger (if it ensures some of the BMS functions) or the Power Conversion System (PCS) or the FSS (Fire Suppression System) in case of large battery systems which is required for functional safety of the battery has to be taken into account in the battery scope for carbon footprint calculation. This part is variable, depending on the application (mobile application or stationary application).

When the battery (including all its functional components) is disconnected from the application, all components staying with the battery must be considered when performing the calculation of its carbon footprint.

7.3 Derivation of the virtual representative products

This section introduces the virtual representative products which have been classified to calculate the Battery Carbon Footprint of the industrial batteries in each application.

There are 5 virtual representative products for the 4 functionality classes considered, each based on the market share of the lithium-based chemistries used in its own functionality class.

For each functionality class, the main types of industrial batteries already on the market today were studied and their main characteristics were averaged. For instance, the representative virtual product voltage as shown below could represent an average between 24V and 110V batteries, thus not corresponding to any voltage present on the market.

REP-MOB: Forklifts (very large market share) , off-road vehicles

REP-MOB	VIRTUAL Product
Voltage	48V
Energy	20 kWh
Charge and discharge rates	1C charge, 0.3 C discharge
Cooling	No
Chemistry	70% LFP/ 20% NMC / 10% LMO
Life duration	7 years
Nb of cycles	2000 cycles

REP- STA: (legacy battery, industrial storage container sets)

For the REP-STA functionality class, there is too much difference between the bill of materials of the legacy battery and industrial/container-sized battery. Therefore, it was decided to create two virtual representative products.

REP-STA	VIRTUAL LEGACY	VIRTUAL CONTAINER
Voltage	200V	1200V
Energy	15 kWh	20 MWh
Charge and discharge rates	0.3C C&D	C Ch & disch

Cooling	No	50% air conditioning 50% liquid cooling)
Chemistry	70% LFP/30%NMC	50% LFP, 50% NMC
Life duration	12 y	15 y
Nb of cycles	5000 cycles	
FSS	No	YES

- OND-MOB Example : Railways auxiliaries

OND-MOB	VIRTUAL AVERAGE
Voltage	300V
Energy	18 kWh
Charge and discharge rates	0.5 C Ch & C Disch
Cooling	Natural ventilation
Chemistry	60% NMC/LTO and 40% LFP/graphite
Life duration	15 years

- OND-STA Example : UPS/ data-centers

OND- STA : UPS/ data centers	VIRTUAL AVERAGE
Voltage	200V
Energy	400 kWh
Charge and discharge rates	0.6C ch and 4C discharge
Cooling	Natural ventilation
Chemistry	LFP
Life duration	15 years
FFS	No

The Table 7 summarizes the main characteristics of each virtual representative product

Elements		REP-MOB	REP-STA (legacy)	REP-STA (container)	OND-MOB	OND-STA
Specify if it is a real or a virtual product		Virtual	virtual	virtual	virtual	Virtual
Description of the product		Repetitive energy supply in mobile equipment, Chemistry composition based on market share	Repetitive energy supply in stationary equipment, Chemistry composition based on market share	Repetitive energy supply in stationary equipment, Chemistry composition based on market share	On-demand energy supply in mobile equipment, Chemistry composition based on market share	On-demand energy supply in stationary equipment, Chemistry composition based on market share
Typical Energy		20 kWh	15 kWh	20 000 kWh	18 kWh	400 kWh
Typical voltage		48 V	200 V	1200 V	300 V	200 V
Bill of materials (BOM) as appropriate		See Part 2				
System boundary	Production stage	Included	Included	included	included	Included
	Use stage	Included	Included	included	included	Included
	EoL stage	Included	Included	included	included	Included
Product Boundary	Charger (except part of battery if any)	Excluded	Excluded	Excluded	Excluded	Excluded
Assumptions related to transportation and storage scenario		Representative conditions of transport for the materials and the batteries are described (see part 2). As today most cell manufacturing is in Asia, the transport of the active material used for this purpose has been considered only locally In addition, as the impact of the transport has been proven negligible in the footprint, no specific condition is described, and default data is provided.				
Assumptions related to use scenario		Only charging energy losses are accounted (related to battery efficiency including BTMS efficiency)				
Assumptions related to EoL		Recycling process of the cell based on “Recycling rechargeable lithium ion batteries: Critical analysis of natural resource savings”, Dewulf et al, Resources, conservation and recycling, 2009 Following steps has been considered in the End-of-Life stage (see part 2) Dismantling process of the battery Pyrometallurgical treatment process for the cell Then, Hydrometallurgical treatment process for the cell				

Table 7 – Representative products for the 4 functionality classes

Due to the large number of applications, and therefore the large number of usage phase descriptions, it is not possible to define a simple benchmark classification applicable for all batteries. Nevertheless, a benchmark is possible per functionality class, based on each of the 5 representative products (see limitations and benchmark restrictions in IEC 63369-2), as long as they use the same default data described in this table.

7.4 System boundaries

The system boundary for a Battery Carbon Footprint of industrial Li-ion batteries includes the life cycle stages described in this section. The processes included in the system boundaries shall be divided, according to the hotspot identification, into **foreground processes** (i.e. core processes where company specific data are required) and **background processes** (i.e. processes in the product life cycle for which common secondary data are used).

The following life cycle stages and processes shall be included in the system boundary:

Life cycle stages		Short description of the processes included
Raw material acquisition	Mining and refining of raw materials	separate /+/ and /-/, up to metal salts.
	Manufacturing of cells active materials	separate /+/ , /-/ where relevant (include precursors and CAM, and any other specific active material)
	Manufacturing of cells and batteries components	Manufacturing of other chemicals (conductive agents, binders, electrolyte), current collectors, mechanical parts, separators, casing and complex component assembly such as electric/electronics components and BTMS. This is done by individual supply chains which feed the cell manufacturer.
Product production	Electrodes and cell /module manufacturing	Manufacturing of electrodes, assembly of cells or modules
	Transport (optional)	
	Battery system assembly	Cells or modules are assembled (into more integrated mechanical structures) up to the battery system, including e.g. BTMS, FSS and electronic components
Distribution		Representative transports of battery to OEM and onward to the end-user
Use phase		Electricity usage during use phase (energy losses due to the battery including BTMS) according to agreed cycles or load profiles
End of life and recycling		Collection, dismantling and recycling.

Table 8 – Life cycle stages

For each life cycle stage, **each party involved is responsible for providing its Component Carbon Footprint calculation to the next party in the battery supply chain** with the assumption of electrical energy source mixes during the use phase. This will depend on the country where the battery will be used and recycled.

The following processes may be excluded based on the cut-off rule (a 1% cut-off based on environmental significance):

– Packaging of intermediate components and packaging of battery systems

– Detailed transport operations description for raw materials, product distribution or end of life: as the impact is usually negligible, only the default data provided shall be used, unless primary data of required quality (see 9) is available.

- Manufacturing of production and material handling equipment (e.g. AGV, trays, packing materials or similar) used in the factory for battery assembly and recycling, as their impacts are usually negligible.
- OEM manufacturing (corresponding to the battery assembly process with the OEM system components) is not considered: it mainly corresponds to mechanical assembly and is incorporated inside the OEM equipment. The specific energy or material consumption for this process are negligible when compared to the manufacturing process of OEM components.
- Secondary data are used for the environmental impact of assembled electronics and mechanical parts, based on the materials composition used.

Each BCF study done in accordance with this document shall provide in the Battery Carbon Footprint study a diagram indicating the organizational boundary and a description of data quality. If recycled material was used in the original battery components, it has to be documented in the Battery Carbon Footprint Study to avoid double counting in the battery recycling (environmental credits).

The manufacturing of the main product includes two main steps: electrodes and cell/module manufacturing, and battery system assembly. The list of mandatory primary company-specific data (foreground) is described in IEC 63369-2 and corresponds to the Figure 4– System Boundaries-life cycle of a Li-ion battery system below.

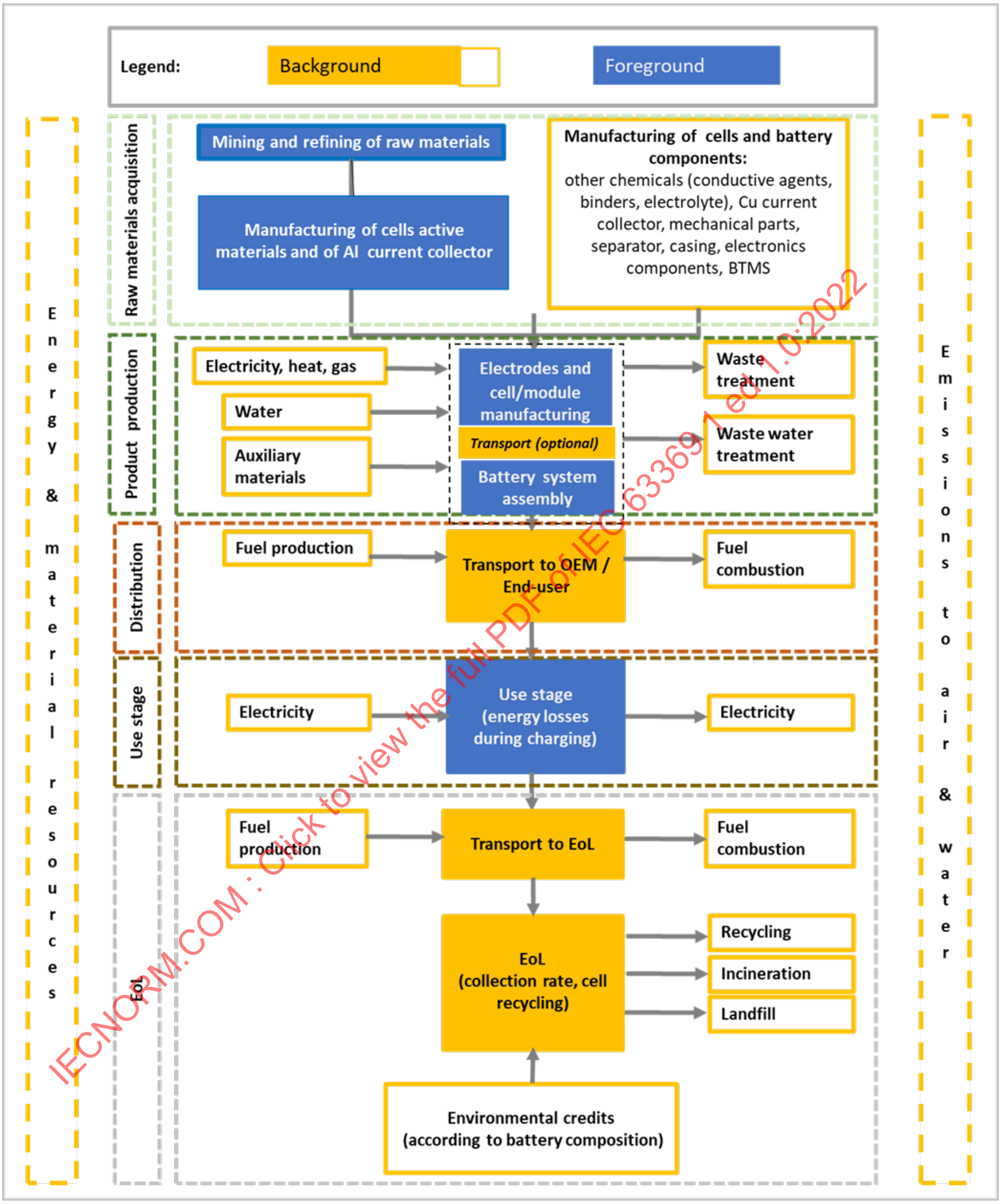


Figure 4 – System Boundaries- life cycle of a Li-ion battery system

These foreground and background data are global assumptions, not considering the four functionality classes defined above.

In case the hotspots, as identified inFigure 4, are different in IEC 63369-2, then IEC 63369-2 foreground data apply.

7.5 Raw material acquisition stage and production stage

The raw material acquisition and production stages include the following steps:

Raw Material Acquisition and Pre-processing

The raw material acquisition and pre-processing stages start when resources are extracted from nature or recovered from the recycling processes and end when the product components enter (through the gate of) the product's production facility. Transportation within and between extraction and pre-processing facilities are included with the usual generic assumptions (locations/countries of suppliers, mode of transport …) , see Annex A.

OEM components manufacturing

- SMU (Safety Management Unit), mainly electronics components,
- BCU (Battery control unit), mainly electric and electronic components like switches and contactors
- BMU (Battery management unit), the electronic part for battery management
- BTMS: the components directly associated with the battery for its thermal management (eg cooling system, etc)
- FSS: Fire Suppression System
- Charger component, when some part is dedicated to the battery.
- Any component which is necessary for the battery to provide the requested service
-

Transport: Transport of raw materials and/or components to the battery production site.

Production: The production stage begins when the product components enter the production site and ends when the finished product leaves the production facility. Production-related activities include:

Manufacture of electrodes

- Ink/slurry preparation (mixing of solids and liquids)
- Coating and drying
- Calendering and slitting

Cell assembly and electrical formation

- Winding or stacking of positive electrode, negative electrode and separator and cell assembly of all cell components (including electrolyte) into the cell casing
- Cell electrical formation

Module assembly

- Cells are assembled in a module
- When needed by the application, the cells are assembled with electronic parts and structural parts such as casings to form the finished module.

Battery system assembly

- Modules (or cells) are assembled in a battery system casing or housing
- When needed by the application, the modules (or cells) are assembled with electronic parts and mechanical parts such as eg battery system housings or cooling systems, to form the finished battery system.

NOTE: Any component which is part of the battery system functional unit and located outside the battery casing (eg the charger or the PCS) are part of the system boundaries for the battery system assembly.

The Figure 5 describes the production of the Li-ion battery. Energy supply, as well as transportation of raw materials to the manufacturing site, are included within the system boundaries.

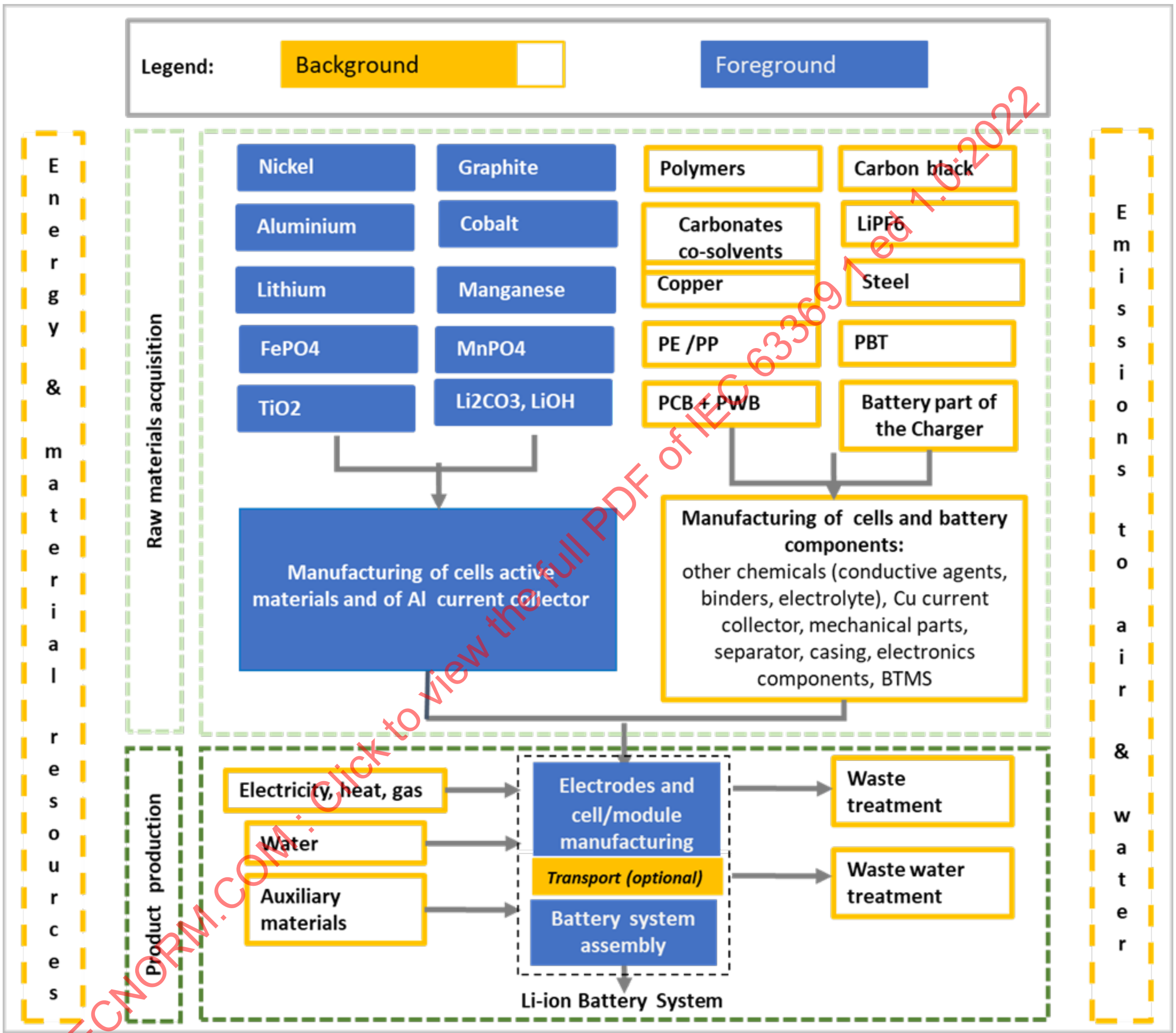


Figure 5 –Li-ion battery production cradle-to-gate processes

In general, the definition of the system boundaries is based on the process and components dedicated to the battery function.

The OEM manufacturing (corresponding to the battery assembly process with the OEM system components) mainly involves integrating mechanical and electronic components in a mechanical assembly process. This process has not been specifically considered in this document as it is not part of the battery assembly process but is incorporated into the OEM equipment assembly line. The specific energy or material consumption for this process are negligible when compared to the manufacturing process of the OEM components. Secondary data are used for the environmental impact of the assembled electronics and mechanical parts, based on the materials composition used.

7.6 Distribution

See annex A for transportation

7.7 Use stage

The energy consumption during the use stage of the battery is defined by:

- For repetitive energy supply: the energy losses inherent to battery cycling including BTMS and BMS during the Reference Service Life of the application under the environmental conditions specified by the end-user at the specified operating location.

- For on-demand energy supply: the energy used to maintain the battery, including BTMS and BMS, ready to provide the back-up energy. The battery is maintained in charge mode over the Reference Service Life and under the environmental conditions specified by the end-user at the specified operating location.

The application operator shall consider in its Product Carbon Footprint profile the total energy consumption and its generation mix during the life cycle of the system powered by the battery, not considering the losses at battery system level. These losses will be taken into account in the Battery Carbon Footprint calculation of the specific battery.

The losses of the battery during the use stage, such as energy consumption compensating the losses e.g. due to Joule effect – ohmic losses-, self-discharge, thermodynamic inefficiency, etc…, shall be considered at battery level.

The overall energy use efficiency depends on the battery and equipment technologies (e.g. thermal control methodology, power line filtering by equipment, etc.) and on the specified application usage conditions.

7.8 End-Of-Life stage

The end-of-life processes shall include:

– Disassembly of the battery system components for re-use, recycling or disposal. This corresponds to the separation of the components added during the battery and OEM assembly processes.

Recycling of disassembled components by mechanical, thermal, pyrometallurgical or hydrometallurgical treatments or combination thereof -example, one currently used Li-ion recycling process is a combined pyro – and hydrometallurgical treatment:

The main outputs of the recycling process are a metallic fraction (containing metals from the battery), and a slag. This metallic fraction can be grinded and refined with a hydrometallurgical process to extract valuable metals or alloys such as cobalt in case of Li-Cobalt or Li NMC based batteries. In the hydrometallurgical treatment step, the metallic alloy obtained in the previous pyrometallurgical step is processed to recover the metal salts which can be used again in manufacturing…

– Other ancillary operations and processes shall be assessed for their energy consumption and emissions.

– The materials recovered as a result of recycling generate environmental credits. These credits are calculated based on the mass of the recycled materials (more details in section 10).

Figure **6**provides an overview of the disassembly and recycling processes of a battery system.

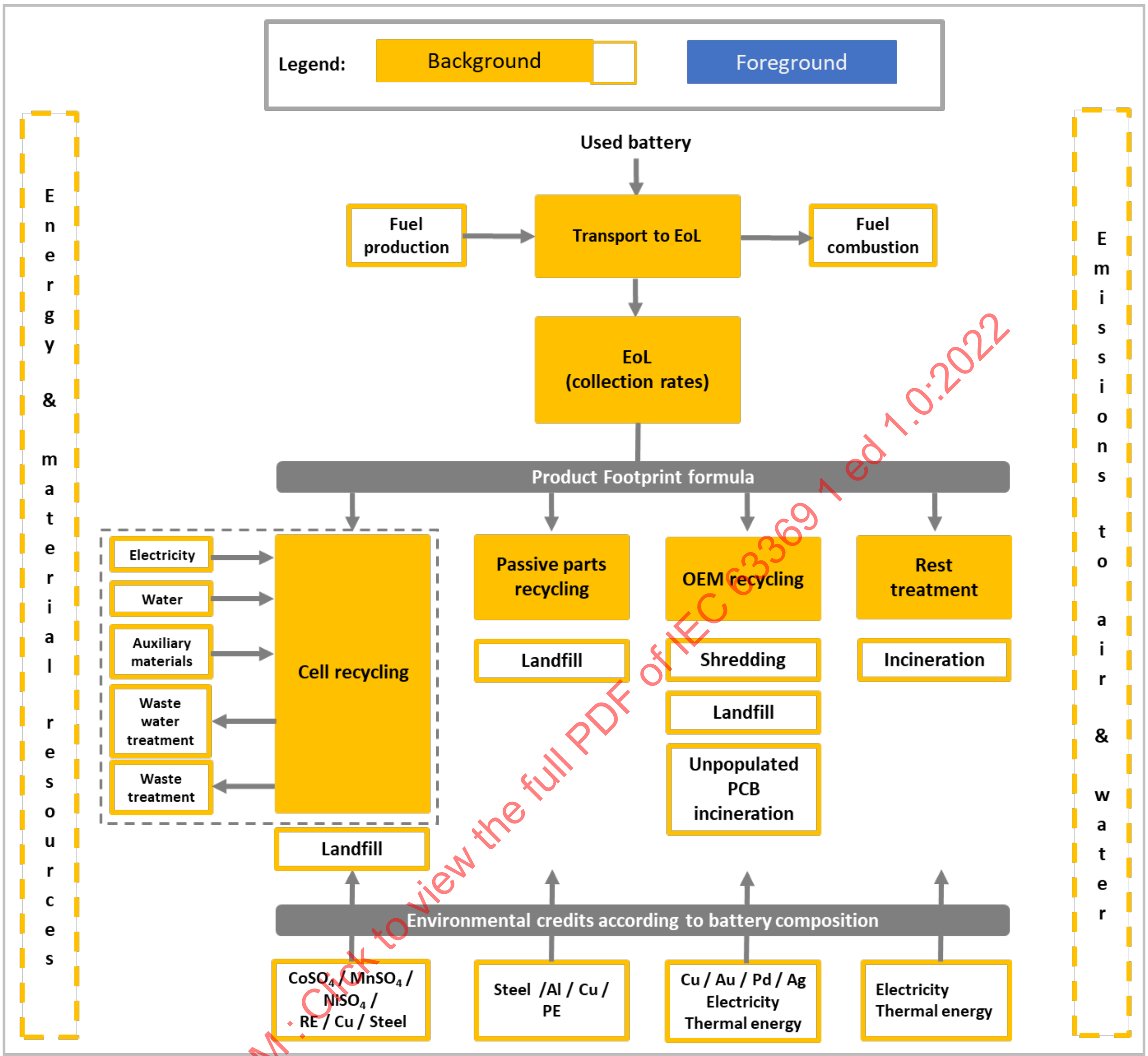


Figure 6 – Disassembly and recycling processes

7.9 Carbon footprint assessment

Each Battery Carbon Footprint study carried out in compliance with this document shall refer to the Table below.

Impact category	Indicator	Unit	Recommended default LCIA method
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Baseline model of 100 years of the IPCC (based on IPCC 2021

Table 9 – Battery Carbon footprint calculation indicator

7.10 Limitations

In carbon footprint studies, limitations to carrying out the analysis may arise and therefore assumptions need to be made. For example, generic data may not completely represent the reality of the product analysed and may be adapted for better representation. Any limitation and assumptions shall be transparently reported and justified.

Packaging materials for battery components and final product shall not be considered, as the contribution to the overall impact has been estimated to be negligible during the screening study.

Benchmark limitations:

For each of the 5 representative products in the 4 functionality classes, the Battery Carbon Footprint results may be used to benchmark products using the same system boundaries, same use stage and EoL scenarios, and similar assumptions for the background data (such as raw materials data and transport conditions, charger and electronics data, proxies…), unless primary data are used.

The use stage shall be precisely described, and the battery performance measured in these same conditions. When the precise usage conditions are not available to the battery manufacturer performing the Carbon Footprint calculation, then the battery performance and environmental impact benchmark shall be assessed using the reference use phase conditions described for the representative product (see 7.7).

In the same way, the secondary data provided for the calculation of the environmental impact of the representative product shall be used in order to obtain benchmark information. It is recommended to modify these secondary data only when primary data can be provided, according the data quality (see9.) and specific requirements (nature, representativity of data, etc).

8 Life cycle inventory

All newly created processes shall be compliant as for quality of data (see 9.).

In case sampling is needed, it shall be conducted as specified in this document. However, sampling is not mandatory and any user of this document may decide to collect the data from all the plants without performing any sampling.

Rules to assess the GHG emissions related to the electricity used to manufacture a battery in the Battery Carbon Footprint Calculation:

The “Product Life Cycle Accounting and Reporting Standard” of the GHG Protocol defines five data quality indicators:

• Technological representativeness: the degree to which the data reflect the actual technology(ies) used in the process

• Geographical representativeness: the degree to which the data reflects actual geographic location of the processes within the inventory boundary (e.g., country or site)

• Temporal representativeness: the degree to which the data reflect the actual time (e.g., year) or age of the process

• Completeness: the degree to which the data are statistically representative of the process sites

• Reliability: the degree to which the sources, data collection methods, and verification procedures used to obtain the data are dependable.

This standard aims to achieve these goals, including geographical and temporal representativeness.

In order to ensure the comparability of the Battery Carbon Footprint calculations, battery manufacturers shall follow the same rules in their calculations in order to properly assess the GHG emissions of electricity used to manufacture and operate the batteries.

Three electricity supply cases will be considered.

Case 1: Energy supplied from the grid, with no consideration of attribute tracking instruments.

Context: electricity using companies may enter in supply contracts with electricity distributors without consideration of attribute tracking instruments. In this case, the Emission Factor (EmF) of the country consumption mix shall be applied to assess the emissions generated to produce the purchased electricity.

Internationally recognized data sources shall be preferred. Amongst such well recognized data sources is the International Energy Agency (IEA) grid emission factors yearly publication.

The GHG Protocol proposes and alternative methodology which is based on the use of the residual mix. Due to the fact that many countries do not have central registries in place to capture the generation, transfer and cancellation of attribute tracking instruments, reliable residual mix EmF cannot be calculated for these areas.

In the case of very large countries such as the USA, Canada, Russia and China in which several electrical grids operate, the grid specific consumption Emission Factor (EmF) shall be used. Preference shall be given to internationally recognized data providers. For the USA, the EPA eGrid data shall be used (https://www.epa.gov/egrid/data-explorer).

In order to ensure full comparability, electricity transport and distribution losses shall be considered, and only the EmF of the country consumption mix shall be used.

Case 2: Electricity supplied from a production asset connected to the energy using plant by means of a direct and dedicated connection:

Context:

This case covers inter alia the following situations: production of electricity by means of a Diesel generator or by means of a renewable energy generation asset such as a PV system or a windmill. The electricity generation assets are located within the premises of the energy using plant or in its vicinity. Remote production assets are usually not connected to a specific energy using plant by means of a direct dedicated connection, but rather through the electrical grid, and therefore are not described by this case.

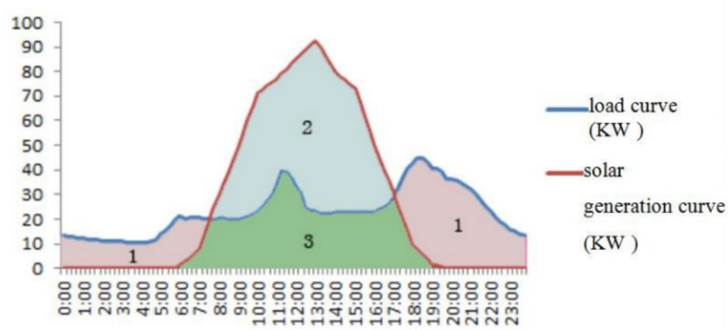
The use of the specific Emission Factor (EmF) of such assets will be subject to the following conditions:

– The energy supplied by such assets is not sold to the grid or to another electricity user, it does not benefit from a feed-in tariff.

– Only the fraction of energy generated by the asset demonstrated to lie below the load curve of the energy using site (as measured in hourly intervals) shall be taken into consideration for use of the asset specific emission factor,

– Consideration of energy generated by the asset and above the load curve can be contemplated if it can be demonstrated that energy storage assets are able to provide the required time-shifting service.

In this chart, only “area 3” electricity energy can be counted as used by the site, with the asset specific EmF.



The energy present in “area 2” is either wasted or injected into the grid, and cannot be associated with the site consumption

The energy present in “area 1” is supplied from the grid and is considered using the appropriate grid characteristics (see case 1 above)

Figure 7 – Typical daily solar generation & load curve

<u>Case 3:</u> Energy attributes instruments contracted by means of a Power Purchasing Agreement entered into with a remote production asset injecting the underlying electrical energy produced into the grid

Context: electricity using companies may enter directly or through intermediaries into Power Purchasing Agreements with low carbon energy producers. In such contractual arrangements, energy using companies may secure ownership of energy attributes instruments such as Guarantees of Origin (GoOs), Renewable Energy Certificates (RECs) or local variation thereof.

Consideration of such energy attributes instruments including the relevant Emission Factor (EmF) for the product carbon footprint calculation of the product shall be subject to the following conditions:

- The generating asset does not benefit from a feed-in tariff, and the asset is additional, that is its construction essential financing was derived from the PPA,
- The contracted asset shall be connected to the same bidding area, to the same grid or shall be located in the same country as the energy using facility,
- A traceability system shall ensure the uniqueness of such instruments. Only instruments sourced tracked, redeemed, cancelled or retired by or on behalf of the energy using company shall be considered, subject to an audit of the contract, third party certification or if handled automatically through other disclosure mechanism such as registries,
- Only the fraction of energy injected into the grid by the contracted asset demonstrated to lie below the load curve of the energy using facility, as demonstrated on an hourly basis on the basis of the date/time stamp of each instrument, shall be taken into consideration.

9 Data quality requirements

The data quality of each dataset and the total CO2 footprint study shall be calculated and reported. The calculation of the DQR shall be based on the following formula:

The DQR shall be based on the following formula with 4 criteria:

$$\mathrm{DQR} = \frac{\overline{Te_R}+\overline{G_R}+\overline{Ti_R}+\overline{P}}{4} \qquad \text{[Equation 1]}$$

Where TeR is the Technological-Representativeness, GR is the Geographical-Representativeness, TiR is the Time-Representativeness, and P is the Precision/uncertainty. 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.

Each data quality criterion to be scored (TeR, GeR, TiR and P) is rated according to the five levels listed in Table 11.

Data Quality Rating of Data Quality Criteria (TeR, GeR, TiR, P)	**Data Quality Level**
1	Excellent
2	Very Good
3	Good
4	Fair
5	Poor

Table 10 - Data Quality Rating (DQR) and data quality levels of each data quality criterion

Five quality levels (from excellent to poor) can be achieved according to the Data Quality Rating (DQR). They are summarized in Table 12.

Overall data quality rating (DQR)	**Overall data quality level**
DQR ≤ 1.5	"Excellent quality"
1.5 < DQR ≤ 2.0	"Very good quality"
2.0 < DQR ≤ 3.0	"Good quality"
3 < DQR ≤ 4.0	"Fair quality"
DQR >4	"Poor quality"

Table 11 - Overall data quality level of compliant-datasets, according to the achieved data quality rating

The DQR formula is applicable to:

1. Company-specific datasets: section 9.1 describes the procedure to calculate the DQR of company-specific datasets;

2. Secondary datasets: when using a secondary *compliant dataset* in a CF study (procedure described in 9.2);

The next sections provide tables with the criteria to be used for the semi-quantitative assessment of each criterion. If a dataset is constructed with company-specific activity data, company -specific emission data and secondary sub-processes, the DQR of each shall be assessed separately.

9.1 Company specific foreground datasets

When creating a company-specific dataset, the data quality of i) the company-specific activity data and ii) the company-specific direct elementary flows (i.e. emission data) shall be assessed separately.

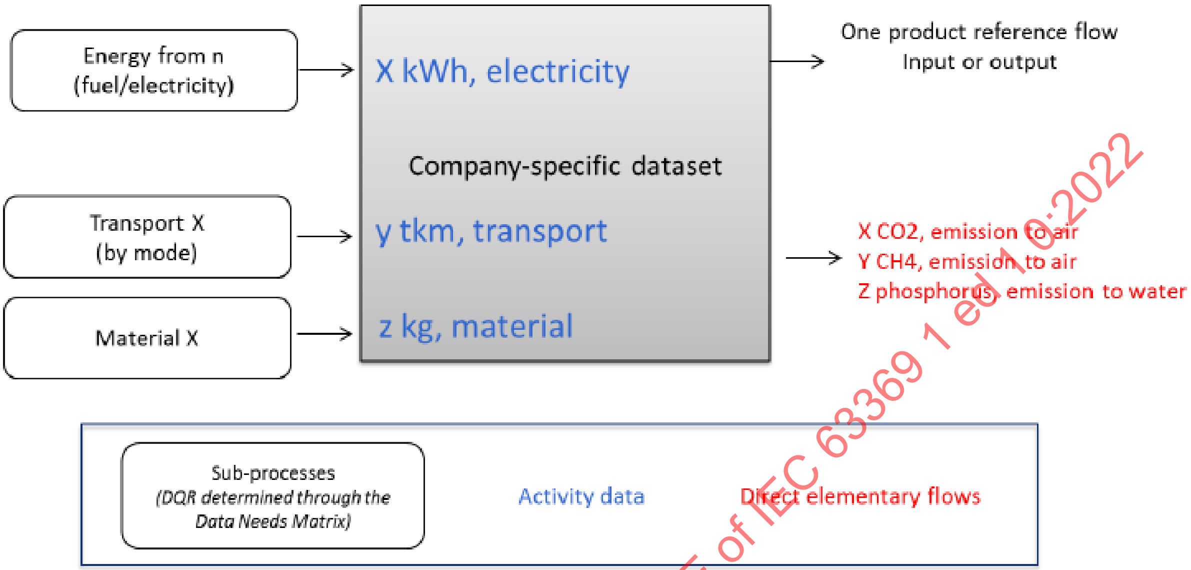


Figure 8 - Graphical representation of a company-specific dataset. A company-specific dataset is a partially disaggregated one: the DQR of the activity data and direct elementary flows shall assessed.

The score of criterion P cannot be higher than 3 while the score for TiR, TeR, and GR cannot be higher than 2 (the DQR score shall be ≤1.6). The DQR shall be calculated at the level-1 disaggregation, before any aggregation of sub-processes or elementary flows is performed.

The DQR of the newly developed dataset shall be calculated as follows:

1) 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 carbon footprint 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 carbon footprint impact of the direct elementary flows.

2) Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and each most relevant direct elementary flow using Table 13.
a. Each most relevant direct elementary flow consists of the amount and elementary flow naming (e.g. 40 g CO_2). For each most relevant elementary flow (EF), the 4 DQR criteria named $Te_{R\text{-}EF}$, $Ti_{R\text{-}EF}$, $G_{R\text{-}EF}$, P_{EF} shall be evaluated (e.g. 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 $Ti_{R\text{-}AD}$, P_{AD}, $G_{r\text{-}AD}$, $T_{er\text{-}AD}$).

c. Considering that both activity data and direct elementary flows shall be company specific, the score of P cannot be higher than 3 while the score for TiR, TeR, and GeR cannot be higher than 2 (the DQR score shall be ≤1.5).

3) Calculate the carbon footprint contribution of each most-relevant activity data (through linking to the appropriate sub-process) and direct elementary flow to the total sum of the carbon footprint of all most relevant activity data and direct elementary flows, in %). 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:

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).

☐ 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).

4) 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.

5) The user of the CFP method shall calculate the total DQR of the newly developed dataset using the equation below, where $\overline{Te_R},\overline{G_R},\overline{Ti_R},\overline{P}$ are the weighted average calculated as specified in point (4).

$$DQR = \frac{\overline{Te_R}+\overline{G_R}+\overline{Ti_R}+\overline{P}}{4} \qquad \text{[Equation 1]}$$

Rating	P_{EF} and P_{AD}	$Ti_{R\text{-}EF}$ and $Ti_{R\text{-}AD}$	$Te_{R\text{-}EF}$ and $Te_{R\text{-}AD}$	$G_{R\text{-}EF}$ and $G_{R\text{-}AD}$
1	Measured/calculated <u>and</u> externally verified	The data refers to the most recent annual administration period with respect to the BCF report publication date	The elementary flows and the activity data exactly 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 BCF 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 BCF 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; **$Ti_{R\text{-}EF}$**: Time Representativeness for elementary flows; **$Ti_{R\text{-}AD}$**: Time representativeness for activity data;; **$Te_{R\text{-}EF}$**: Technology representativeness for elementary flows; **$Te_{R\text{-}AD}$**: Technology representativeness for activity data**;** **$G_{R\text{-}EF}$**: Geographical representativeness for elementary flows; **$G_{R\text{-}AD}$:** Geographical representativeness for activity data.

Table 12 - How to assign the values to DQR criteria when using company-specific information. No criteria shall be modified

For the quality assessment of the energy used, the geographic criteria is applicable.

The processes with substituted activity data/sub-processes shall be declared and will automatically enter the list of issue to be checked by the external verifier. The dataset used for substitution shall be CO2 footprint compliant, publicly available, and have at least the same quality as the substituted default process.

9.2 Secondary datasets

This section describes the procedure to calculate the DQR of secondary datasets used in a CF study. This means that the DQR of the “EF compliant secondary dataset” (calculated by the data provider) shall be re-calculated, when they are used in the modelling of most relevant processes (see 4.6.5.4), to allow the user of the CF method to assess the context-specific DQR criteria (i.e. TeR, TiR and GeR of most relevant processes). The TeR, TiR and GeR criteria shall be re-evaluated based on Table 15. It is not allowed to modify any criteria. The total DQR of the dataset shall be recalculated using equation 19.

Rating	Ti_R	Te_R	Ge_R
1	The BCF report publication date happens within the time validity of the dataset	The technology used in the BCF study is exactly the same as the one in scope of the dataset	The process modelled in the BCF study takes place in the country the dataset is valid for
2	The BCF report publication date happens not later than 2 years beyond the time validity of the dataset	The technologies used in the BCF study is included in the mix of technologies in scope of the dataset	The process modelled in the BCF study takes place in the geographical region (e.g. Europe) the dataset is valid for
3	The BCF report publication date happens not later than 4 years beyond the time validity of the dataset	The technologies used in the BCF study are only partly included in the scope of the dataset	The process modelled in the BCF study takes place in one of the geographical regions the dataset is valid for
4	The BCF report publication date happens not later than 6 years beyond the time validity of the dataset	The technologies used in the BCF study are similar to those included in the scope of the dataset	The process modelled in the BCF study takes place in a country that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement.

5	The BCF report publication date happens later than 6 years after the time validity of the dataset, or the time validity is not specified	The technologies used in the BCF study are different from those included in the scope of the dataset	The process modelled in the BCF study takes place in a different country than the one the dataset is valid for

TiR: Time representativeness; **TeR**: Technology representativeness; **GeR:** Geographic representativeness.

Table 13 - How to assign the values to DQR criteria when using secondary datasets

10 End of Life Modelling

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

The end of life stage shall be modelled using the Circular Footprint Formula (CFF). The following sections describe the formula and parameters to be used.

10.1 The Circular Footprint Formula (CFF)

The Circular Footprint Formula is a combination of "material + energy + disposal", i.e.:

Material

$$(1-R1)EV+R1\times(AErecycled+(1-A)EV\times QSinQp)+(1-A)R2\times(ErecyclingEoL-EV*\times QSoutQP)$$

Energy

$$(1-B)R3\times(EER-LHV\times XER,heat\times ESE,heat-LHV\times XER,elec\times ESE,elec)$$

Disposal

$$(1-R2-R3)\times ED$$

Equation 2 - The Circular Footprint Formula (CFF)

10.2 Parameters of the CFF

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.

Qsin: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.

Qsout: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.

Qp: 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.