The Advanced Rechargeable & Lithium Batteries Association

PEFCR - Product Environmental Footprint Category Rules for High Specific Energy Rechargeable Batteries for Mobile Applications

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Preface

This document has been developed with the Technical Secretariat of the Batteries Pilot during the Commission PEF Project

Authors	Company name	Sector
Clémence Siret	Saft	Battery manufacturer
Jan Tytgat	Umicore	Material producer and battery recycler
Thomas Ebert	Apple	OEM manufacturer
Mark Mistry	Nickel Institute	Metals producer
Colin Thirlaway	Stanley Black & Decker	OEM manufacturer
Bertrand Schutz	Eramet	Material producer and battery recycler
Demosthene Xhantopoulos	Eramet	Material producer and battery recycler
Jean-Pol Wiaux	Recharge	Battery manufacturer
Claude Chanson	Recharge	Battery manufacturer
Willy Tomboy	Recharge	Battery manufacturer
Carol Pettit	Cobalt Institute	Metals producer
Johannes Gediga	Thinkstep	LCA Specialist
Marta Bonell	Thinkstep	LCA Specialist
Viviana Carrillo	Thinkstep	LCA Specialist

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III. Acronyms

AF	Allocation Factor
AP	Acidification Potential
AR	Allocation Ratio
B2B	Business to Business
B2C	Business to Consumer
BHU	Battery control unit
BMU	Battery management unit
BoC	Bill of Components
BoM	Bill of Materials
BP	Bonne Pratique
BREF	Best Available Techniques Reference Document
CF	Characterization Factor
CFF	Circular Footprint Formula
CFF-M	Circular Footprint Formula – Modular form
CMWG	Cattle Model Working Group
CPA	Classification of Products by Activity
CPT	Cordless power tool
DC	Distribution Centre
DMI	Dry Matter Intake
DNM	Data Needs Matrix
DOD	Depth of Discharge (Battery % of use at each cycle)
DPE	Domestic person equivalent
DQR	Data Quality Rating
EA	Economic Allocation
EC	European Commission
EF	Environmental Footprint
EI	Environmental Impact
ELCD	European Life Cycle Database
ELV	Electric vehicles (e-mobility)
EoL	End-of-Life
EP	Eutrophication Potential
FU	Functional Unit
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GE	Gross Energy intake
GR	Geographical Representativeness
GHG	Greenhouse Gas
GWP	Global Warming Potential
HD	Helpdesk
HEV	Hybrid Electric Vehicle
ICT	Information and Communication Technology
IEC	International Electrochemical Commission

ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
LCDN	Life Cycle Data Network
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
Li	Lithium metal
LCO	Lithium battery using a Cobalt Oxide based cathode
LFP	Lithium battery using an Iron Phosphate based cathode
LT	Lifetime
MSI	Materials Sustainability Index (provided by SAC)
NDA	Non Disclosure Agreement
NGO	Non-Governmental Organisation
NMVOC	Non-methane volatile compounds
NiMH	Nickel Metal Hydride
NMC	Lithium battery using a Nickel Manganese Cobalt Oxide based cathode
ODP	Ozone Depletion Potential
OEM	Original Equipment Manufacturer
P	Precision
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEHV	Plug-In Hybrid Electric Vehicle
POCP	Photochemical Ozone Creation Potential
PWB-PCB	Populated Printed Wiring Board
RF	Reference Flow
RP	Representative Product
SB	System Boundary
SC	Steering Committee
SLI	Starting-Lighting-Ignition-battery
SMRS	Sustainability Measurement & Reporting System
SS	Supporting study
TAB	Technical Advisory Board
TeR	Technological Representativeness
ThMU	Thermal management unit
TiR	Time Representativeness
TS	Technical Secretariat
UNEP	United Nations Environment
UPS	Uninterruptible power supply
USGS	United States Geological Survey
UUID	Universally Unique Identifier
VOC	Volatile Organic Compound
Wh	Watt-hour

IV. Definitions

For all terms used in this Guidance and not defined below, please refer to the most updated version of the Product Environmental Footprint (PEF) Guide, ISO 14025:2006, ISO 14040-44:2006, and the ENVIFOOD Protocol.

Activity data - This term refers to information which is associated with processes while modelling Life Cycle Inventories (LCI). In the PEF Guide it is also called "non-elementary flows". The aggregated LCI results of the process chains that represent the activities of a process, are each multiplied by the corresponding activity data[1] and then combined to derive the environmental footprint associated with a process (See Figure 1). Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc. In the context of PEF the amounts of ingredients from the bill of material (BOM) shall always be considered as activity data.

Active materials: Battery material directly linked to the electrochemical performance: includes the Cathode, Anode, Electrolyte and Separator.

Aggregated dataset - This term is defined as a life cycle inventory of multiple unit processes (e.g. material or energy production) or life cycle stages (cradle-to-gate), but for which the inputs and outputs are provided only at the aggregated level. Aggregated datasets are also called "LCI results", "cumulative inventory" or "System processes" datasets. The aggregated dataset can have been aggregated horizontally and/or vertically. Depending on the specific situation and modelling choices a "unit process" dataset can also be aggregated. See Figure 1[2].

Allocation: An approach to solving multi-functionality problems. It refers to partitioning the input or output flows of a process, a product system or a facility between the system under study and one or more other systems" (based on ISO 14040:2006).

Application specific - it refers to the generic aspect of the specific application in which a material is used. For example, the average recycling rate of PET in bottles.

Benchmark – A standard or point of reference against which any comparison can be made. In the context of PEF, the term 'benchmark' refers to the ***average*** environmental performance of the representative product sold in the EU market. A benchmark may eventually be used, if appropriate, in the context of communicating environmental performance of a product belonging to the same category.

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[1] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2004).

[2] Source: UNEP/SETAC "Global Guidance Principles for LCA Databases"

Bill of materials – A bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture an end product.

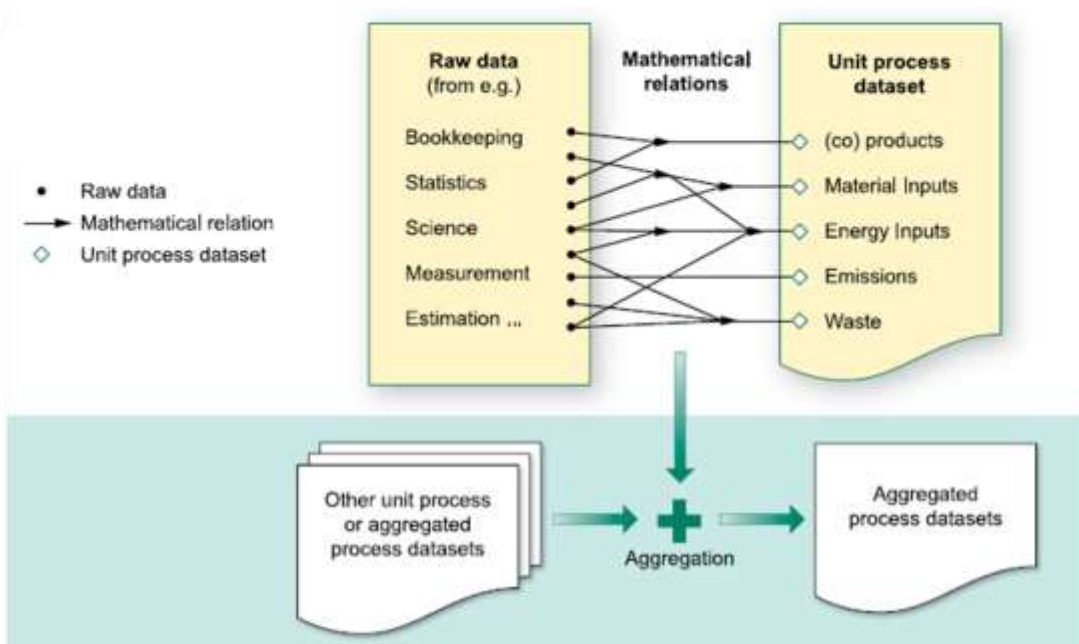

Figure 1: Definition of a unit process dataset and an aggregated process dataset

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

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

Close loop & open loop: A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties. [based on ISO 14044:2006]

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

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

Commissioner of the EF study - Organisation (or group of organisations) that finances the EF study in accordance with the EF Guide, EF Guidance and the relevant PEFCR, if available (definition adapted from ISO 14071/2014, point 3.4).

Company-specific data – it refers to directly measured or collected data representative of activities at a specific facility or set of facilities. It is synonymous to "primary data".

Comparative assertion – environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (adapted from ISO 14025:2006).

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

Data Quality Rating (DQR) - Semi-quantitative assessment of the quality criteria of a dataset based on Technological representativeness, Geographical representativeness, Time-related representativeness, and Precision. The data quality shall be considered as the quality of the dataset as documented.

Direct elementary flows - All emissions and resource use (also named elementary flows) that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite. See Figure 2.

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

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

EF report - Document that summarises the results of the EF study. For the EF report the template provided as annex to the PECFR Guidance shall be used. In case the commissioner of the EF study decides to communicate the results of the EF study (independently from the communication vehicle used), the EF report shall be made available for free through the commissioner's website. The EF report shall not contain any information that is considered as confidential by the commissioner, however the confidential information shall be provided to the verifier(s).

EF study - Term used to identify the totality of actions needed to calculate the EF results. It includes the modelisation, the data collection, and the analysis of the results.

Electricity tracking[3] **-** Electricity tracking is the process of assigning electricity generation attributes to electricity consumption.

Elementary flow - Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.

Energy (battery): electric energy which a battery delivers under specified conditions
Note: The SI unit for energy is joule (1 J = 1 W · s), but in practice, battery energy is usually expressed in watthours (Wh) (1 Wh = 3 600 J) or kilo-watthours (1 kWh= 1000 Wh).

Environmental aspect – element of an organization's activities or products or services that interacts or can interact with the environment (ISO 14001:2015)

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

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

Functional Unit*:* quantified performance of a product system for use as a reference unit. [based on ISO 14044:2006]

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

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

Intermediate product - an intermediate product is a product that requires further processing before it is saleable to the final consumer.

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

Life cycle: Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal [based on ISO 14040:2006].

Life Cycle Inventory (LCI) - The combined set of exchanges of elementary, waste and product flows in an LCI dataset.

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3 https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii

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

Material-specific - it refers to a generic aspect of a material. For example, the recycling rate of PET.

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

Partially disaggregated dataset - A dataset with an LCI that contains elementary flows and activity data, and that only in combination with the complementing aggregated datasets that represent the activities yields a complete aggregated LCI data set. We refer to a partially disaggregated dataset at level 1 in case the LCI contains elementary flows and activity data, while at least some of the complementing sub-processes are in their aggregated form (see an example in Figure 2). The underlying sub-processes should be based on EF-compliant secondary datasets (if available).

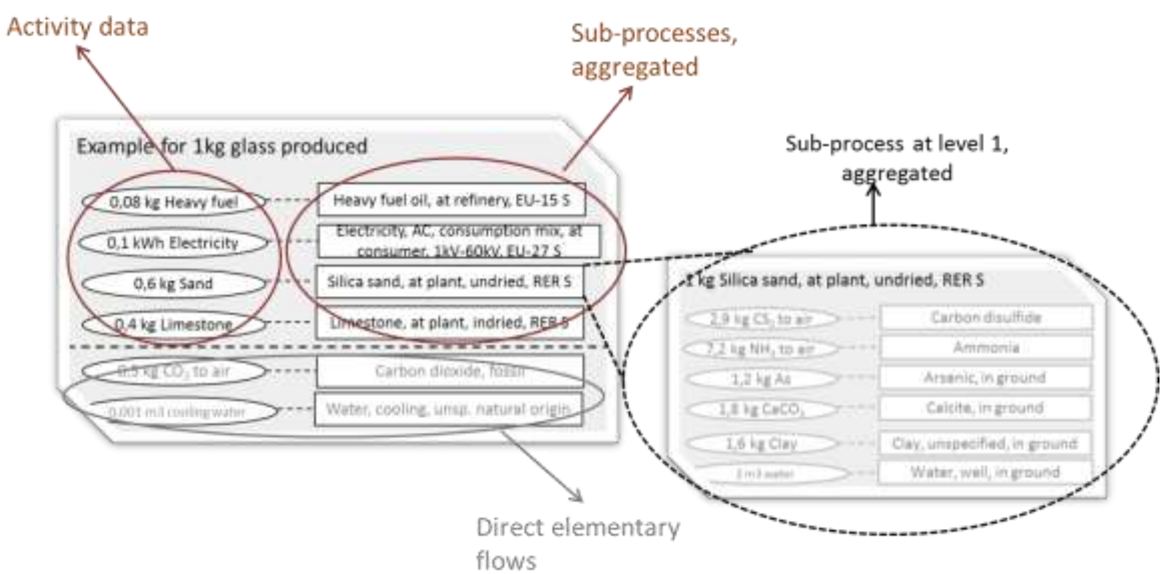

Figure 2: An example of a partially aggregated dataset, at level 1.

The activity data and direct elementary flows are to the left, and the complementing sub-processes in their aggregated form are to the right. The grey text indicates elementary flows

Passive materials: Battery materials not directly producing the electrochemical performance: cell casing, battery casing and OEM parts**.**

PEFCR Supporting study – the PEF study done on the basis of a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

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

PEF screening – a preliminary study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and data quality needs to derive the preliminary indication about the definition of the benchmark for the product category/sub-categories in scope, and any other major requirement to be part of the final PEFCR.

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

Practitioner of the EF study - Individual, organisation or group of organisations that performs the EF study in accordance with the EF Guide, EF Guidance and the relevant PEFCR if available. The practitioner of the EF study can belong to the same organisation as the commissioner of the EF study (adapted from ISO 14071/2014, point 3.6).

Primary data[4] - This term refers to data from specific processes within the supply-chain of the company applying the PEFCR. Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for a same product) or supply-chain-specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the company applying the PEFCR. In this Guidance, primary data is synonym of "company-specific data" or "supply-chain specific data".

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

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

Product Environmental Footprint Category Rules (PEFCRs) – Product category-specific, life-cycle-based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category. PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the PEF guide.

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[4] Based on GHG protocol scope 3 definition from theCorporate Accounting and Reporting Standard (World resources institute, 2004).

Reference flow: Measure of the outputs from processes in a given product system required to fulfil the function expressed by the unit of analysis (based on ISO 14040:2006). The reference flow is the amount of product needed in order to provide the defined function. All other input and output flows in the analysis quantitatively relate to it. The reference flow can be expressed in direct relation to the unit of analysis or in a more product-oriented way

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

Representative product (model) - The "representative product" may or may not be a real product that one can buy on the EU market. Especially when the market is made up of different technologies, the "representative product" can be a virtual (non-existing) product built, for example, from the average EU sales-weighted characteristics of all technologies around. A PEFCR may include more than one representative product if appropriate.

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

Resource Use and Emissions Profile results: Outcome of a Resource Use and Emissions Profile that catalogues the flows crossing the PEF boundary and provides the starting point for the EF impact assessment.

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

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

Secondary data[5] - refers to data not from specific process within the supply-chain of the company applying the PEFCR. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third-party life-cycle-inventory database or other sources. Secondary data includes industry-average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and can also be based on financial data, and contain proxy data, and other generic data. Primary data that go through a horizontal aggregation step are considered as secondary data.

[5] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2004)

Specific Energy: quotient of electric energy of a battery by the mass of the battery, expressed in Wh/kg.

Sub-population - In this document this term indicates any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes an homogenous sub-set of the whole population. Sometimes the word "stratum" can be used as well.

Sub-processes - those processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes can be presented in their (partially) aggregated form (see Figure 2).

Sub-sample - In this document this term indicates a sample of a sub-population.

Supply-chain - refers to all of the upstream and downstream activities associated with the operations of the company applying the PEFCR, including the use of sold products by consumers and the end-of-life treatment of sold products after consumer use.

Supply-chain specific - it refers to a specific aspect of the specific supply-chain of a company. For example, the recycled content value of an aluminium can produced by a specific company.

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

Type III environmental declaration – An environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information (ISO 14025:2006). The predetermined parameters are based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044.

Unit process dataset - Smallest element considered in the life cycle inventory analysis for which input and output data are quantified (ISO 14040:2006). In LCA practice, both physically not further separable processes (such as unit operations in production plants, then called "unit process single operation") and also whole production sites are covered under "unit process", then called "unit process, black box" (ILCD Handbook).

Verification report - Documentation of the verification process and findings, including detailed comments from the *Verifier(s)*, as well as corresponding responses from the *commissioner of the EF study.* This document is mandatory, but it can be confidential. However, it shall be signed, electronically or physically, by the *verifier or in case of a* verification panel, by the lead verifier.

Verification statement - Conclusive document aggregating the conclusions from the *verifiers* or the verification team regarding the EF study. This document is mandatory and shall be electronically or physically signed by the *verifier or in case of a* verification panel, by the lead verifier. The minimum content of the verification statement is provided in this document.

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

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

Waste: Substances or objects which the holder intends or is required to dispose [based on ISO 14025].

1 Introduction

The Product Environmental Footprint Category Rules (PEFCR) provides detailed and comprehensive technical guidance on how to conduct a PEF study. PEF studies may be used for a variety of purposes, including in-house management and participation in voluntary or mandatory programmes.

For all requirements not specified in this PEFCR the applicant shall refer to the most recent version of the PEFCR Guidance: European Commission, PEFCR Guidance document, - Guidance for the development of Product Environmental Footprint Category Rules (PEFCRs), version 6.3, December 2017.

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

This PEFCR provides Product Environmental Footprint Category Rules (PEFCR) for developing Product Environmental Footprints for high specific energy rechargeable batteries used in mobile application for the

following three application fields:

- e-mobility (e.g., e-bikes, EV, PHEV, cars, bus/trucks)
- ICT (e.g., tablets and phones, computers, cameras, games)
- Cordless power tools (e.g., drills, electric screwdrivers)

The structure of this document follows the “Template for Product Environmental Footprint Category Rules”/PEF pilot Guidance/ PEFCR version 6.3, December 2017.

Terminology: shall, should and may

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

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

2 General information about the PEFCR

This PEFCR provides a structure to ensure that all Product Environmental Footprints (PEF) for high specific energy rechargeable batteries used in these applications are derived, verified and presented in a harmonised way.

The function described is to supply electrical current at a desired voltage range from an on-board rechargeable battery with a high specific energy, which is the main storage of energy for a mobile application, during a given service life. The purpose of high specific energy rechargeable batteries is to store and supply autonomous energy to electrical equipment. The scientific unit of measure for the electrical energy is the Watt-hour (Wh). In the case of rechargeable batteries, the total service provided can be measured by the total watt-hours delivered over the life of the rechargeable battery, measured in kilo-watt-hours (kWh).

The energy consumption during the use stage of the battery is defined by the energy losses linked to the battery and charger efficiency during charge, discharge and storage. The total energy transmitted by the battery to the application has to be taken into account by the mobile application provider for the use phase of its PEF profile.

Rechargeable batteries are final products used in different applications. The mobile application itself or the vehicle itself (e.g. e-bike, cell phone) is not covered by this PEFCR. For the development of a PEF profile of a mobile application where a battery in this scope is one of the components, the PEFCR shall be used as reference for the rechargeable battery.

2.1 Technical secretariat

Name of the organization	*Type of organization*	*Name of the members (not mandatory).*	*Participation since*
RECHARGE	Batteries Industry Association	Claude Chanson Willy Tomboy	December 2013
SAFT	Battery Manufacturer	Clemence Siret	December 2013
APPLE	OEM Manufacturer	Thomas Ebert	December 2013
COBALT INSTITUTE	Metals producers	Carol Pettit	December 2013
ERAMET	Material Producer and Battery recycler	Stephane Chorlet	December 2013
NICKEL INSTITUTE	Metals producers	Mark Mistry	December 2013
Stanley Black & Decker	OEM Producer	Colin Thirlaway	December 2013

Umicore	Material producer and battery recycler	Jan Tytgat	December 2013
Thinkstep	Consultant, LCA Specialist	Johannes Gediga Marta Bonell Viviana Carrillo	December 2013

2.2 Consultations and stakeholders

This PEFCR has been developed during the EU Commission PEF pilot study period of 2014-2016. The 1st physical consultation for this pilot took place on the 25th of February 2014 in Brussels. Stakeholders could submit comments through the Environmental Footprint wiki webpage, and by e-mail until the 25th of March 2014, a total of 94 comments were received (from VUB, Digital Europe, EUROBAT, ACEA, EPBA, ILA, The international EPD system.

The online consultation on the 1st draft of the PEFCR was open until the 24th of August 2015, the consultation was sent to 156 registered stakeholders. This second consulattion received 6 comments (from DG environment and Schünemann). A third consultation for the final version of the PEFCR was made from August 1st to Sept 16th 2016, and received 82 comments (from DG Environment, EEB, Bureau Veritas, Belgium - Federal Public Service - Health, Food chain safety and Environment, ALABC-EUROBAT).

The consultations documents are placed on the webpage for the PEFCR development: https://webgate.ec.europa.eu/fpfis/wikis/display/EUENVFP/PEFCR+Pilot%253A+Portable+rechargeable+batteries

2.3 Review panel and review requirements of the PEFCR

Members of the review panel:

Role	Name	Affiliation
Chair	Ugo Pretato	Studio Fieschi & soci Srl
Team member	Etienne Lees-Perasso	Bureau Veritas/CODDE
Team member	Mikko Samuli Vaija	Orange

The reviewers have verified that the following requirements have been fulfilled:

- The PEFCR has been developed in accordance with the requirement provided in the PEFCR Guidance 6.3, and where appropriate in accordance with the requirements provided in the most recent approved version of the PEF Guide, and supports creation of credible and consistent PEF profiles,

- The functional unit, allocation and calculation rules are adequate for the product category under consideration,
- Company-specific and secondary datasets used to develop this PEFCR are relevant, representative, and reliable,
- The selected LCIA indicators and additional environmental information are appropriate for the product category under consideration and the selection is done in accordance with the guidelines stated in the PEFCR Guidance version 6.3 and the most recent approved version of the PEF Guide,
- The benchmarks are correctly defined,
- Both LCA-based data and the additional environmental information prescribed by the PEFCR give a description of the significant environmental aspects associated with the product.

The detailed review report in provided in annex 3 of this PEFCR.

2.4 Review statement

This PEFCR has been developed in compliance with Version 6.3 of the PEFCR Guidance, and with the PEF Guide adopted by the Commission on Annex II to the Recommendation 2013/179/EU, 9 April 2013. Published in the official journal of the European Union Volume 56, 4 May 2013

The representative product(s) correctly describe the average product(s) sold in Europe for the product group in scope of this PEFCR.

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

2.5 Geographic validity

This PEFCR is valid for products in scope sold/consumed in the European Union + EFTA.

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

2.6 Language

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

2.7 Conformance to other documents

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

- PEFCR Guidance 6.3 December 2017. For any technical question related to the content of this guidance, please refer to the functional mailbox env-environmental-footprint@ec.europa.eu

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

3 PEFCR scope

This document provides Product Environmental Footprint Category Rules (PEFCR) for product environmental footprints (PEF) of high specific energy rechargeable batteries used in mobile applications. Rechargeable batteries are final products used in different applications (equipment, vehicles, etc.). The equipment or vehicle itself (e.g. e-bike, cell phone, etc.) is not covered by this PEFCR. For the development of a PEF profile of an application where the battery is included, this PEFCR shall be used as reference when developing PEFCRs for products further down in the supply chain.

Included battery types for this PEFCR

The system consists of the rechargeable battery and the charger in the case of ICT and cordless power tool application since it is considered to be part of the system. On the contrary, in the case of electric vehicles, the charging stations are considered to be part of the infrastructure and not part of the battery (see note 1). The scope of this PEFCR is wide and it has been necessary to identify sub-categories based on different applications (case B of the guidance).

This PEFCR is applicable for rechargeable single cells or/and batteries used in the following equipment or vehicle:

- E-mobility (e.g., e-bikes, ELV, PHEV, cars, bus/trucks) – excluding charging unit (see system boundaries description in section 0);
- Information & Communication Technologies (e.g., tablets and phones, computers, cameras, games) – incl. charging unit;
- Cordless power tools (e.g., drills, electric screwdrivers) incl. charging unit.

The following technologies and chemistries are considered:

- Battery technology: Li-Ion and NiMH
- Battery chemistry for Li-ion technology includes: LCO ($LiCoO_2$), NMC ($LiNi_xMn_yCo_zO_2$), LiMn ($LiMnO_2$), LFP ($LiFePO_4$)

Excluded battery types from this PEFCR:

Other applications use different criteria for assessing battery performance, such as the service time of the battery, the power, the mass, the efficiency, etc. Therefore, batteries used in such applications are excluded from this PEFCR, and PEF for the batteries and applications listed below should be developed separately from this document.

Some examples of such excluded applications are:

- Stationary power stations, back-up power systems (for train, aircrafts, UPS, etc.): the main function is the service time of the back-up availability. The unit of analysis is not the total energy delivered, but total life time of the installation. In addition, for many of the stationary applications, the weight of the battery is not a key factor so a high specific energy is not required.
- Starting-lighting-ignition (SLI) batteries and start stop hybrid batteries: One of the main functions is the high power, for a short period of time, required to start a vehicle. The unit of analysis is the energy delivered at the required power.
- Batteries with different expected quality and/or additional function (for example forklift batteries are selected for their total energy over lifetime, but a counterweight is often used in the application as an additional function). The maximum specific energy, which is clearly a major characteristic of the function definition in the scope, is not a primary requirement for these applications. Consequently, the batteries used in applications such as forklifts, golf-carts, wheelchairs, etc. will not be considered in this study.
- Non- rechargeable batteries cannot be mixed with rechargeable batteries, as they don't provide the same function: they are not a storage of energy, but a source of energy. They are capable of providing electrical energy based on their chemical composition, introduced during the assembly, without being electrically charged as rechargeable batteries. The total service life of an application (cumulative energy delivered over service life) can be obtained with many products, each one being discharged only once.

<u>Charger inclusion/exclusion explanatory note</u>:

The charger for the rechargeable batteries is included in the case of ICT and cordless power tool application since it is considered to be part of the system provided to the user.
On the contrary, in the case of electric vehicles, the charging stations are considered to be part of the infrastructure and not part of the battery. A single charging station can be used for many batteries/electric cars, and there is no clear allocation per battery. Therefore, the charger for e-mobility is not part of the system.
Rationale: The definition of the boundary for the charger depend on the expected benefit for the PEF result quality:

- approach A- charger included for electric mobility: this corresponds to an "all inclusive" approach, and is homogeneous with the requirement for the other types of mobile batteries.
- approach B- charger excluded for electric mobility: this approach recognizes that the charger for electric mobility is not a "mobile" charger, as it is for the other applications.

Both approaches have benefits and drawbacks, with the following consequences:

o The EV charger is often a complete different equipment, not directly linked to the vehicle. Consequently, his design is more depending on infrastructure requirements (regulation in private and public places, urban design requirements, etc…), and is not under the vehicle manufacturer responsibility.

o The public EV chargers are large piece of equipment, but are used generally for a large number of vehicles. In addition, their life duration is linked to other factors than the batteries durability. From this point of view, they should be considered as infrastructure equipment.

Therefore, the possible way for approach A would be to define a "representative" virtual charger, including calculated portions of public and private charger for e-mobility, in order to have an associated burden included in the PEF. The theoretical benefit of such an approach A would be to have a harmonized calculation with the other batteries types. Nevertheless, considering that the benchmark with the other type of batteries is not meaningful, this is not a practical benefit. On the contrary, the addition of a “flat burden” to all type of e-mobility batteries would only reduce the sensitivity of the PEF and the ability to improve the result by battery design changes. Therefore, the approach B has been selected.

3.1 Product classification

The CPA codes for the products included in this PEFCR are:

Table 1: Product classification according to CPA

Material	CPA
Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators	27.20.23

The types of battery in the scope of the PEFCR only comprise part of the broader category of batteries identified under the CPA (European classification of products by activity) code: 27.20.23. (27. Electrical equipment/20. Batteries and accumulators/23. Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators).

3.2 Representative products

The main components of the representative products are identified as followed:

The battery cell components (assembled during the battery assembly stage, including the Safety Management Unit (SMU), in general based on electronics components
OEM components (depending on the application):

- The BCU (Battery control unit), mainly electronic components likes switches and contactors
- The BMU (Battery management unit), the electronic part for battery management. The ensemble of all electric/electronic parts of the batteries, including BCU and BMU is called the BMS (Battery Management System).
- The Heat Management Systems, or ThMU (Thermal management unit), the 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 charger, when it is dedicated to the battery (see explanatory note parag 3.)

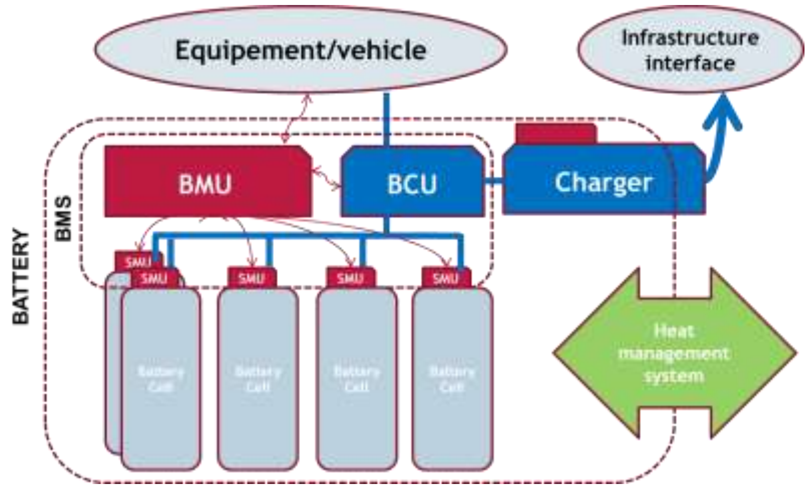

Figure 3: representative products components

This section introduces the representative products which have been defined to calculate the environmental impacts of the batteries in each application.

A "representative product" has been defined for the screening study, for each of the applications considered, based on the market share of the battery chemistries used in each application (data published in 2013 by Avicenne company have been used for this purpose).

- One for each of the 3 applications considered, based on the market share of the Lithium based chemistries used.
- One for ICT based on the Nickel- metal hydride chemistry.

The following table displays the structure and content of the representative products used for the PEF screening study.

Table 2: Representative products for the 4 subcategories

Elements	CPT Li-ion	ICT Li-ion	ICT Ni-MH	e-mobility Li-ion
Specify if it is a real or a virtual product	Virtual	virtual	virtual	virtual
Description of the product	CPT- Li-ion battery Chemistry composition based on market share	ICT- Li-ion battery Chemistry composition based on market share	ICT- Ni-MH battery Chemistry composition based on market share	e-mobility- Li-ion battery Chemistry composition based on market share
Quantity of functional units based on battery industry standard /IEC 61951-2/ /IEC 61960/	14,4 kWh	11,2 kWh	0,704 kWh	8000 kWh
Bill of materials (BOM) as	See parag 6.1 and 6.3			

appropriate					
System boundary	Production stage	Included	Included	included	included
	Use stage	Included	Included	included	included
	EoL stage	Included	Included	included	included
Product Boundary	Charger	Included	Included	Included	Excluded
Assumptions related to transportation and storage scenario		Representative conditions of transport for the materials and the batteries are described (see parag 6.4). as the majority of the cells manufacturing is in Asia, the transport of the active material used for this purpose has been considered only locally, and not in Europe. In addition, as the impact of the transport has been proved negligible in the PEF, no specific condition is described, and default data are provided			
Assumptions related to use scenario		Only charging energy losses are accounted (related to battery efficiency and charger efficiency)			
Assumptions related to EoL		Recycling process of the cell based on "Recycling rechargeable lithium ion batteries: Critical analysis of natural resource savings"/ Recycling battery processes ref 11/, / Recycling battery processes ref 12/ and /Directive 2006/66 EC/ Following steps has been considered in the End-of-Life stage (see parag 6.6) Dismantling process of the battery Pyrometallurgical treatment process for the cell Then, Hydrometallurgical treatment process for the cell			
Assumptions related to land use and infrastructure		The land use has been assessed for the size of the plants needed for the manufacturing of one unit of analysis for batteries, used during 50 years. The infrastructure has been assessed based on the equipment requested to manufacture one unit of analysis of batteries.			

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 sub-category, based on each of the 4 representative products (see limitations and benchmark restrictions in parag 3.6), as long as they use the same default data described in this table.

The screening study is available upon request to the TS coordinator (see RECHARGE contact at the end of the report) that has the responsibility of distributing it with an adequate disclaimer about its limitations

3.3 Functional unit and reference flow

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

The energy consumption during the use stage of the battery is defined by the energy losses linked to the battery and charger efficiency during charge, discharge and storage. The total energy transmitted by the battery to the application has to be taken into account by the mobile application provider, for the use phase of its PEF profile (application of the "delta approach").

Table 1 defines the key aspects used to define the FU.

Table 3 Key aspects of the Functional Unit

What?	Electrical energy, measured in Wh or kWh (current and voltage during a unit of time).
How much?	1 kWh of the total energy delivered over 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/kg). Specific product standards and technical properties of the high specific energy rechargeable batteries PEF shall be declared in the PEF documentation
How long?	The amount of cumulative energy delivered over service life of the high specific energy rechargeable 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.

The reference flow is the amount of product needed to fulfil the defined function and shall be measured in **kg of battery per kWh of the total energy required by the application over its 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 adapted to deliver 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 unit of analysis) to deliver the total Wh over the service life required by the application.

The reference flow for high specific energy rechargeable batteries is calculated as follows, based on an example of Cordless Power Tool battery (CPT) system:

<u>Step 1: Calculation of the quantity of functional unit per battery</u>

The purpose is to calculate the total service of the battery during the use stage, expressed in quantity of functional units.

$$QUa = Edc \times Nc \times Acc$$

Table 4: Parameters used for the calculation of functional unit based on an example

Abbr.	Parameter	CPT battery	Unit
Edc	Energy delivered per cycle	0,045	kWh/cycle
Nc	Number of cycles	400	number
Acc	Average capacity per cycle	80%	%
QUa	Quantity of functional unit	14,4	kWh over service life / per battery

The calculation of the functional unit is made according to the battery industry standard /IEC 61951-2/ and /IEC 61960/.

These standards describe the procedure to test the endurance in life cycles through permanent charge and discharge process. The test stops when the delivered energy in one cycle drops below 60% of the initial energy. The minimum number of cycles required is 400. Accordingly, the minimum energy provided over life can be calculated as 400 times the average capacity per cycle (80% of initial energy).

Please see paragraph 6.5 about the use stage calculation for the battery system.

Step 2: Calculation of the quantity of functional units for application service

The application service (AS) is the energy required by the application per service life (kWh).

The following formula is applied for the calculation of the number of batteries needed to fulfil the application service:

$$Nbbatt = \frac{AS}{QUa}$$

The number of batteries needed to fulfil the reference flow shall be used as a conversion factor to recalculate the Life Cycle Assessment results to enable the comparison of PEF results of different batteries used in the same application / vehicle.

Example

In the following table an example is given for the calculation of the number batteries required in order to provide the total energy required by the application (AS=29,6 kWh in this example) for two different batteries. Battery A and Battery B provide different energy [kWh] over their service life (14,4kWh and 29,6 kWh accordingly). Therefore to fulfil the total energy required per application AS, for Battery A 2,06 batteries are necessary while for Battery B only 1 battery.

Table 5: Parameters used for the association to the reference flow

Abv.	Parameter	Battery A	Battery B	Unit
Qua	Quantity functional unit	14,4	29,6	kWh over service life / per battery
AS	Application service	29,6	29,6	[kWh] total energy required per application
Nb batt	Number batteries	2,06	1	[-] number of batteries to fulfil the total energy required by the application

Step 3: Calculation of the reference flow

The reference flow (Rf) is obtained in calculating the amount of battery mass required to fulfil the service (kg battery/kWh)

$$Rf = \frac{Nb\ batt * mass}{AS}$$

3.4 System boundary

The system boundary for a PEF of rechargeable batteries includes the life cycle stages described in this section. The processes included in the system boundaries shall be divided into foreground processes (i.e. core processes in the product life cycle for which direct access to information is available) and background processes (i.e. those processes in the product life cycle for which no direct access to information is possible).

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

Table 6: Life cycle stages

Life cycle stage	Short description of the processes included
Raw material acquisition	Includes mining and pre-processing, up to the Manufacturing of cells and batteries components (active materials, separator, electrolyte, casings, active and passive battery components) and

	electric/electronics components.
Main product production	Assembly of cells and assembly of batteries with the cells and the electric/electronic components
Distribution	Representative transports to consumer and collection
Use phase	Electricity usage during use phase
End of life and recycling	Collection, dismantling and recycling.

According to this PEFCR, the following processes may be excluded based on the cut-off rule (a 1% cut-off for all impact categories based on environmental significance):

- Detailed transport operations description for raw materials, product distribution or end of life: as the impact has been calculated as negligible, only the default data provided shall be used, unless primary data of required quality (see parag 5.4) is available.
- Manufacturing of equipment for batteries assembly and recycling, as impacts have been calculated as negligible.
- OEM manufacturing (corresponding to the battery assembly process with the OEM system components) is not taken into account: it mainly corresponds to mechanical assembly, and is incorporated inside the OEM equipment or vehicle assembly line. 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 PEF study done in accordance with this PEFCR shall provide in the PEF study a diagram indicating the organizational boundary, to highlight those activities under the control of the organization and those falling into Situation 1, 2 or 3 of the data need matrix.

Figure 4: System Boundaries- life cycle of a battery system shows a general overview of the boundaries among the whole Life Cycle of a battery system, divided into foreground and background data.

The manufacturing of the main product includes four main steps: electrodes manufacturing, cells manufacturing and formation, battery manufacturing, and OEM manufacturing adding specific components that are part of the battery when incorporated in the equipment or vehicle. The list of mandatory primary (company-specific) is described in the paragraph 5.1 and corresponds to this main product manufacturing stage as described in the figure 4 below.

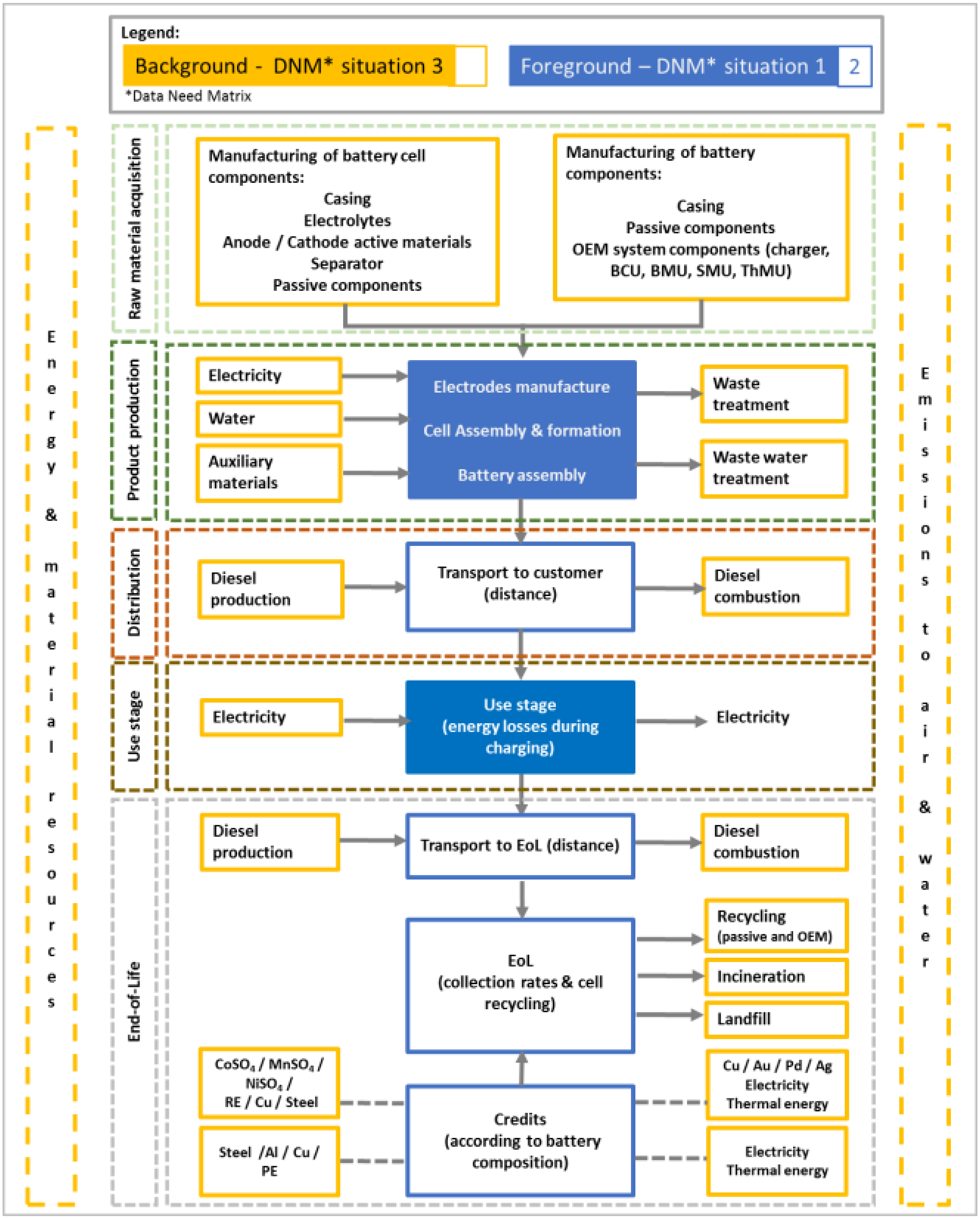

Figure 4: System Boundaries- life cycle of a battery system

3.4.1 Raw material acquisition stage and Production stage

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

Raw Material Acquisition and Pre-processing

The raw material acquisition and pre-processing stage starts when resources are extracted from nature and ends 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.

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
Heat management system (ThMU), the components directly associated to the battery for its thermal management.
Charger, when it is dedicated to the battery.

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

- Raw material preparation
- Ink preparation (mixing of powder and solvent)
- Coating
- Calendaring and slitting

Cell assembly and formation

- (Winding) and cell assembly
- Cell electrical formation

Battery assembly

- Cells are assembled in a battery casing
- When needed by the application, the cells are assembled with electronic parts and mechanical parts such as casings or cooling systems, and charger, to form the finished battery

Figure 5**Erreur ! Source du renvoi introuvable.** describes the production of the Li-ion battery. Energy supply, as well as transportation of raw materials to the manufacturing site, is included within the system boundaries.

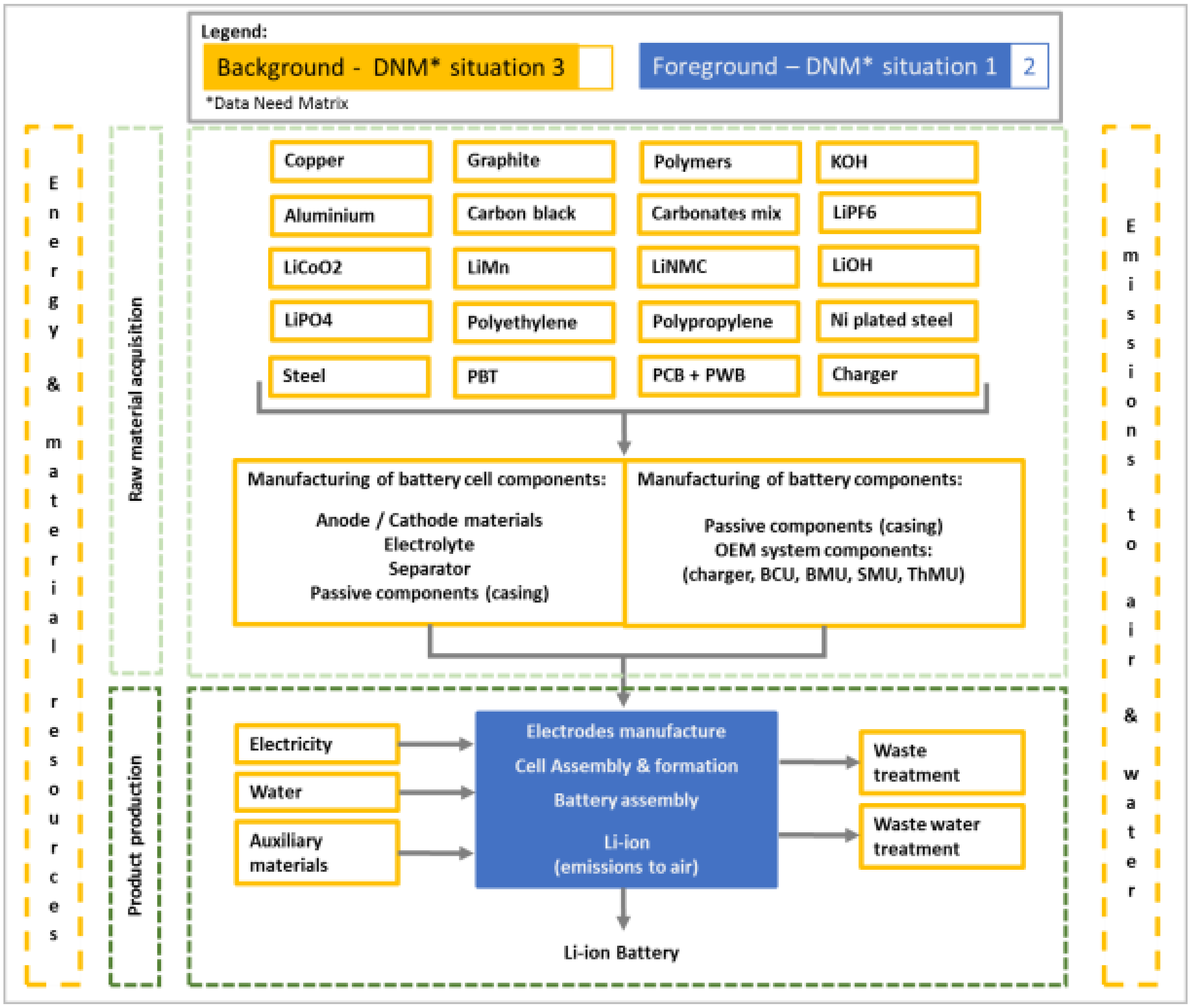

Figure 5: cradle to gate process for Li-ion battery production

The battery manufacturing and assembly stages of a nickel metal hydride (NiMH) battery are organised in a similar scheme to those of the lithium-ion battery.

Figure 6 describes the production of a NiMH battery.

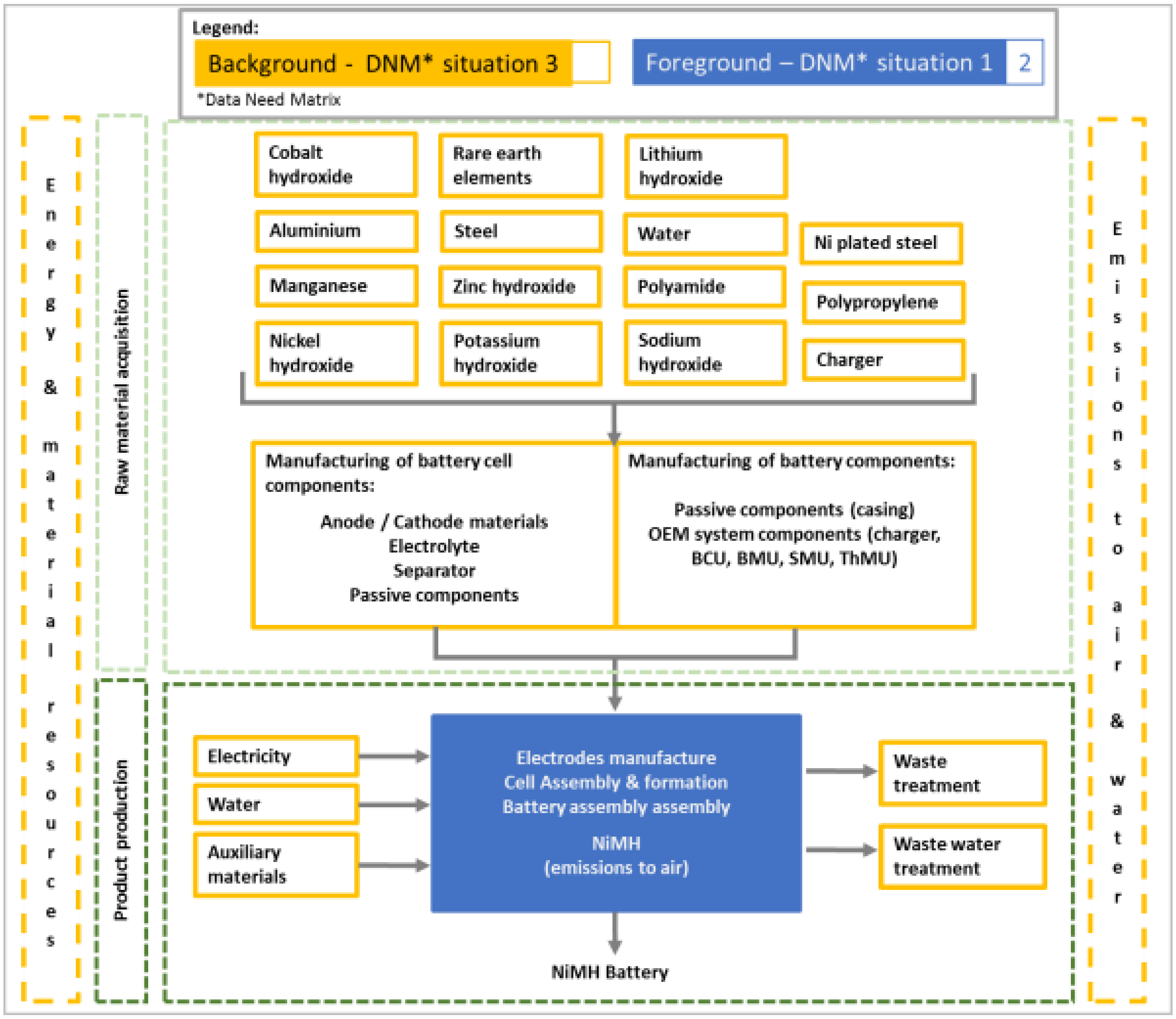

Figure 6: cradle to gate processes for Ni-MH battery production

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 study as it is not part of the battery assembly process but is incorporated into the OEM equipment or vehicle 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.

3.4.2 Use stage

The energy consumption during the use stage of the battery is defined by the energy losses due to the battery and charger efficiency during the whole life of the application. The mobile application provider has to consider in its PEF profile the total energy consumption during the life cycle of its product.

During the use stage, the energy consumption associated with the use of the charger and the battery shall be considered (losses due to Joule effect, thermodynamic efficiency, etc.). The global energy efficiency depends on the battery and equipment technology and on the application usage conditions (see parag 6.5 for more details).

3.4.3 End-of-Life stage

The end-of-life processes shall include:

- Dismantling of components; the components such as casings, cooling systems, plastics and other parts are separated from the batteries; these correspond to the separation of most of the components added during the OEM assembly process, and some of the components from the battery assembly.
- Conversion into recycled material: pyrometallurgical treatment, followed by hydrometallurgical treatment. The main output of the recycling process is a metallic fraction, containing metals from the battery, and the slag. This metallic fraction can be 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 second step of hydrometallurgical treatment step the metallic alloy obtained in the previous step is processed to recover the metal-sulphate which can be used again to manufacture the batteries active materials.
- Other operation: In case shredding processes are needed as a first (recycling) treatment, it is recommended to account for the energy consumption as well as to evaluate the possible emissions.
- Credits: as a result of cell recycling, after the refining, certain flows are credited. The mass of these flows are calculated according to the stoichiometric calculation of the cell materials input proportionally to the cell recycling outputs. Please see parag 6.6 for more details.

Figure 7 provides an overview of the dismantling and recycling processes of a battery system.

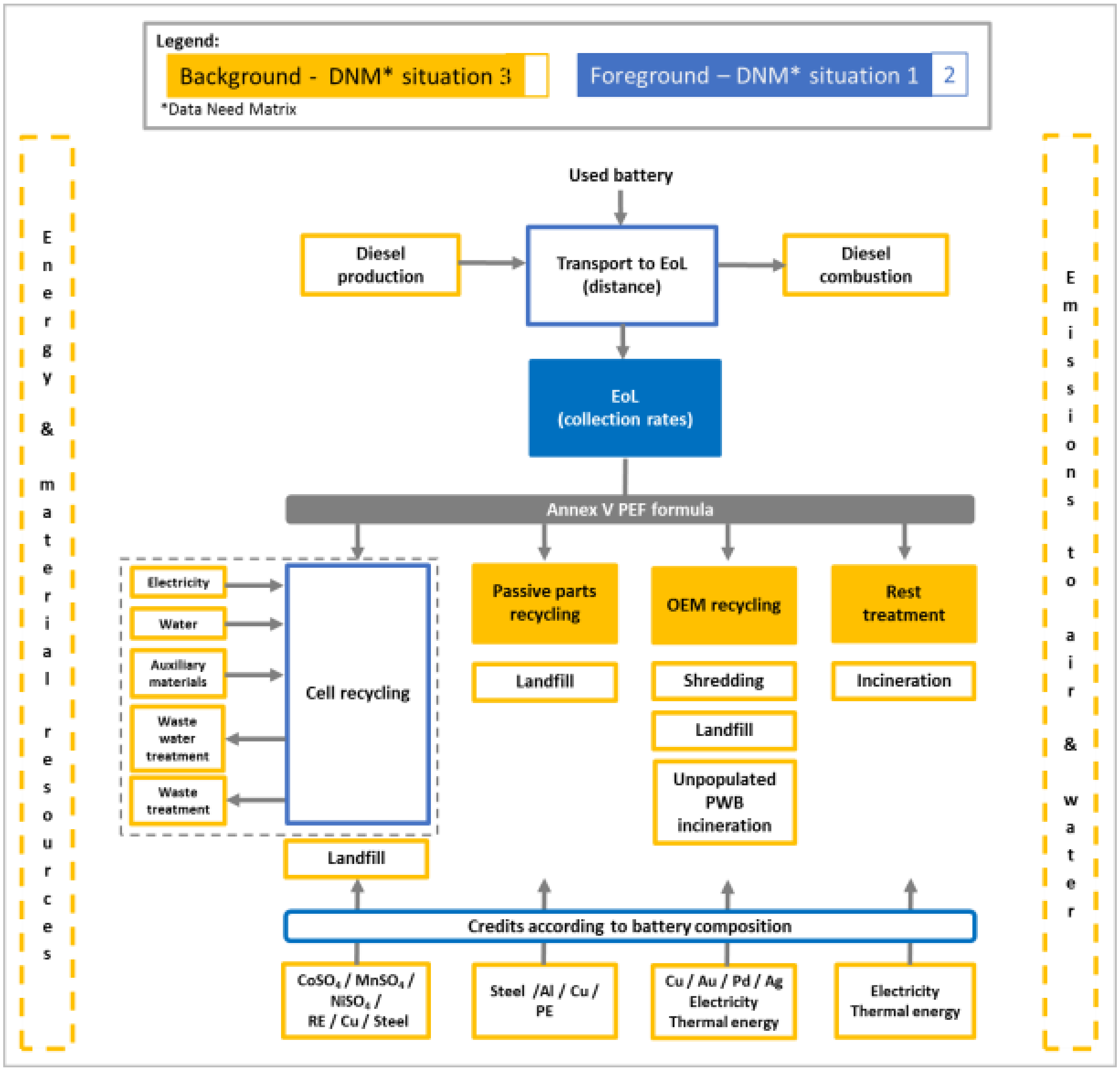

Figure 7: Dismantling and recycling processes

3.5 EF impact assessment

Each PEF study carried out in compliance with this PEFCR shall calculate the PEF-profile including all PEF impact categories listed in the Table below.

Land transformation is not calculated separately, as the results calculated from the screening studies are comparatively very small.

Table 7: List of the impact categories to be used to calculate the PEF profile

Impact category	Indicator	Unit	Recommended default LCIA method
Climate change - Climate change – land use and land transformation *** - Climate change – biogenic ***	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Baseline model of 100 years of the IPCC (based on IPCC 2013)
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 $_{eq}$	Steady-state ODPs 1999 as in WMO assessment
Human toxicity, cancer*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)
Human toxicity, non-cancer*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)
Particulate matter/respiratory inorganics	Impact on human health	disease incidence	UNEP recommended model (Fantke et al 2016)
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq $U^{235}{}_{eq}$	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC $_{eq}$	LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe
Acidification	Accumulated Exceedance (AE)	mol H+ $_{eq}$	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N $_{eq}$	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P $_{eq}$	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N $_{eq}$	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe
Ecotoxicity, freshwater*	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	USEtox model, (Rosenbaum et al, 2008)
Land use	• Soil quality index[6] • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• Dimensionless (pt) • kg biotic production[7] • kg soil • m^3 water • m3 groundwater	• Soil quality index based on LANCA (EC-JRC)[8] • LANCA (Beck et al. 2010) • LANCA (Beck et al. 2010) • LANCA (Beck et al. 2010) • LANCA (Beck et al. 2010)

[6] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for land use

[7] This refers to occupation. In case of transformation the LANCA indicators are without the year (a)

[8] Forthcoming document on the update of the recommended Impact Assessment methods and factors for the EF

Impact category	Indicator	Unit	Recommended default LCIA method
*Water use***	*User deprivation potential (deprivation-weighted water consumption)*	*m^3 world $_{eq}$*	*Available WAter REmaining (AWARE) Boulay et al., 2016*
Resource use, minerals and metals	*Abiotic resource depletion (ADP ultimate reserves)*	*kg Sb $_{eq}$*	*CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.*
Resource use, fossils	*Abiotic resource depletion – fossil fuels (ADP-fossil)*	*MJ*	*CML 2002 (Guinée et al., 2002) and van Oers et al. 2002*

*Long-term emissions (occurring beyond 100 years) shall be excluded from the toxic impact categories. Toxicity emissions to this sub-compartment have a characterisation factor set to 0 in the EF LCIA (to ensure consistency). If included by the applicant in the LCI modelling, the sub-compartment 'unspecified (long-term)' shall be used.

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

The full list of characterization factors (EC-JRC, 2017a) is available at this link http://eplca.jrc.ec.europa.eu/uploads/LCIA-characterization-factors-of-the-ILCD.pdf

**The results for water use might be overestimated and shall therefore be interpreted with caution. Some of the EF datasets tendered during the pilot phase and used in this PEFCR/OEFSR include inconsistencies in the regionalization and elementary flow implementations. This problem has nothing to do with the impact assessment method or the implementability of EF methods, but occurred during the technical development of some of the datasets. The PEFCR/OEFSR remains valid and usable. The affected EF datasets will be corrected by mid-2019. At that time it will be possible to review this PEFCR/OEFSR accordingly, if seen necessary.

*** The sub-indicators 'Climate change - biogenic' and 'Climate change - land use and land transformation' shall not be reported separately because their contribution to the total climate change impact, based on the benchmark results, is less than 5% each

3.6 Limitations

In PEF 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.

The identified limitations of the PEFCR are listed below:

- Due to the high number of battery components and the complexity of the processes, the PEFCR limits the process and component analysis to the battery-specific parts. For non-specific components, secondary data shall be used from the reference database or following the process for data-gaps described in paragraph 5o This applies to electronics components (either when used in the battery manufacturing stage or during the OEM manufacturing stage), metals, and plastics used for mechanical parts. Company or site specific datasets shall only be used if there is clear evidence that the specific datasets are more representative for the product under investigation. The secondary datasets to be used are those listed in this PEFCR.

- Some data sets are replaced by proxy, with the consequence of a significant impact on the environmental profile (based on the results of the various scenarios during the screening studies of the the pilot phase). For example, cobalt metal is used for cobalt sulphate, nickel metal for nickel hydroxyde, and lithium hydroxide for lithium hexafluorophosphate (see Table 15**: List of data gaps and proxies to be used**
-).
- the ADP -ultimate reserve- methodology is used to calculate the resources usage impact. The outcome of this method in the case of metals and minerals should be used with caution because the result of ADP after normalization may be overestimated, due to possible database inconsistencies.
- Due to the change of the End of life formula (50/50 approach) to the CFF formula (see paragraph 5.11) at the end of the PEF pilot process, some of the PEF data sets are based on the 50/50 approach. Consequently, the calculation for the benefit of batteries recycling, where the usage of recycled material is not included (R1=0), is not correctly assessed, and can be only considered as relative to the current methodology.
- It is assumed that waste water and auxiliary materials from battery manufacture/assembly are sent to waste water treatment, except for the organic solvent NMP (a 50% recycling process has been used for the representative product manufacturing to reflect average industrial situation).
- A study of the chargers used in different applications indicated that the charger size is directly linked to the battery size and energy. Due to the lack of detailed data on the specific charger technology used in each application, the Bill of Materials for the CPT charger of the published EPTA study shall be used for CPT and ICT battery systems. Based on the final reviewer expertise, it is recognized that the Bill Of Material selected may include a too complex PCB (8-layers), inducing higher impacts. A study of the chargers compositions per application would be required to have a more accurate representation.
- 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 4 representative products, the PEF 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, proxys…), unless primary data are used. The use stage shall be precisely described, and the battery performance measured in this same conditions. When the precise usage conditions are not available for the organization realizing a PEF, then the batteries performance and environmental impact benchmark shall be realized using the reference use phase conditions described for the representative product (see parag. 3). 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 information about benchmark. It is recommended to modify these secondary data only when primary data can be provided, according the Data Need Matrix (Table 17). In this case, the environmental impact of the product shall be recalculated using these data, but cannot be benchmarked with other PEF using different assumptions.

4 Most relevant impact categories, life cycle stages and processes

The most relevant impact categories for each sub-category in the scope of this PEFCR are identified in blue in the following table:

Table 8: most relevant impact categories

Impact category	Contribution to the total impact (%)			
	CPT - Li-ion	ICT - Li-ion	ICT - NiMH	e-mobility Li-ion
Acidification terrestrial and freshwater	3%	5%	15%	2%
Climate Change (biogenic)	0%	0%	0%	0%
Climate Change (fossil)	24%	25%	20%	32%
Climate Change (land use change)	0%	0%	0%	0%
Eutrophication freshwater	0%	0%	0%	0%
Eutrophication marine	1%	1%	1%	1%
Eutrophication terrestrial	2%	2%	1%	2%
Ionising radiation - human health	1%	2%	1%	3%
Land Use	0%	0%	0%	0%
Ozone depletion	0%	0%	0%	0%
Photochemical ozone formation - human health	2%	3%	3%	3%
Resource use, energy carriers	15%	18%	13%	26%
Resource use, mineral and metals	44%	33%	28%	20%
Respiratory inorganics	7%	9%	17%	8%
Water scarcity	1%	2%	1%	2%

The most relevant impact categories are the same for all product subcategory: Climate change, Resource use energy carriers, Resource use minerals and metals, and Respiratory inorganics, with in addition the impact Acidification for the Ni-MH batteries.

As climate change is selected as a relevant impact category, the PEF applicant shall report the total climate change as the sum of the three sub-indicators ‘Climate change- fossil’, 'Climate change - biogenic' and 'Climate change - land use and land transformation'.

The most relevant life cycle stages for each sub-categories in the scope of this PEFCR are identified in blue in the following tables: (characterized results per functional unit 1kWh, for each sub category in blue is indicated the 80% cumulative contribution – please note that the sum of line is not equal to 100% due to the credits from the CFF formula).

Table 9: most relevant life cycle stages

CPT - Li-ion battery

Impact category	Raw Material acquisition	Production of the main product	Product distribution	Use stage	End-of-Life
Climate Change (fossil) [kg CO2 eq.]	82%	8%	0%	7%	3%
Resource use, energy carriers [MJ]	77%	11%	0%	9%	3%
Resource use, mineral and metals [kg Sb eq.]	87%	0%	0%	0%	13%
Respiratory inorganics [kg PM2.5 eq.]	79%	4%	0%	3%	15%

ICT - Li-ion battery

Impact category	Raw Material acquisition	Production of the main product	Product distribution	Use stage	End-of-Life
Climate Change (fossil) [kg CO2 eq.]	65%	15%	0%	11%	9%
Resource use, energy carriers [MJ]	60%	18%	0%	12%	10%
Resource use, mineral and metals [kg Sb eq.]	81%	1%	0%	0%	18%
Respiratory inorganics [kg PM2.5 eq.]	69%	5%	0%	3%	23%

ICT - NiMH battery

Impact category	Raw Material acquisition	Production of the main product	Product distribution	Use stage	End-of-Life
Acidification terrestrial & freshwater [Mole of H+ eq.]	68%	2%	0%	1%	28%
Climate Change (fossil) [kg CO2 eq.]	63%	3%	0%	12%	22%
Resource use, energy carriers [MJ]	59%	4%	0%	15%	21%
Resource use, mineral and metals [kg Sb eq.]	67%	2%	0%	0%	31%
Respiratory inorganics [kg PM2.5 eq.]	70%	2%	0%	2%	27%

e-mobility Li-ion battery

Impact category	Raw Material acquisition	Production of the main product	Product distribution	Use stage	End-of-Life
Climate Change (fossil) [kg CO2 eq.]	45%	26%	0%	17%	12%
Resource use, energy carriers [MJ]	43%	29%	0%	18%	10%
Resource use, mineral and metals [kg Sb eq.]	65%	1%	0%	0%	34%
Respiratory inorganics [kg PM2.5 eq.]	66%	13%	0%	6%	41%

The most relevant life cycles stages include always the raw material acquisition for the most relevant impacts categories. In addition, the end of life is relevant for all product subcategories, at least for the Respiratory Inorganics impact. Finally, the use stage is relevant for the Resource use, energy carriers impact, except for the CPT LI-ion batteries.

The most relevant processes for each of the sub-categories in scope of this PEFCR are highlighted in blue in the following tables (Hotspots >50% cumulative contribution to most relevant impact categories), for each of the 4 identified larger impact categories (Climate change, Resource use energy carriers, Resource use minerals and metals, and Respiratory inorganics).

Table 10: most relevant processes

Acidification terrestrial & freshwater	**Unit process / Contribution % (excluding toxicity impact categories)**	
Life cycle stage	**ICT - NiMH**	
Raw material acquisition	GLO: Nickel	54%
	EPTA: Charger	8%
Production of the main product		
Product distribution		
Use stage		
End-of-life	GLO: Nickel	24%

Climate Change (fossil)	**Unit process / Contribution % (excluding toxicity impact categories)**							
Life cycle stage	**CPT - Li-ion**		**ICT - Li-ion**		**ICT - NiMH**		**e-mobility Li-ion**	
Raw material acquisition	EPTA: Charger	48%	EPTA: Charger	37%	EPTA: Charger	41%	Safety management unit	13%
			LiCoO	11%			LiCoO	1%
	Safety management unit	6%	CN: Lithium Nickel Manganese Cobalt Oxide	5%	GLO: Nickel	6%	CN: Lithium Nickel Manganese Cobalt Oxide	4%
	CN: Lithium Nickel Manganese Cobalt Oxide	5%			CN: Rare earth concentrate	3%	RER: methylpyrolidone production	5%
							EU-28+3: Aluminium ingot mix (high purity)	8%
							Thermal managment unit	3%
Production of the main product	EU-28+3: Electricity grid mix 1kV-60kV	13%	EU-28+3: Electricity grid mix 1kV-60kV	10%	EU-28+3: Electricity grid mix 1kV-60kV	4%	EU-28+3: Electricity grid mix 1kV-60kV	18%
Product distribution								
Use stage	EU-28+3: Electricity grid mix 1kV-60kV	8%	EU-28+3: Electricity grid mix 1kV-60kV	10%	EU-28+3: Electricity grid mix 1kV-60kV	11%	EU-28+3: Electricity grid mix 1kV-60kV	15%
End-of-life	GLO: Cobalt	2%	GLO: Cobalt	9%	GLO: Ferronickel	17%	GLO: Cobalt	7%
							EU-28+3: Aluminium ingot mix (high purity)	4%

							EU-28+3: Process steam from natural gas	2%

Resource use, energy carriers	Unit process / Contribution % (excluding toxicity impact categories)							
Life cycle stage	**CPT - Li-ion**		**ICT - Li-ion**		**ICT - NiMH**		**e-mobility Li-ion**	
Raw material acquisition	EPTA:Charger	39%	EPTA:Charger	30%	EPTA: Charger	36%	Safety management unit	9%
	Safety management unit	4%	CN: LiCoO	11%	GLO: Nickel	8%	RER: methylpyrolidone production	6%
	CN: Lithium Nickel Manganese Cobalt Oxide	4%	CN: Lithium Nickel Manganese Cobalt Oxide	4%			RER: Carbon black, general purposes production	2%
	EU-28+3: Aluminium ingot mix (high purity)	3%	RER: methylpyrolidone production	5%			CN: Lithium Nickel Manganese Cobalt Oxide	4%
	RER: methylpyrolidone production	3%					Thermal managment unit	3%
	EU-28+EFTA: PP granulates	2%					EU-28+EFTA: PP granulates	2%
							World w/o EU-28+EFTA: Polycarbonate (PC) granulate	2%
							EU-28+3: Aluminium ingot mix (high purity)	6%
Production of the main product	EU-28+3: Electricity grid mix 1kV-60kV	15%	EU-28+3: Electricity grid mix 1kV-60kV	11%	EU-28+3: Electricity grid mix 1kV-60kV	4%	EU-28+3: Electricity grid mix 1kV-60kV	19%
Product distribution								
Use stage	EU-28+3: Electricity grid mix 1kV-60kV	9%	EU-28+3: Electricity grid mix 1kV-60kV	12%	EU-28+3: Electricity grid mix 1kV-60kV	14%	EU-28+3: Electricity grid mix 1kV-60kV	16%
End-of-life					GLO: Ferronickel	16%	GLO: Cobalt	6%
	GLO: Cobalt	3%	GLO: Cobalt	9%	GLO: Nickel	3%	EU-28+3: Aluminium ingot mix (high purity)	4%

Resource use, mineral and metals	Unit process / Contribution % (excluding toxicity impact categories)							
Life cycle stage	**CPT - Li-ion**		**ICT - Li-ion**		**ICT - NiMH**		**e-mobility Li-ion**	
Raw material acquisition	EPTA: Charger	47%	EPTA: Charger	55%	EPTA: Charger	46%	Safety management unit	32%
	Safety management unit	9%	CN: LiCoO	9%	GLO: Nickel	16%	GLO: Copper	37%
	GLO: Copper sheet	17%	CN: Lithium Nickel Manganese Cobalt Oxide	4%				
			GLO: Copper sheet	8%				
Production of the main product								

Product distribution								
Use stage								
End-of-life	GLO: Copper Cathode	19%	GLO: Cobalt	8%	GLO: Ferronickel	19%	GLO: Copper Cathode	21%

Respiratory inorganics	**Unit process / Contribution % (excluding toxicity impact categories)**							
Life cycle stage	**CPT - Li-ion**		**ICT - Li-ion**		**ICT - NiMH**		**e-mobility Li-ion**	
Raw material acquisition	EPTA: Charger	39%	EPTA: Charger	24%	EPTA: Charger	13%	LiNiMnCoO	11%
	Safety management unit	5%	CN: Lithium Nickel Manganese Cobalt Oxide	11%	GLO: Nickel	42%	Safety management unit	10%
			GLO: Copper sheet	8%			Thermal managment unit	5%
			LiCoO	22%			RER: methylpyrolidone production	5%
							LiCoO	3%
	CN: Lithium Nickel Manganese Cobalt Oxide	14%	LiCoO	9%	CN: Rare earth concentrate	7%	LiMn	9%
Production of the main product	EU-28+3: Electricity grid mix 1kV-60kV	5%					EU-28+3: Electricity grid mix 1kV-60kV	6%
Product distribution								
Use stage	EU-28+3: Electricity grid mix 1kV-60kV	3%					EU-28+3: Electricity grid mix 1kV-60kV	5%
End-of-life	GLO: Nickel	9%	GLO: Cobalt	15%	GLO: Ferronickel	5%	GLO: Cobalt	12%
	GLO: Cobalt	5%			GLO: Nickel	18%	GLO: Nickel	14%

5 Life cycle inventory

All newly created processes shall be EF-compliant (see definitions).

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

5.1 List of mandatory company-specific data

As the process for manufacturing of the main product includes both

1-assembly of cells and

2-assembly of batteries with the cells and the electric/electronic components, and passive components,

two different type of companies may be involved, which may have no access to the primary information for the whole process. Therefore, two options are proposed following this PEFCR to allow for the companies having primary information for only part 1 or only part 2.

At least one of the two cases below shall be selected by the company realizing the PEF.

- **Case 1**: PEFCR based on Cell manufacturer company specific data:

  Mandatory process run by the company (situation 1 -option 1 of the data need matrix): cell assembly and formation.

- **Case 2:** PEFCR based on Battery manufacturer company specific data:

  Mandatory process run by the company (situation 1 -option 1 of data need matrix): battery assembly

In all cases, the list of material for the battery manufacturing and the list of energy inputs according the list of the reference product are required for all PEF-studies.

Process step	Life cycle stage	Process	Units
Manufacture of battery	Electrodes & cell manufacturing	- Raw material preparation - Ink preparation - Coating - Calendaring and slitting - Winding and cell assembly	kg
Battery Assembly and testing	Manufacturing	- Materials - Energy - Water - Wastes	kg and MJ
OEM Assembly	Manufacturing	- Charger - Electronics	kg and piece
Electricity consumption	Use stage	Use stage	kWh
End-of-Life	End-of-Life	- Collection rate - Recycling of the cell - Landfill - Incineration	kg/ MJ

Case 1-

Table 11: Mandatory process: Cell assembly and formation process

Requirements for data collection purposes			Requirements for modelling purposes								
Activity data to be collected	specific requirments	Unit of measurement (output)	Default dataset to be used (PEF compliant)	Geografical reference	Dataset source	UUID	Default DQR (estimated) P	TiR	GR	TeR	DQR average
Cells Manufacturing											
Others											
Power_electrode		MJ	Electricity grid mix 1kV-60kV	EU-28+EFTA	PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	3	3	2
Power_cell forming		MJ	Electricity grid mix 1kV-60kV	EU-28+EFTA	PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	3	3	2
Power_battery assembly		MJ	Electricity grid mix 1kV-60kV	EU-28+EFTA	PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	1	1	1
Water		kg	Tap water	EU-28+EFTA	PEF DB	{212b8494-a769-4c2e-8d82-9a6ef61baad7}	2	1	1	1	1
Auxiliary materials		kg	Hydrochloric acid production	RER	PEF DB	{d5953cab-21fd-44ea-ab3a-17a44ed3c260}	2	1	3	2	2
		kg	methylpyrolidone production	RER	PEF DB	{d869bd05-01fa-4f49-8610-f3ffb48a6bd1}	2	1	3	2	2
		kg	Nitric acid production	RER	PEF DB	{153d694d-6e48-47c4-9797-ff4bb6678612}	2	1	3	2	2
		kg	De-ionised water production	RER	PEF DB	{8040e11a-715f-4cd9-823c-a57124a553b2}	2	1	3	2	2
Waste water treatment		kg	Treatment of residential wastewater, large plant	EU-28+EFTA	PEF DB	{f5ec4a19-70da-406d-be31-a7eeef2f8372}	2	1	3	2	2
Active components per cell											
Anode											
Aluminium foil		kg	Aluminium foil	EU-28+EFTA	PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Cobalt hydroxide		kg	Cobalt	GLO	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2
Copper foil		kg	Copper sheet	EU-28+EFTA	PEF DB	{cb8a2255-c375-4d5d-9402-d62ca38787d7}	2	1	4	4	3
Graphite powder		kg	Carbon black, general purposes production	RER	PEF DB	{fde4abff-7cd7-4535-b472-481321d7d936}	2	1	4	4	3
Manganese		kg	Manganese	GLO	PEF DB	{38085a7e-98a3-4b5d-9381-8cefce00cc27}	2	1	3	2	2
Nickel hydroxide		kg	Nickel	GLO	PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Plastic compound		kg	Polyvinylidene fluoride (PVDF)	GLO	PEF DB	{8fd31112-01c1-46d3-8c8d-29e2bdfa6e38}	2	1	3	2	2
		kg	Styrene-butadiene rubber (SBR)	GLO	PEF DB	{5312a57a-4dc4-4ee7-9c77-72afdd38f1ea}	2	1	3	2	2
Rare earth		kg	Rare earth concentrate	CN	PEF DB	{4d5a1b20-880a-4e48-8206-972f35bf27c1}	2	1	1	2	2
Steel sheet part		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Cathode											
Cathode material (sulphates)		MJ	Electricity grid mix 1kV-60kV	CN	PEF DB	{8233263a-bf2e-416e-97a4-7f632248075a}	2	1	1	1	1
		kg	Manganese sulphate production	GLO	PEF DB	{b848a196-e27e-4e8e-953e-7de7cbc54c57}	2	1	3	2	2
		kg	Nickel sulphate production	RER	PEF DB	{3b369ae8-1f45-47ed-8dcf-af5f71593067}	2	1	4	4	3
		kg	Sodium hydroxide production	RER	PEF DB	{2ba49ead-4683-4671-bded-d52b80215e9e}	2	1	4	4	3
		kg	Sulphuric acid production	RER	PEF DB	{eb6abe54-7e5d-4ee4-b3f1-08c1e220ef94}	2	1	4	4	3
		kg	lithium carbonate production	GLO	PEF DB	{e57086c5-1bde-4f28-ac57-ac7d72db18bc}	2	1	3	2	2
		kg	Cobalt	GLO	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2
Plastic compound		kg	Polyvinylidene fluoride (PVDF)	GLO	PEF DB	{8fd31112-01c1-46d3-8c8d-29e2bdfa6e38}	2	1	3	2	2
		kg	Styrene-butadiene rubber (SBR)	GLO	PEF DB	{5312a57a-4dc4-4ee7-9c77-72afdd38f1ea}	2	1	3	2	2
Carbon black		kg	Carbon black, general purposes production	RER	PEF DB	{fde4abff-7cd7-4535-b472-481321d7d936}	2	1	4	4	3
Cobalt hydroxide		kg	Cobalt	GLO	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2
Nickel hydroxide		kg	Nickel	GLO	PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Aluminium foil		kg	Aluminium foil	EU-28+EFTA	PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Steel sheet part		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Zinc hydroxide		kg	Zinc	GLO	PEF DB	{d27a6fb8-561d-4c2a-aea3-0d0a9fd80621}	2	1	3	2	2
Electrolyte											
Carbonates mix		kg	dimethyl carbonate production	RER	PEF DB	{663a2d9b-f7ab-4941-8a27-80e96413c1d1}	2	1	4	4	3
		kg	ethylene carbonate production	RER	PEF DB	{57d3c404-37e1-4077-9c55-93c51f590997}	2	1	4	4	3
		kg	Polycarbonate (PC) granulate	GLO	PEF DB	{e7202044-f727-4aa7-bfc4-a8cfd1ed5812}	2	1	3	2	2
		kg	dimethyl carbonate production	RER	PEF DB	{663a2d9b-f7ab-4941-8a27-80e96413c1d1}	2	1	4	4	3
Lithium hydroxide		kg	lithium hydroxide production	GLO	PEF DB	{d08bdd01-a59f-4f80-87e8-5ad30c6934d3}	2	1	3	2	2
Potassium hydroxide		kg	potassium hydroxide production	GLO	PEF DB	{b5f5bcfd-24d3-44f4-b583-d4fe503cee97}	2	1	3	2	2
Caustic soda		kg	Sodium hydroxide production	RER	PEF DB	{2ba49ead-4683-4671-bded-d52b80215e9e}	2	1	4	4	3
Water		kg	De-ionised water production	RER	PEF DB	{8040e11a-715f-4cd9-823c-a57124a553b2}	2	1	4	4	3
Lithium Hexaflurophosphate		kg	lithium hydroxide production	GLO	PEF DB	{d08bdd01-a59f-4f80-87e8-5ad30c6934d3}	2	1	3	2	2
Separator											
Polyamide foil		kg	Nylon 6 granulate	EU-28+EFTA	PEF DB	{216a7eca-761e-414f-a040-233478c88ffa}	2	1	4	4	3
Polyethylene terephthalate foil		kg	Plastic Film, PET	EU-28+EFTA	PEF DB	{01bdd631-5c7a-4e0f-9b4d-f4a9996f9a5c}	2	1	4	4	3
Polypropylene film		kg	Plastic Film, PP	EU-28+EFTA	PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	4	4	3
Polyethylene foil		kg	Plastic Film, PE	EU-28+EFTA	PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	4	4	3
Passive components per cell											
Cell casing											
Steel nickel plated		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
		kg	Nickel	GLO	PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Aluminium sheet		kg	Aluminium sheet rolling	EU-28+EFTA	PEF DB	{1dd6e422-65eb-4bdb-ba1c-ee0aff723580}	2	1	4	4	3
		kg	Aluminium ingot mix (high purity)	EU-28+EFTA	PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	4	4	3
Polypropylene Film		kg	Plastic Film, PP	EU-28+EFTA	PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	4	4	3
Aluminium foil		kg	Aluminium foil	EU-28+EFTA	PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Steel sheet		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Copper		kg	Copper cathode	EU-28+EFTA	PEF DB	{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	4	4	3

Case 2-

Table 12: Mandatory process: Battery OEM assembly

Requirements for data collection purposes			Requirements for modelling purposes								
Activity data to be collected	**specific requirments**	**Unit of measurement (output)**	**Default dataset to be used (PEF compliant)**	**Geografical reference**	**Dataset source**	**UUID**	**Default DQR (estimated)**				
							P	TiR	GR	TeR	DQR average
Battery OEM system											
Battery casing											
Polybutylene Terephthalate Granulate		kg	Polybutylene Terephthalate (PBT) Granulate	World w/o EU-28+EFTA	PEF DB	{51bb1958-c494-4490-a080-c453e90d4d7d}	2	1	3	3	2
Polyethylene Film		kg	Plastic Film, PE	EU-28+EFTA	PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
Polypropylene Film		kg	Plastic Film, PP	EU-28+EFTA	PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	2	2	2
Steel sheet		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	2	2	2
BCU (E-MOBILITY)											
Switch PCB		sqm	Populated Printed wiring board (PWB) (2-layer)	World	PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
Polyethylene Film		kg	Plastic Film, PE	EU-28+EFTA	PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
Polypropylene Film		kg	PP granulates	EU-28+EFTA	PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
BMU (E-MOBILITY)											
Switch PCB		sqm	Populated Printed wiring board (PWB) (2-layer)	World	PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
Polyethylene Film		kg	Plastic Film, PE	EU-28+EFTA	PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
Polypropylene Film		kg	PP granulates	EU-28+EFTA	PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
Connector		kg	Connector for printed wiring board (PWB)	World	PEF DB	{79ad97bb-fd4e-41d5-8e61-8ef9c2406ba6}	2	1	2	2	2
Charger											
Charger		kg	Charger components EPTA u-so	EU-28+EFTA	EPTA / Recharge	{dc2bdc1b-6b7d-4ac5-a838-9d22f468dde0}	2	1	2	2	2
		kg	Cable, three-conductor cable	EU-28+EFTA	PEF DB	{0ced4acc-2a9f-4179-9801-c22795a47f6c}	2	1	2	2	2
		kg	Steel external plug	World	PEF DB	{26c88ecd-a9a3-4b36-b6ab-c5b14d896e82}	2	1	2	2	2
		sqm	Populated Printed wiring board (PWB) (8-layer)	World	PEF DB	{3b2e60de-2e05-4761-9c0d-06fb9320db9f}	2	1	2	2	2
		kg	PP granulates	EU-28+EFTA	PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
Passive cooling system											
Aluminium sheet		kg	Aluminium sheet rolling	EU-28+EFTA	PEF DB	{1dd6e422-65eb-4bdb-ba1c-ee0aff723580}	2	1	2	2	2
		kg	Aluminium ingot mix (high purity)	EU-28+EFTA	PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
Steel sheet		kg	Steel cold rolled coil	EU-28+EFTA	PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	2	2	2
Safety management unit											
Switch PCB		sqm	Populated Printed wiring board (PWB) (2-layer)	World	PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
ThMU (E-MOBILITY)											
Aluminium extrusion profile		kg	Aluminium extrusion	EU-28+EFTA	PEF DB	{f6af2ce4-e899-46d3-8806-9bb34e3b32e4}	2	1	2	2	2
Aluminium ingot		kg	Aluminium ingot mix (high purity)	EU-28+EFTA	PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
Polypropylene Granulate		kg	PP granulates	EU-28+EFTA	PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
Steel sheet part		kg	Steel cast part alloyed	EU-28+EFTA	PEF DB	{366a0afd-88e4-45dc-999a-8acc20fd0ead}	2	1	2	2	2

Direct elementary flow collection requirements for mandatory processes

All the relevant flows according case 1 or 2, as identified below, shall be collected for the manufacturing phase.

Table 13: elementary flows

Emissions / resources	Elementary flow	Frequency of measurement	Default measurement method[9]	Remarks
Emissions to air				
Particles (dust PM10)	kg/kg battery] Amount of emission to air	Yearly average	N/A	
Particles (dust PM2.5)	kg/kg battery] Amount of emission to air	Yearly average	N/A	
SO2_air	kg/kg battery] Amount of emission to air	Yearly average	N/A	
NOx_air	kg/kg battery] Amount of emission to air	Yearly average	N/A	

Table 14: other flows

Emissions / resources	other flow	Frequency of measurement	Default measurement method[10]	Remarks
Energy & water	[MJ/kg battery] Manufacturing electricity	Yearly average	N/A	
Electrodes manufacturing	[MJ/kg battery] Manufacturing electricity	Yearly average	N/A	
Cell assembly & forming	[MJ/kg battery] Manufacturing electricity	Yearly average	N/A	
Battery assembly	[MJ/kg battery] Manufacturing electricity	Yearly average	N/A	
Water (tap)	[kg/kg battery] Amount of water used	Yearly average	N/A	
Auxiliary materials				
Water deionized (anode + production)	kg/kg battery] Amount of water deionized	Yearly average	N/A	
n-methyl Pyrolidone	kg/kg battery] Amount of n-methyl	Yearly average	N/A	

[9] Unless specific measurement methods are foreseen in a country specific legislation

[10] Unless specific measurement methods are foreseen in a country specific legislation

(cathode)				
Chlorhydric acid (NiMH)	[kg/kg battery] Amount of Cl acid	Yearly average	N/A	
Nitric acid (NiMH)	kg/kg battery] Amount of nitric acid	Yearly average	N/A	

Comment: both electronic components (charger and/or battery management units, safety units) and the cathode materials have to be accurately defined, as they may become the main contributor for the climate change and resource usage impacts.

Sampling procedure for data acquisition:

All the elementary flows identified in the Table 13 are relative to continuous or semi-continuous industrial processes. For such processes, measurements shall be collected:

- First, at the points of consumption or emission directly relative to the process considered for the battery in the scope.
- If some of these data are not available (for example, the battery process is run in the same plant with multiple other processes) then a calculation for an allocation of the flows is allowed, with appropriate documentation. The allocation shall be based on a kg of battery produced.

A company quality system (i.e. ISO 9001 or equivalent) shall be in place in order to demonstrate that the measured values are representative of a yearly average of the elementary flows dedicated to the manufacturing of the battery in the scope.

5.2 List of processes expected to run by the company

In the case the cell manufacturer is also the battery manufacturer and OEM/assembly, then the full list of processes described in 5.1 shall be used.

5.3 Data gaps

In case data gaps appear while using this PEFCR (should the data used for the representative product not be applicable), they shall be filled using the data hierarchy presented in paragraph 5.6.
Any data used to fill data gaps shall be reported and justified.

The following shall be applied unless more specific information is available. The use of more specific information shall be clearly justified in the PEF report.

List of data gaps in available datasets and the proxies to be used by PEF studies:

- for Charger: when the company calculating the PEF has no primary data about the charger composition and weight, it shall use the "EPTA Charger" data.

- the following proxis shall be used:

Table 15: List of data gaps and proxies to be used

Data gap	unit	Proxi to be used
Stainless Steel slab (X6CrNi17)	kg/kg battery	Recycling of steel into steel scrap: Steel billet (St) {dadc8eb8-3ebe-4114-afc4-90d45a0b74b4}
Cobalt sulfate	kg/kg battery	Cobalt GLO {c76002c7-dfef-4d17-a100-fecd7910cfad}
Nickel hydroxide	kg/kg battery	Nickel GLO {bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}
Lithium Hexafluorophosphate	kg/kg battery	lithium hydroxide production GLO{d08bdd01-a59f-4f80-87e8-5ad30c6934d3}
Manganese sulfate	kg/kg battery	Manganese {38085a7e-98a3-4b5d-9381-8cefce00cc27}
Switch PCB (EPTA)*	kg/kg battery	Populated Printed wiring board (PWB) (2-layers) {91064ae4-3cf1-4b09-a430-9e01488ad11b}
Plastic granulate secondary (low metal contamination)	kg/kg battery	not available, select proxy data according hierarchy indicated in paragraph 5.6

* Concerning the charger, the Technical secretariat has referred to publicly available information, based on realistic product for the Cordless Power Tools application. There have been no specific studies to demonstrate that the components are representative for the chargers of other applications. For these cases, the charger has to be considered as a proxy. See detailed description for the charger in annex 4 .

In addition, carbon black is used instead of graphite for the anode material, as graphite was not available in the database at the time of calculation.

5.4 Data quality requirements

The data quality of each dataset and the total EF 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:

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

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.

The next chapters 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.

COMPANY SPECIFIC DATASETS

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 company-specific datasets shall be calculated as following:

1) Select the most relevant sub-processes and direct elementary flows that account for at least 80% of the total environmental impact of the company-specific dataset, listing them from the most contributing to the least contributing one.

2) Calculate the DQR criteria TeR, TiR, GR and P for each most relevant process and each most relevant direct elementary flow. The values of each criterion shall be assigned based on Table 16

> 2.a) Each most relevant elementary flow consists of the amount and elementary flow naming (e.g. 40 g carbon dioxide). For each most relevant elementary flow, evaluate the 4 DQR criteria named $Te_{R\text{-}EF}$, $Ti_{R\text{-}EF}$, $G_{R\text{-}EF}$, P_{EF}. It shall be evaluated for example, the timing of the flow measured, for which technology the flow was measured and in which geographical area.
>
> 2.b) Each most relevant process is a combination of activity data and the secondary dataset used. For each most relevant process, the DQR is calculated by the applicant of the PEFCR as a combination of the 4 DQR criteria for activity data and the secondary dataset: (i) Ti_R and P shall be evaluated at the level of the activity data (named $Ti_{R\text{-}AD}$, P_{AD}) and (ii) Te_R, Ti_R and G_R shall be evaluated at the level of the secondary dataset used (named $Te_{R\text{-}SD}$, $Ti_{R\text{-}SD}$ and $G_{R\text{-}SD}$). As Ti_R is evaluated twice, the mathematical average of $Ti_{R\text{-}AD}$ and $Ti_{R\text{-}SD}$ represents the Ti_R of the most relevant process.

3) Calculate the environmental contribution of each most-relevant process and elementary flow to the total environmental impact of all most-relevant processes and elementary flows, in % (weighted using 13 EF impact categories, with the exclusion of the 3 toxicity-related ones). For example, the newly developed dataset has only two most relevant processes, contributing in total to 80% of the total environmental impact of the dataset:

- Process 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).
- Process 1 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 Te_R, Ti_R, G_R and P criteria of the newly developed dataset as the weighted average of each criterion of the most relevant processes and direct elementary flows. The weight is the relative contribution (in %) of each most relevant process and direct elementary flow calculated in step 3.

5) The applicant of the PEFCR shall the total DQR of the newly developed dataset using the equation B.2, where $\overline{Te_R}, \overline{G_R}, \overline{Ti_R}, \overline{P}$ are the weighted average calculated as specified in point 4).

$$DQR = \frac{\overline{Te_R}+\overline{G_R}+\overline{Ti_R}+\overline{P}}{4}$$ *[Equation 2]*

NOTE: in case the newly developed dataset has most relevant processes filled in by non-EF compliant datasets (and thus without DQR), then these datasets cannot be included in step 4 and 5 of the DQR calculation. (1) The weight of step 3 shall be recalculated for the EF-compliant datasets only. Calculate the environmental contribution of each most-relevant EF compliant process and elementary flow to the total environmental impact of all most-relevant EF compliant processes and elementary flows, in %. Continue with step 4 and 5. (2) The weight of the non-EF compliant dataset (calculated in step 3) shall be used to increase the DQR criteria and total DQR accordingly. For example:

- Process 1 carries 30% of the total dataset environmental impact and is ILCD entry level compliant. The contribution of this process to the total of 80% is 37.5% (the latter is the weight to be used).
- Process 1 carries 50% of the total dataset environmental impact and is EF compliant. The contribution of this process to all most-relevant EF compliant processes is 100%. The latter is the weight to be used in step 4.
- After step 5, the parameters $\overline{Te_R}, \overline{G_R}, \overline{Ti_R}, \overline{P}$ and the total DQR shall be multiplied with 1.375.

Table 16: How to assess the value of the DQR criteria for datasets with company-specific information

DQR	P_{EF} and P_{AD}	$Ti_{R\text{-}EF}$ and $Ti_{R\text{-}AD}$	$Ti_{R\text{-}SD}$	$Te_{R\text{-}EF}$ and $Te_{R\text{-}SD}$	$G_{R\text{-}EF}$ and $G_{R\text{-}SD}$
1	*Measured/calculated and externally verified*	*The data refers to the most recent annual administration period with respect to the EF report publication date*	*The EF report publication date happens within the time validity of the dataset*	*The elementary flows and the secondary dataset reflect exactly the technology of the newly developed dataset*	*The data(set) 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 3 annual administration periods with respect to the EF report publication date*	*The EF report publication date happens not later than 2 years beyond the time validity of the dataset*	*The elementary flows and the secondary dataset is a proxy of the technology of the newly developed dataset*	*The data(set) 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 5 annual administration periods with respect to the EF report publication date*	*Not applicable*	*Not applicable*	*Not applicable*

DQR	P_{EF} and P_{AD}	Ti_{R-EF} and Ti_{R-AD}	Ti_{R-SD}	Te_{R-EF} and Te_{R-SD}	G_{R-EF} and G_{R-SD}
4-5	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*	*Not applicable*

For the quality assessment of the energy used, the geographic criteria as in Table 19 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 PEF compliant, publicly available, and have at least the same quality as the substituted default process

5.5 Data needs matrix (DNM)

All processes required for modelling of the product and outside the list of mandatory company-specific (listed in section 5.1) shall be evaluated using the Data Needs Matrix (see Table 17). The DNM shall be used by the PEFCR applicant to evaluate which data is needed and shall be used within the modelling of its PEF, depending on the level of influence the applicant (company) has on the specific process. The following three cases are found in the DNM and are explained below:

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

Table 17: Data Needs Matrix (DNM)[11] *Disaggregated datasets shall be used.

<table>
<tr><th></th><th></th><th>Most relevant process</th><th>Other process</th></tr>
<tr><td rowspan="2">Situation 1: process run by the company applying the PEFCR</td><td>Option 1</td><td colspan="2">Provide company-specific data (as requested in the PEFCR) and create a company specific dataset partially disaggregated at least at level 1 (DQR ≤1.6).

Calculate the DQR values (for each criteria + total)</td></tr>
<tr><td>Option 2</td><td></td><td>Use default secondary dataset in PEFCR, in aggregated form (DQR ≤3.0).

Use the default DQR values</td></tr>
<tr><td rowspan="3">Situation 2: process <u>not</u> run by the company applying the PEFCR but with access to (company-)specific information</td><td>Option 1</td><td colspan="2">Provide company-specific data (as requested in the PEFCR) and create a company specific dataset partially disaggregated at least at level 1 (DQR ≤1.6).

Calculate the DQR values (for each criteria + total)</td></tr>
<tr><td>Option 2</td><td>Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets (DQR ≤3.0).*

Re-evaluate the DQR criteria within the product specific context</td><td></td></tr>
<tr><td>Option 3</td><td></td><td>Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets (DQR ≤4.0).

Use the default DQR values</td></tr>
<tr><td rowspan="2">Situation 3: process <u>not</u> run by the company applying the PEFCR and <u>without</u> access to (company)-specific information</td><td>Option 1</td><td>Use default secondary dataset, in aggregated form (DQR ≤3.0).

Re-evaluate the DQR criteria within the product specific context</td><td></td></tr>
<tr><td>Option 2</td><td></td><td>Use default secondary dataset in PEFCR, in aggregated form (DQR ≤4.0)

Use the default DQR values</td></tr>
</table>

[11] The options described in the DNM are not listed in order of preference

5.5.1 Processes in situation 1

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

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

Situation 1/Option 1

For all processes run by the company and where the company applying the PEFCR uses company specific data. The DQR of the newly developed dataset shall be evaluated as described in section 5.4.1.

Situation 1/Option 2

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

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

5.5.2 Processes in situation 2

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

- The company applying the PEFCR has access to extensive supplier-specific information and wants to create a new EF-compliant dataset[12] (Option 1);
- The company has some supplier-specific information and want to make some minimum changes (Option 2).
- The process is not in the list of most relevant processes and the company prefers to use a secondary dataset (option 3).

Situation 2/Option 1

For all processes run by the company and where the company applying the PEFCR uses company specific data. The DQR of the newly developed dataset shall be evaluated as described in section 5.4.1.

[12] The review of the newly created dataset is optional

Situation 2/Option 2

Company-specific activity data for transport are used and the sub-processes used for electricity mix and transport with supply-chain specific PEF compliant datasets are substituted starting from the default secondary dataset provided in the PEFCR.

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

The applicant of the PEFCR shall make the DQR values of the dataset used context-specific by re-evaluating TeR and TiR, using the Table 18. The criteria GR shall be lowered by 30% and the criteria P shall keep the original value.

Situation 2/Option 3

For the non-most relevant processes, the applicant may use the corresponding secondary dataset listed in the PEFCR together with its DQR values.

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

Table 18: **How to assign the values to parameters in the DQR formula when secondary datasets are used**

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

5.5.3 Processes in situation 3

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

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

Situation 3/Option 1

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

Situation 3/Option 2

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

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

5.6 Which datasets to use?

The secondary datasets to be used by the applicant are those listed in this PEFCR. Whenever a dataset needed to calculate the PEF-profile is not among those listed in this PEFCR, then the applicant shall choose between the following options (in hierarchical order):

- Use an EF-compliant dataset available on one of the following nodes:
  - http://eplca.jrc.ec.europa.eu/EF-node
  - http://lcdn.blonkconsultants.nl
  - http://ecoinvent.lca-data.com
  - http://lcdn-cepe.org
  - https://lcdn.quantis-software.com/PEF/
  - http://lcdn.thinkstep.com/Node
- Use an EF-compliant dataset available in a free or commercial source;
- Use another EF-compliant dataset considered to be a good proxy. In such case this information shall be included in the "limitation" section of the PEF report.
- Use an ILCD-entry level-compliant dataset. In such case this information shall be included in the "data gap" section of the PEF report.

5.7 How to calculate the average DQR of the study

In order to calculate the average DQR of the EF study, the applicant shall calculate separately the TeR, TiR, GR and P for the EF study as the weighted average of all most relevant processes, based on their relative environmental contribution to the total single score (excluding the 3 toxicity-related ones). The calculation rules explained in chapter 5.4 shall be used.

5.8 Allocation rules

As there are no identified cases of co-products in the batteries manufacturing processes, no specific guidance is provided for allocation rules. However, in case co-products should be associated with the main battery manufacturing process, the following PEF multi-functionality decision default hierarchy shall be applied for resolving all multi-functionality problems:

(1) subdivision or system expansion;
(2) allocation based on a relevant underlying physical relationship (substitution may apply here);
(3) allocation based on some other relationship.

5.9 Electricity modelling

The guidelines in this section shall only be used for the processes where company-specific information is collected (situation 1 / Option 1 & 2 / Option 1 of the DNM).

The following electricity mix shall be used in hierarchical order:

(i) Supplier-specific electricity product shall be used if:
   (a) available, and
   (b) the set of minimum criteria to ensure the contractual instruments are reliable is met.

(ii) The supplier-specific total electricity mix shall be used if:
   (a) available, and
   (b) the set of minimum criteria that to ensure the contractual instruments are reliable is met.

(iii) As a last option the 'country-specific residual grid mix, consumption mix' shall be used (available at http://lcdn.thinkstep.com/Node/). Country-specific means the country in which the life cycle stage occurs. This may be an EU country or non-EU country. The residual grid mix characterizes the unclaimed, untracked or publicly shared electricity. This prevents double counting with the use of supplier-specific electricity mixes in (i) and (ii).

Note: if for a country, there is a 100% tracking system in place, case (i) shall be applied.

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

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

<u>Set of minimal criteria to ensure contractual instruments from suppliers:</u>

A supplier-specific electricity product/mix may only be used when the applicant ensures that any contractual instrument meets the criteria specified below. If contractual instruments do not meet the criteria, then 'country-specific residual grid mix, consumption mix' shall be used in the modelling.

A contractual instrument used for electricity modelling shall:

1. Convey attributes:
    - Convey the energy type mix associated with the unit of electricity produced.
    - The energy type mix shall be calculated based on delivered electricity, incorporating certificates sourced and retired on behalf of its customers. Electricity from facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the environmental attributes of the country residual consumption mix where the facility is located.
2. Be a unique claim:
    - Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.
    - Be tracked and redeemed, retired, or cancelled by or on behalf of the company (e.g. by an audit of contracts, third-party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).
3. Be as close as possible to the period to which the contractual instrument is applied.

<u>Modelling 'country-specific residual grid mix, consumption mix':</u>

Datasets for residual grid mix, per energy type, per country and per voltage have been purchased by the European Commission and are available in the dedicated node (http://lcdn.thinkstep.com/Node/). In case the necessary dataset is not available, an alternative dataset shall be chosen according to the procedure described in section B.5.8. If no dataset is available, the following approach may be used:

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

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

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

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

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

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

Allocation rules:

Allocation may be needed: (i) to subdivide the electricity consumption among multiple products for each process and (ii) to reflect the ratios of production/ratios of sales between EU countries/regions when a product is produced in different locations or sold in different countries. Where such data are not available, the average EU mix (EU-28 +EFTA), or region representative mix, shall be used. The following allocation rules shall be used:

Table 19: Allocation rules for electricity.

Process	Physical relationship	Modelling instructions
Battery manufacturing	Mass (Kg of battery)	The allocation of energy shall be based for the manufacturing plant on the total kg of battery produced, on a yearly base.
Battery usage	Total kWh during usage (kWh)	In case of specific country electricity usage, an allocation shall be made based on the total kWh of energy used per country, based the ratio of batteries sold per country (expressed in kg) , and the total energy used per kg of battery

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

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

a. The production (and related electricity consumption) of a product occurs in a separate site (building), the energy type physical related to this separated site may be used.
b. The production (and related electricity consumption) of a product occurs in a shared space with specific energy metering or purchase records or electricity bills, the product specific information (measure, record, bill) may be used.
c. All the products produced in the specific plant are supplied with a public available PEF study. The company who wants to make the claim shall make all PEF studies available. The allocation rule applied shall be described in the PEF study, consistently applied in all PEF studies connected to the site and verified. An example is the 100% allocation of a greener electricity mix to a specific product.

On-site electricity generation:

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

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

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

- If possible, apply subdivision.
- Subdivision applies both to separate electricity productions or to a common electricity production where you can allocate based on electricity amounts the upstream and direct emissions to your own consumption and to the share you sell out of your company (e.g. if a company has a wind mill on its production site and export 30% of the produced electricity, emissions related to 70% of produced electricity should be accounted in the PEF study.
- If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution[13].
- Subdivision is considered as not possible when upstream impacts or direct emissions are closely related to the product itself.

5.10 Climate change modelling

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

[13] For some countries, this option is a best case rather than a worst case.

1. Climate change – fossil: This sub-category includes emissions from peat and calcination/carbonation of limestone. The emission flows ending with '(fossil)' (e.g., 'carbon dioxide (fossil)'' and 'methane (fossil)') shall be used if available.
2. Climate change – biogenic: This sub-category covers carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of biomass by means of its transformation or degradation (e.g. combustion, digestion, composting, landfilling) and CO_2 uptake from the atmosphere through photosynthesis during biomass growth – i.e. corresponding to the carbon content of products, biofuels or aboveground plant residues such as litter and dead wood. Carbon exchanges from native forests[14] shall be modelled under sub-category 3 (incl. connected soil emissions, derived products, residues). The emission flows ending with '(biogenic)' shall be used.

   A simplified modelling approach shall be used when modelling the foreground emissions: Only the emission 'methane (biogenic)' is modelled, while no further biogenic emissions and uptakes from atmosphere are included. When methane emissions can be fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining fossil methane.

   As the product life cycle or part of the life cycle is never expected to have a carbon storage beyond 100 years, credits from biogenic carbon storage shall not be modelled.

3. Climate change – land use and land transformation: This sub-category accounts for carbon uptakes and emissions (CO_2, CO and CH_4) originating from carbon stock changes caused by land use change and land use. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (incl. soil carbon emissions). For native forests, all related CO_2 emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forest[15] and residues), while their CO_2 uptake is excluded. The emission flows ending with '(land use change)' shall be used.

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

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

[15] Following the instantaneous oxidation approach in IPCC 2013 (Chapter 2).

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

1) Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out, no emissions from land use change should be included in the assessment.

2) Where the timing of land use change cannot be demonstrated to be more than 20 years, or a single harvest period, prior to making the assessment (whichever is the longer), it shall be assumed that the land use change occurred on the 1st January of either:

- the earliest year in which it can be demonstrated that the land use change had occurred; or
- or the year in which the assessment of GHG emissions and removals is being carried out.

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

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

Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used. Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied.

Data sources, location and timing of land use change associated with inputs to products shall be reported.

Soil carbon storage shall not be modelled, calculated and reported as additional environmental information.

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

The sub-category 'Climate change-biogenic' shall be reported separately.

The sub-category 'Climate change-land use and land transformation' shall be reported separately.

5.11 Modelling of waste and recycled content

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

The Circular Footprint Formula is used to model the End-of-Life of products as well as the recycled content and is a combination of "material + energy + disposal", i.e.:

Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

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

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

With the following parameters:

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

B: allocation factor of energy recovery processes: it applies both to burdens and credits. It shall be set to zero for all PEF studies.

Qs_{in}: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.

Qs_{out}: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.

Q_p: quality of the primary material, i.e. quality of the virgin material.

R_1: it is the proportion of material in the input to the production that has been recycled from a previous system.

R_2: 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.

R_3: it is the proportion of the material in the product that is used for energy recovery at EoL.

$E_{recycled}$ (E_{rec}): specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.

$E_{recyclingEoL}$ (E_{recEoL}): specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.

E_v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.

E^*_v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.

EER: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, …).

$E_{SE,heat}$ and $E_{SE,elec}$: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.

ED: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.

$X_{ER,heat}$ and $X_{ER,elec}$: the efficiency of the energy recovery process for both heat and electricity.

LHV: Lower Heating Value of the material in the product that is used for energy recovery.

The reference scenario and the relevant parameters for this PEFCR are described in paragraph 6.6.

6 Life cycle stages

6.1 Raw material acquisition and pre-processing

Below is provided the list of all processes taking place in this life cycle stage (transport in separate table), and the default values used for the representative products. As the parameter R1 (see recycled content paragraph 6.6) is set as 0 per default, it is not mentioned in this table.

Table 20: Raw material acquisition and processing

Material/ Process	PEFCR Geographical reference	PEFCR Dataset name ()	Unit (output)	Default amount per FU				EF compliant dataset used	EF Geographical reference	Proxy (yes/ no)	Comment	Data set source	UUID	Default DQR (estimated)				
				Power tool	ICT		e-mobility							P	TiR	GR	TeR	DQR average
				Li-ion (power)	Li-ion (energy)	NiMH	Li-ion (Large/ EV)											
Active components per cell																		
Anode																		
Aluminium foil	EU-27	Aluminium foil	kg/kg battery	0	0	0.005	0	Aluminium foil	EU-28+EFTA	no		PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Cobalt hydroxide	GLO	Cobalt hydroxide	kg/kg battery	0	0	0.029	0	Cobalt	GLO	yes	worst case proxy (overestimate)	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2
Copper foil	CN	Copper Foil (11 µm) for 1 m2	kg/kg battery	0.199	0.073	0	0.074	Copper sheet	EU-28+EFTA	yes	foil and CN process needed	PEF DB	{cb8a2255-c375-4d5d-9402-d62ca38787d7}	2	1	4	4	3
Graphite powder	CN	Graphite powder (estimate)	kg/kg battery	0.085	0.182	0	0.126	Carbon black, general purposes production	RER	yes	best case proxy (underestimate) / CN process needed	PEF DB	{fde4abff-7cd7-4535-b472-481321d7d936}	2	1	4	4	3
Manganese	ZA	Manganese	kg/kg battery	0	0	0.016	0	Manganese	GLO	no		PEF DB	{38085a7e-98a3-4b5d-9381-8cefce00cc27}	2	1	3	2	2
Nickel hydroxide	DE	Nickel hydroxide	kg/kg battery	0	0	0.153	0	Nickel	GLO	yes	worst case proxy (overestimate)	PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Plastic compound	DE	Polyvinylidene fluoride (emulsion polymerization) (PVDF)	kg/kg battery	0.002	0.0045	0	0.002	Polyvinylidene fluoride (PVDF)	GLO	no		PEF DB	{8fd31112-01c1-46d3-8c8d-29e2bdfa6e38}	2	1	3	2	2
	DE	Styrene-Butadiene Rubber (SBR) Mix	kg/kg battery	0.002	0.0045	0	0.002	Styrene-butadiene rubber (SBR)	GLO	no		PEF DB	{5312a57a-4dc4-4ee7-9c77-72afdd38f1ea}	2	1	3	2	2
Rare earth	CN	Rare earth elements - extraction (Sichuan)	kg/kg battery	0	0	0.094	0	Rare earth concentrate	CN	no		PEF DB	{4d5a1b20-880a-4e48-8206-972f35bf27c1}	2	1	1	2	2
Steel sheet part	EU-27	Steel sheet part	kg/kg battery	0	0	0.081	0	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Cathode																		
Cathode material (sulphates)	CN	Electricity grid mix	MJ/kg battery	n.a.	n.a.	n.a.	n.a.	Electricity grid mix	CN	no		PEF DB	{8233263a-bf2e-416e-97a4-7f632248075a}	2	1	1	1	1
	DE	Manganese sulphate (estimation)	kg/kg battery	0.128	0.364	0	0.237	Manganese sulphate production	GLO	no		PEF DB	{b848a196-e27e-4e8e-953e-7de7cbc54c57}	2	1	3	2	2
	DE	Nickel Sulfate from electrolytnickel	kg/kg battery					Nickel sulphate production	RER	no		PEF DB	{3b369ae8-1f45-47ed-8dcf-af5f71593067}	2	1	4	4	3
	EU-27	Sodium hydroxide (caustic soda) mix (100%)	kg/kg battery					Sodium hydroxide production	RER	no		PEF DB	{2ba49ead-4683-4671-bded-d52b80215e9e}	2	1	4	4	3
	EU-27	Sulphuric acid (96%)	kg/kg battery					Sulphuric acid production (100%)	RER	no		PEF DB	{eb6abe54-7e5d-4ee4-b3f1-08c1e220ef94}	2	1	4	4	3
	GLO	Lithium Carbonate mix	kg/kg battery					lithium carbonate production	GLO	no		PEF DB	{e57086c5-1bde-4f28-ac57-ac7d72db18bc}	2	1	3	2	2
	GLO	Cobalt sulfate	kg/kg battery					Cobalt	GLO	yes	worst case proxy (overestimate)	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2
Plastic compound	DE	Polyvinylidene fluoride (emulsion polymerization) (PVDF)	kg/kg battery	0	0.09	0	0.001	Polyvinylidene fluoride (PVDF)	GLO	no		PEF DB	{8fd31112-01c1-46d3-8c8d-29e2bdfa6e38}	2	1	3	2	2
	DE	Styrene-Butadiene Rubber (SBR) Mix	kg/kg battery	0	0.09	0	0.001	Styrene-butadiene rubber (SBR)	GLO	no		PEF DB	{5312a57a-4dc4-4ee7-9c77-72afdd38f1ea}	2	1	3	2	2
Carbon black	DE	Carbon black (furnace black; general purpose)	kg/kg battery	0.004	0.009	0	0.012	Carbon black, general purposes production	RER	no		PEF DB	{fde4abff-7cd7-4535-b472-481321d7d936}	2	1	4	4	3
Cobalt hydroxide	GLO	Cobalt hydroxide	kg/kg battery	0	0	0.013	0	Cobalt	GLO	yes	worst case proxy (overestimate)	PEF DB	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	3	2	2

Nickel hydroxide	DE	Nickel hydroxide	kg/kg battery	0	0	0.169	0	Nickel	GLO	yes	worst case proxy (overestimate)	PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Aluminium foil	EU-27	Aluminium foil	kg/kg battery	0.071	0.036	0	0.045	Aluminium foil	EU-28+EFTA	no		PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Steel sheet part	EU-27	Steel sheet part	kg/kg battery	0	0	0.023	0	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Steel scrap	GLO	Value of scrap	kg/kg battery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		PEF DB	{d27a6fb8-561d-4c2a-aea3-0d0a9fd80621}	2	1	3	2	2
Zinc hydroxide	GLO	Zinc mix	kg/kg battery	0	0	0.006	0	Zinc	GLO	no	some water flows appear open							
Electrolyte																		
Carbonates mix	DE	Dimethyl carbonate (DMC)	kg/kg battery	0.082	0.1	0	0.086	dimethyl carbonate production	RER	no		PEF DB	{663a2d9b-f7ab-4941-8a27-80e96413c1d1}	2	1	4	4	3
	DE	Ethylene carbonate	kg/kg battery					ethylene carbonate production	RER	no		PEF DB	{57d3c404-37e1-4077-9c55-93c51f590997}	2	1	4	4	3
	DE	Propylene carbonate	kg/kg battery					Polycarbonate (PC) granulate	GLO	yes		PEF DB	{e7202044-f727-4aa7-bfc4-a8cfd1ed5812}	2	1	3	2	2
	DE	Dimethyl carbonate (DMC) (for EMC)	kg/kg battery					dimethyl carbonate production	RER	no		PEF DB	{663a2d9b-f7ab-4941-8a27-80e96413c1d1}	2	1	4	4	3
Lithium hydroxide	DE	Lithium hydroxide	kg/kg battery	0	0	0.001	0	lithium hydroxide production	GLO	no		PEF DB	{d08bdd01-a59f-4f80-87e8-5ad30c6934d3}	2	1	3	2	2
Potassium hydroxide	DE	Potassium hydroxide (KOH)	kg/kg battery	0	0	0.041	0	potassium hydroxide production	GLO	no		PEF DB	{b5f5bcfd-24d3-44f4-b583-d4fe503cee97}	2	1	3	2	2
Caustic soda	EU-27	Sodium hydroxide (caustic soda) mix (100%)	kg/kg battery	0	0	0.003	0	Sodium hydroxide production	RER	no		PEF DB	{2ba49ead-4683-4671-bded-d52b80215e9e}	2	1	4	4	3
Water	EU-27	Water (deionised)	kg/kg battery	0	0	0.176	0	De-ionised water production	RER	no		PEF DB	{8040e11a-715f-4cd9-823c-a57124a553b2}	2	1	4	4	3
Lithium Hexaflurophosphate	JP	Lithium Hexaflurophos phate (LiPF6)	kg/kg battery	0.014	0.014	0	0.015	lithium hydroxide production	GLO	yes		PEF DB	{d08bdd01-a59f-4f80-87e8-5ad30c6934d3}	2	1	3	2	2
Separator																		
Polyamide foil	DE	Polyamide foil (PA 6) (without additives)	kg/kg battery	0	0	0.011	0	Nylon 6 granulate	EU-28+EFTA	yes		PEF DB	{216a7eca-761e-414f-a040-233478c88ffa}	2	1	4	4	3
Polyethylene terephthalate foil	DE	Polyethylene terephthalate foil (PET) (without additives)	kg/kg battery	0	0	0	0	Plastic Film, PET	EU-28+EFTA	yes		PEF DB	{01bdd631-5c7a-4e0f-9b4d-f4a9996f9a5c}	2	1	4	4	3
Polypropylene film	EU-27	Polypropylene Film (PP) without additives	kg/kg battery	0.01575	0.027	0.011	0.045	Plastic Film, PP	EU-28+EFTA	no		PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	4	4	3
Polyethylene foil	EU-27	Polyethylene foil (PE-HD) without additives	kg/kg battery	0.00525	0.009	0	0.015	Plastic Film, PE	EU-28+EFTA	yes		PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	4	4	3
Passive components per cell																		
Cell casing																		
Steel nickel plated	EU-27	Steel sheet part	kg/kg battery	0	0	0.016	0	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
	GLO	Nickel mix	kg/kg battery					Nickel	GLO	no		PEF DB	{bb78c02b-70da-4e9e-a5a3-c5c45a5dcdb0}	2	1	3	2	2
Aluminium sheet	DE	Aluminium sheet mix	kg/kg battery	0	0	0	0.06	Aluminium sheet rolling	EU-28+EFTA	no		PEF DB	{1dd6e422-65eb-4bdb-ba1c-ee0aff723580}	2	1	4	4	3
Polypropylene Film	EU-27	Polypropylene Film (PP) without additives	kg/kg battery	0	0.036	0.032	0	Plastic Film, PP	EU-28+EFTA	no		PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	4	4	3
Aluminium foil	EU-27	Aluminium foil	kg/kg battery	0.001	0.001	0	0.007	Aluminium foil	EU-28+EFTA	no		PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	4	4	3
Steel sheet	EU-27	Steel sheet part	kg/kg battery	0.078	0	0.114	0	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{49a32f83-b59d-4f7b-b0f6-2efe9f9997aa}	2	1	4	4	3
Steel scrap	GLO	Value of scrap	kg/kg battery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	4	4	3
Copper	GLO	Copper mix (99,999% from electrolysis)	kg/kg battery	0.001	0.001	0	0.011	Copper cathode	EU-28+EFTA	no	GLO needed	PEF DB	{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	4	4	3
Battery casing																		
Polybutylene Terephthalate Granulate	DE	Polybutylene Terephthalate Granulate (PBT) Mix	kg/kg battery	0.003	0.001	0	0.002	Polybutylene Terephthalate (PBT) Granulate	GLO	no		PEF DB	{51bb1958-c494-4490-a080-c453e90d4d7d}	2	1	3	3	2
Polyethylene Film	EU-27	Polyethylene Film (PE-HD) without additives	kg/kg battery	0.065	0.004	0	0.005	Plastic Film, PE	EU-28+EFTA	no		PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
Polypropylene Film	EU-27	Polypropylene Film (PP) without additives	kg/kg battery	0.171	0.088	0	0.126	Plastic Film, PP	EU-28+EFTA	no		PEF DB	{3f9f3fb2-1aad-4cdf-a419-928c9818d62d}	2	1	2	2	2
Steel sheet	EU-27	Steel sheet part	kg/kg battery	0.031	0.012	0	0.052	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	2	2	2
Steel scrap	GLO	Value of scrap	kg/kg battery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.								

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

Reminder: the applicant shall decide the situation according parag 5.1 (case 1 or case 2) . The corresponding processes, expected to be run by the company, shall be calculated with primary data.

The global transport data are not a relevant impact, they are provided in the paragraph 6.4, including both raw material transport and distribution phase.

Modelling the recycled content is not applicable in this PEFCR.

6.2 (reserved)

6.3 Manufacturing

The manufacturing process shall include all steps as described in the system boundaries (see paragraph 3.4)

Below is provided the list of the materials to be taken onto account for the manufacturing stage, and the default values used for the representative products. Defaults in the table shall be used where the use of secondary data is allowed according to 5.1.

Table 21: **Manufacturing- cell assembly and formation.**

Material/ Process	PEFCR Geographical reference	PEFCR Dataset name (GaBi ts dataset)	Unit (output)	Default amount per FU: Power tool	Default amount per FU: ICT		Default amount per FU: e-mobility	EF compliant dataset used	EF Geographical reference	Proxy (yes/ no)	Comment	Dataset source	UUID	Default DQR (estimated)				
				Li-ion (power)	Li-ion (energy)	NiMH	Li-ion (Large/ EV)							P	TiR	GR	TeR	DQR average
Manufacturing																		
Others																		
POWER_ ELECTRODE	EU-27	Electricity grid mix	MJ/kg battery	40	40	12.5	40	Electricity grid mix 1kV-60kV	EU-28+EFTA	no		PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	3	3	2
POWER_ CELL FORMING	EU-27	Electricity grid mix	MJ/kg battery	1.2	1.2	0.4	1.2	Electricity grid mix 1kV-60kV	EU-28+EFTA	no		PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	3	3	2
POWER_ BATTERY ASSEMBLY	EU-27	Electricity grid mix	MJ/kg battery	0.001	0.001	0.001	0.001	Electricity grid mix 1kV-60kV	EU-28+EFTA	no		PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	1	1	1
WATER	EU-27	Tap water	kg/kg battery	11	11	5.5	11	Tap water	EU-28+EFTA	no		PEF DB	{212b8494-a769-4c2e-8d82-9a6ef61baad7}	2	1	1	1	1
AUXILIARY MATERIALS	DE	Hydrochloric acid mix (100%)	kg/kg battery	0.308	0.453	0	0.37	Hydrochloric acid production	RER	no		PEF DB	{d5953cab-21fd-44ea-ab3a-17a44ed3c260}	2	1	3	2	2
	DE	n-Methylpyrolidone (NMP)	kg/kg battery	0.077	0.219	0	0.143	methylpyrolidone production	RER	no		PEF DB	{d869bd05-01fa-4f49-8610-f3ffb48a6bd1}	2	1	3	2	2
	EU-27	Nitric acid (98%)	kg/kg battery	0	0	0.006	0	Nitric acid production	RER	no		PEF DB	{153d694d-6e48-47c4-9797-ff4bb6678612}	2	1	3	2	2
	EU-27	Water (deionised)	kg/kg battery	0	0	0.006	0	De-ionised water production	RER	no		PEF DB	{8040e11a-715f-4cd9-823c-a57124a553b2}	2	1	3	2	2

WASTE WATER TREATMENT	EU-27	Municipal waste water treatment (sludge incineration)	kg/kg battery	11.8	12.1	5.71	11.9	Treatment of residential wastewater, large plant	EU-28+EFTA	no		PEF DB	{f5ec4a19-70da-406d-be31-a7eeef2f8372}	2	1	3	2	2

Table 22: Manufacturing- battery assembly

Material/ Process	PEFCR Geographical reference	PEFCR Dataset name (GaBi ts dataset)	Unit (output)	Default amount per FU				EF compliant dataset used	EF Geographical reference	Proxy (yes/no)	Comment	Dataset source	UUID	Default DQR (estimated)				
				Power tool	ICT		e-mobility											
				Li-ion (power)	Li-ion (energy)	NiMH	Li-ion (Large / EV)							P	TiR	GR	TeR	DQR average
BCU (E-MOBILITY)																		
SWITCH PCB	EU-27	Switch PCB (EPTA)	kg/kg battery					Populated Printed wiring board (PWB) (2-layer)	GLO	yes		PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
POLYETHYLENE FILM	EU-27	Polyethylene foil (PE-HD) (without additives)	kg/kg battery	0	0	0	0.0027	Plastic Film, PE	EU-28+EFTA	yes		PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
POLYPROPYLENE FILM	EU-27	Polypropylene Granulate (PP)	kg/kg battery					PP granulates	EU-28+EFTA	no		PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
BMU (E-MOBILITY)																		
SWITCH PCB	EU-27	Switch PCB (EPTA)	kg/kg battery					Populated Printed wiring board (PWB) (2-layer)	GLO	yes		PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
POLYETHYLENE FILM	EU-27	Polyethylene foil (PE-HD) (without additives)	kg/kg battery	0	0	0	0.0042	Plastic Film, PE	EU-28+EFTA	yes		PEF DB	{cc8ee5f1-84b3-4e04-bae3-6a531aafb606}	2	1	2	2	2
POLYPROPYLENE FILM	EU-27	Polypropylene Granulate (PP)	kg/kg battery					PP granulates	EU-28+EFTA	no		PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
CONNECTOR	DE	Connector (small, w/o Au, PBTGF30 Basis - Automotive)	kg/kg battery					Connector for printed wiring board (PWB)	GLO	yes		PEF DB	{79ad97bb-fd4e-41d5-8e61-8ef9c2406ba6}	2	1	2	2	2
Charger*																		
CHARGER	GLO	Charger EPTA	kg/kg battery	0.59	0.59	0.59	0	Charger EPTA	EU-28+EFTA	n.a.	not available in PEF DB	EPTA / Recharge	{dc2bdc1b-6b7d-4ac5-a838-9d22f468dde0}	2	1	2	2	2
												PEF DB	{0ced4acc-2a9f-4179-9801-c22795a47f6c}	2	1	2	2	2
												PEF DB	{26c88ecd-a9a3-4b36-b6ab-c5b14d896e82}	2	1	2	2	2
												PEF DB	{3b2e60de-2e05-4761-9c0d-06fb9320db9f}	2	1	2	2	2
												PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
Passive cooling system																		
ALUMINIUM SHEET	DE	Aluminium sheet mix	kg/kg battery					Aluminium sheet rolling	EU-28+EFTA	no		PEF DB	{1dd6e422-65eb-4bdb-ba1c-ee0aff723580}	2	1	2	2	2
STEEL SHEET	EU-27	Steel sheet part	kg/kg battery	0.003	0.012	0	0.018	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
STEEL SCRAP	GLO	Value of scrap	kg/kg battery					n.a.	n.a.	n.a.		PEF DB	{3e5ff637-ffc2-4920-9051-11055b1d2d18}	2	1	2	2	2
Safety management unit																		

SWITCH PCB	EU-27	Switch PCB (EPTA)	kg/kg battery	0.037	0.014	0	0.057	Populated Printed wiring board (PWB) (2-layer)	GLO	yes		PEF DB	{91064ae4-3cf1-4b09-a430-9e01488ad11b}	2	1	2	2	2
ThMU (E-MOBILITY)																		
ALUMINIUM EXTRUSION PROFILE	EU-27	Aluminium extrusion profile <t-agg>	kg/kg battery	0	0	0	0.2195	Aluminium extrusion	EU-28+EFTA	no		PEF DB	{f6af2ce4-e899-46d3-8806-9bb34e3b32e4}	2	1	2	2	2
ALUMINIUM INGOT	EU-27	Aluminium ingot mix PE	kg/kg battery					Aluminium ingot mix (high purity)	EU-28+EFTA	no		PEF DB	{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
POLYPROPYLENE GRANULATE	EU-27	Polypropylene Granulate (PP)	kg/kg battery					PP granulates	EU-28+EFTA	no		PEF DB	{eb6c15a5-abcd-4d1a-ab7f-fb1cc364a130}	2	1	2	2	2
STEEL SHEET PART	EU-27	Steel sheet part	kg/kg battery					Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		PEF DB	{366a0afd-88e4-45dc-999a-8acc20fd0ead}	2	1	2	2	2
STEEL SCRAP	GLO	Value of scrap	kg/kg battery					n.a.	n.a.	n.a.								

*See details for the charger in annex 4

Reminder: the applicant shall decide the situation according parag 5.1 (case 1 or case 2) . The corresponding processes, expected to be run by the company, shall be calculated with primary data.

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

The waste of products used during the manufacturing shall be included in the modelling. By default, direct wastes from manufacturing shall be included based on an increase of 5% of the cell mass components amounts and 3% increase for passive components, unless correctly measured and identified in the bill of material. In addition, the emissions of the electrode manufacturing process have to be included, as indicated above. Auxiliary manufacturing flows, such as auxiliary solvents, shall be taken into account. These may be only partially recycled depending on each plant. Energy requirements shall also be taken into account.

6.4 Distribution stage

In general transportation has a negligible impact on the environment in the life cycle of a rechargeable battery /SCREENING 2015/.

The transport from factory to final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as the user (use phase).

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

For the battery PEF profiles the following scenario shall be used, including all phases of transport in the product life, except if a specific detailed assessment can be documented. In case supply-chain-specific information is available for one or several transport parameters, they may be applied following the Data Needs Matrix.

(Note: air transport is not considered in the reference case. In case of air transport, the activity data shall be assessed accordingly).

a- Nonspecific transport conditions (according PEF guidance 6.3)

From component supplier to OEM factory:transport in Europe (utilisation ratio 64%)

- 130 km by truck (28-32 t, EURO 5; 28-32 t, EURO 5; UUID 0aa65e8b-70c8-4b7f-b1d7-91a6403d2b5a), PEFCR specific utilisation ratio; and
- 240 km by train (average freight train; UUID 02e87631-6d70-48ce-affd-1975dc36f5be); and
- 270 km by ship (barge; UUID 4cfacea0-cce4-4b4d-bd2b-223c8d4c90ae).

From OEM factory to user (Use Phase): (utilisation ratio 64%) intracontinental supply chain: 200 km by truck (28-32 t, EURO 5; UUID 0aa65e8b-70c8-4b7f-b1d7-91a6403d2b5a) (Eurostat 2014),

Transport to the EoL recycling: (utilisation ratio 64%) intracontinental supply chain: 200 km by truck (28-32 t, EURO 5; UUID 0aa65e8b-70c8-4b7f-b1d7-91a6403d2b5a) (Eurostat 2014),

b- Batteries specific conditions (utilisation ratio 64%) :

- Active material: transport from China to Korea 300 km by truck, 200km by rail and 10000 km by ship
- Passive material: transport 300 km in Japan by truck, 200 km by rail and 18000 km by ship
- Cell: transport from Japan, Korea or China to Europe => transport 300 km by truck, 200 km by rail and 18000 km by ship
- The storage of the batteries at different stages of their life cycle is not specified (also not specific conditions or requirements such as temperature control).

Table 23: Distribution.

Transport mode	GaBi ts dataset		EF compliant dataset used	EF Geographical reference	Proxy (yes/no)	Comment	Data set source	UUID	Default DQR (estimated)				
	PEFCR country	PEFCR dataset name							P	TiR	GR	TeR	DQR average
Truck-trailer	GLO	Truck-trailer	Articulated lorry transport, Euro 4, Total weight >32 t (without fuel)	EU-28+EFTA	no		PEF DB	{938d5ba6-17e4-4f0d-bef0-481608681f57}	2	1	2	2	2
Diesel mix at refinery	EU-27	Diesel mix at refinery	Diesel mix at refinery	EU-28+EFTA	no		PEF DB	{da248653-790b-44bf-9e43-d4ae66cafbe1}	2	1	2	2	2
Rail transport cargo - average	GLO	Rail transport cargo - average	Freight train, average (without fuel)	EU-28+EFTA	no		PEF DB	{02e87631-6d70-48ce-affd-1975dc36f5be}	2	1	2	2	2
Diesel mix at refinery	EU-27	Diesel mix at refinery	Diesel mix at refinery	EU-28+EFT	no		PEF DB	{da248653-790b-44bf-9e43-d4ae66cafbe1}	2	1	2	2	2

				A									
Electricity grid mix	EU-27	Electricity grid mix	Electricity grid mix 1kV-60kV	EU-28+EFTA	no		PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	2	2	2
Bulk commodity carrier	GLO	Bulk commodity carrier	Transoceanic ship, bulk	EU-28+EFTA	no		PEF DB	{82b202c3-826c-4053-b49f-bc6ef737420a}	2	1	2	2	2
Light fuel oil at refinery	EU-27	Light fuel oil at refinery	n.a.	n.a.	n.a.	fuel included in ship process							
Heavy fuel oil at refinery	EU-27	Heavy fuel oil at refinery	n.a.	n.a.	n.a.	fuel included in ship process							

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

By default, there is no waste of products during the distribution and retail stage.

6.5 Use stage

The use stage of the battery is defined by the energy losses due to the battery and charger efficiency. The mobile application manufacturer has to consider in its PEF profile the total energy consumption during the life cycle of its product.

The use stage scenarios are defined by:

- Energy losses due to battery and charger efficiency over battery life time
- Country specific energy mix

Explanation:

For electricity consumed during the use stage of products, the energy mix shall reflect ratios of sales between countries or regions. Where such data are not available, the average EU consumption mix, or otherwise most representative mix, shall be used.

The energy losses (activity data) of the specific battery system shall be indicated by the PEFCR user. They shall include the losses at the charge (as provided by the charger supplier) and the losses at the battery.

The following formula for the batteries may be used to calculate the losses, or in absence of technical information, the default data provided below per battery chemistry.

$$Energy\ efficiency = \left(\frac{V_p}{V_c}\right)\left(\frac{I_p T_p}{I_c T_c}\right) = (voltage\ efficiency)(\mathbf{coulumb}\ efficiency)$$

V, I, and T are respectively Voltage, Current and Time for Charge and Discharge.

Losses= (1 - Energy efficiency)(Application Service energy)

<u>Characteristics of different technologies:</u>

- Ni- Cd and Ni-MH have a similar behaviour: coulomb eff. 85% and voltage efficiency: (1,23V)/(1,38V) = 89%, energy eff. = 76% [16]

[16] Saft Ni-Cd technical leaflets: SPH range, Uptimax range (www.saftbatteries.com)

- Li-ion have a coulomb efficiency close to 100% (no side reaction when charged up to 100%), and voltage efficiency (3,6V)/(3,75V) =96%, leading to an energy efficiency = 96%[17]
- In addition to the battery energy efficiency, the charger efficiency is taken into account according the specification provided by the charger manufacturer. Typical data re provided as default data.

Concerning the use stage, the following table shall be used to provide the correct Application Service energy (quantity of Functional Units) according the user knowledge about the battery performance and the application requirements. In this table, "knowledge" refers to the understanding and availability of information concerning the battery usage during the use stage. "Global knowledge" means the knowledge of the battery life duration in the usage conditions (charging and discharging temperature and rate conditions, representative cycle with state of charge variations, number of cycles), and the knowledge of the application (number of batteries used per equipment or vehicle during its life).

Table 24: Guideline for calculation of quantity of Functional Units and Reference flow

Use phase situation knowledge	Application	Battery	Number of batteries per application	Reference flow (Rf)
1 global knowledge	application service (AS=Total Wh need) known	Total Wh in application known (QuA)	Known or calculated Nb= AS/QuA	Rf= Nb*mass/AS
2 battery knowledge only	Unknown	Total Wh in application known (QuA)	unknown	Rf= mass/QuA
3 Application knowledge only	application service (AS=Total Wh need) known	Nb batteries needed is known		Rf= Nb batt*mass/AS
4 lack of knowledge	Un known	Total Wh in application Unknown, but life cycle at 100% DOD according the std known: Apply QuA= Wh per cycle* Nbcycles* 80%		Rf= mass/QuA
5 no knowledge	Un known	Battery life unknown. Apply QuA=Wh per cycle*400*80%		Rf= mass/QuA

Concerning the number of cycles of the battery over life, the applicant should to use the battery manufacturer data proving the life span of the battery in the application (it can be a specific life cycle testing, or a measurement of the battery life in the application). In case no data is available, the applicant shall use the value of cycles measured according the IEC standards. In all cases, the reference of the selected information source shall be provided in the PEF report.

[17] Saft Li-ion technical leaflet: Evolion system(www.saftbatteries.com)

Table 25: Use stage.

Material/ Process	PEFCR Geographical reference	Unit (output)	Default amount per FU					EF compliant dataset used	EF Geographical reference	Dataset source	UUID	Default DQR (estimated)				
			Power tool	ICT		e-mobility										
			Li-ion (power)	Li-ion (energy)	NiMH	Li-ion (Large/ EV)						P	TiR	GR	TeR	DQR average
Use stage (recharging loses)																
Power	EU-27	kWh/kg battery	6.9	11.7	11.6	9.6		Electricity grid mix	EU-28+EFTA	PEF DB	{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	1	1	1

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

For the use stage the consumption grid mix shall be used. The electricity mix shall reflect the ratios of sales between EU countries/regions. To determine the ratio a physical unit shall be used (kg of product). Where such data are not available, the average EU consumption mix (EU-28 +EFTA), or region representative consumption mix, shall be used (see parag. 5.9.)

There are no waste of products during the use stage of the batteries in the scope of this PEFCR.

6.6 End of life

The End-of-Life stage is a life cycle stage that in general includes the waste of the product in scope, such as the food waste, primary packaging, or the product left at its end of use.

For the batteries, all the processes for collection and recycling are described (see parag 3.4- boundaries for End of Life stage).

Below is provided the list of all processes taking place in this life cycle stage (transport in separate table), and the default values that shall be used in absence of primary data (see also annex 4).

Table 26: End of Life.

Material / Process	PEFCR Geographical reference	PEFCR Dataset name (GaBi ts dataset)	Unit (output)	Default amount per FU				EF compliant dataset used	EF Geographical reference	Proxy (yes/ no)	Comment	UUID	Default DQR (estimated)				
				Power tool	ICT		e-mobility										
				Li-ion (power)	Li-ion (energy)	NiMH	Li-ion (Large/ EV)						P	TiR	GR	TeR	DQR average
Battery cell recycling	EU-27	Electricity grid mix	MJ/kg battery	0.3	0.42	0.41	0.69	Electricity grid mix	EU-28+EFTA	no		{34960d4d-af62-43a0-aa76-adc5fcf57246}	2	1	2	2	2
	EU-27	Thermal energy from natural gas	MJ/kg battery	0.9	1.24	1.23	2.07	Thermal energy from natural gas	EU-28+EFTA	no		{81675341-f1af-44b0-81d3-d108caef5c28}	2	1	2	2	2
	EU-27	Process steam from natural gas 90%	MJ/kg battery	2.82	3.39	3.86	6.48	Process steam from natural gas	EU-28+EFTA	no		{2e8bee44-f13b-4622-9af3-74954af8acea}	2	1	2	2	2
	EU-27	Tap water	kg/kg battery	3.31	4.58	4.53	7.63	Tap water	EU-28+EFTA	no		{212b8494-a769-4c2e-8d82-9a6ef61baad7}	2	1	2	2	2
	DE	Lime (CaO; quicklime lumpy)	kg/kg battery	0.02	0.03	0.03	0.04	Lime production	RER	yes		{64e2bd59-5f61-4eb3-bfd7-d19c3aec60b5}	2	1	2	2	2
	EU-27	Hard coal mix	kg/kg battery	0.01	0.02	0.02	0.03	Hard coal mix	EU-27	no		{932ce7a6-5bc6-41be-ad62-8daad6c5355c}	2	1	2	2	2

	EU-27	Sodium hydroxide (caustic soda) mix	kg/kg battery	0.08	0.12	0.12	0.19	Sodium hydroxide production	RER	no		{2ba49ead-4683-4671-bded-d52b80215e9e}	2	1	2	2	2
	EU-27	Sulphuric acid (96%)	kg/kg battery	0.28	0.4	0.39	0.66	Sulphuric acid production (100%)	RER	no		{eb6abe54-7e5d-4ee4-b3f1-08c1e220ef94}	2	1	2	2	2
	EU-27	Landfill for inert matter (Steel)	kg/kg battery	0.03	0.05	0.05	0.09	Landfill of inert (steel)	EU-28+EFTA	no		{33d6d221-f91d-4a33-9b00-9fb1ea8cd3ca}	2	1	2	2	2
	EU-27	Municipal waste water treatment (sludge incineration)	kg/kg battery	3.6	4.98	4.93	8.27	Treatment of residential wastewater, large plant	EU-28+EFTA	no		{f5ec4a19-70da-406d-be31-a7eeef2f8372}	2	1	2	2	2
Battery cell recycling credits (depending on cell composition)	EU-27	Process steam from natural gas 90%	kg/kg battery	0.64	0.88	0.87	1.46	Process steam from natural gas	EU-28+EFTA	no		{2e8bee44-f13b-4622-9af3-74954af8acea}	2	1	2	2	2
	CN	Rare earth elements - extraction (Sichuan)	kg/kg battery	0	0	0.01	0	Rare earth concentrate	CN	no		{4d5a1b20-880a-4e48-8206-972f35bf27c1}	2	1	1	2	2
	DE	Manganese sulphate (estimation)	kg/kg battery	0.03	0.04	0	0.2	Manganese	GLO	no		{38085a7e-98a3-4b5d-9381-8cefce00cc27}	2	1	2	2	2
	DE	Nickel Sulfate from electrolytnickel	kg/kg battery	0.03	0.03	0.15	0.04	Nickel sulphate production	RER	no		{3b369ae8-1f45-47ed-8dcf-af5f71593067}	2	1	2	2	2
	GLO	Cobalt sulfate	kg/kg battery	0.03	0.12	0.02	0.05	Cobalt	GLO	yes	worst case proxy (overestimate)	{c76002c7-dfef-4d17-a100-fecd7910cfad}	2	1	2	2	2
	GLO	Copper mix (99,999% from electrolysis)	kg/kg battery	0.04	0.01	0	0.03	Copper cathode	EU-28+EFTA	no		{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	2	2	2
	EU-27	Steel sheet part	kg/kg battery	0	0	0.06	0	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		{366a0afd-88e4-45dc-999a-8acc20fd0ead}	2	1	2	2	2
	GLO	Value of scrap	kg/kg battery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.							
Passive parts recycling	DE	EAF Steel billet / Slab / Bloom	kg/kg battery	0.05	0.01	0.05	0.47	Recycling of steel into steel scrap: Steel billet (St)	EU-28+EFTA	no		{dadc8eb8-3ebe-4114-afc4-90d45a0b74b4}	2	1	2	2	2
	EU-27	Landfill for inert matter (Steel)	kg/kg battery	n.a.	n.a.	n.a.	n.a.	Landfill of inert (steel)	EU-28+EFTA	no		{33d6d221-f91d-4a33-9b00-9fb1ea8cd3ca}	2	1	2	2	2
	EU-27	Aluminium recycling (2010)	kg/kg battery	3.37E-04	4.77E-04	0	0.07	Recycling of aluminium into aluminium scrap - from post-consumer	EU-28+EFTA	no		{c4f3bfde-c15f-4f7f-8d35-bed6241704db}	2	1	2	2	2
	EU-27	Landfill for inert matter	kg/kg battery	n.a.	n.a.	n.a.	n.a.	Landfill of inert material (other materials)	EU-28+EFTA	no		{448ab0f1-4dd6-4d85-b654-35736bb772f4}	2	1	2	2	2
	DE	EAF Steel billet / Slab / Bloom	kg/kg battery	0	0	0.002	0	Recycling of steel into steel scrap: Steel billet (St)	EU-28+EFTA	no		{dadc8eb8-3ebe-4114-afc4-90d45a0b74b4}	2	1	2	2	2
	EU-27	Recycling of copper from electronic scrap	kg/kg battery	3.37E-04	4.77E-04	0	0.01	Recycling of copper from electronic and electric waste	EU-28+EFTA	no		{1827dd93-8b53-4b5c-8430-01d10d51e86c}	2	1	2	2	2
	DE	Plastic granulate secondary	kg/kg battery	0.10	0.05	0.01	0.10	Plastic granulate secondary (low metal contamination)	EU-28	//	not available in PEF DB / data gap cover with GaBi data						
Passive parts credits	EU-27	Aluminium ingot mix	kg/kg battery	3.04E-04	4.30E-04	0	0.06	Aluminium ingot mix (high purity)	EU-28+EFTA	no		{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
	DE	Stainless Steel slab (X6CrNi17)	kg/kg battery	0	0	0.71	0	Recycling of steel into steel scrap: Steel billet (St)	EU-28+EFTA	yes		{dadc8eb8-3ebe-4114-afc4-90d45a0b74b4}	2	1	2	2	2
	GLO	Value of scrap	kg/kg battery	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.							
	GLO	Copper mix (99,999% from electrolysis)	kg/kg battery	3.06E-04	4.33E-04	0	0.009	Copper cathode	EU-28+EFTA	no		{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	2	2	2
	DE	Polyethylene Low Density Granulate (LDPE/PE-LD)	kg/kg battery	0.06	0.03	0.01	0.06	LDPE granulates	EU-28+EFTA	no		{d327f4a5-93a1-4ead-856c-aeb8b2f25080}	2	1	2	2	2
	EU-27	Steel sheet part	kg/kg battery	0.04	0.005	0.05	0.05	Steel cast part alloyed	EU-28+EFTA	no		{366a0afd-88e4-45dc-999a-8acc20fd0ead}	2	1	2	2	2
Recycling of OEM parts	EU-27	Aluminium recycling (2010)	kg/kg battery	0.00115	0.000375	0	0.04	Recycling of aluminium into aluminium scrap - from post-consumer	EU-28+EFTA	no		{c4f3bfde-c15f-4f7f-8d35-bed6241704db}	2	1	2	2	2
	EU-27	Recycling of copper from electronic scrap	kg/kg battery	0.0191	0.0187	0.0211	0	Recycling of copper from electronic and electric waste	EU-28+EFTA	no		{1827dd93-8b53-4b5c-8430-01d10d51e86c}	2	1	2	2	2
	DE	EAF Steel billet / Slab / Bloom	kg/kg battery	0.0109	0.0106	0.012	0.0988	Recycling of steel into steel scrap: Steel billet (St)	EU-28+EFTA	no		{dadc8eb8-3ebe-4114-afc4-90d45a0b74b4}	2	1	2	2	2
	DE	Plastic granulate secondary	kg/kg battery	0.15	0.15	0.17	0.053	Plastic granulate secondary (low metal contamination)	EU-28	//	not available in PEF DB / data gap cover with GaBi data						
Recycling of OEM electronic parts	EU-27	Recycling of copper from electronic scrap	kg/kg battery	1.27E-09	1.24E-09	6.98E-10	1.05E-09	Recycling of copper from electronic and electric waste	EU-28+EFTA	no		{1827dd93-8b53-4b5c-8430-01d10d51e86c}	2	1	2	2	2
	EU-27	Recycling of gold from electronic scrap	kg/kg battery	2.99E-16	2.93E-16	1.65E-16	2.47E-16	Recycling of gold from electronic and electric scrap	EU-28+EFTA	no		{27f18feb-4aa7-4c49-a495-6849945890bf}	2	1	2	2	2
	EU-27	Recycling of palladium from electronic scrap	kg/kg battery	1.35E-16	1.32E-16	7.44E-17	1.12E-16	Recycling of palladium, from electronic and electric scrap	EU-28+EFTA	no		{012626e4-62d9-4ac9-b1dd-9d9a42a611c5}	2	1	2	2	2
	EU-27	Recycling of silver from electronic scrap	kg/kg battery	1.81E-13	1.78E-13	1.00E-12	1.50E-13	Recycling of silver, from electronic and electric scrap	EU-28+EFTA	no		{502a8a4f-c7bc-4d3c-87ce-44c3aad3e332}	2	1	2	2	2
dataOEM parts credits	EU-27	Aluminium ingot mix	kg/kg battery	0.00103	0.000338	0	0.03	Aluminium ingot mix (high purity)	EU-28+EFTA	no		{e3f12a3b-6cb9-49ab-b437-f6f7df83ec62}	2	1	2	2	2
	GLO	Copper mix (99,999% from electrolysis)	kg/kg battery	0.0174	0.017	0.0191	0	Copper cathode	EU-28+EFTA	no		{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	2	2	2
	EU-27	Steel sheet part	kg/kg battery	0.01	0.01	0.75	0.09	Steel cold rolled coil / Steel cast part alloyed	EU-28+EFTA	no		{366a0afd-88e4-45dc-999a-8acc20fd0ead}	2	1	2	2	2
	DE	Polyethylene Low Density Granulate (LDPE/PE-LD)	kg/kg battery	0.10	0.09	0.11	0.03	LDPE granulates	EU-28+EFTA	no		{d327f4a5-93a1-4ead-856c-aeb8b2f25080}	2	1	2	2	2
OEM electronic parts credits	GLO	Copper mix (99,999% from electrolysis)	kg/kg battery	1.15E-09	1.13E-09	6.34E-10	9.52E-10	Copper cathode	EU-28+EFTA	no		{0b292f4d-c283-4df9-9bee-f194096ba0e1}	2	1	2	2	2
	GLO	Gold mix	kg/kg battery	2.93E-16	2.87E-16	1.61E-16	2.42E-16	Gold (primary route)	GLO	no		{e8e47de2-87ef-41cf-b202-51d15a9e77cc}	2	1	2	2	2

	GLO	Palladium mix	kg/kg battery	1.32E-16	1.30E-16	7.29E-17	1.09E-16	Palladium	GLO	no		{93eeb7db-08d5-4695-bfb4-a3d4280381d8}	2	1	2	2	2
	GLO	Silver mix	kg/kg battery	1.77E-13	1.17E-12	9.77E-14	1.47E-13	Silver	GLO	no		{a28acad1-3e38-45fd-b071-eca95457b624}	2	1	2	2	2
	EU-27	Waste incineration of glass/inert material	kg/kg battery	0.00638	0.00625	0.00352	0.00528	Waste incineration of inert material	EU-28+EFTA	no		{55cd3dde-21f9-47f8-8f15-bc319c732107}	2	1	2	2	2
	EU-27	Landfill for inert matter	kg/kg battery	0.00638	0.00625	0.00352	0.00528	Landfill of inert material (other materials)	EU-28+EFTA	no		{448ab0f1-4dd6-4d85-b654-35736bb772f4}	2	1	2	2	2
Treatment of unsorted battery fraction	EU-27	Waste incineration of glass/inert material	kg/kg battery	0.148	0.149	0.148	0	Waste incineration of inert material	EU-28+EFTA	no		{55cd3dde-21f9-47f8-8f15-bc319c732107}	2	1	2	2	2
	EU-27	Landfill for inert matter	kg/kg battery	0.756	0.762	0.754	0.0634	Landfill of inert material (other materials)	EU-28+EFTA	no		{448ab0f1-4dd6-4d85-b654-35736bb772f4}	2	1	2	2	2
Unsorted fraction credits	EU-27	Electricity grid mix	kg/kg battery	n.a.	n.a.	n.a.	n.a.	Electricity grid mix	EU-28+EFTA	no							
	EU-27	Thermal energy from natural gas	kg/kg battery	n.a.	n.a.	n.a.	n.a.	Thermal energy from natural gas	EU-28+EFTA	no							

The applicant shall report the DQR for all the datasets used for the most relevant processes, the new ones created.

The electricity mix shall be adapted to the country (countries) specific conditions of the end-of-life stage

The end of life shall be modelled using the formula and guidance provided in chapter 'End of life modelling' of this PEFCR together with the default parameters listed in the Table 27.

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

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

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

Following the evaluation for recyclability, the appropriate R_2 values (supply-chain specific or default) shall be used. If one criterion is not fulfilled or the sector-specific recyclability guidelines indicate a limited recyclability an R_2 value of 0% shall be applied.

Company-specific R_2 values (measured at the output of the recycling plant) shall be used when available. If no company-specific values are available and the criteria for evaluation of recyclability are fulfilled (see below), application-specific R_2 values shall be used as listed in the table below,

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

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

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

The following End-of-Life scenario shall be used, except when the PEFCR user can document that specific values for collection and recycling are applied to the battery under study. The reference values are applicable for Europe.

Table 27: EoL Scenario in EU to be applied in the PEF declaration

Waste treatment	CPT+ICT	e-mobility
Collection for recycling	45%	95%
Unidentified stream	30%	5%
Landfill	16%	-
Incineration	9%	-

Applying the CFF formula for batteries in the scope of this PEFCR, the following values of the parameters shall be used:

Parameter A=0.2 for metals and 0.5 for plastics.

Parameter B=0.

Parameter R1=0, as no battery specific data is available for the recycling content.

The parameter R2 is corresponding to the Table 27 (Collection for recycling)and refer to the whole product. The conversion to the recycling output rate (R2) for the different materials is included in the EF -compliant dataset. A value for the different materials applies (see Annex 4).

The quality ratio Qsout/Qp associated to the recycled content is equal to 1, as mainly metals are recycled. Applying a conservative approach, the landfill scenario is applied by default to the part of batteries considered as "unidentified".

Packaging is not considered in the batteries PEF.

In case no primary data for the activity data of the recycling process of the battery system is available, the activity data provided by default in table 25 shall be used.

7 PEF results

7.1 Benchmark values

It is not possible to anticipate all potential uses of the benchmark due to the large number of products and applications. Uses can range from benchmarking two similar products competing for direct substitution in the same Original Equipment Manufacturer (OEM) product to comparing different battery technologies in different OEM products.

For reference, the environmental impacts calculated for the representative products are listed in the table below:

Table 28: Characterised benchmark values for the 4 representative products

(Absolute numbers (w/o normalization & weighting) per functional unit 1kWh)

Impact category		CPT - Li-ion (Use stage)		ICT - Li-ion (Use stage)		ICT - NiMH (Use stage)		e-mobility Li-ion (Use stage)	
	Unit	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage
Acidification terrestrial and freshwater	mol $H+_{eq}$	4.2E-03	2.8E-04	3.0E-03	2.6E-04	1.8E-02	6.7E-04	5.7E-04	3.6E-04
Climate Change	kg $CO_{2\,eq}$	9.5E-01	9.1E-02	5.7E-01	8.7E-02	8.0E-01	2.2E-01	4.2E-01	1.2E-01
Eutrophication freshwater	kg P_{eq}	3.1E-05	1.9E-07	2.7E-05	1.8E-07	2.2E-05	4.7E-07	1.7E-05	2.5E-07
Eutrophication marine	kg N_{eq}	8.1E-04	5.4E-05	5.1E-04	5.1E-05	6.1E-04	1.3E-04	3.4E-04	7.0E-05
Eutrophication terrestrial	mol N_{eq}	8.1E-03	5.5E-04	5.0E-03	5.2E-04	6.0E-03	1.3E-03	3.4E-03	7.1E-04
Ionising radiation - human health	kBq U^{235}_{eq}	1.0E-01	3.8E-02	5.7E-02	3.7E-02	6.4E-02	9.4E-02	8.1E-02	5.0E-02
Land Use	Dimensionless (pt)	2.7E+00	6.7E-01	1.7E+00	6.4E-01	2.3E+00	1.6E+00	1.7E+00	8.6E-01
Ozone depletion	kg CFC-11_{eq}	3.5E-09	3.4E-11	8.3E-09	3.3E-11	9.0E-09	8.5E-11	2.4E-09	4.5E-11
Photochemical ozone formation - human health.	kg $NMVOC_{eq}$	2.3E-03	1.5E-04	1.4E-03	1.4E-04	2.6E-03	3.6E-04	8.8E-04	1.9E-04
Resource use, energy carriers	MJ	1.3E+01	1.6E+00	8.3E+00	1.5E+00	1.0E+01	3.9E+00	7.0E+00	2.0E+00
Resource use, mineral and metals	kg Sb_{eq}	3.2E-05	3.0E-08	1.8E-05	2.8E-08	2.9E-05	7.3E-08	6.8E-06	3.9E-08
Respiratory inorganics	kg PM2.5 eq.	5.5E-08	2.8E-09	4.2E-08	2.7E-09	1.6E-07	6.9E-09	2.2E-08	3.6E-09
Water scarcity	m^3 $world_{eq}$	2.1E-01	1.3E-02	1.6E-01	1.2E-02	2.3E-01	3.1E-02	8.5E-02	1.6E-02

Table 29: normalized benchmark values for the 4 representative products

(numbers with normalization, per functional unit 1kWh)

Impact category	CPT - Li-ion (Use stage)		ICT - Li-ion (Use stage)		ICT - NiMH (Use stage)		e-mobility Li-ion (Use stage)	
	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage
Acidification terrestrial and freshwater	7.6E-05	5.0E-06	5.3E-05	4.7E-06	3.2E-04	1.2E-05	1.0E-05	6.4E-06
Climate Change	1.2E-04	1.2E-05	7.3E-05	1.1E-05	1.0E-04	2.9E-05	5.4E-05	1.5E-05
Eutrophication freshwater	1.2E-05	7.5E-08	1.1E-05	7.1E-08	8.5E-06	1.8E-07	6.7E-06	9.7E-08
Eutrophication marine	2.9E-05	1.9E-06	1.8E-05	1.8E-06	2.2E-05	4.7E-06	1.2E-05	2.5E-06
Eutrophication terrestrial	4.6E-05	3.1E-06	2.8E-05	3.0E-06	3.4E-05	7.6E-06	1.9E-05	4.0E-06
Ionising radiation - human health	2.4E-05	9.1E-06	1.3E-05	8.7E-06	1.5E-05	2.2E-05	1.9E-05	1.2E-05
Land Use	2.0E-06	5.0E-07	1.3E-06	4.8E-07	1.7E-06	1.2E-06	1.3E-06	6.5E-07
Ozone depletion	1.5E-07	1.5E-09	3.5E-07	1.4E-09	3.9E-07	3.6E-09	1.0E-07	1.9E-09
Photochemical ozone formation - human health.	5.6E-05	3.6E-06	3.5E-05	3.5E-06	6.4E-05	8.9E-06	2.2E-05	4.7E-06
Resource use, energy carriers	2.0E-04	2.4E-05	1.3E-04	2.3E-05	1.6E-04	5.9E-05	1.1E-04	3.1E-05
Resource use, mineral and metals	5.5E-04	5.1E-07	3.0E-04	4.9E-07	5.1E-04	1.3E-06	1.2E-04	6.7E-07
Respiratory inorganics	8.6E-05	4.4E-06	6.6E-05	4.2E-06	2.6E-04	1.1E-05	3.4E-05	5.7E-06
Water scarcity	1.9E-05	1.1E-06	1.4E-05	1.1E-06	2.0E-05	2.7E-06	7.4E-06	1.4E-06

Table 30: Weighted and normalized benchmark values for the 4 representative products

(numbers with normalization and weighting, per functional unit 1kWh)

Impact category	CPT - Li-ion (Use stage)		ICT - Li-ion (Use stage)		ICT - NiMH (Use stage)		e-mobility Li-ion (Use stage)	
	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage	Lice cycle excluding use stage	Use stage
Acidification terrestrial and freshwater	5.0E-06	3.3E-07	3.5E-06	3.1E-07	2.1E-05	8.1E-07	6.9E-07	4.3E-07
Climate Change	2.7E-05	2.6E-06	1.6E-05	2.5E-06	2.3E-05	6.4E-06	1.2E-05	3.4E-06
Eutrophication freshwater	3.6E-07	2.2E-09	3.2E-07	2.1E-09	2.5E-07	5.4E-09	2.0E-07	2.9E-09
Eutrophication marine	9.0E-07	5.9E-08	5.6E-07	5.7E-08	6.7E-07	1.5E-07	3.8E-07	7.7E-08
Eutrophication terrestrial	1.8E-06	1.2E-07	1.1E-06	1.2E-07	1.3E-06	3.0E-07	7.6E-07	1.6E-07
Ionising radiation - human health	1.3E-06	4.9E-07	7.2E-07	4.7E-07	8.1E-07	1.2E-06	1.0E-06	6.3E-07
Land Use	1.7E-07	4.2E-08	1.1E-07	4.0E-08	1.5E-07	1.0E-07	1.1E-07	5.5E-08
Ozone depletion	1.0E-08	9.9E-11	2.4E-08	9.4E-11	2.6E-08	2.4E-10	6.8E-09	1.3E-10
Photochemical ozone formation - human health.	2.8E-06	1.8E-07	1.8E-06	1.8E-07	3.3E-06	4.5E-07	1.1E-06	2.4E-07
Resource use, energy carriers	1.8E-05	2.1E-06	1.1E-05	2.0E-06	1.4E-05	5.3E-06	9.6E-06	2.8E-06
Resource use, mineral and metals	4.4E-05	4.2E-08	2.5E-05	4.0E-08	4.1E-05	1.0E-07	9.5E-06	5.4E-08
Respiratory inorganics	8.2E-06	4.2E-07	6.3E-06	4.0E-07	2.5E-05	1.0E-06	3.2E-06	5.4E-07
Water scarcity	1.7E-06	1.0E-07	1.3E-06	9.5E-08	1.8E-06	2.4E-07	6.7E-07	1.3E-07

7.2 PEF profile

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

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

Together with the PEF report, the applicant shall develop an aggregated EF-compliant dataset of its product in scope. This dataset shall be made available on the EF node (http://eplca.jrc.ec.europa.eu/EF-node). The disaggregated version may stay confidential.

7.3 Additional technical information

No additional technical information is required in this PEFCR.

7.4 Additional environmental information

Concerning the impact on biodiversity, as this may also arise from site-based practices rather than material flows, it may be possible to indicate under Additional Environmental Information if a material risk of biodiversity impacts resulting from site-based practices is identified. The supporting studies have not indicated significant possible impacts (i.e. limited land use), therefore this impact is not at the moment of concern.

8 Verification

The verification of an EF study/report carried out in compliance with this PEFCR shall be done according to all the general requirements included in Section 8 of the PEFCR Guidance 6.3 and the requirements listed below.
The verifier(s) shall verify that the EF study is conducted in compliance with this PEFCR.
These requirements will remain valid until an EF verification scheme is adopted at European level or alternative verification approaches applicable to EF studies/report are included in existing or new policies.

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

- the verifier shall check if the correct version of all impact assessment methods was used. For each of the most relevant impact categories, at least 50% of the characterisation factors (for each of the most relevant EF impact categories) shall be verified, while all normalisation and weighting factors of all ICs shall be verified. In particular, the verifier shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with[18];
- all the newly created datasets shall be checked on their EF compliancy (for the meaning of EF compliant datasets refer to Annex H of the Guidance). All their underlying data (elementary flows, activity data and sub processes) shall be validated;
- the aggregated EF-compliant dataset of the product in scope (meaning, the EF study) is available on the EF node (http://eplca.jrc.ec.europa.eu/EF-node).
- for at least 70% of the most relevant processes in situation 2 option 2 of the DNM, 70% of the underlying data shall be validated. The 70% data shall including all energy and transport sub processes for those in situation 2 option 2;
- for at least 60% of the most relevant processes in situation 3 of the DNM, 60% of the underlying data shall be validated;
- for at least 50% of the other processes in situation 1, 2 and 3 of the DNM, 50% of the underlying data shall be validated.

In particular, it shall be verified for the selected processes if the DQR of the process satisfies the minimum DQR as specified in the DNM.

The selection of the processes to be verified for each situation shall be done ordering them from the most contributing to the less contributing one and selecting those contributing up to the identified percentage starting from the most contributing ones. In case of non-integer numbers, the rounding shall be made always considering the next upper integer.

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[18] Available at: http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml

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

The verification of the EF report shall be carried out by randomly checking enough information to provide reasonable assurance that the EF report fulfils all the conditions listed in section 8 of the PEFCR Guidance.

9 References

Supporting information: Supporting information on the PEFCR described in the screening study, open stakeholder consultations and PEFCR review report are provided on the RECHARGE website (http://www.rechargebatteries.org/knowledge-base/environment/)

List of references

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DATA PEFCR	Michele Galatola (EC, DG ENV), Keith James (UK DEFRA), EF Helpdesk, Data requirements in Product Environmental Footprint Category Rules (PEFCRs), Version 1.0 – 12 May 2015
ISO 14040, 2006	ISO 14040 Environmental management – Life cycle assessment – Principles and Framework, 2006
ISO 14044, 2006	ISO 14044 Environmental management – Life cycle assessment – Requirements and guidelines, 2006
VAN OERS, 2002	van Oers et al, Abiotic resource depletion in LCA: Improving characterisation factors abiotic resource depletion as recommended in the new Dutch LCA handbook, 2002
CPA, 2008	Regulation (EC) No 451/2008 of the European Parlament and of the Council of 23 April 2008 establishing a new statistical classification of products by activity (CPA) and repealing Council Regulation (EEC) No 3696/93
NACE	Statistical classification of economic activities in the European Community (NACE), European Commission
SCREENING 2015	Recharge: Screening study for high-specific rechargeable batteries, 2015
PEF pilot Guidance	Product Environmental Footprint Pilot Guidance, Guidance for the implementation of the EU Product Environmental Footprint (PEF) during the Environmental Footprint (EF) pilot phase, version 6.0. (2016)
PEF Guide 2013/179/EU	EUROPEAN COMMISSION: COMMISSION RECOMMENDATION of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations (Text with EEA relevance) (2013/179/EU)
IEC 61960	International Electrochemical Commission standards (http://webstore.iec.ch/Webstore/webstore.nsf/ArtNum_PK/45223!opendocument

	&preview=1)
IEC 61951-2	International Electrochemical Commission standards (http://webstore.iec.ch/Webstore/webstore.nsf/ArtNum_PK/45161!opendocument&preview=1)
Recycling battery processes ref 11	Dewulf J, et al. Recycling rechargeable lithium ion batteries: Critical analysis of natural resource savings. Resour Conserv Recy (2009), doi:10.1016/j.resconrec.2009.08.004
Recycling battery processes ref 12	Journal of Power Sources 177 (2008) 512–527, A review of processes and technologies for the recycling of lithium-ion secondary batteries, J. Xua et al.
Bill of Material for CPT battery and charger ref 1	LCA of a corded and cordless power tool against the background of activities relating to EuP –author: EPTA/thinkstepthinkstep international. (2009) http://www.epta.eu/energy-a-resource-efficency/life-cycle-analysis:
JAMES, GALATOLA 2015	James, Keith; Galatola, Michele (2015), Screening and hotspot analysis: procedure to identify the hotspots and the most relevant contributions (in terms of impact categories, life cycle stages, processes and flows), Version 4.0, 24 April 2015
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LCA Studies	Öko-Institut: Life Cycle Assessment (LCA) of Nickel Metal Hydride Batteries for HEV Application, 2010 EPTA (PE): LCA of a corded and cordless power tool against the background of activities relating to EuP directive, 2009 BIO Intelligence Service: Comparative Life-Cycle Assessment of nickel-cadmium (NiCd) batteries used in Cordless Power Tools (CPTs) vs. their alternatives nickel-metal hydride (NiMH) and lithium-ion (Li-ion) batteries, 2011 Ford – Umicore: LCA as a Tool to Drive Sustainability: A Working Example, 2009 Renault: FLUENCE and FLUENCE Z.E. Life Cycle Assessment, 2011 Umicore: Recycling rechargeable lithium ion batteries: Critical analysis of natural resource savings, 2009 EMPA: Contribution of Li-ion batteries to the environmental impact of electric vehicles, 2009 EMPA: Supporting Information to the manuscript entitled Contribution of Li-ion batteries to the environmental impact of electric vehicles, 2009 University of Trondheim: Life Cycle Environmental Assessment of Lithium-Ion and Nickel Metal Hydride Batteries for Plug-In Hybrid and Battery Electric Vehicles, 2011 Argonne National Laboratory: A review of Life Cycle Analysis: State of Knowledge and Critical Needs, 2010 Yale University: Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack, 2013 EPA: Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles, 2013

ADEME: ACV comparative VE-VT - Final report (study of two 2 vehicles LUV and PC), 2012
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HTC: Environmental Product Declaration, http://gryphon.environdec.com/data/files/6/8228/epd291_1.1.pdf; 2013
EMPA, TUBS, RWTH: Guideline for the LCA of electric vehicles, http://www.elcar-project.eu/fileadmin/dokumente/Guideline_versions/eLCAr_guidelines.pdf, 2013
Recommendation 2013/179/EU on The use of common methods to measure and communicate the life cycle environmental performance of products and organizations
Product Environmental Footprint Pilot Guidance, Guidance for the implementation of the EU Product Environmental Footprint (PEF) during the Environmental Footprint (EF) pilot phase, version 4.0

ANNEX 1 – List of EF normalisation and weighting factors

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

Impact category	Unit	Normalisation factor	Normalisation factor per person	Impact assessment robustness	Inventory coverage completeness	Inventory robustness	Comment
Climate change	kg $CO_{2\ eq}$	5.35E+13	7.76E+03	I	II	I	
Ozone depletion	kg CFC-11 $_{eq}$	1.61E+08	2.34E-02	I	III	II	
Human toxicity, cancer	CTUh	2.66E+05	3.85E-05	II/III	III	III	
Human toxicity, non-cancer	CTUh	3.27E+06	4.75E-04	II/III	III	III	
Particulate matter	disease incidence	4.39E+06	6.37E-04	I	I/II	I /II	NF calculation takes into account the emission height both in the emission inventory and in the impact assessment.
Ionising radiation, human health	kBq $U^{235}{}_{eq}$	2.91E+13	4.22E+03	II	II	III	
Photochemical ozone formation, human health	kg NMVOC $_{eq}$	2.80E+11	4.06E+01	II	III	I/II	
Acidification	mol H+ $_{eq}$	3.83E+11	5.55E+01	II	II	I/II	
Eutrophication, terrestrial	mol N $_{eq}$	1.22E+12	1.77E+02	II	II	I/II	
Eutrophication, freshwater	kg P $_{eq}$	1.76E+10	2.55E+00	II	II	III	
Eutrophication, marine	kg N $_{eq}$	1.95E+11	2.83E+01	II	II	II/III	
Land use	pt	9.20E+15	1.33E+06	III	II	I I	The NF is built by means of regionalised CFs.

Ecotoxicity, freshwater	CTUe	8.15E+13	1.18E+04	II/III	III	III	
Water use	m^3 world eq	7.91E+13	1.15E+04	III	I	II	The NF is built by means of regionalised CFs.
Resource use, fossils	MJ	4.50E+14	6.53E+04	III	I	II	
Resource use, minerals and metals	kg Sb eq	3.99E+08	5.79E-02	III			

Weighting factors for Environmental Footprint

	Aggregated weighting set	Robustness factors	Calculation	**Final weighting factors**
	(50:50)	(scale 1-0.1)		
WITHOUT TOX CATEGORIES	A	B	C=A*B	C scaled to 100
Climate change	15.75	0.87	13.65	**22.19**
Ozone depletion	6.92	0.6	4.15	**6.75**
Particulate matter	6.77	0.87	5.87	**9.54**
Ionizing radiation, human health	7.07	0.47	3.3	**5.37**
Photochemical ozone formation, human health	5.88	0.53	3.14	**5.1**
Acidification	6.13	0.67	4.08	**6.64**
Eutrophication, terrestrial	3.61	0.67	2.4	**3.91**
Eutrophication, freshwater	3.88	0.47	1.81	**2.95**
Eutrophication, marine	3.59	0.53	1.92	**3.12**
Land use	11.1	0.47	5.18	**8.42**
Water use	11.89	0.47	5.55	**9.03**
Resource use, minerals and metals	8.28	0.6	4.97	**8.08**
Resource use, fossils	9.14	0.6	5.48	**8.92**

ANNEX 2 - check-list for the PEF study

Each PEF study shall include this annex, completed with all the requested information.

ITEM	**Included in the study (Y/N)**	**Section**	**Page**
[This column shall list all the items that shall be included in PEF studies. One item per row shall be listed.]	[The PEF study shall indicate if the item is included or not in the study]	[The PEF study shall indicate in which section of the study the item is included]	[The PEF study shall indicate in which page of the study the item is included]
Summary			
General information about the product			
General information about the company			
Diagram with system boundary and indication of the situation according to DNM			
List and description of processes included in the system boundaries			
List of co-products, by-products and waste			
List of activity data used			
List of secondary datasets used			
Data gaps			
Assumptions			
Scope of the study			
(sub)category to which the product belongs, including a technical description of the battery and its application.			
DQR calculation of each dataset used for the most relevant processes and the new ones created.			
DQR (of each criteria and total) of the study			

ANNEX 3 - Critical review report of the PEFCR

Product Environmental Footprint pilots: Batteries **PEFCR External Panel Review**							
Note: only the comments about the issues identified in the PEFCR version 6.3 (Jan 2018) have been reported							
Reviewer	**0**	**1**	**2**	**3**	**4**	**5**	**6**
	Comment number	**reference to chapter/annex number**	**Paragraph/figure/table**	**page number**	**comment**	**proposed change**	**action/answer to comment**
Ugo Pretato Etienne Lees-Perasso	**8**	3.7	general	16	Not accepted: page 23 refers to the guidance version 6.2 instead of 6.3 (in 3 places)	Refer to the new guidance v6 and implement any new requirements compared to the previous version, giving priority to those requirements potentially affecting the remodeling exercise. Same for annexes 10, 12.6 and 12.7	3 references modified
Mikko Samuli VAIJA - Orange Labs Products & Services	**17**		Table 4-3 and Table 8-1	21 and 64	Can't found table 12-2 or 12-3 in the document. There are two table 12 : "Allocation rules for electricity" (page 60) and "Raw material acquisition and processing " (page 66). If I update the "List of Tables" (page 6) it seems there are a lot of dead links (only Table 1, 2 and 15 are correctly displayed) In Table 2 (page 29) it's written "Pyrometallurgical process for the cell Hydrometallurgical treatment for the cell "		tables and list of table corrected and updated. Text in Table 2 clarified

Mikko Samuli VAIJA - Orange Labs Products & Services	**20**		Figure 4-3	26	Table 12 "Raw material acquisition and processing" shows indeed that the polymer mix is 50 % PVFD / 50 % SBR. But Figure 5 "Cradle to gate processes for Li-ion battery production" (page 26) is still about "Polymer" without any explanation on the compound.		Lihtium polymer is a generic name for Lithium batteries with a a soft casing (also named "pouch cells"). It does not refer to the type of polymer used. The specific materials for this soft casing is included in the representative products BoM.
Mikko Samuli VAIJA - Orange Labs Products & Services	**27**		4.5 and Table 4-5	30	The reference for the EPTA (PE) charger LCA (http://www.epta.eu/energy-a-resource-efficency/life-cycle-analysis:) is incorrect (JERROR_LAYOUT_THE_PAGE_YOU_WHERE_LOOKING_FOR). If I remove the ":" and go to : "http://www.epta.eu/energy-a-resource-efficency/life-cycle-analysis" I get an elusive web page about EPTA and LCA. With the "read more" option it's possible to download a PDF file. The only information provided by this document is that an LCA was carried out in 2008 (10 years ago...). We don't know anything about the charger's design (only that it includes a 2-layers PCB). In Chapter 4 (page 45) the charger is a key unit process for the CPT and the two Li-ion batteries for Climate Change, Resources Use energy carriers and Resources Use minerals and metals. It's quite troublesome to have an item with such high contribution and no to know anything about it's design. For example, for Resources Use minerals and metals a 2008 charger might be quite bulky, with a design that relies mostly on through-hole mounted electronic components or integrated circuits with thick wire bonding. Check if the the reference is correct and if it is possible to obtain the BoM of the charger. Otherwise consider to disclose the BoM in an annex.		Added the BoM of the charger in the annex, and explanatory comment in the parag 5.3. See also comment below about the components of the charger.

Mikko Samuli VAIJA - Orange Labs Products & Services	**44**		5.3.1	36	Consider using the terms of the PEFCR guidance for cut-of "In case processes are excluded from the model this shall be done based on a 1% cut-off for all impact categories based on environmental significance […]" if it's what is meant by "negligeable"		accepted and included
Mikko Samuli VAIJA - Orange Labs Products & Services	**61**		5.8	44	accepted if the applicable annex is Annex 4		reference to annex 4 in he relevant paragraphs.
Ugo Pretato	**78**	Annex VIII	general	64-65	There are some inconsistencies in the elementary flow collection table (§5.1, pp 48-49) - all flows under "energy & water" or "auxiliary" ar not elementary, therefore should be moved to another table or section - particles emissions shall be distinguished according to the particle size (e.g. 2.5, 10, etc.) as the characterization factors may be different		The tables for elementary flows have been modified. Concerning the particles emissions, the flows for Dust PM 2.5 and Dust PM 10 have been separated.

Mikko Samuli VAIJA - Orange Labs Products & Services	**83**		Table 12-6	70	There are several designs for TO-263 components. For example I retrieved two complete material declaration for this type of component: - Semtech's EZ1581CMTRT which weights 1435 mg and contains 1,2 mg of gold and 0,85 mg of silver - Infineon's IPB065N15N3 G which weights 1532 mg but is based on non-noble metal technology (i.e. does not contain gold, silver, palladium, platinum, etc.). Its wiring is made of aluminium and the leadframe is a copper/aluminium alloy rather than a copper/tin/silver alloy as in Semtech's product The gold and silver contained in the Semtech component are equivalent to an Abiotic Resources Depletion score of 6,34E-05 kg eq. Sb. That's more than for the Li-ion battery's entire life cycle (to be mitigated with the fact the only a fraction of the battery's SMU might be allocated for this FU) . But if one SMU is allocated to the FU then with one wrong pick on a component it's possible to change completely the outcome of the study (i.e. is the charger a key component for Abiotic Resources Depletion for ex.).		The comment is valid. The Technical secretariat has referred to publicly available information, based on realistic product for the Power tools application, using component with chemical and subsequently electrolytic gold-on-nickel finishing. There has been no specific studies to demonstrate that the components are representative for the chargers of other applications. Additive limitation will be indicated in the paragraph 5.3 for the charger. In any case the change of the reference components is only possible when the primary datafor the actual charger are available, thus eliminating the risk of wrong picking the components.
Mikko Samuli VAIJA - Orange Labs Products & Services	**96**	3.3 Functional unit and reference flow	Table 1 (or Table 3)	30	The text indicates "Table 1defines the key aspects used to define the FU." but the table about FU is Table 3. Check the tables numbering in the text as well as in the titles.		references corrected
Mikko Samuli VAIJA - Orange Labs Products & Services	**97**	3.4 System boundary	Figure 2 (or Figure 4)	33 and 34	The text indicates "Figure 2 shows a general overview of the boundaries among the whole Life Cycle of a battery system" but that's what Figure 4 is about. Check the figures numbering in the text as well as in the titles.		references corrected

Mikko Samuli VAIJA - Orange Labs Products & Services	**98**	6 Life cycle stages	Table 12 ; Table 13 ; Table 14 ; Table 16 and Table 17	66, 67, 68, 70 and 71	All these tables were pasted as pictures in the Word file, therefore it's impossible to copy/select the text. That's especially bothersome for UUIDs. No one wants to try to decipher these 32 characters long identifiers in order to find the model that was used. For the sake of readability consider pasting these tables as they are in Excel or create new tables directly in Word (i.e. like Annex 4).		The tables have been modified to increase readability. In addition, the tables in parag 6 are now in Excell format, allowing for a copy/paste of the content.
Etienne Lees-Perasso - Bureau Veritas CODDE	**99**	III. List of acronyms		8	The title must be "Acronyms"		corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**100**	I. Terms and definitions		10	The title must be "Definitions"		corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**101**	3.2	Table 2, last line	29	Correct the typo in the last line	The infrastructures have been assessed based on	corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**102**	3.4		33	"According to this PEFCR, the following processes may be excluded based on the cut-off rule: - Detailed transport operations description for raw materials, product distribution or end of life: as the impact has been calculated as negligible, only the default data provided shall be used. " There is an inconsistency between the first "may", then the "shall": do we must use the default data, even if we have actual primary data?	Clarify	clarification that the default data shall be used unless primary data of required quality according parag 5.4 is available.
Etienne Lees-Perasso - Bureau Veritas CODDE	**103**	3.4.1, 3.4.2, 3.4.3		35-38	The chapters titles are not in line with table 6. That could lead to confusion (especially for the production stage, including bothe the raw material acquisition and the main product production)	Clarify	Title parag 3.4.1 clarified

Etienne Lees-Perasso - Bureau Veritas CODDE	**104**	3.4.1	Last paragraph p 35	35	The reference to figure 3 is obsolete	Update the reference to figure 5	corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**105**	3.4.1	Last paragraph p 36	35	The reference to figure 4 is obsolete	Update the reference to figure 6	corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**106**	3.4.3	Last paragraph p 38	35	The reference to figure 5 is obsolete	Update the reference to figure 7	corrected
Etienne Lees-Perasso - Bureau Veritas CODDE	**107**	3.5		41	Even though the link is the one stated in the guidance 6.3, it refers to an invalid address. The website or the link should be updated		link updated
Etienne Lees-Perasso - Bureau Veritas CODDE	**108**	3.6	Tables	43	The sum of lines or columns are not equal to 100%, due to the CFF that gives credit. It should be explained to avoid confusion	Clarify	comment added
Etienne Lees-Perasso - Bureau Veritas CODDE	**109**	5.1, 6.1, 6.3, 6.4, 6.5, 6.6	Tables	47, 48, 66, 67, 68, 70, 71	The tables are small. While we can see the content by zooming in, it is not visible when printing the document	Put the table in landscpae layout	The tables have been modified to increase readability. In addition, the tables in parag 6 are now in Excell format, allowing for a copy/paste of the content.
Etienne Lees-Perasso - Bureau Veritas CODDE	**110**	6.4		67	The guidance v.6.3 indicates the following sentences must be added in this part: *The transport from factory to final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as …* [to be filled in]. *In case supply-chain-specific information is available for one or several transport parameters, they may be applied following the Data Needs Matrix.*	Add the sentences	sentences added

ANNEX 4 - Other Annexes

Recycling process details

Default activity data for cell recycling /step 1

Recycling: step 1 pyrometallurgical				
Recycling of the cell and recovery of the metal: shredding, calcination, smelting				
Input				
Active Components				
	Cell	1	kg	
Energy				
	Electricity	0.551	kWh	
Water				
	Tap water (cooling water)	14400	kg	
Auxiliary materials				
	CaO	0.129	kg	
	Steam	6.11	kg	
	Preheated air 400°C	1.042	kg	
Output				
Materials recovered				
	Alloy	0.483	kg	
	Slag	0.252	kg	used for backfilling
	Steam 15 bars	11.76	MJ	heat recovery as utility
Emission to water				
	Cooling water	14400	kg	close loop

Default activity data for cell recycling / step 2

Recycling step 2 hydrometallurgical			
Metallic alloy treatment			
Input			
	Alloy	0.483	kg
	water (tap)	22.22	kg
	H2SO4	1.93	kg
	Thermal	6037	kJ

	NaOH	0.562	kg
Output			
Waste			
Emission to water	Waste water	24.16	kg
Materials recovered	Material mix	1.034	kg

Default metal recuperation proportion according to Screening study virtual products

Materials recovered	Formula	CPT Li-ion	ICT Li-ion	ICT Ni-MH	e-mobility Li-ion
Copper	Cu	0.51	0.12	0.00	0.18
Cobalt sulphate	CoSO4	0.18	0.60	0.09	0.15
Nickel sulphate	NiSO4	0.18	0.14	0.75	0.10
Manganese sulphate	Mn SO4	0.17	0.17	0.00	0.60
Iron	Fe	0.00	0.00	0.11	0.00
Rare earth metals	RE	0.00	0.00	0.08	0.00

Bill of Material for the reference EPTA charger

When no primary data is available, the following Bill of Materials will be used for the charger, based on the weight of the reference charger indicated in Table 21 for each application, and the data description of table 21.

Material/process	PEFCR geographical reference	PEFCR dataset name	Unit= %
Cable	EU-28+EFTA	Cable, three conductors	9%
Plug+ DC/DC	World	steel	70%
Populated printed W board	World	PWB 8-layer	7%
Plastic casing	EU-28+EFTA	PP granulates	14%