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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: <input type="checkbox"/> Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
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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**

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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- withdrawn,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.

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INTRODUCTION

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13 **METHODOLOGY FOR THE CARBON FOOTPRINT CALCULATION**
14 **APPLICABLE TO INDUSTRIAL LITHIUM-ION BATTERIES**
15 **Part 1: General requirements and global methodology**
16
17
18

19 **1 Scope**

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

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

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

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

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

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

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

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

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

41
42 **2 Normative references**

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

47
48 IEC 62619:2022 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety
49 requirements for secondary lithium cells and batteries, for use in industrial applications

50
51 IEC TS 62933-2-2:2022 Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing
52 methods - Application and performance testing
53

- 54 IEC TS 62933-3-1:2018 Electrical energy storage (EES) systems 212 - Part 3-1: Planning and performance
55 assessment of electrical energy storage systems - General specification
56
- 57 IEC 62973-1:2018 Railway applications - Rolling stock - Batteries for auxiliary power supply systems - Part
58 1: General requirements
59
- 60 IEC 60896-21:2004 Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test
61
- 62 ISO/IEC 17020:2012 Conformity assessment -- Requirements for the operation of various types of bodies
63 performing inspection
64
- 65 ISO 15686-8:2008 Buildings and constructed assets — Service-life planning — Part 8: Reference service
66 life and service-life estimation
67
- 68 ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for
69 quantification
70
- 71 ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework
72
- 73 ISO 14025:2006 Environmental labels and declarations — Type III environmental declarations —
74 Principles and procedures

75 **3 Terms, definitions and abbreviated terms**

76 **3.1 Terms and definitions**

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

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

- 80 • IEC Electropedia: available at <http://www.electropedia.org/>
- 81 ISO Online browsing platform: available at <http://www.iso.org/obp>
- 82 •

83 **3.1.1**

84 **Company-specific data**

85 **Primary data**

86 **Foreground data**

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

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

91 **3.1.2**

92 **Secondary data**

93 **Background data**

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

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

98 Note 2 to entry: Secondary data includes industry average data (e.g., from published production
99 data, government statistics, and industry associations), literature studies, engineering studies and
100 patents, and may also be based on financial data, and contain other generic data.

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

103 Note 4 to entry: more details on secondary data selection is provided in IEC63369- 2
104

105 **3.1.3**

106 **Battery manufacturer**

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

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

111 **3.1.4**

112 **Battery system sizing**

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

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

117 **3.1.5**

118 **Component manufacturer**

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

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

121 **3.1.6**

122 **Functionality class**

123 < of batteries >

124 Grouping where the battery system presents similarities in their functioning

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

126 **3.1.7**

127 **Representative virtual product**

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

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

131 **3.1.8**

132 **Battery System**

133 **Battery**

134 <for Li-ion >

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

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

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

142

143 3.1.9

144 **Functional unit**

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

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

149 3.1.10

150 **Reference flow**

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

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

155

156 3.1.11

157 **Reference Service Life**

158 **RSL**

159 **<of a battery system>**

160

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

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

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

168 [SOURCE : ISO 15686-8, modified]

169 3.1.12

170 **Set**

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

172 3.1.13

173 **compliant dataset**

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

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

176 3.1.14

177 **Life cycle inventory**

178 **LCI**

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

180

181 3.1.15

182 **Life cycle inventory dataset**

183 A document or file with life cycle information of a specified product or other reference (e.g., site,
184 process), covering descriptive metadata and quantitative life cycle inventory.

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

187 3.1.16

188 **Partially disaggregated dataset**

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

192

193 3.1.17

194 **communication vehicles**

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

198 3.1.18

199 **point of substitution**

200 point in the value chain where secondary materials substitute primary materials

201

202 3.2 Abbreviated terms

203	BCF	Battery Carbon Footprint
204	BTMS	Battery Thermal Management System
205	CAM	Cathode Active Material
206	CCF	Component Carbon Footprint
207	CF	CO ₂ Footprint
208	CFF	Circular Footprint Formula
209	DQR	Data Quality Rating
210	EF	Elementary Flow
211	EmF	Emission Factor
212	EPA	Environmental Protection Agency
213	FSS	Fire Suppression System
214	FU	Functional Unit
215	GHG	Green House Gas
216	GoO	Guarantee of Origin
217	GWP	Global Warming Potential
218	IEA	International Energy Agency
219	IPCC	Intergovernmental Panel on Climate Change
220	LCI	Life Cycle Inventory
221	LFP	Lithium Iron Phosphate cathode material
222	LTO	Lithium Titanium Oxide anode material
223	MOB	Mobile applications
224	NMC	Nickel Manganese Cobalt cathode material
225	OEM	Original Equipment Manufacturer

226	OND	On-demand Cycling
227	PCB	Printed Circuit Board
228	PCF	Product Carbon Footprint
229	PCS	Power Conversion System
230	PPA	Power Purchase Agreement
231	PV	Photovoltaic
232	REC	Renewable Energy Certificate
233	REP	Repetitive Cycling
234	STA	Stationary applications

235

236 **4 General information**

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

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

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

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

248 **5 Classification of industrial Li-ion batteries**

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

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

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

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

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

258 **5.1 Repetitive energy supply**

259 **5.1.1 Repetitive energy supply in mobile equipment (“REP-MOB”)**

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

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

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

264 **5.1.2 Repetitive energy supply in stationary equipment (“REP-STA”)**

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

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

268
269 In such an application, the gravimetric energy density is less important than for mobile applications.

270 **5.2 On-demand energy supply**

271 **5.2.1 On-demand energy supply in mobile equipment (“OND-MOB”)**

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

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

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

277 **5.2.2 On-demand energy supply in stationary equipment (“OND-STA”)**

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

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

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

284

285 **5.3 Potential combination of functionality classes**

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

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

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

295

296 **6 Functional unit**297 **6.1 Functional Unit: generalities**

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

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

307 To ensure the same functional unit, it is possible to size the battery system in different ways. Table
 308 1 provides an example with dummy figures for comparing either a large battery for the entire
 309 service life or several smaller batteries to be replaced over time.

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

312

	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 fonctionnal 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_batter y_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

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

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

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

323

324 **6.2 Functional Unit and Reference Flow for repetitive energy supply (REP-MOB & REP- 325 STA)**

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

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

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

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

341

342 **6.2.1 Example of REP-MOB load profile – Forklift**

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

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

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

348

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.

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

351 6.2.2 Example of REP-STA load profile – ESS container

352 Examples of Load profiles for ESS are found in technical specifications 62 933-3.2, 62 933 -3.3,
353 61 427-2). The real Reference Service Life including load profiles, operating conditions, ... shall
354 be stated by the battery purchaser as the base of all the calculations.

355

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/m ² 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.

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

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

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

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

366

367 **6.3 Functional Unit and Reference Flow for On-demand energy supply (OND-MOB &** 368 **OND-STA)**

369

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

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

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

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

379 Example of a back-up cycle for Stationary: 500 kW during 20 minutes in an hospital in case of failure of the
380 main grid energy supply then recharging according to the end-user request (see examples of values in the
381 virtual representative product). Typically, one or two cycles per month with the battery(ies) lasting around
382 20 years in these conditions.

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

386

<i>What?</i>	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
<i>How much?</i>	1 kWh of the total energy delivered over service life per year
<i>How well?</i>	Maximum specific energy delivering the load profile, measured in Wh/kg for mobile application
<i>How long?</i>	The amount of energy delivered on-demand over service life as specified by the end-user in years

387

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

<i>What?</i>	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
<i>How much?</i>	1 kWh of the total energy delivered over service life per year
<i>How well?</i>	Maximum specific energy delivering the load profile, measured in Wh/m ³ for stationary applications
<i>How long?</i>	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

390
391
392 Note: In this case, the use is three times per year, but the end-user still qualifies this battery as
393 "on-demand" battery.

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

398 Depending on the application constraints, the size and/or the durability of the battery may not be
399 capable of delivering "back-up cycle" that can be performed once a year over the application
400 service life. In this case, the number of batteries per application will be increased (and hence the
401 number of units required for analysis) to deliver the total Wh over the Reference Service Life
402 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 functional 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 eq * battery over life => 1650 t CO2 eq (**)	=1350 t CO2 eq * 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

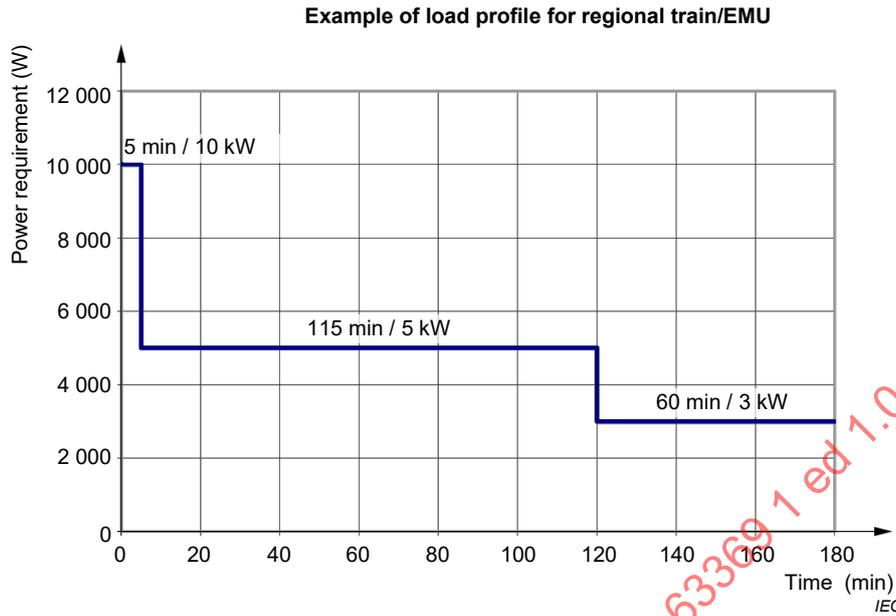
403
404

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

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

411

412 **6.3.1 Example of OND-MOB load profile –IEC 62973-1 Regional train / EMU**



413

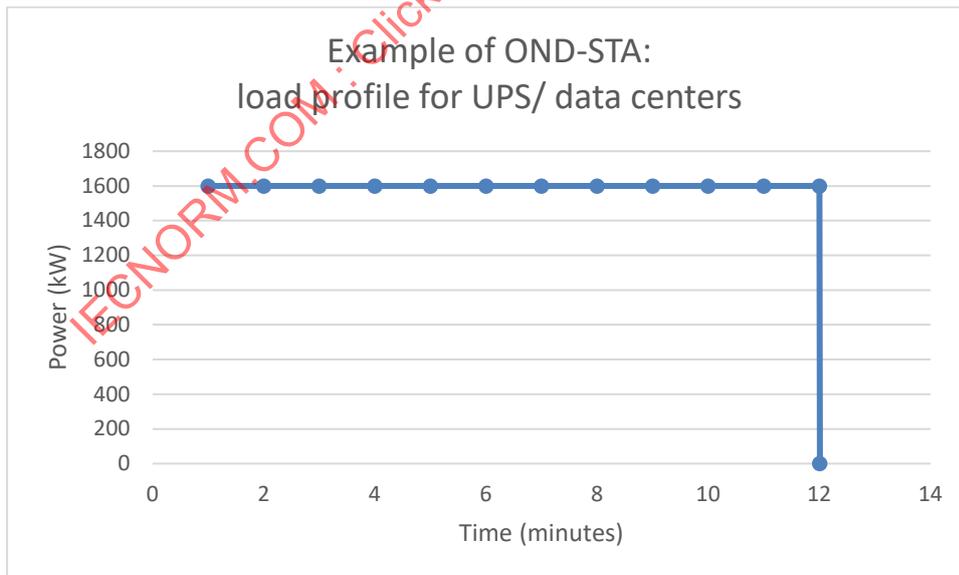
414 **Figure 1 – Example of OND-MOB: load profile for regional train / EMU**
 415 **(without starting up segment)**

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

418

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

421 **6.3.2 Example of OND-STA load profile: IEC 60896-21**



422

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

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

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

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

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

435 **7 Calculation methodology**

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

437 - **Step 1) Derivation of a virtual representative product**

438 ○ The components and processes having a significant carbon footprint (“hot spots”)
439 shall be identified.

440 ○ These items shall receive particular attention during the calculation of the Battery
441 Carbon Footprint.

442 ○ For this purpose, a virtual product is defined (see 7.3) to identify the hotspots.

443 - **Step 2) Derivation of carbon footprint data of actual products**

444 ○ The components and process steps with a significant carbon footprint (“hotspots”)
445 shall be investigated and documented with company specific data.

446 ○ For other components and production processes of the Bill Of Materials (BOM)
447 (“cold spots”), secondary data are acceptable.

448 ○ In part 2, the carbon footprint calculation of actual products will be performed using
449 primary data for “hotspots” and agreed common secondary data for “cold spots”.
450 Global Data platforms to access the data needed for the BCF calculations will be
451 defined in part 2.

452 **7.1 Concept of virtual representative product**

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

457
458 Virtual representative products are used to describe a large variety of active materials and other
459 components that are existing in different technologies. They include a little amount of every
460 potential actual product, so we are able to have them identified in the virtual product; then parts
461 of the virtual products which are not part of the Bill of Materials of the actual product should be
462 removed in the part 2 when the carbon footprint of the actual product will be calculated.

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

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

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

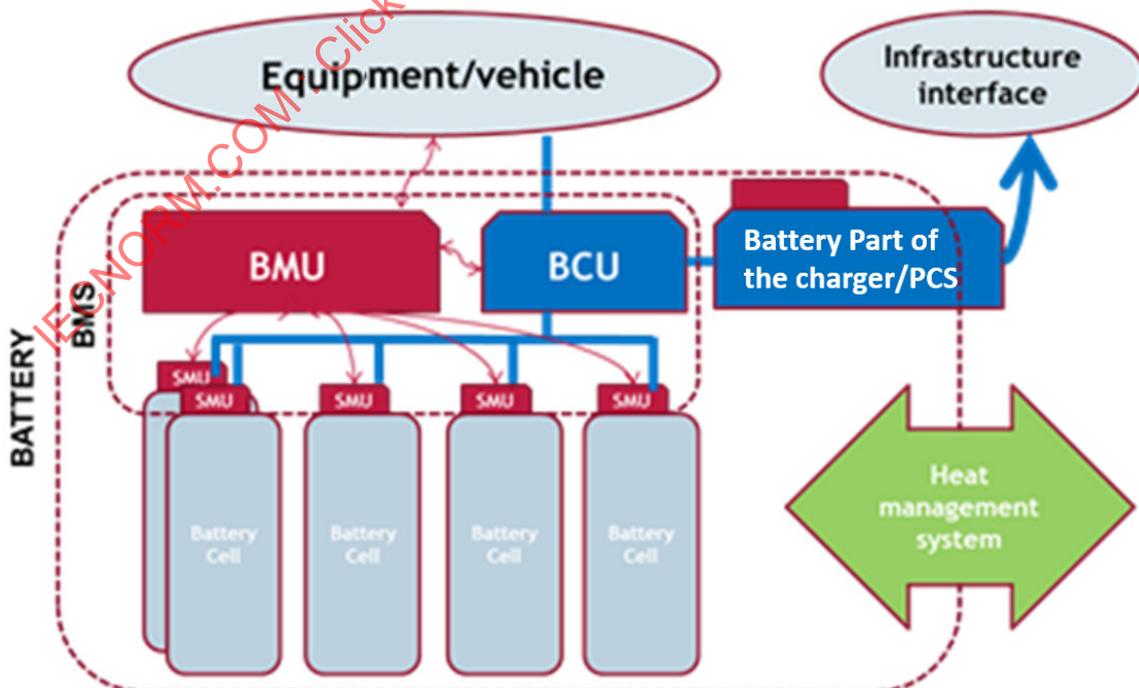
471

472 7.2 Composition of the virtual representative product

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

- 474 - The cell and its safety essential components (Safety Management Unit -SMU) incorporated
 475 during the battery assembly stage and, if present, the modules and their structures.
- 476 - The system component parts necessary for ensuring proper battery function as required
 477 for the application:
 - 478 ○ The BMS (Battery Management System):
 - 479 ▪ The BCU (Battery Control Unit) consisting of electronic components like
 480 switches and contactors
 - 481 ▪ The BMU (Battery Management Unit) consisting of the electronic part for
 482 battery management (Note: A SMU may be incorporated in a BMS for the presentation
 483 of the BCF results)
 - 484 ○ The BTMS (Battery Thermal Management System) consisting of components
 485 directly associated to the battery for its thermal management. It can consist in
 486 various components allowing for static or dynamic heat exchanges such as thermal
 487 conductive parts, tubes for circulating fluids, etc..
- 488 • - The final outer casing of the battery if applicable
- 489 • In some configurations part of the BMS might be positioned in the charger or application (for
 490 example: contactors or switches). In this case, these components are considered to be part
 491 of the BMS.

492



493

494

Figure 3 – representative products components

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

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

502 7.3 Derivation of the virtual representative products

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

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

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

511 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

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

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

516

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

517

518 - OND-MOB Example : Railways auxiliaries

519

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

520

521 - OND-STA Example : UPS/ data-centers

522

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
FSS	No

523

524 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		<p>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</p> <p>Following steps has been considered in the End-of-Life stage (see part 2)</p> <p>Dismantling process of the battery</p> <p>Pyrometallurgical treatment process for the cell</p> <p>Then, Hydrometallurgical treatment process for the cell</p>				

525

Table 7 – Representative products for the 4 functionality classes

526 Due to the large number of applications, and therefore the large number of usage phase
527 descriptions, it is not possible to define a simple benchmark classification applicable for all
528 batteries. Nevertheless, a benchmark is possible per functionality class, based on each of the 5

529 representative products (see limitations and benchmark restrictions in IEC 63369-2), as long as
530 they use the same default data described in this table.

531 7.4 System boundaries

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

537 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.

538 **Table 8 – Life cycle stages**

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

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

- 545 – Packaging of intermediate components and packaging of battery systems
- 546 – Detailed transport operations description for raw materials, product distribution or end of life:
547 as the impact is usually negligible, only the default data provided shall be used, unless primary
548 data of required quality (see 9) is available.

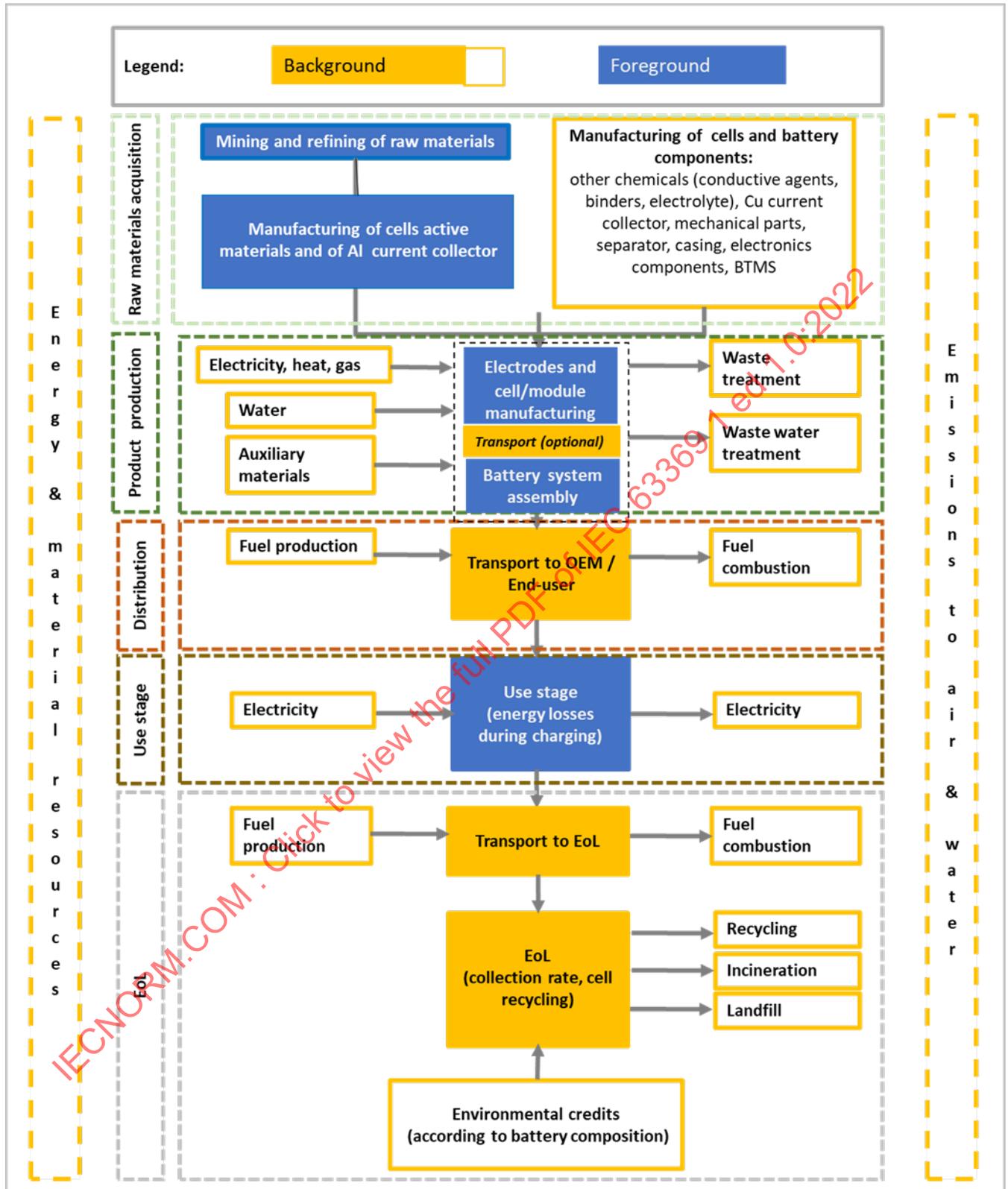
- 549 – Manufacturing of production and material handling equipment (e.g. AGV, trays, packing
550 materials or similar) used in the factory for battery assembly and recycling, as their impacts
551 are usually negligible.
- 552 – OEM manufacturing (corresponding to the battery assembly process with the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

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

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

567

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568

569

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

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

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

574 **7.5 Raw material acquisition stage and production stage**

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

576 Raw Material Acquisition and Pre-processing

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

582 OEM components manufacturing

- 583 – SMU (Safety Management Unit), mainly electronics components,
- 584 – BCU (Battery control unit), mainly electric and electronic components like switches and
585 contactors
- 586 – BMU (Battery management unit), the electronic part for battery management
- 587 – BTMS: the components directly associated with the battery for its thermal management (eg
588 cooling system, etc)
- 589 – FSS: Fire Suppression System
- 590 – Charger component, when some part is dedicated to the battery.
- 591 – Any component which is necessary for the battery to provide the requested service
- 592 –

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

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

597 **Manufacture of electrodes**

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

601 **Cell assembly and electrical formation**

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

605 **Module assembly**

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

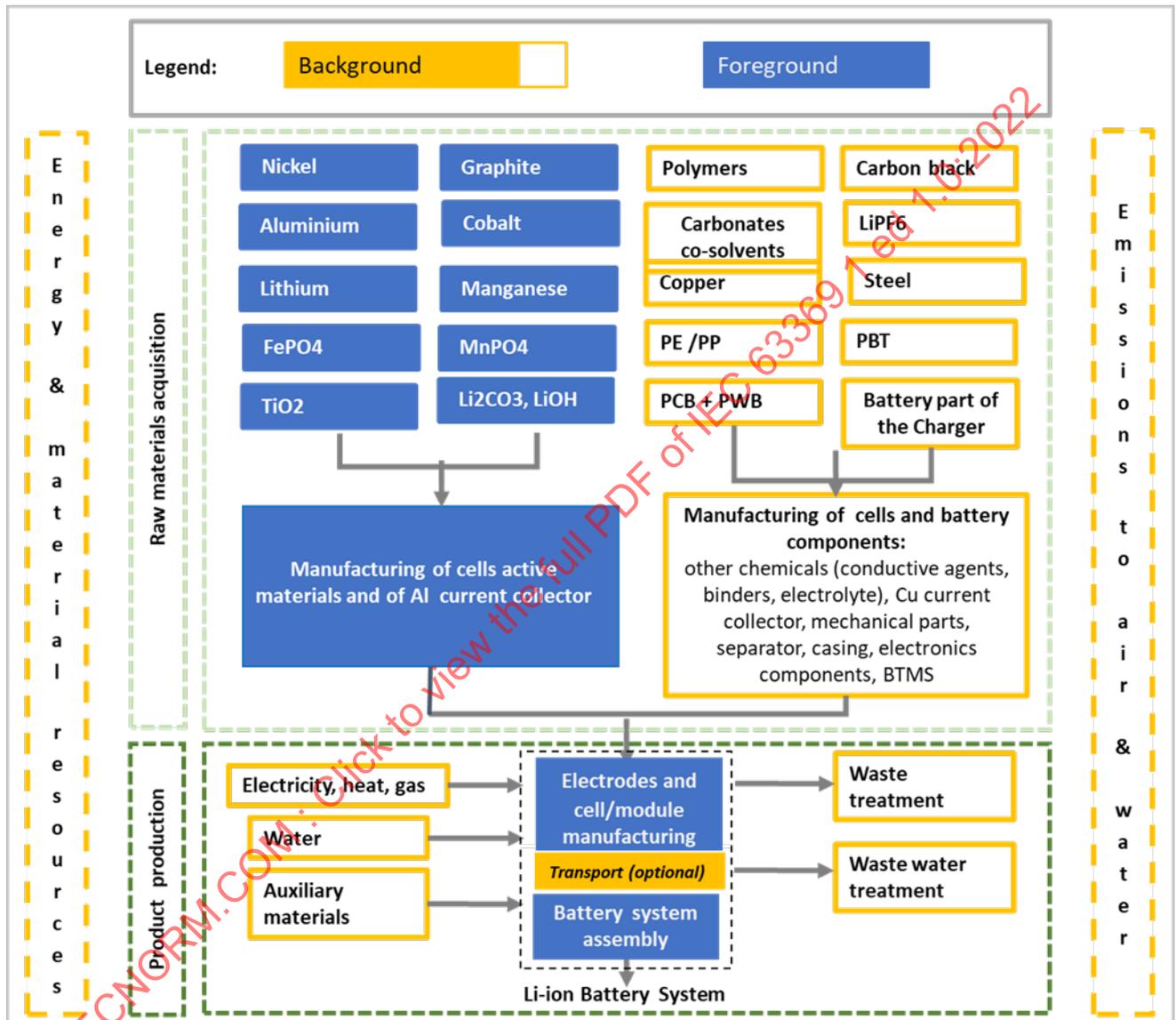
609

610 **Battery system assembly**

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

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

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



621

622

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

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

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

633 7.6 Distribution

634 See annex A for transportation

635 7.7 Use stage

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

- 637 • For repetitive energy supply: the energy losses inherent to battery cycling including BTMS
638 and BMS during the Reference Service Life of the application under the environmental
639 conditions specified by the end-user at the specified operating location.
- 640 • For on-demand energy supply: the energy used to maintain the battery, including BTMS
641 and BMS, ready to provide the back-up energy. The battery is maintained in charge mode
642 over the Reference Service Life and under the environmental conditions specified by the
643 end-user at the specified operating location.

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

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

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

654 7.8 End-Of-Life stage

655 The end-of-life processes shall include:

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

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

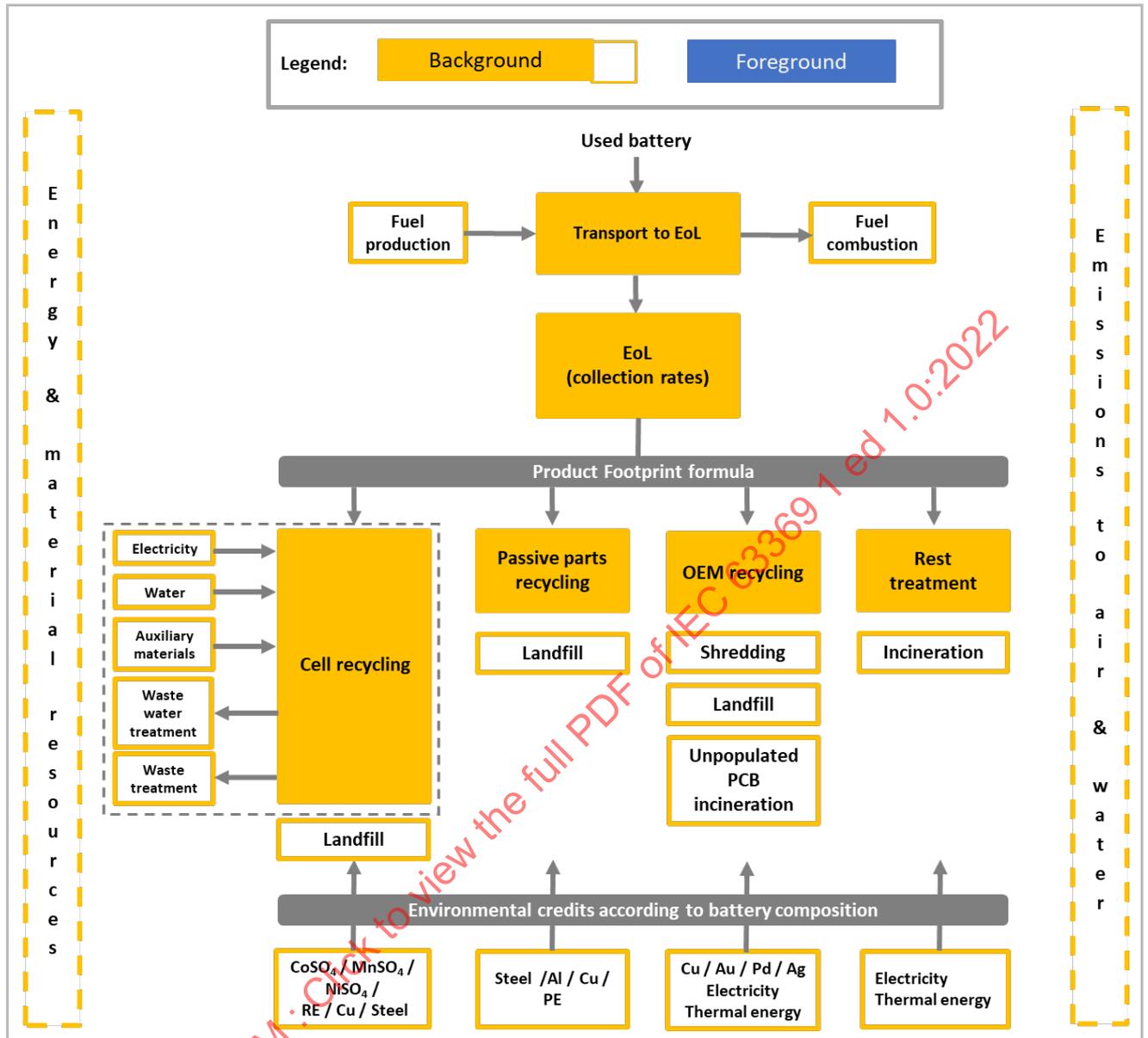
662 The main outputs of the recycling process are a metallic fraction (containing metals from the
663 battery), and a slag. This metallic fraction can be grinded and refined with a hydrometallurgical
664 process to extract valuable metals or alloys such as cobalt in case of Li-Cobalt or Li NMC based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

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

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

672

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



674

675

Figure 6 – Disassembly and recycling processes

676

7.9 Carbon footprint assessment

677

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

678

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)

679

Table 9 – Battery Carbon footprint calculation indicator

680

681 7.10 Limitations

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

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

688

689 **Benchmark limitations:**

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

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

700 In the same way, the secondary data provided for the calculation of the environmental impact of
701 the representative product shall be used in order to obtain benchmark information. It is
702 recommended to modify these secondary data only when primary data can be provided, according
703 to the data quality (see 9.) and specific requirements (nature, representativity of data, etc).

704 **8 Life cycle inventory**

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

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

709 **Rules to assess the GHG emissions related to the electricity used to manufacture a battery 710 in the Battery Carbon Footprint Calculation:**

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

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

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

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

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

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

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

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

727

728 Three electricity supply cases will be considered.

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

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

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

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

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

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

746

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

749 Context:

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

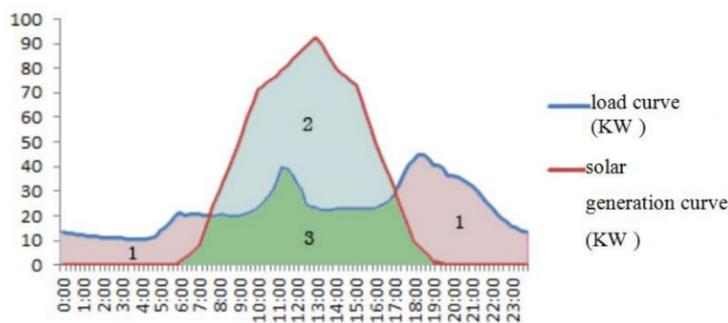
756 The use of the specific Emission Factor (EmF) of such assets will be subject to the following
757 conditions:

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

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

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

766 In this chart, only “area 3” electricity energy can be counted as used by the site, with the asset
767 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)

'''

778 **Figure 7 – Typical daily solar generation & load curve**

779 **Case 3:** Energy attributes instruments contracted by means of a Power Purchasing Agreement
780 entered into with a remote production asset injecting the underlying electrical energy produced
781 into the grid

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

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

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

800 **9 Data quality requirements**

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

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

$$804 \text{ DQR} = \frac{\overline{\text{TeR}} + \overline{\text{GR}} + \overline{\text{TiR}} + \overline{\text{P}}}{4} \quad [\text{Equation 1}]$$

805

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

808 representativeness (technological, geographical and time-related) characterises to what degree
809 the processes and products selected are depicting the system analysed, while the precision
810 indicates the way the data is derived and related level of uncertainty.

811 Each data quality criterion to be scored (TeR, GeR, TiR and P) is rated according to the five
812 levels listed in Table 11.
813

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

814
815 **Table 10 - Data Quality Rating (DQR) and data quality levels of each data quality criterion**

816 Five quality levels (from excellent to poor) can be achieved according to the Data Quality
817 Rating (DQR). They are summarized in Table 12.
818

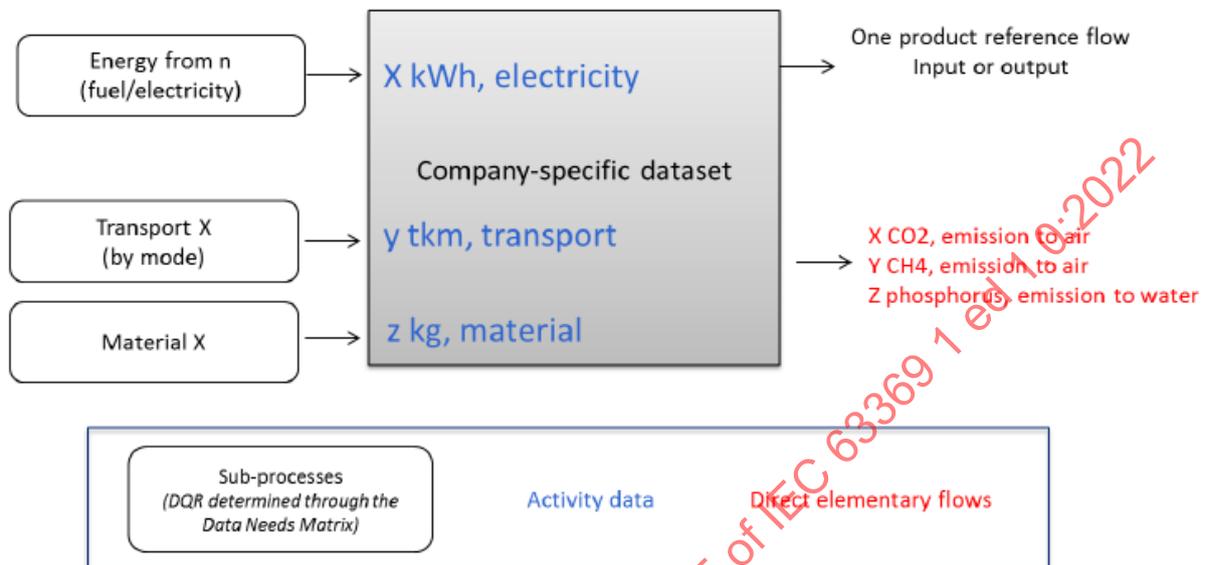
Overall data quality rating (DQR)	Overall data quality level
$DQR \leq 1.5$	"Excellent quality"
$1.5 < DQR \leq 2.0$	"Very good quality"
$2.0 < DQR \leq 3.0$	"Good quality"
$3 < DQR \leq 4.0$	"Fair quality"
$DQR > 4$	"Poor quality"

819
820 **Table 11 - Overall data quality level of compliant-datasets, according to the achieved data**
821 **quality rating**

822
823 The DQR formula is applicable to:
824 1. Company-specific datasets: section 9.1 describes the procedure to calculate the DQR of
825 company-specific datasets;
826 2. Secondary datasets: when using a secondary *compliant dataset* in a CF study (procedure
827 described in 9.2);
828 The next sections provide tables with the criteria to be used for the semi-quantitative assessment
829 of each criterion. If a dataset is constructed with company-specific activity data, company -specific
830 emission data and secondary sub-processes, the DQR of each shall be assessed separately.

831 **9.1 Company specific foreground datasets**

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



835
 836 **Figure 8 - Graphical representation of a company-specific dataset. A company-specific**
 837 **dataset is a partially disaggregated one: the DQR of the activity data and direct elementary**
 838 **flows shall assessed.**

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

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

843
 844 1) Select the most relevant activity data and direct elementary flows: most relevant activity
 845 data are the ones linked to sub-processes (i.e. secondary datasets) that account for at least
 846 80% of the total carbon footprint impact of the company-specific dataset, listing them from
 847 the most contributing to the least contributing one. Most relevant direct elementary flows
 848 are defined as those direct elementary flows contributing cumulatively at least with 80% to
 849 the total carbon footprint impact of the direct elementary flows.

850 2) Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and
 851 each most relevant direct elementary flow using Table 13.

852 a. Each most relevant direct elementary flow consists of the amount and elementary flow
 853 naming (e.g. 40 g CO₂). For each most relevant elementary flow (EF), the 4 DQR criteria
 854 named TeR-_{EF}, TiR-_{EF}, Gr-_{EF}, P_{EF} shall be evaluated (e.g. the timing of the flow measured, for
 855 which technology the flow was measured and in which geographical area).

856 b. For each most relevant activity data, the 4 DQR criteria shall be evaluated (named TiR-_{AD},
 857 P_{AD}, Gr-_{AD}, TeR-_{AD}).

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

861
 862 3) Calculate the carbon footprint contribution of each most-relevant activity data (through
 863 linking to the appropriate sub-process) and direct elementary flow to the total sum of the
 864 carbon footprint of all most relevant activity data and direct elementary flows, in %). For

865 example, the newly developed dataset has only two most relevant activity data,
866 contributing in total to 80% of the total environmental impact of the dataset:

867

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

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

872 4) Calculate the Te_R , Ti_R , Ge_R and P criteria of the newly developed dataset as the
873 weighted average of each criteria of the most relevant activity data and direct elementary
874 flows. The weight is the relative contribution (in %) of each most relevant activity data and
875 direct elementary flow calculated in step 3.

876 5) The user of the CFP method shall calculate the total DQR of the newly developed dataset
877 using the equation below, where Te_R, Ge_R, Ti_R, P are the weighted average calculated as specified
878 in point (4).

$$879 \quad DQR = \frac{Te_R + Ge_R + Ti_R + P}{4} \quad \text{[Equation 1]}$$

880

881

Rating	P_{EF} and P_{AD}	Ti_{R-EF} and Ti_{R-AD}	Te_{R-EF} and Te_{R-AD}	Ge_{R-EF} and Ge_{R-AD}
1	Measured/calculated and 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

882 **P_{EF}**: Precision for elementary flows; **P_{AD}**: Precision for activity data; **Ti_{R-EF}**: Time
 883 Representativeness for elementary flows; **Ti_{R-AD}**: Time representativeness for activity data;;
 884 **Te_{R-EF}**: Technology representativeness for elementary flows; **Te_{R-AD}**: Technology
 885 representativeness for activity data; **Ge_{R-EF}**: Geographical representativeness for elementary
 886 flows; **Ge_{R-AD}**: Geographical representativeness for activity data.

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

889

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

891

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

895 9.2 Secondary datasets

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

902

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
---	--	--	--

903 **Tir:** Time representativeness; **Ter:** Technology representativeness; **Ger:** Geographic representativeness.

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

905 10 End of Life Modelling

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

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

912 10.1 The Circular Footprint Formula (CFF)

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

914 Material

915 $(1-R1)EV+R1 \times (A E_{recycled} + (1-A)EV \times Q_{sinQp}) + (1-A)R2 \times (E_{recyclingEoL} - EV \times Q_{soutQP})$

916 Energy

917 $(1-B)R3 \times (EER - LHV \times XER, heat \times ESE, heat - LHV \times XER, elec \times ESE, elec)$

918 Disposal

919 $(1-R2-R3) \times ED$

920 Equation 2 - The Circular Footprint Formula (CFF)

921 10.2 Parameters of the CFF

922 **A:** allocation factor of burdens and credits between supplier and user of recycled materials.

923 **B:** allocation factor of energy recovery processes. It applies both to burdens and credits.

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

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

928 **Qp:** quality of the primary material, i.e. quality of the virgin material.

929 **R1:** it is the proportion of material in the input to the production that has been recycled from a
930 previous system.

931 **R2:** it is the proportion of the material in the product that will be recycled (or reused) in a
932 subsequent system. R2 shall therefore take into account the inefficiencies in the collection and
933 recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.

934 **R3:** it is the proportion of the material in the product that is used for energy recovery at EoL.