European Commission

Draft JRC study on harmonised rules for the calculation and verification of recycled content in batteries

JRC draft recommendations to support the provisions of Article 8 of Regulation (EU) 2023/1542

Background document for stakeholder workshop, 27 November 2024

November, 2024

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Joint Research Centre (JRC)

Joint Research Centre

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1 Introduction

1.1 Rationale and objectives and of the JRC work

1.1.1 Policy context

Article 8 of the Batteries Regulation (EU) 2023/1542 indicates that "*From 18 August 2028 or 24 months after the date of entry into force of the delegated act referred to in the third subparagraph, whichever is the latest, industrial batteries with a capacity greater than 2 kWh, except those with exclusively external storage, electric vehicle batteries and SLI batteries that contain cobalt, lead, lithium or nickel in active materials, shall be accompanied by documentation containing information about the percentage share of cobalt, lithium or nickel that is present in active materials and that has been recovered from battery manufacturing waste or post-consumer waste, and the percentage share of lead that is present in the battery and that has been recovered from waste, for each battery model per year and per manufacturing plant.*" Minimum percentage share of cobalt, lithium or nickel that has been recovered from certain wastes in those batteries have been laid down in Article 8(2) and Article 8(3) for the years 2031[1] and 2036[2], respectively. These targets may possibly be revised in 2029 as per Article 8(5) of the Regulation.

1.1.2 JRC mandate for this study

DG ENV and DG GROW requested the JRC to formulate techno-scientific recommendations that could serve as a technical basis for the delegated act indicated in Article 8(1) of the Batteries Regulation, indicating that:

"*the Commission shall adopt a delegated act in accordance with Article 89 to supplement this Regulation by establishing, for the batteries referred to in the first and second subparagraphs, the methodology for the calculation and verification of the percentage share of cobalt, lithium or nickel that is present in active materials and that has been recovered from battery manufacturing waste or post-consumer waste, and the percentage share of lead that is present in the battery and that has been recovered from waste, and the format for the documentation.*"

The JRC recommendations of the JRC based on best available scientific and technical knowledge may then be considered by DG ENV and DG GROW, amongst other elements, when developing the Commission's proposal for the delegated act. However, none of the recommendations made in this report have any binding character whatsoever.

1.2 Methodology of the study

The JRC embarked on this project by collecting relevant techno-scientific information required to develop the recommendations from literature and stakeholders. Representatives and battery experts from EU trade/business/professional associations, EU Member States and other institutions such as think tanks, research and academic institutions have been consulted during the process. The role of the representatives and experts is to participate in the process of sharing knowledge and providing non-binding expert feedback and advice to the JRC.

In April 2024, an online data inventory meeting was held with different industry players to collect information on e.g. existing guidelines and standards applied for (voluntary) claims on recycled content. At other occasions,

[1] From 18 August 2031, for industrial batteries with a capacity greater than 2 kWh, except those with exclusively external storage, electric vehicle batteries and SLI batteries that contain cobalt, lead, lithium or nickel in active materials, the technical documentation referred to in Annex VIII shall demonstrate that those batteries contain, in active materials, the following minimum percentage share of, respectively, cobalt, lithium or nickel that has been recovered from battery manufacturing waste or post-consumer waste, and the minimum percentage share of lead that is present in the battery and that has been recovered from waste, for each battery model per year and per manufacturing plant: (a) 16 % cobalt; (b) 85 % lead; (c) 6 % lithium; (d) 6 % nickel.

[2] From 18 August 2036, for industrial batteries with a capacity greater than 2 kWh, except those with exclusively external storage, electric vehicle batteries, LMT batteries and SLI batteries that contain cobalt, lead, lithium or nickel in active materials, the technical documentation referred to in Annex VIII shall demonstrate that those batteries contain, in the active materials, the following minimum percentage share of, respectively, cobalt, lithium or nickel that has been recovered from battery manufacturing waste or post-consumer waste, and the minimum percentage share of lead that is present in the battery and that has been recovered from waste, for each battery model per year and per manufacturing plant: (a) 26 % cobalt; (b) 85 % lead; (c) 12 % lithium; (d) 15 % nickel.

bilateral meetings have been held between JRC and industry organisations to expand the knowledge and technical information.

All information collected and inventoried has been summarised and reported in a structured way in the current version of this document. The purpose is to further develop and adapt this document throughout the process so it underpins the JRC recommendations with technical insights and arguments, also based on complementary insights from stakeholders and information obtained during the consultation rounds. This report is to be used as background document in preparation of the workshop to be organised on 27th November 2024.

1.3 Structure of this document

The JRC report aims to depart from a solid technical understanding of the battery supply chain as well as related experience on circularity and recycled content calculations, also in other sectors. After the introduction (section 1) and a recap of the legal framework and scope (Section 2), section 3 of the report provides a general overview of the technical background for this work. It builds on a review of the Li, Co, Ni and Pb supply chains (section 3.1), chain of custody models to support traceability (section 3.2) and existing standards and guidelines for product, materials and battery sustainability claims (section 3.3). This information is then taken forward in section 4 that presents a first draft version of the JRC recommendations for discussion and feedback at the November 2024 stakeholder workshop. Conclusions and an overview of the next steps of the JRC work is given in section 5. The report is annexed by supplementary information on the supply chains and battery manufacturing processes, existing standards and guidelines, and an overview of the insights from previous consultations rounds of the project.

2 Legal framework and scope

2.1 Article 8 of Regulation EU No 2023/1542

In order to ensure that the calculations and verifications of recovery of materials rates are accurate and reliable and ensure that there is greater legal certainty, the power to adopt acts in accordance with Article 290 TFEU has been delegated to the Commission. It is, however, important to stress that - according to the referenced Article 290 - essential elements of an area are reserved for the legislative act and accordingly shall not be the subject of a delegation of power.

Hence, the following provisions have already been set as per Article 8 of the Batteries Regulation (EU) 2023/1542, and will thus not be further subject to discussion in this JRC report:

— Types of batteries: industrial batteries with a capacity greater than 2 kWh, except those with exclusively external storage, electric vehicle batteries and SLI batteries that contain cobalt, lead, lithium or nickel in active materials.

— Battery component in scope: (i) for cobalt, lithium or nickel: the active materials, and (ii) for lead: the battery.

— Waste sources: (i) for recovered cobalt, lithium and nickel: battery manufacturing waste or post-consumer waste, and (ii) for recovered lead: waste only. Battery manufacturing waste is defined in the Regulation as "the materials or objects rejected during the battery manufacturing process, which cannot be re-used as an integral part in the same process and need to be recycled". By-products of battery manufacturing that are re-used in the manufacturing process, such as manufacturing scrap, do not constitute waste and should therefore not be counted as part of the recycled content targets. Waste is defined in the Directive 2008/98/EC (Waste Framework Directive, Article 3) as "any substance or object which the holder discards or intends or is required to discard".

— Collection for documentation: for each battery model per year and per manufacturing plant. This implies that batteries produced by manufacturing plants at different geographic locations, as well as different battery models at the same manufacturing plant have to report and meet the recycled content obligations, during a one year reporting period.

— The new legislative framework package reinforces the application and enforcement of internal market legislation. It sets, amongst others, clear and transparent rules for the accreditation of the notified bodies, boosts the quality of and confidence in the conformity assessment of products through stronger and clearer rules on the requirements for the notification of conformity assessment bodies, and establishes a common legal framework for industrial products in the form of a toolbox of measures for use in future legislation. Hence, 'conformity assessment' is defined in the Batteries Regulation as the process demonstrating whether the sustainability (e.g. carbon footprint), safety, labelling, information and due diligence requirements of this [batteries] Regulation have been fulfilled. The conformity assessment procedures set out in the Batteries Regulation to demonstrate compliance with Article 8 and 17 (D1 and G) and require the drawing up technical documentation and implementation of a quality system (D1, for batteries manufactured in series), and the intervention of conformity assessment bodies. The technical documentation shall contain "a study supporting the recycled content share referred to in Article 8, containing the calculations made in accordance with the methodology set out in the delegated act adopted pursuant to Article 8(1), second subparagraph, and the evidence and information determining the input data for those calculations". Link to wider policy initiatives

Aligned with the circularity goals of the European Green Deal, the Batteries Regulation is the first European law to adopt a comprehensive life-cycle approach. This legislation covers sourcing, manufacturing, usage, re-use/re-purposing and recycling within a single framework. The new regulation aim to ensure batteries have a low carbon footprint on their life cycles, use fewer harmful substances, require fewer raw materials, and are extensively collected, reused, and recycled within the EU.

Batteries and vehicles are also listed as a key product supply chain in the 2020 Commission's Circular Economy Action Plan because urgent, comprehensive and coordinated action was required for the sector to meet climate and industrial EU ambitions.

Batteries being made of high share of Critical and Strategic Raw Materials, the Battery regulation and in particular this piece of work greatly relates to the 2024 Critical Raw Materials Act[3], that contains some ambitious benchmarks in terms of EU recycling capacity (Article 15) and ambition in terms of recycled content of selected raw materials (e.g. Art. 29).

[3] http://data.europa.eu/eli/reg/2024/1252/oj

3 Technical background

3.1 Li, Ni, Co, Pb supply chains

A good technical understanding of the complexity of the battery supply chains and of the manufacturing steps from raw materials to finished battery products is an essential basis for this work. A full review of the sources of primary and secondary raw materials, and the production steps for batteries and their active materials is provided in Annex 1 of this report. This section briefly lists key take-aways from the review of the lithium, nickel, cobalt and lead supply chains that are important considerations for the development of the calculation and verifications rules for recycled content in batteries.

Processing of lithium, nickel, cobalt and lead are partially connected: for instance, and production and recycling of nickel, cobalt and copper occur together; or lead and copper are simultaneously extracted from ores. Similarly, the analysis of their material flows are connected too. Understanding the material supply chains offers a tool to grasp the complexity of a possible traceability system throughout the supply chain as well as to evaluate possible calculation and verification rules for recycled content in batteries.

Primary production, recycling, refining, production of active materials and the assembly of batteries are recurring steps in the supply chains. The supply chains are mostly worldwide distributed, meaning that the different steps of primary production, recycling, refining and product manufacturing commonly occur in different locations with consequent implications on the traceability of those materials. In addition, an economic operator often has different suppliers for the same intermediate product so that the inputs may have to be shipped from different geographic locations. The higher the number and locations of operators for a single step, the more complex the network of connections along which materials might be. Similarly, the level of complexity increases with length and number of steps in the supply chain. The complexity is similar for the four metal supply chains and does not make a particular difference in the mutual comparison. At times, different supply chain steps may be executed together at a single production site, e.g. at "battery gigafactories".

The first processing of lithium is carried out very close to the extraction site to limit as much as possible the process cost, while nickel processing is commonly executed in specific countries (e.g. Russia, Philippines, Australia, Indonesia, China) already at early steps. Processing of nickel and cobalt regularly implies movements of these materials among different countries even within the same process step and this entangles the network of involved operators. Contrary to Li, Co and Ni, secondary production of lead is about 50% of its total and more than 80% of the lead for PbA batteries on the European market comes from recycling.

Other factors affecting the metal supply chains are the volatility of the materials and the variety of their applications. Concerning the volatility, as seen, cobalt content in Li-based batteries (particularly in the NMC chemistries) has a descending trend but such trend also fluctuates with the trend of its price from primary extraction. A common way for operators to face volatility is to diversify the suppliers to minimise any risk of shortages: this consolidated practice has, however, the drawback of increasing the complexity of the supply chain due to the higher number of upstream operators. Additionally, as volatility can vary in one year, an operator can also choose to vary the number and type of suppliers over a short period, even less than a year. As for the applications, they affect the materials demand and determine, at the same time, the possible sources of secondary materials after recycling. It is important to consider not only the variety of applications but also the type and its quality requirements. Hence, both lithium and lead might have less applications in number than nickel and cobalt with consequent restriction of possible sources of secondary raw materials. Most lithium applications are dissipative (pharmaceuticals) or not convenient to recycle (e.g. ceramics) and Li-based battery is, at the moment, the only source for recycling. In addition, Li-based battery is the pulling, and expanding, application for lithium demand. In analogy with lithium, PbA batteries are almost the sole source of secondary lead for the recycled content but, contrarily to lithium, volumes of PbA batteries have been stable for decades and are expected to decrease after 2035. Analysing applications of nickel and cobalt is more difficult, since there are more and more different applications with a demand of material as alloy – e.g. nickel in steels – or as compounds – e.g. cobalt oxides for batteries as well as for catalysts. Defining materials flows for nickel and cobalt is, hence, not trivial and primary and secondary raw materials can be mixed at production (feeding the primary production also with waste to be recycled) as well as at the refining step (treating together compounds from primary and secondary production).

Concerning the manufacturing of active materials (i.e. the oxides deposited at the electrodes), those often run in continuous with raw materials fed in continuous too. This means that if primary and secondary raw materials are mixed in input to the process, there is no control from the operator running the process on when exactly secondary raw materials enter the process, but they have control on the average amount of secondary raw materials in the process. In any case, the input is assumed to be homogenous. Depending on customer needs the manufacturing of active materials can also be carried out in batch, if the objective is to produce a battery designed and customised for specific applications. Next steps of battery manufacturing can also occur in continuous or in batch depending on the type of battery (e.g. portable vs EV batteries) or application (e.g. LMT batteries vs. ad-hoc industrial batteries). Hence, it is not possible to define one type of process either for the same step of the battery manufacturing process.

In conclusion, key take-aways common to the supply chains of lithium, nickel, cobalt and lead are that these supply chains are worldwide distributed and they can be (highly) dynamic, meaning that suppliers might change during the year and also per geographic position. Furthermore, a same step of the manufacturing process might occur even for the same type of battery in continuous as well as in batch according to customer requests. These considerations anticipate that the analysis of traceability and chain of custody models in **3.2** should take into account the flexibility required for such complex and dynamic supply chains.

3.2 Traceability and chain of custody models

As awareness and demand for sustainable practices continue to rise on a global scale, traceability has gained attention in supply chain management. By facilitating communication and data exchange between different actors, traceability systems improve the overall performance of the supply chain because they allow to track materials from the origin to the end product.

In the context of recycled content, traceability is crucial for determining the proportion of recycled materials used in products, enabling companies to meet regulatory requirements and consumers expectations. This can ultimately lead to an increased competitive advantage in the market.

A chain of custody (CoC) is a chain of responsibility for the ownership of materials moving through a supply chain. Chain of custody systems are used to ensure, to a certain extent, that the characteristics claimed for a specific material correspond to the ones delivered in the output.

In view of the new provisions on recycled content laid down in Article 8 of the Battery Regulation, the battery manufacturer or the entity placing the battery on the market will have to disclose the amount of recycled content present in the battery (see section 1.1.1). The implementation of traceability and chain of custody systems will be hence essential to trace recycled materials in the battery supply chain and to demonstrate compliance with the recycled content targets.

In the following sections, key terminologies and concepts of traceability and chain of custody are presented.

3.2.1 Traceability of products across the supply chain

In the ISO standard 22095[4] **traceability** is defined as the "*ability to trace the history, application, location or source(s) of a material or product throughout the supply chain*". A **traceability system** is a "*manual or electronic system that provides the ability to access any or all information relating to the material or product under consideration throughout their life cycle, by means of accessing documented information*".

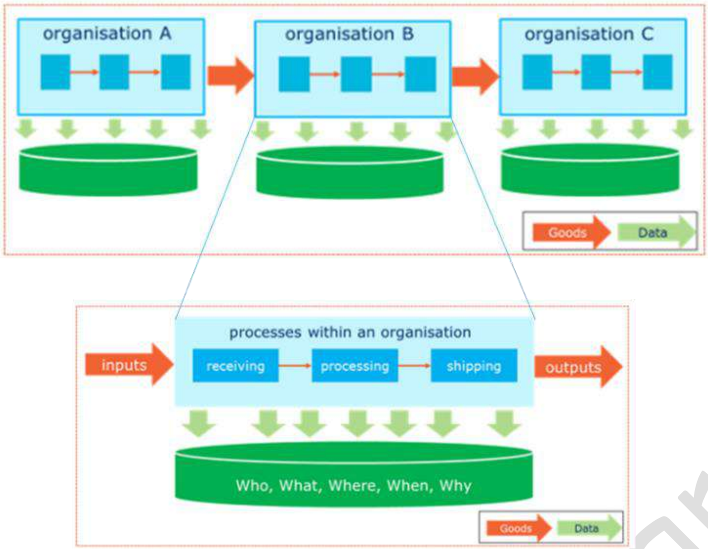
A traceability system is used to record and track materials or products along the supply chain and to record the associated information either in writing or in electronic form (ISEAL, 2016).

The **Global Traceability Standard**[5] provides guidance on the design and implementation of traceability systems. Transparency is a key driver for traceability. Traceability systems require traceability data, generated through business processed carried out by each actor in the supply chain (see **Figure 1**).

[4] ISO 22095 Chain of custody – General methodology and models: https://www.iso.org/obp/ui/en/#iso:std:iso:22095:ed-1:v1:en

[5] Global Traceability Standard: https://www.gs1.org/standards/gs1-global-traceability-standard/current-standard#1-Introduction+1-1-Objective

Figure 1. Generation of traceability data in the supply chain



Source: (GS1, 2017)

In each organisation, the 5 main data points that are collected are (GS1, 2017):

— Who: which parties are involved?

— What: what is the primary object being traced? Which related objects need to be traced?

— Where: where did these movements or events take place?

— When: when did a movement or event that included that object occur?

— Why: what business process was happening at the time the event took place? What business transactions were taking place? Why was the object at that location at that time?

Each organisation shall establish processes to define and collect the relevant data in the different process steps. Each actor in the supply chain should be able to trace back to the direct suppliers and to track forward to the direct recipients (GS1, 2017).

End-to-end traceability is "*the ability to track and trace an object through its entire life cycle and through all parties involved in its production, custody, trade, transformation, use, maintenance, recycling or destruction*" (GS1, 2017).

The main challenge of this approach is that the chain of custody is not defined in advance. For instance, looking downstream, a manufacturer may not be able to track all the different destinations of products; looking upstream, a manufacturer may not know the identity of tier 2 suppliers (suppliers of its suppliers) and beyond. This knowledge is in fact often confidential (GS1, 2017).

Five main models for sharing traceability data across organisations can be distinguished (see **Figure 2**):

— **One step up, one step down**: each actor keeps traceability data in its own local system. Data can be shared between immediate trading partners upstream or downstream.

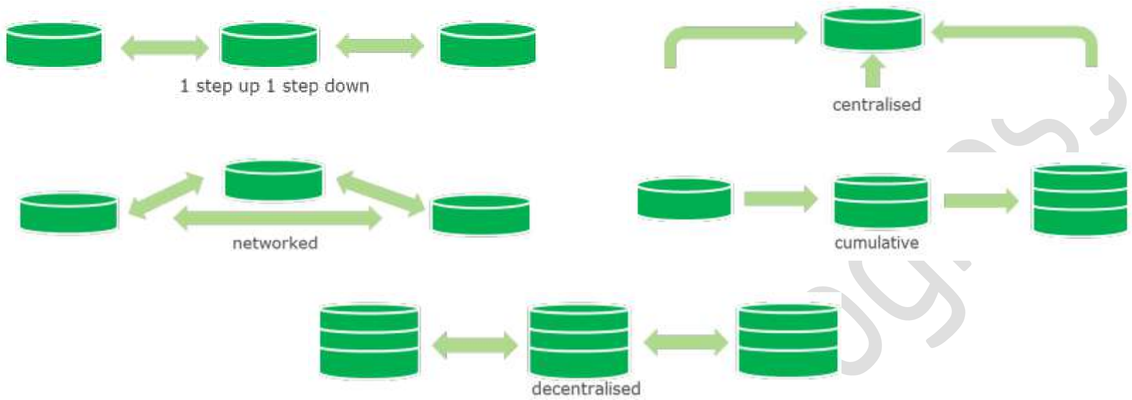
— **Centralised**: actors share data in a central repository. The access to the repository may vary based on the access control policy, e.g. access can be granted to all parties, only to privileged actors, or only to the owner of the repository.

— **Networked**: actors keep data in their own local systems and supply chain partners are able to access/retrieve the data.

— **Cumulative**: data is systematically enhanced and pushed forward to the next party in the supply chain, in parallel of the product flow. It allows to share upstream data with parties downstream, but not the other way around.

— **Decentralised and replicated**: a mix of the cumulative and the networked scenario, typically used in the blockchain technology. Data is systematically enhanced and all actors in the supply chain keep a local copy of all data.

Figure 2. Models to share traceability data



Source: (GS1, 2017)

3.2.2 Chain of custody models

In the ISO standard 22095[6] **chain of custody** is defined as a "*process by which inputs and outputs and associated information are transferred, monitored and controlled as they move through each step in the relevant supply chain*".

A chain of custody (CoC) model is an approach used to control inputs and outputs and to demonstrate the link between the verified unit in the supply chain and the claim about the output products. It is possible to combine different chain of custody models throughout the supply chain (ISEAL, 2016).

All chain of custody models are designed to ensure that volumes of certified material[7] sold match or do not exceed volumes of certified material bought. One needs however to account for conversion rates (ISEAL, 2016).

Entities willing to make a claim about their products have to follow a specific set of requirements or standards. Within the purpose of the current work, the claim refers to the content of recycled lithium, nickel, cobalt and lead in each battery model produced in a given production plant within a reference year. Therefore, the origin of the material as well as possible blending between recycled and virgin material need to be controlled and documented along the supply chain, to substantiate the claims on recycled content.

The following sub-sections describe the main chain of custody models, using the standard ISO 22095 as the primary reference. Its implications for supply chain actors[8] are described.

3.2.2.1 Identity preservation

a) Definition

Identity preservation is defined in ISO 22095 as a "*chain of custody model in which the materials or products originate from a single source and their specified characteristics are maintained throughout the supply chain*".

[6] ISO 22095 Chain of custody – General terminology and models: https://www.iso.org/obp/ui/en/#iso:std:iso:22095:ed-1:v1:en

[7] Certified material refers in general to mass or content from a source with a specific characteristic which may include but is not limited to recycled material (e.g. recycled content in batteries), sustainably sourced material (e.g. organic cotton), or having a specific geographic origin.

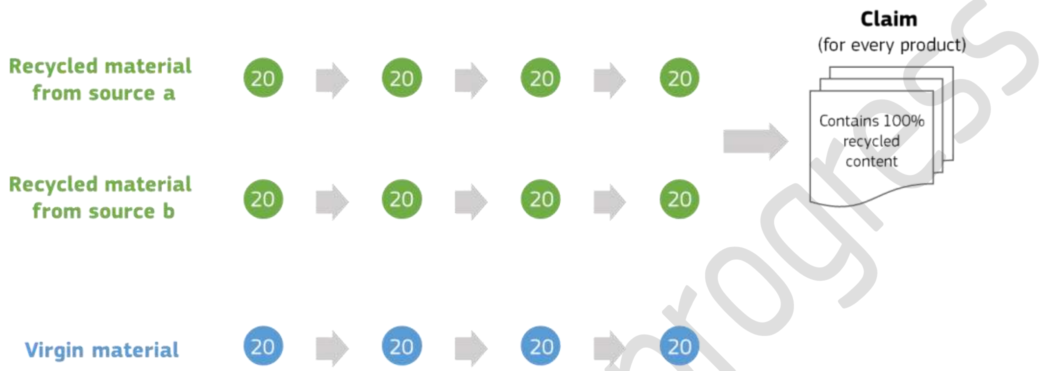
[8] This section has presents impacts for supply chain actors that have been subdivided into general categories: recycler, metal refiner, manufacturer of active material and battery manufacturer. Note that this list may not be a complete representation of all supply chain actors, but enables a simplified representation for different value chain that perform main supply chain steps.

Certified materials from a certified site are kept separate from other sources (during transport, storage and production) and can be uniquely traced throughout the supply chain. It is hence possible to trace material to its source and to its single point of origin (ISEAL, 2015; Schmidt et al., 2019).

b) Application of the model to trace recycled material

Figure 3 represents a simplified scheme of this model. Recycled material from a given origin cannot be physically mixed neither with recycled material from another origin nor with virgin material. Each batch of recycled material is treated and kept separate from other sources and from virgin material along the whole supply chain. Consequently, each good produced using recycled material would contain 100% recycled content.

Figure 3. Exemplary scheme of the identity preservation model



Source: own elaboration based on (ISEAL, 2016)
NB: each bubble represents an actor in the supply chain; numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model does not allow mixing virgin materials with recycled materials, nor mixing recycled materials from different sources.

In the following we analyse the possible implications for each actor of the battery supply chain, assuming that the identity preservation model is applied along the whole supply chain, for illustration purposes only. In reality different chain of custody models may be combined by the different actors.

— Recycler: waste from different origins cannot be processed together in the recycling plant, implying that each type of waste should be processed on a separate line or in different batches. No blending with virgin materials is allowed.

— Metal refiner: recycled material from different origins or presenting different characteristics cannot be mixed, resulting in secondary metals from individual points of origin. No blending with virgin materials is allowed.

— Producer of active material: secondary metals cannot be mixed neither with primary metals nor with secondary metals from different points of origin. The produced active material consists exclusively of recycled material from a specific origin and with homogeneous characteristics.

— Battery manufacturer: active materials from different manufacturers cannot be mixed, unless they originate from the same source and present the same characteristics. The battery manufacturer could make claims about recycled content only if recycled lithium, nickel, cobalt or lead from a specific source have not been mixed with their primary equivalents or with recycled material originating from other sources.

3.2.2.2 Segregation

a) Definition

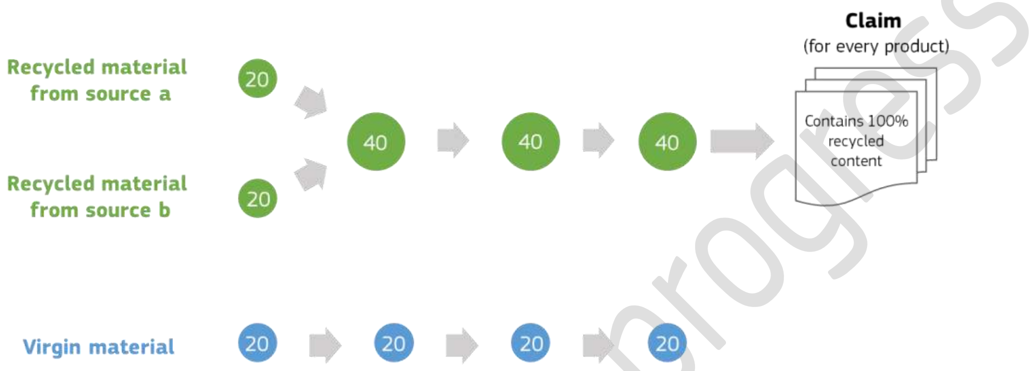
Segregation is defined in ISO 22095 as a "*chain of custody model in which specified characteristics of a material or product are maintained from the initial input to the final output*". In the standard it is specified that "*addition of material with different characteristics and/or grade to the input is not allowed*".

Certified materials are kept separate from non-certified sources throughout the supply chain. It is allowed to mix certified materials from different certified sources, as long as they present identical characteristics. It is hence assured that the final product originates from certified sources, but it may not be possible to identify the exact origin for each molecule (ISEAL, 2015; Schmidt et al., 2019).

b) Application of the model to trace recycled material

Figure 4 depicts a schematic representation of this model. Recycled material from different sources can be mixed at any step of the supply chain, as it presents the same characteristics. Blending with virgin material is not allowed. Each good produced using recycled material from different sources would contain 100% recycled content.

Figure 4. Exemplary scheme of the segregation model



Source: own elaboration based on (ISEAL, 2016)
NB: each bubble represents an actor in the supply chain; numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model does not allow mixing recycled materials with virgin materials, but it does allow mixing recycled materials from different sources.

In the following we analyse the possible implications for each actor of the battery supply chain, assuming that the segregation model is applied along the whole supply chain, for illustration purposes only. In reality different chain of custody models may be combined by the different actors.

— Recycler: should keep track of the origin of the waste processed but is allowed to mix waste from different sources. No blending with virgin materials is allowed.

— Metal refiner: can process only recycled material, resulting in secondary metals originating from different waste sources. No blending with virgin materials is allowed.

— Producer of active material: secondary metals from different refiners can be mixed, resulting in active material exclusively made of recycled materials.

— Battery manufacturer: active materials from different manufacturers can be mixed, as long as they consists entirely of recycled materials. The battery manufacturer could make claims about recycled content only if recycled lithium, nickel, cobalt or lead originating from different sources have not been mixed with their primary equivalents at any point in the supply chain.

3.2.2.3 Controlled blending

a) Definition

Controlled blending, also referred to as 'single percentage method', is defined in ISO 22095 as a "*chain of custody model in which materials or products with a set of specified characteristics are mixed according to certain criteria with materials or products without that set of characteristics resulting in a known proportion of the specified characteristics in the final output*".

Mixing of certified and non-certified materials is allowed, as long as the ratio between inputs is known for all outputs at all times for a given unit of volume (e.g. shipment, storage facility, production batch).

The quantity of physical inputs and outputs shall be monitored and documented. Certified materials shall be processed over a specified timeframe.

b) Application of the model to trace recycled material

Figure 5 displays a simplified example. The manufacturer can mix a specific amount of recycled and virgin materials (e.g. 20 units of recycled material and 20 units of virgin material). The resulting product would thus contain 50% recycled content. The proportion of inputs is consistently known for all outputs within a defined volume (e.g. batch, shipment, storage facility) at all times.

Figure 5. Exemplary scheme of the controlled blending model

Source: own elaboration
NB: each bubble represents an actor in the supply chain; numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model allows mixing recycled and virgin materials as long as the exact proportions are known.

In the following we analyse the possible implications for each actor of the battery supply chain, assuming that the controlled blending model is applied along the whole supply chain, for illustration purposes only. In reality different chain of custody models may be combined by the different actors.

— <u>Recycler</u>: can mix recycled materials from different sources and can use virgin materials for specific purposes, as long as the proportions of each material are controlled and recorded.

— <u>Metal refiner</u>: is allowed to mix virgin and recycled materials in the refining unit, resulting in recovered metal with a known proportion of recycled material.

— <u>Producer of active material</u>: is allowed to process secondary metals and primary metals in the same manufacturing unit, resulting in active material with a known proportion of recycled material.

— <u>Battery manufacturer</u>: active materials from different producers and with different compositions can be mixed, as long as the blending process is controlled. The battery manufacturer could make claims about recycled content only if the proportion of recycled material in each battery produced is known.

3.2.2.4 Mass balance

a) Definition

Mass balance is defined in ISO 22095 as a "*chain of custody model in which materials or products with a set of specified characteristics are mixed according to defined criteria with materials or products without that set of characteristics. The proportion of the input with specified characteristics might only match the initial proportions on average and will typically vary across different outputs*".

It is allowed to mix certified and non-certified materials at any step of the production process, as long as the quantities are controlled and recorded. The exact origin of the final product may not be easy to identify, as it may be lost with physical blending (ISEAL, 2015; Schmidt et al., 2019).

b) Implementation method

Mass balance consists of the reconciliation of inputs and outputs of the certified material through the production process. The standard ISO 22095 describes two implementation methods for mass balance models:

— **Rolling average percentage method**: which allows the organisation to demonstrate the average percentage of certified content in the output during a specified time frame. The organisation shall calculate the average proportion of certified materials used as input and the average proportion of certified materials in the output during the claim period. The calculated rolling average percentage can be used as basis for claiming the average percentage of certified content in the products for the specified time frame.

— **Credit method**: which allows the organisation to allocate credits based on the mass of certified materials used in products. This method is commonly used when multiple inputs are used in a product. The mass of certified materials in the output shall correspond to the mass of certified materials used as input, taking into account conversion factors. For each product the organisation shall carry out a credit account for each type of input used for an output claim, ensuring it does not result in a negative balance during the accounting period. Credit balance shall be calculated using formula (1) when the conversion factor is applied before the material enters the account and formula (2) when the conversion factor is applied when the material leaves the account.

$$C_b = C_{bp} + (M_{in} \times cf) - M_0 \tag{1}$$

$$C_b = C_{bp} + M_{in} - (M_{in} \, / \, cf) \tag{2}$$

Where:

C_{bp} is the credit balance by the end of previous period;

C_b is the credit balance;

M_{in} is the purchased material or product, into the credit account;

M_o is the produced material or product, deducted from the credit account;

cf is the conversion factor.

When using the mass balance approach, the manufacturer can make claims on certified materials, as long as the volumes of certified and non-certified materials are balanced within the **accounting period**, i.e. a predefined timeframe. The organisation shall ensure a zero or positive balance within the balancing period.

Volume reconciliation can be applied at different levels: batch-level, site-level and group-level (ISEAL, 2016). These three sub-categories of mass balance are described in the following.

3.2.2.4.1 Batch-level mass balance

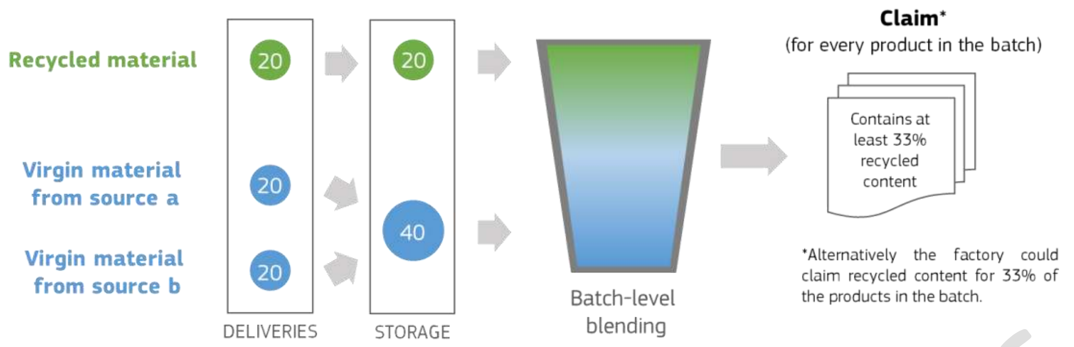
a) Definition

In the batch-level mass balance (also called percentage blending or batch blending mass balance), segregation is maintained until the final point of blending for a specific batch of a product. The proportion of certified and non-certified product is recorded, hence it can be ensured that the end-product contains a given share of certified product (ISEAL, 2016).

b) Application of the model to trace recycled material

An exemplary scheme of this model is represented in **Figure 6**. The manufacturer purchases 40 units of virgin material from different sources and 20 units of recycled material. Virgin and recycled materials are blended at batch-level. The manufacturer can claim either that each product in the batch contains 33% recycled content (so-called percentage claim) or that 33% of the goods contain recycled content (so-called certified sourced content claim), when the credit method is used.

Figure 6. Exemplary scheme of the batch-level mass balance model



Source: own elaboration based on (ISEAL, 2016)
NB: numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model allows to mix virgin and recycled materials only at batch-level. The batch-level mass balance model could be applied for the production of batteries with a specific content of recycled materials. It presents a higher degree of flexibility compared to the controlled blending model.

In the following we analyse the possible implications for each actor of the battery supply chain, assuming that the batch-level mass balance model is applied along the whole supply chain, for illustration purposes only. In reality different chain of custody models may be combined by the different actors.

— Recycler: can mix recycled materials and virgin materials at batch level (e.g. in the smelter) for specific purposes, e.g. to reach a targeted quality.

— Metal refiner: is allowed to mix virgin and recycled materials within the batch. The refined metals present a specific percentage of recycled materials, which is homogeneous within each batch.

— Producer of active material: is allowed to blend primary and secondary metals from different refineries, only if the purchased recycled and virgin metals have not been blended by the previous actor. The active material produced in the batch where blending occurs present a known proportion of primary/secondary metals.

— Battery manufacturer: is allowed to blend virgin and recycled materials only at batch-level. No reconciliation measure can be applied, as the duration of the process corresponds to the accounting period. All batteries produced in the batch contain in average the same amount of recycled material.

3.2.2.4.2 Site-level mass balance

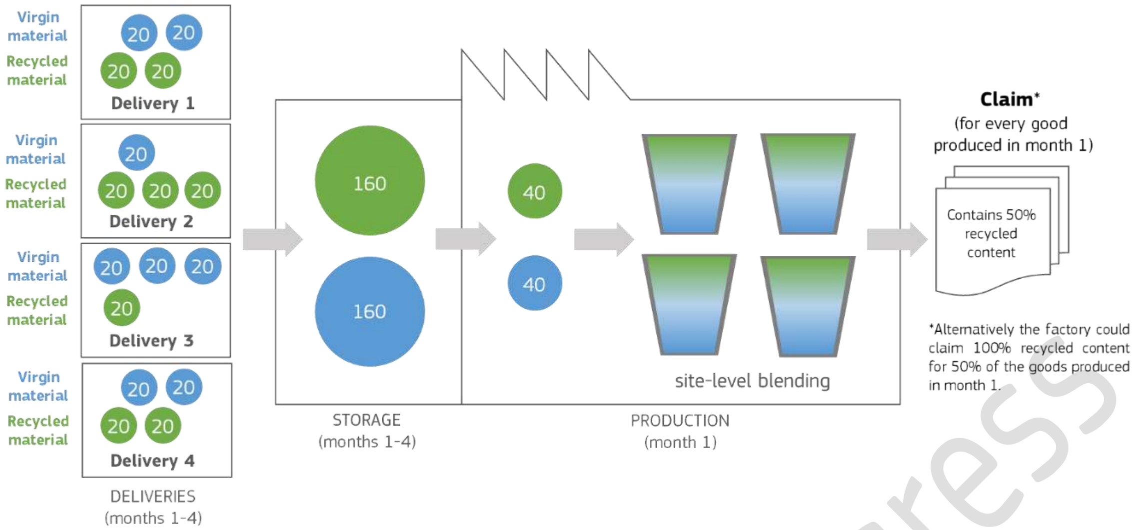
a) Definition

In the site-level mass balance (also called controlled blending or factory gate mass balance), segregation is maintained until the manufacturing or processing step in the supply chain, when the certified product can be mixed with non-certified product. The proportion of certified content entering and leaving the site is known. The percentage of certified content in the final product is not known for every single batch or shipment of output material, but can be averaged for output over a certain period (ISEAL, 2016).

b) Application of the model to trace recycled material

Figure 7 depicts a possible application of this model to trace recycled materials. The producer purchases an equal amount of virgin and recycled materials over 4 months (exemplary accounting period in the figure). During month 1, 40 units of recycled material are blended with 40 units of virgin material at site-level. The manufacturer can either claim that each good produced in month 1 contains 50% recycled material or that 50% of the goods produced in month 1 contain 100% recycled material, when the credit method is permitted.

Figure 7. Exemplary scheme of the site-level mass balance model (with a 4-month accounting period)



Source: own elaboration based on (ISEAL, 2016)
NB: numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model allows to mix virgin and recycled materials within the production site and to balance volumes within an accounting period. This model could be applied for the production of batteries with a specific amount of recycled content at site-level (not for each battery produced). It presents a higher degree of flexibility compared to the batch-level mass balance.

Below we analyse the implications for each actor of the battery supply chain, assuming that the site-level mass balance model is applied along the whole supply chain and that an accounting period of 1 year is chosen. In reality different chain of custody models may be combined by the different actors.

— Recycler: can mix recycled materials and virgin materials at site level for specific purposes, e.g. to reach a targeted quality.

— Metal refiner: is allowed to mix virgin and recycled materials in the refinery and to balance volumes within the year. The exact proportion of recycled materials physically present in the final product may be unknown at a given time.

— Producer of active material: can purchase primary and secondary metals from different refineries or other suppliers and is allowed to blend them at a specific point in time. As blending occurs at site-level, the share of primary and secondary materials in the active material produced in each batch is not known.

— Battery manufacturer: must record the amount of recycled and virgin material entering the plant and is allowed to mix recycled and virgin material within a battery or in a number of batteries within the accounting period. The overall amount of recycled content declared to be present in the batteries produced on the site must match the amount of recycled material purchased within the period of reconciliation. There is no guarantee that each individual battery produced contains recycled material, as there might be variations in the process.

3.2.2.4.3 Group-level mass balance

a) Definition

The group-level mass balance (also called multi-site mass balance), is used when the production process encompasses more than one site. Physical mixing or volume reconciliation of certified and non-certified products is allowed at any step in the production process (ISEAL, 2016).

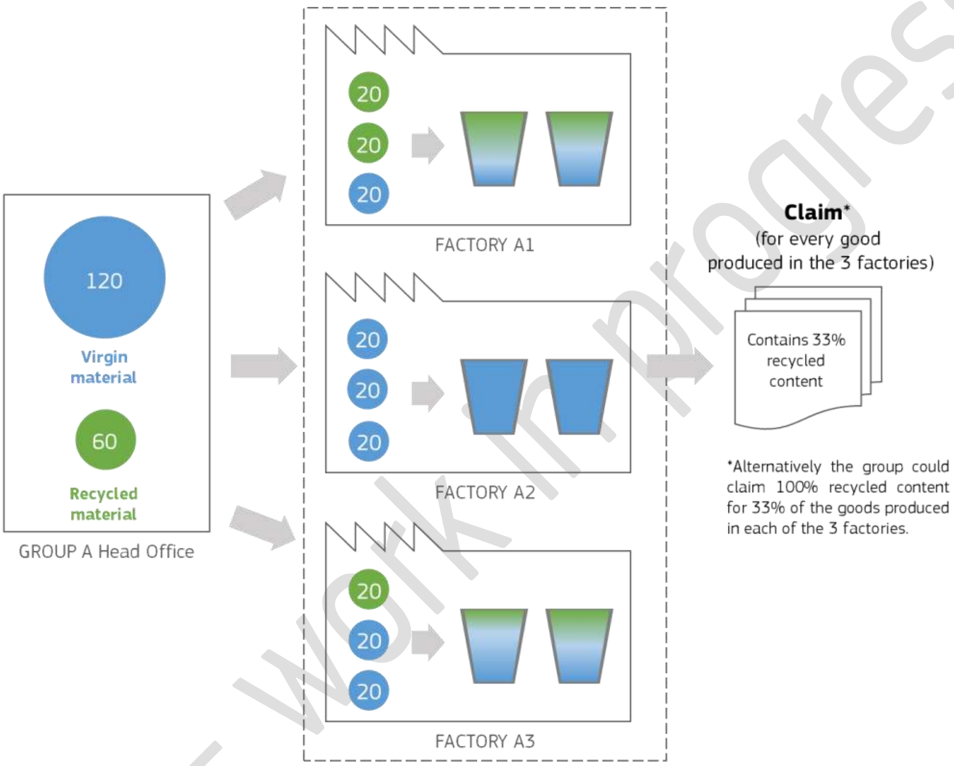
b) Application of the model to trace recycled material

Figure 8 provides an exemplary representation of this model. A head office manages three factories belonging to group A (A1, A2 and A3). The head office purchases 120 units of virgin material and 60 units of recycled material and distributes them across the three factories in different amounts:

- 40 units of recycled material and 20 units of virgin material to factory A1;
- 60 units of virgin material to factory A2;
- 20 units of recycled material and 40 units of virgin material to factory A3.

If the head office uses the same reconciliation scheme for the three factories, it could declare that every good produced in factory A1, A2 and A3 contains 33% recycled material. In practice, only factory A1 and A3 blend virgin and recycled material, whereas factory A2 uses only virgin material as input. Hence, the claim matches the proportion of purchased materials in the whole group, not the recycled content physically present in each good. Alternatively, the group could declare that 33% of the goods produced in the three factories have 100% recycled content.

Figure 8. Exemplary scheme of the group-level mass balance model



Source: own elaboration based on (ISEAL, 2016)
NB: numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model allows to mix virgin and recycled materials within different production sites belonging to the same group, as long as they produce the same materials and they are managed by the same head office. As in the site-level mass balance, volumes are balanced within an accounting period. This model could be applied for the production of batteries with a pre-defined amount of recycled content at group-level (not for every battery produced). It presents a higher degree of flexibility compared to the site-level mass balance.

Below we analyse the implications for each actor of the battery supply chain, assuming that the group-level mass balance model is applied along the whole supply chain and that an accounting period of 1 year is chosen. In reality different chain of custody models may be combined by the different actors.

— Recycler: can mix recycled materials and virgin materials at group level for specific purposes, e.g. to reach a targeted quality.

— Metal refiner: is allowed to mix virgin and recycled materials in the refinery and to balance volumes within the year. The proportion of recycled materials actually present in the final product may be unknown.

— Producer of active material: can purchase primary and secondary metals from different refineries and is allowed to blend them in different proportions in the production plants belonging to the same group. As blending occurs at group-level, the physical composition of the active material produced is not known.

— Battery manufacturer: must record the quantity of recycled material purchased in the whole group and is allowed to claim only an equivalent or lower amount of recycled content in the batteries produced in the group within the accounting period. There is no guarantee that each individual battery produced contains recycled material.

3.2.2.5 Book and claim

a) Definition

Book and claim, also referred to as 'certificate trading model' or 'credit trading', is defined in ISO 22095 as a "*chain of custody model in which the administrative record flow is not necessarily connected to the physical flow of material or product throughout the supply chain*". This model "*is often used where the certified/specified material cannot, or only with difficulty, be kept separate from the non-certified/specified material, such as green credits in an electricity supply*".

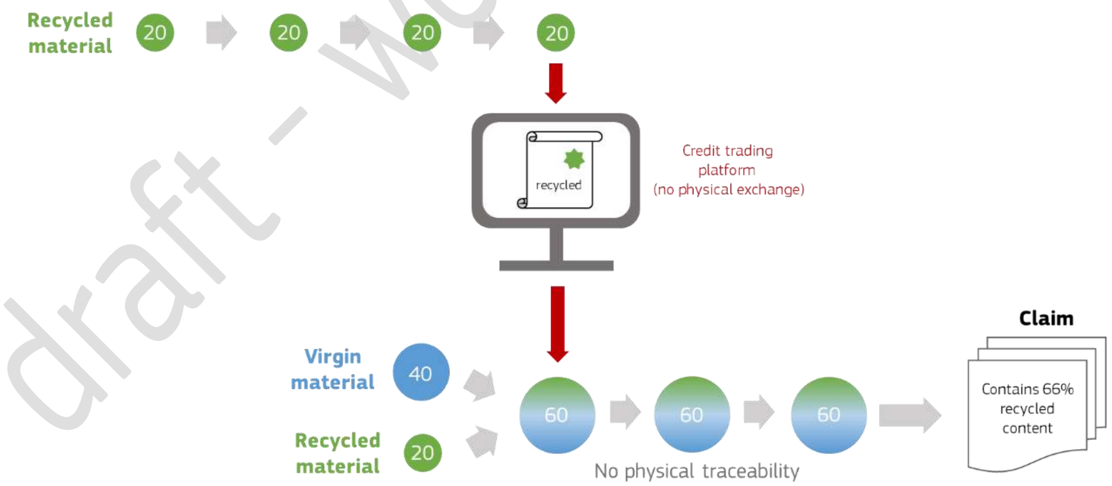
There is no link between the administrative record flow and the physical flow of certified materials. Certified and non-certified materials freely flow through the supply chain. Certificates of credits can be exchanged via a credit trading platform, independently of the physical delivery of certified materials. Physical traceability is lost and there is no guarantee that the final product contains the certified materials (ISEAL, 2015; Schmidt et al., 2019).

b) Application of the model to trace recycled material

A schematic representation of this model is presented in **Figure 9** Different actors in the battery supply chain can purchase certificates on recycled materials through a trading platform.

In the depicted example a producer purchases 40 units of virgin materials and 20 units of recycled material. The materials are physically blended, resulting in a product with 33% recycled content. The producer buys a certificate equivalent to 20 units of recycled material, being hence able to claim 66% recycled content. The claim is hence decoupled from the physical composition of the product.

Figure 9. Exemplary scheme of the book and claim model



Source: own elaboration based on (ISEAL, 2016)
NB: each bubble represents an actor in the supply chain; numbers represent a hypothetical unit of product

c) Implications for the battery supply chain actors

This model allows mixing of primary and secondary materials at any step of the supply chain. This model could be applied for the production of batteries with a pre-defined recycled content, however the recycled content physically present may not match the claim.

In the following we analyse the possible implications for each actor of the battery supply chain, assuming that the book and claim model is applied along the whole supply chain, for illustration purposes only. In reality different chain of custody models may be combined by the different actors.

— Recycler: can mix virgin materials with a given proportion of recycled material and purchase specific credits on recycled content.

— Metal refiner: can produce refined metal with a given proportion of recycled material and purchase specific credits on recycled content. The metal refiner could supply refined metal with a higher content of recycled material than the content physically present.

— Producer of active material: can process primary and secondary metals from different metal refiners in the same manufacturing line to produce a blended active material and can additionally purchase credits on recycled content. The claim on recycled content for the produced active material corresponds to the sum of recycled material contained in purchased secondary material and the amount virtually acquired through certificates.

— Battery manufacturer: the produced batteries may not contain a single molecule of recycled material and the amount of recycled content declared to be present in the batteries may exceed the amount of purchased recycled material (a portion of virgin material is virtually replaced by a certificate on recycled materials).

3.2.2.6 Properties and requirements of chain of custody models

As stated in the ISO standard 22095, the selection of a suitable CoC model depends upon the desired benefits and quality sought by the supply chain actors. The choice of the CoC model has impacts on the implementation of administrative, logistical, and organisational elements.

Table 1 summarises the main properties of the chain of custody models presented above.

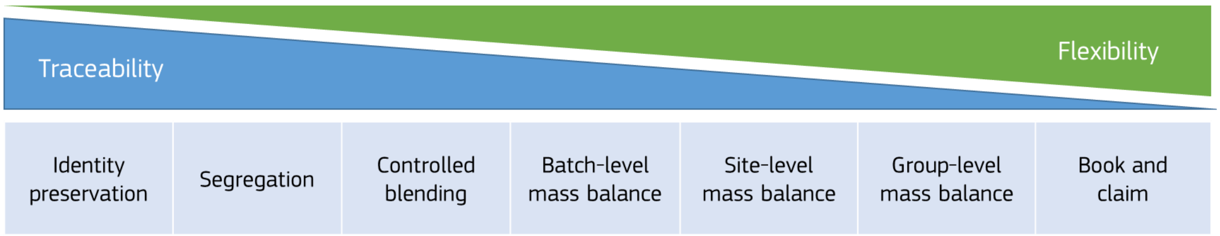
Table 1. Summary of the properties of each chain of custody model

	Identity preservation	**Segregation**	**Controlled blending**	**Batch-level mass balance**	**Site-level mass balance**	**Group-level mass balance**	**Book and claim**
Mixing of recycled / virgin materials allowed	No	No	Yes	Yes	Yes	Yes	Yes
Physical traceability	Yes	Yes	Yes	Yes	Yes, to point of blending	Not always	No
Origin of recycled material can be identified in final product	Yes	Yes, but not always up to the specific point of origin	Yes	Not always, May be lost with physical blending	Not always, May be lost with physical blending	Not always, May be lost with physical blending	No
Volumes of recycled material sold match / do not exceed purchased volumes	Yes	Yes	Yes	Yes	Yes, over the accounting period	Yes, over the accounting period	No, it matches volumes and certificates purchased

Source: own elaboration based on (ISEAL, 2016)

Figure 10 illustrate the ranking of chain of custody models according to the physical presence of a material with specified characteristics (e.g. recycled material) and the flexibility provided by the model. Each model impacts the claims made about materials or products within a specific chain of custody and their alignment with the expectations of consumers or final users.

Figure 10. Chain of custody models ranked according to traceability and flexibility



Source: JRC own elaboration based on ISO 22095

Identity preservation guarantees the highest level of traceability, as no mixing is allowed. The operator will have to keep track of all incoming materials and will have to store material from different origins separately. No flexibility is permitted in this model.

Although more flexible than the identity preservation model, the segregation model still guarantees a high level of traceability by allowing mixing only materials with the same characteristics.

The controlled blending model allows to mix materials with different characteristics, while still identifying the amount of material with specific characteristics in the final product.

Mass balance models offers a higher level of flexibility, as volumes can be reconciled within the accounting period. The physical presence of materials with a given set of characteristics can be traced only to a certain extent, as it is often averaged over the accounting period.

In book and claim the physical presence is decoupled from the claim (high flexibility), hence the level of traceability that ca be guaranteed is relatively low.

Each organisation shall apply a chain of custody model that is suitable to the type and complexity of the organisation to ensure conformity with the requirements set in ISO 22095. In a supply chain perspective, the organisation shall use either the same CoC model as its supplier or a model with a lower traceability level. Book and claim cannot be combined with any other model within the same supply chain.

3.3 Review of existing standards, certification schemes and guidelines for calculation, traceability and verification of sustainability reporting

Pro-environmental claims may cover a broad set of claim types, including but not limited to recycled content, organically sourced or grown feedstocks, product carbon footprints, as well as product types (batteries, food products, textiles, etc.). Economic entities making voluntary claims commonly rely on collaborative schemes set up by an independent body, in charge of storing relevant data and sharing information as well as of providing certifications of a specific nature. Multi-stakeholder initiatives that have already set up traceability schemes and/or standards for different commodities.

Also legislation may impose rules for companies who wish to make such claims. For instance, producers, manufacturers, importers, service providers and wholesalers placing their products and/or services on the EEA market can apply for the EU Ecolabel. Depending on the product/service group, you may need to provide declarations, documents, data sheets and test results to prove compliance with the EU Ecolabel criteria. Minimum requirements and (calculation/verification) rules can also be set in Regulation, as exemplified by the proposal for an EU Green Claims Directive[9] or the common rules for calculating, verifying and reporting on recycled plastic content in single-use plastic beverage bottles[10].

Often international standards set out guidelines that serve as a basis for such voluntary or mandatory required claims and to establish a common terminology for different traceability options and CoC models. For instance, the international standard ISO 14021[11] (environmental labels and declarations) sets requirements for self-declared environmental claims, and brings forward a definition of "recycled content", whereas EN 45557[12] defines a general method for assessing the proportion of recycled content in energy related products. Also relevant is the ISO standard 22095[13] that defines and describes CoC models.

This section provides the key-take-aways from the reviewed information existing standards and guidelines for calculation, traceability and verification of sustainability reporting that are relevant to develop the draft JRC recommendations for the calculation and verification rules. Full details and references can be found in Annex 2.

3.3.1 Traceability

Chain of custody models play a crucial role in the enhancement of traceability and transparency in supply chains. These models contribute significantly to the overall goal of maintaining the truthfulness of sustainability claims and promoting responsible sourcing practices. By tracking materials from their origin to the final product, CoC models empower consumers to make informed purchasing decisions when it comes to certified products.

Different terminologies are used across the presented voluntary standards and guidelines to refer to the chain of custody models defined in the standard ISO 22095 (Annex 2). Standards and certification schemes commonly permit different chain of custody models as described in section 3.2.2, and adapt the wording of the claim to properly flag the approach and specificities of the applied approach. No harmonised approach to trace recycled content in batteries has been developed to date. However, the European standard EN 45557 for energy-related products provides guidelines on scope definition, material assessment, input tracing and the mass balance accounting system. The standard concludes that mass balance is the preferred CoC model for tracing recycled content in energy-related products, but also other CoC models are outlined to achieve traceability. Allocation within the accounting period is permitted, and may cover for instance balancing the recycled content over multiple batches or production lines.

The general requirements for a mass balance system involve the allocation of claims based on known quantities of inputs and outputs over a defined balancing period, supported by a material accounting system that tracks input and output quantities during that timeframe. Mass balances should be kept material-specific and should reflect the system boundaries and restrictions of the chosen chain of custody model. An accounting period must be defined (commonly up to 12 months), and no negative balances can be carried out beyond the accounting period. Allocation of recycled content may be possible between identical products and between actors belonging to the same company, with each site maintaining mass balance calculations and records.

Some multi-stakeholder initiatives have set up online traceability platforms for specific commodities, to facilitate communication and data exchange between certified members of those supply chains.

3.3.2 Calculation

For accurate calculation of recycled content, both the system boundaries, including input and output measurement points, should be clearly defined at each supply chain level.

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9 Proposal for an EU Green Claims Directive: https://environment.ec.europa.eu/publications/proposal-directive-green-claims_en

10 Rules for calculating, verifying and reporting on recycled plastic content in single-use plastic beverage bottles: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13467-Single-use-plastic-beverage-bottles-EU-rules-for-calculating-verifying-and-reporting-on-recycled-plastic-content_en

11 ISO 14021: https://www.iso.org/standard/66652.html

12 EN 45557: https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:65711,2240017&cs=11DE675105E5C170B5A3D691A5808E91F

13 ISO standard 22095: https://www.iso.org/standard/72532.html

Certified content is commonly defined on a mass basis, thus as the mass of the certified material divided by the total mass of the (intermediate) product. For instance, recycled content is defined in ISO 14021 as "*proportion, by mass, of recycled material in a product or packaging*".

Conversion factors play a crucial role, as they account for the change in quantity of a specific material due to processing when converting certified content from input to output materials. These factors should be calculated on a site-specific and product-specific basis, using actual data such as processing or production data. Conversion factors must be provided by all elements in the chain of custody where changes in quantities occur and should be clearly documented, and are to be in the numerator as well as denominator to ensure accuracy of the calculation.

Certified materials are also monitored at the production plant level over a specific accounting period to ensure that certified input materials are not double-counted by being attributed to different output materials, include materials subject to various certification schemes or requirements. Calculations performed at production plant levels are thus contribution to the prevention of 'mass balance fraud'.

The European standard EN 45557 seems a good starting point also for the development of calculation rules required to address mass balance fraud. It provides formulas to calculate recycled content from defined waste sources, including pre- and post-consumer waste. Flows of mass and recycled content over a defined balancing period is then calculated based on records of inputs, outputs, conversion factors, waste generation and changes in stocks.

3.3.3 Verification

Verification of compliance with sustainability standards is commonly performed based on the evaluation of technical documentation collected by an economic entity. For recycled content, it can be based on a review of the quality system, data and certificates of supply chain actors, and calculations performed. Existing verification systems often involve third-party conformity assessment bodies, as also set out as a requirement in the Batteries Regulation for Article 8. The verification and validation techniques of the carbon footprint of electric vehicle batteries include an assessment visit of different supply chain actors, also upstream to the battery manufacturer.

Verification should ensure that (i) all actors in the supply chain, including outsourced contractors and middlemen, adhere to the rules and that verification mechanisms are in place to check compliance at different supply chain steps, (ii) necessary certificates and documented are transferred along the supply chain to ensure end-to-end traceability, and (iii) calculations at the level of (intermediate) products and supply chain actors are correctly and accurately executed, based on the specified chain of custody model rules and formula set out in the guidance or legislation.

4 JRC recommendations for traceability schemes, calculation and verification rules for recycled content in batteries

4.1 Guiding elements and principles

The following elements and principles were considered when developing the JRC recommendations for calculation and verification rules. The recommendations outlined in section 4.2 also aim to strike a proper balance to manage potential trade-offs amongst the guiding principles.

4.1.1 Coherence with the legal text of Article 8 and other EU legislation

Since the JRC work on recycled content in batteries comes aims to support the implementation of Article 8 of the Battery Regulation. Coherence needs to be ensured with the legal text of Article 8. In a broader perspective, coherence with other relevant EU legislations can be pursued.

Article 8 of the Batteries Regulation indicates batteries shall be accompanied by documentation containing information about *the percentage share of [cobalt, lithium, nickel, or lead] that is present in the active material [or lead for the battery] and that has been recovered […] for each battery model per year and per manufacturing plant*. The documented recycled content in batteries should, thus, as accurately as possible reflect the actual proportion contained in a material. This principle also ensures coherence with the EU Green Claims Directive (recital 20) "In order for the environmental claim to be considered robust, it should reflect as accurately[14] as possible the environmental performance of the specific product or trader", and be subject to verification along the supply chain (e.g. recital 42). In addition, it also aligns to the traceability rules on recycled plastic content in single-use plastic beverage bottles that are recycled as part of a process containing a single output for which the recycled content can be calculated[15].

This guiding principle is an element of the legislative act and shall accordingly not be the subject of a delegation of power when developing the delegated act for the methodology for the calculation and verification.

4.1.2 Clear, accurate and verifiable rules to build trust

To achieve significant impact, it is essential that customers and consumers trust and easily understand the information provided. Complex, counterintuitive or untrustworthy methodology and calculation rules for recycled content may result in affected parties not understanding the characteristics of the products they obtain. In the absence of trust, the provision of pro-environmental information will actually have little or no impact on consumer choices, including purchase decisions for certified products (Yokessa & Marette, 2020). Aligned to the legal basis, a situation where a product could be placed on the market with a declaration a specific amount of recycled content of metals while containing only very small fractions of actual recycled content is thus to be avoided. It is critical to provide clear, accurate, accessible information to industry actors and the wider public involved in the batteries supply chain about the calculation and verification methodologies. Third-party verification at every supply chain step adds further trust.

For downstream actors in the battery supply chain, it is important to have full and transparent information on the characteristics of the materials and intermediate products they purchase, further process and ship to their customers. This is particularly important for (new) materials containing recycled content, with a view to ensure product quality and full control of the material. Information and awareness of product specifications and recycled content may be important to determine the potential causes in case of lack of compliance with product quality standards and material deficiencies. It may likewise be important to demonstrate compliance with legal requirements, for instance on the presence of impurities.

[14] Accuracy refers to how close a measurement is to the true or accepted value. This meaning is also retained in EU legislation, e.g. Regulation (EU) No 601/2012 on the monitoring and reporting of greenhouse gas emissions defining accuracy' as "the closeness of the agreement between the result of a measurement and the true value of the particular quantity or a reference value determined empirically using internationally accepted and traceable calibration materials and standard methods, taking into account both random and systematic factors".

[15] Commission Implementing Decision (EU) 2023/2683 laying down rules for the application of Directive (EU) 2019/904 of the European Parliament and of the Council as regards the calculation, verification and reporting of data on recycled plastic content in single-use plastic beverage bottles. https://eur-lex.europa.eu/eli/dec_impl/2023/2683/oj

Citizens may lose trust in products, secondary raw materials, and circular economy when the claimed recycled content is actually not present in the batteries they have purchased. Consumers often feel deceived when they discover that items they believed were recycled are not actually. This may create intrinsic socio-political feedback loops that undermine support by citizens in favour of green policies, and provide opposing groups an opportunity to make a case for policy redesign and legal instability for economic operators over time (Edmondson et al., 2019).

4.1.3 Keep it simple

Businesses should be motivated to make provable claims and embrace the challenge of incorporating recycled materials in products for the EU market. The rules should prioritise simplicity by focussing on only the minimum specification that represents the common core needs to achieve the objectives of truthful and robust reporting of recycled content so the implementation cost and administrative burden is minimised. A fully transparent traceability method prevents additional administrative burden to companies and certification authorities from e.g. an intricate credit trading and certification system with complex accounting and book-keeping mechanisms. At present verification is based on certificates from different supply chain operators, but scientific developments are underway to assess and measure recycled content in different (intermediate) products, including batteries (Schyns et al., 2022; SMI-HUB, 2021; SUSTRAB, 2024). Hence, aligning declared to actual recycled content where possible may potentially facilitate its future verification in a straightforward manner, and provide further tools for companies to crosscheck claims from their suppliers.

4.1.4 Providing flexibility within the boundary conditions of the Regulation

While adhering to the principles outlined above, industry may benefit from a certain level of flexibility and consideration of the specificities of the batteries manufacturing techniques and the supply chain. This may be particularly required to accommodate processing techniques constraints in the upstream supply chain operators, for which it is impossible to determine the physically present recycled content in every share of the output material. The rules should accommodate the continued use of existing production processes, such as batch (e.g. chemical mixing at batch level) and continuous chemical production processes. They must also accommodate varying levels of process integration along the transformation pathway from raw materials to finished products in a single production plant.

4.1.5 Building on existing standards and certification schemes

Some firms and businesses have already voluntarily implemented strategies to incorporate and claim recycled content in batteries. Voluntary certification schemes and international standards already developed guidance and rules on traceability, calculations and (third-party) verification procedures. Recycled content is traced across the entire batteries supply chain, with verification procedures in place at each supply chain step and operator. This ensures that the recycled content can be attributed to the (secondary) raw materials and products can be verified as the sum of product parts. With a view to impose minimal disruption to existing business processes and to leverage existing business practices, the recommended calculation and verification rules may build on such documents to facilitate their implementation for Article 8 of the Regulation, when relevant.

4.2 JRC draft recommendations

This section presents the JRC draft proposals on traceability (section 4.2.2), calculation (section 4.2.3) and verification (section 4.2.4) rules, for further discussion and consultation by the stakeholders. The draft JRC recommendations introduce a set of terms, not previously defined in the Batteries Regulation, that are defined (section 4.2.1) to ensure an accurate interpretation. The draft JRC recommendations are presented in grey boxes, and accompanied by further explanations and implications in the sub-section below to ensure a good understanding by the reader of the technical arguments that underpin the proposals.

4.2.1 Terminology and definitions

Term	Definition
Recycled material	Materials obtained from eligible waste materials outlined in Article 8 of the Batteries Regulation following a recycling process, or derived materials thereof obtained after further mixing and transformation processes.
Origin (of waste)	Specific source or point from where waste material arise, such as post-consumer waste (originating from consumers) and manufacturing waste (originating from manufacturing processes).
Recycled content (ReCo)	Proportion, by mass, of recycled to total material in a product. Source: based on ISO 14021:2016 (adapted)
Manufacturing/production plant	Location with geographical boundaries at which defined activities under the control of an organisation are carried out. [Note 1 to entry: Sites may be in one geographical area but need not be contiguous. For example, a road can separate two geographical areas that are operated as a single site]. Source: based on ISO 22095:2020 (adapted)
Battery manufacturer	Any natural or legal person who manufactures a battery or has a battery designed or manufactured, and markets that battery under its own name or trademark or puts it into service for its own purposes. Source: Batteries Regulation ((EU) 2023/1542)
Supply chain	Series of processes or activities involved in the production and distribution of a material or product through which it passes from the source [Note 1 to entry: A supply chain is typically composed of a series of different organisations]. Source: ISO 22095:2020
Supply chain actor	An actor that is part of the supply chain. An actor is an entity or group of people and facilities with an arrangement of responsibilities, authorities and relationships and identifiable objectives. Source: based on ISO 22095:2020 (adapted)
Supply chain step	A step in the battery supply chain, managed by a supply chain actor, in which processing of materials occurs (e.g. recycling, refining, production of active materials, manufacturing of batteries).
Input	Material or product that enters a production process of a supply chain actor [Note 1 to entry: Input may be used at any step of the supply chain; Note 2 to entry: Input may also include recycled materials; Note 3 to entry: Input will have associated information]. Source: based on ISO 22095:2020 (adapted)

Output	Material or product that leaves enters a production plant of a supply chain actor [Note 1 to entry: Output can be created at any step of the supply chain; Note 2 to entry: Output might include other products resulting from production processes; Note 3 to entry: Output will have associated information]. Source: based on ISO 22095:2020 (adapted)
Precursor	Any output of a production process that is upstream to the active material production step for Li, Co and Ni; any output of a production process that is upstream to the battery manufacturing process for Pb.
Process	Set of interrelated or interacting activities that use inputs to deliver an intended output [Note 1 to entry: A process can include services]. Source: ISO 22095:2020
Trading process	Exchange of products between different supply chain actors, i.e. the process in which materials produced by a supply chain actor are transferred to the next actor.
Traceability	The ability to trace the history, application, location or source(s) of a material or product throughout the supply chain. Source: ISO 22095:2020
Chain of custody	A process by which inputs and outputs and associated information are transferred, monitored and controlled as they move through each step in the relevant supply chain. Source: ISO 22095:2020
Accounting period	Timeframe defined by the manufacturer for bookkeeping purposes, to reconcile input and output materials and to reallocate volumes of recycled material.
Volume reconciliation	Reconciliation of inputs and outputs through the production process within the accounting period. Source: based on (ISEAL, 2016)
Conversion factor	A factor that describes the change in quantity of a specific material due to processing. It shall be calculated for each processing step and shall be based on actual data. Source: based on ISO 22095 and (Australian Government, 2023)

4.2.2 Traceability approach

The JRC has developed two different options for traceability requirements. The first option is strictly in line with Article 8 of the Regulation in the sense that it will ensure that physically present recycled content in the battery model is equivalent to the documented share of recycled content by the battery manufacturer (averaged over a period of 12 months and per manufacturing plant).

Because the traceability system outlined in option 1 may have important implications on existing industrial practices, the JRC has also developed a second option on traceability. In agreement with Article 8 of the Regulation, it also strives and is, in the main, successful to align documented and physically present recycled content in the battery, but enables more flexibility for certain supply chain operators. It is noted that option 2 remains the view of the JRC staff. Still, the JRC would already be partial to collect feedback on this option from experts representing Member States, industry and NGOs.

4.2.2.1 Option 1

4.2.2.1.1 JRC draft comparison of options for traceability and chain of custody

Two sub-options are presented, with option 1a exclusively relying on segregation and controlled blending as eligible chain of custody models. The difference between 1a and 1b is that 1b allows a mass balance approach for the battery manufacturer with a view to accommodate for variations in recycled content across output fractions, as long as the documented recycled contents meet the physically present recycled content *for each battery model per year and per manufacturing plant*.

— Under option 1a, the ratio between inputs is known for all outputs at all times for a given unit of volume (e.g. production batch). Hence, every battery and output fraction contains a recycled content share, and this content can be determined and known. This would allow the manufacturer to document the recycled content for all battery models that are produced within one year at a certain manufacturing plant.

— Under option 1b, a battery manufacturer must record the amount of recycled and virgin material entering the plant over a given accounting period and is allowed to mix recycled and virgin material within a battery or in a number of batteries (of the same model) within the accounting period. The overall amount of recycled content declared to be present in the battery model produced (within a manufacturing plant) must match the amount of recycled material purchased within the accounting period. There is, however, no guarantee that each individual battery produced contains recycled material, as there might be variations in the process. Hence, the mass balance model included under option 1b provides flexibility for processes when the recycled content in the final product is not known for every single batch or shipment of output material, but can be averaged for output over a certain period, still fully meeting the obligations set out in Article 8.

4.2.2.1.2 JRC recommendation for option 1

OPTION 1a

1. Chain of custody

1.1 Monitoring input and output materials

Each actor in the supply chain involved in the chain of custody shall ensure that the quantity of inputs and outputs are monitored at least at the production plant level. A battery manufacturer shall monitor inputs and outputs also at the battery model level.

1.2 Applicable chain of custody models

(I) The proportion of recycled material in the outputs shall be known for a contained volume (e.g. a batch, shipment). Recycled content shall be calculated for that volume using **segregation** or **controlled blending**.

(II) Each supply chain actor shall use the same chain of custody model as the previous actor or a model with a lower level of traceability[16] of recycled content in the output. **Mass balance and book and claim models cannot be applied** at any step of the battery supply chain.

1.3 Requirements for chain of custody

(I) When using segregation, the following requirements shall apply:

a) Recycled materials eligible to be used as input shall be kept physically separated from virgin materials and other materials non-compliant with the input requirements laid down in Article 8 throughout all steps of the manufacturing and the trading process.

b) The amount of recycled content in the output shall correspond to the amount of recycled content used as input, in line with an appropriate conversion factor[17].

(II) When using controlled blending, the following requirements shall apply:

a) Recycled materials eligible to be used as input shall be kept physically separated from virgin materials and other materials non-compliant with the input requirements laid down in Article 8 until the point of blending.

b) The amount of recycled content in the output shall correspond to the amount of recycled content used as input, in line with an appropriate conversion factor[18].

c) The quantities received and supplied to customers shall be reconciled within a defined accounting period, to verify that outputs relate to the inputs.

d) The accounting period shall correspond to the contained volume (e.g. batch) and shall not exceed twelve months[19].

2. Traceability

Traceability requirements shall apply to the whole supply chain, starting at the recycling step – including information on the origin of processed waste - and ending at the point at which batteries are placed on the market.

The amount of recycled content in the outputs that are passed on to the next supply chain actor shall be calculated at each step in the supply chain. Traceability information to be shared with downstream supply chain actors shall include at least the amount of recycled content in the outputs and the applied chain of custody model.

This information shall be shared using at least a "**one step up, one step down**" traceability approach. All supply chain actors shall strive to extend traceability beyond their direct trading partners, aiming to promote transparency throughout the supply chain.

<u>OPTION 1b</u>

Option 1b would be equal to option 1a, with the following differences:

In point 1.2, it is added:

"(III) The battery manufacturer may also apply **mass balance with rolling average percentage implementation**. Credit methods are not applicable.

[16] Chain of custody models are ranked from higher to lower level of traceability as follows: identity preservation, segregation, controlled blending, mass balance, book and claim.

[17] A conversion factor describes the change in quantity of a specific material due to processing. It shall be calculated for each processing step and shall be based on actual data.

[18] See footnote 22.

[19] The battery manufacturer can use information from different contiguous accounting periods to develop the documentation that shows compliance with Article 8 (for every battery model, per year and per manufacturing plant).

In point 1.3, it is added:

"(III) When using mass balance, the following requirements shall apply:

a) The quantities received and supplied to customers shall be reconciled within a defined accounting period, to verify that outputs relate to the inputs.

b) The accounting period shall not exceed twelve months[20]. The accounting period is representative for the production volume. Each accounting period shall be continuous in time and shall not necessarily fall within the same calendar year. Accounting periods shall be contiguous one to the other.

c) Within the defined accounting period the battery manufacturer may apply volume reconciliation of recycled materials at batch level or at production line level producing the same battery model within a single production plant.

d) Conversion factors[21] may be used to account for losses and for use of recycled materials for other applications.

e) A positive account of recycled content may be carried over into the next period, if at least the equivalent amount of the recycled material is physically in stock. Transferring negative balances beyond the accounting period is not permitted.

f) In case of multi-output processes (e.g. a battery manufacturer producing different battery models), recycling content shall be attributed proportionally to the different outputs (i.e. proportionally across the different battery models) within the accounting period. The rate of recycled content shall correspond to the calculated rolling average percentage.

g) Virtual allocation of recycled content is not allowed at any time.

4.2.2.1.3 Implications and rationale (option 1)

Rationale for point 1.1

Monitoring of input and output materials for each actor involved in the chain of custody is crucial to ensure the integrity and accuracy of recycled content calculations and is proposed as minimum requirement. The level of aggregation for the monitoring may be different for the battery manufacturer (twelve months as set out in Article 8 of the Regulation) than for the upstream supply chain actors. The latter are given more flexibility to choose an allocation period, taking into consideration organisation- and process specific parameters, including representative production volumes.

Rationale for point 1.2

The direct rationale for recommending the traceability option 1 is Article 8 of the Regulation, which states that recycled content should be present in the battery active materials or in the battery. If mass balance or book and claim methods would be applied, particularly at supply chain steps upstream of the battery manufacturer, this objective would not be ensured. Therefore, book and claim (for all supply chain actors including the battery manufacturer) and mass balance (for all supply chain actors, except the battery manufacturer in option 1b) are excluded as possible chain of custody models. Segregation and controlled blending allow determining with certainty the recycled content in the output fraction, and thus for each shipment to a specific customer, based on the known inputs of recycled content to that batch and the mass produced.

Even though no formal impact assessment is required for the adoption of a delegated act laying down the calculation and verification rules for recycled content, we believe it is relevant to assess in a preliminary manner the impacts to ensure the feasibility of the JRC recommendations. This holds particularly true since experts have flagged that it may not be feasible to apply segregation and controlled blending for certain industrial production techniques and commercial supply chain settings (as described in section 3.1). In continuous production processes, particularly those conducted in large reactors with varying amounts of recycled and virgin

[20] The battery manufacturer can use information from different contiguous accounting periods to develop the documentation that shows compliance with Article 8 (for every battery model, per year and per manufacturing plant).

[21] A conversion factor describes the change in quantity of a specific material due to processing. It shall be calculated for each processing step and shall be based on actual data.

inputs as a function of time, it is not feasible to determine the recycled content in the output fractions allocated to different customers. As a matter of fact, the ISO 22095:2020 standard on chain of custody models indicates that controlled blending can be used when "*The ratio between inputs is known for all outputs at all times for a contained volume (e.g. batch, shipment, storage facility)*". For example, the smelting process for extracting cobalt and nickel usually runs continuously, with smelters receiving both primary and secondary metals (like battery materials recovered from waste and ores) at different times. It is a standard industry practice to experience some variability in the input materials in such a setup, such as changes in suppliers and the characteristics of the materials provided. Metal-rich alloys are then produced after the continuous molten output cools down. Consequently, the exact recycled content in the output fractions cannot be precisely determined and will fluctuate e.g. based on the fluctuating input and the time elapsed since their input to the smelter. Therefore, the proportion of recycled content in the final output fractions, which may be distributed to different customers, will vary over time for some real industrial settings. Such continuous processes are sometimes favoured over batch processes by producers due to certain advantages in industrial settings, such as lower energy requirements, faster production speeds, and lower unit costs and thus to achieve economic and environmental benefits through economies of scale.

Hence, this preliminary assessment indicates that a traceability approach based solely on segregation and controlled blending would not accommodate all industrial practices. As a result, existing industrial practices would need to be adapted to fully comply with chain of custody requirements, potentially leading to additional costs for the industry, new infrastructure, and increased energy consumption. In our view, these impacts are undesirable, disproportionate to the potential benefits, and may not promote a competitive, green industry in the EU.

Therefore, the JRC has developed a second option for evaluation (see below), including a possibility <u>for all supply chain actors</u> to deviate from the segregation and controlled blending model and <u>apply a mass balance</u> (with certain restrictions) when needed for technical or logistic reasons.

Rationale for point 1.3

In addition to outlining possible chain of custody models, it is essential to offer guidance on their appropriate application. The proposed requirements for segregation and controlled blending are aligned with the general requirements for implementation of the chain of custody models given in the standard ISO 22095.

For **segregation and controlled blending** it shall be ensured that **compliant materials are kept separate from non-compliant and virgin materials**.

While for segregation, recycled content in the output shall exactly match the amount of recycled material used as input (taking into account possible conversion factors), for controlled blending it should be verified that recycled content in the output matches the amount of recycled materials used in the accounting period (not exceeding twelve months, in line with the requirement to declare recycled content per year).

When applying mass balance (option 1b), an **accounting period** representative for the production volume shall be defined. The **maximum** accounting period allowed is **twelve months**, but it shall not necessarily fall within a calendar year. The **battery manufacturer** is allowed to reallocate volumes of recycled content **only between the same battery model** produced within the same manufacturing plant. This ensures the legal constraints of Article 8 are met.

The amount of recycled content claimed in the outputs shall be equal to (or lower than) the amount of recycled material in the input over the accounting period. For instance, once the accounting period carried out by a supply chain actor for a specific unit of volume is concluded, there could be a surplus of recycled material in stock that has not been used in the production process during that accounting period. This would imply that recycled materials in the inputs is higher than recycled content in the outputs over the accounting period, resulting in a positive balance. This positive balance can be transferred to the next accounting period, as long as recycled material is physically in stock. **No negative balances** can occur. Conversion factors can be used for the balance, to account e.g. for losses.

In case of multi-output processes (e.g. a battery manufacturer producing different battery models), the **rolling average implementation method** shall be used: recycling content shall be attributed proportionally to the different outputs (i.e. proportionally across the different battery models) within the accounting period. Virtual allocation of recycled content shall not be permitted, as it hinders traceability and it goes against the principle of "clear, accurate and verifiable rules".

Rationale for point 2

As per Article 8, secondary lead (to be incorporated in the battery) can originate from any type of waste, while secondary cobalt, lithium and nickel (to be incorporated in the battery active materials) can originate from battery manufacturing waste or from any type of post-consumer waste. It is hence important to keep track of the origin of the waste supplied to the recycler. **Traceability** of recycled content **shall** therefore **start** from the moment at which waste is processed into secondary metals (**recycling plant**).

The requirement to report the rate of recycled content applies to battery manufacturers, positioned at the end of the supply chain. To enable the battery manufacturers to make accurate and reliable claims, it is crucial to ensure the **transfer of relevant data and information throughout the entire supply chain**. Information to be passed on to the next actor should consists at least of the amount of recycled content and the applied chain of custody models, in line with the recommendations for verification (see section 4.2.4).

To facilitate this process, it is proposed to apply a "**one step up, one step down**" traceability approach, ensuring that information is shared at least between immediate trading partners. However, by **extending traceability beyond direct trading partners**, all economic operators can benefit from increased transparency and better cooperation. It is therefore proposed that all actors should strive to increase transparency and data sharing in the supply chain.

4.2.2.2 Option 2

4.2.2.2.1 JRC recommendation for option 2

1. Chain of custody

1.1 Monitoring input and output materials

Each actor in the supply chain involved in the chain of custody shall ensure that the quantity of inputs and outputs are monitored at least at the production plant level. A battery manufacturer shall monitor inputs and outputs also at the battery model level.

1.2 Applicable chain of custody models

(I) All supply chain actors shall strive to use a chain of custody model with the highest level of traceability possible, aiming to promote physical traceability of recycled content throughout the supply chain[22].

(II) If the proportion of recycled material in the outputs is known for a contained volume (e.g. a batch, shipment), recycled content shall be calculated for that volume using **segregation** or **controlled blending**.

(III) If it can be demonstrated that neither segregation nor controlled blending are favourable for technical or logistical reasons, **mass balance with rolling average percentage implementation** may be applied. Credit methods are not applicable.

(IV) Each supply chain actor shall use the same chain of custody model as the previous actor or a model with a lower level of traceability[23] of recycled content in the output. Once mass balance is applied at a given step in the supply chain, it shall be applied by all actors downstream. **Group-level mass balance and book and claim models cannot be applied** at any step of the battery supply chain.

1.3 Requirements for chain of custody

(I) When using segregation, the following requirements shall apply:

a) Recycled materials eligible to be used as input shall be kept physically separated from virgin materials and other materials non-compliant with the input requirements laid down in Article 8 throughout all steps of the manufacturing and the trading process.

[22] Chain of custody models are ranked from higher to lower level of traceability as follows: identity preservation, segregation, controlled blending, mass balance, book and claim.

[23] See footnote 22.

b) The amount of recycled content in the output shall correspond to the amount of recycled content used as input, in line with an appropriate conversion factor[24].

(II) When using controlled blending, the following requirements shall apply:

a) Recycled materials eligible to be used as input shall be kept physically separated from virgin materials and other materials non-compliant with the input requirements laid down in Article 8 until the point of blending.

b) The amount of recycled content in the output shall correspond to the amount of recycled content used as input, in line with an appropriate conversion factor[25].

c) The quantities received and supplied to customers shall be reconciled within a defined accounting period, to verify that outputs relate to the inputs.

d) The accounting period shall correspond to the contained volume (e.g. batch) and shall not exceed twelve months[26].

(III) When using mass balance, the following requirements shall apply:

a) The quantities received and supplied to customers shall be reconciled within a defined accounting period, to verify that outputs relate to the inputs.

b) The accounting period shall not exceed twelve months[27]. The accounting period is representative for the production volume. Each accounting period shall be continuous in time and shall not necessarily fall within the same calendar year. Accounting periods shall be contiguous one to the other.

c) All supply chain actors may apply volume reconciliation of recycled materials at batch level within the accounting period.

d) In addition, within the defined accounting period:

(i) all supply chain actors preceding the battery manufacturer may also apply volume reconciliation of recycled materials at the production line level within a single production plant;

(ii) the battery manufacturer may also apply volume reconciliation of recycled materials at production line level producing the same battery model within a single manufacturing plant.

e) Conversion factors[28] may be used to account for losses and for use of recycled materials for other applications.

f) A positive account of recycled content may be carried over into the next period, if at least the equivalent amount of the recycled material is physically in stock. Transferring negative balances beyond the accounting period is not permitted.

g) In case of multi-output processes (e.g. a battery manufacturer producing different battery models), recycling content shall be attributed proportionally to the different outputs (i.e. proportionally across the different battery models) within the accounting period. The rate of recycled content shall correspond to the calculated rolling average percentage.

h) Virtual allocation of recycled content is not allowed at any time.

2. Traceability

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[24] A conversion factor describes the change in quantity of a specific material due to processing. It shall be calculated for each processing step and shall be based on actual data.

[25] See footnote 24.

[26] The battery manufacturer can use information from different contiguous accounting periods to develop the documentation that shows compliance with Article 8 (for every battery model, per year and per manufacturing plant).

[27] See footnote 26.

[28] See footnote 24.

Traceability requirements shall apply to the whole supply chain, starting at the recycling step – including information on the origin of processed waste - and ending at the point at which batteries are placed on the market.

The amount of recycled content in the outputs that are passed on to the next supply chain actor shall be calculated at each step in the supply chain. Traceability information to be shared with downstream supply chain actors shall include at least the amount of recycled content in the outputs and the applied chain of custody model.

This information shall be shared using at least a "**one step up, one step down**" traceability approach. All supply chain actors shall strive to extend traceability beyond their direct trading partners, aiming to promote transparency throughout the supply chain.

4.2.2.2.2 Implications and rationale (option 2)

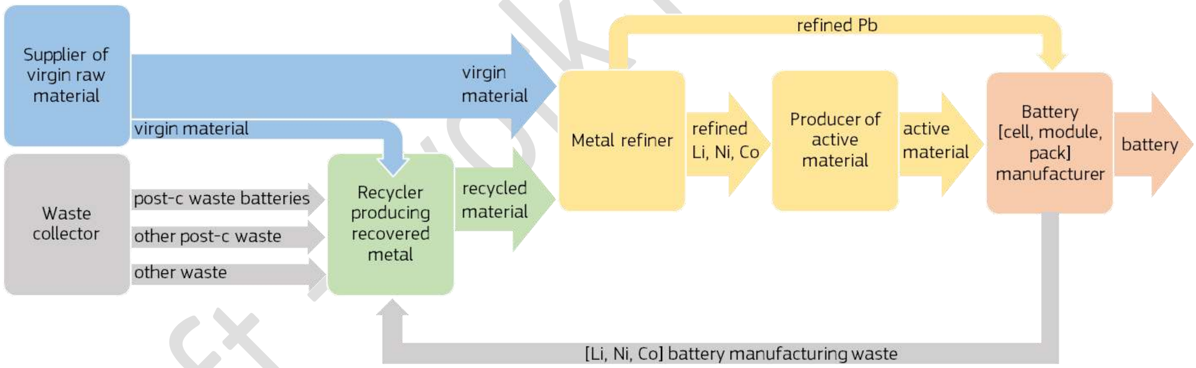
Rationale for point 1.1

This point remains unchanged. The rationale elucidated above in section 4.2.2.1.3 is therefore also valid for option 2.

Rationale for point 1.2

The suitability of a chain of custody model depends upon the complexity of the supply chain, among other factors. As highlighted in section 3.1, the battery supply chain is very complex and encompasses a wide range of actors, from waste collectors, recyclers, metal refiners, producers of active materials, to battery manufacturers, located at different geographic locations (see simplified scheme in **Figure 11**).

Figure 11. Generic representation of the battery supply chain. Note that this simplified representation may not fully correspond and be representative for all industrial setting.



Source: JRC own elaboration

In section 3.2.2 the different chain of custody models have been described in depth and the possible implications for the individual supply chain actors have been discussed. To come up with preliminary recommendations for possible chain of custody models, the applicability of the individual models is further assessed below.

Identity preservation could be applied only by the recycler, requiring however to keep waste originating from different sources separate, which does not seem realistic. Mixing waste from different sources is a common practice to absorb fluctuations in the input materials. This model does not allow to trace a certain amount of recycled content in batteries or precursors, as it excludes *a priori* mixing recycled and virgin materials. Therefore it cannot be applied neither by metal refiners, nor by producers of active materials and batteries.

As in the case of identity preservation, **segregation** excludes *a priori* mixing recycled and virgin materials and **could be applied only by the recycler**. It needs however to be noted that often recyclers mix waste with virgin materials. In that case the model would not be applicable. The considerations made above on the suitability of identity preservation for the other supply chain actors are also valid for segregation.

Controlled blending can be applied for the production of batteries or precursors with a specific amount of recycled material, when the amount of recycled material physically present matches the claim for volume of products (e.g. batch, shipment). This does not necessarily require the operator to carry out bookkeeping, as the blending percentages are recorded for each unit of volume produced; thus the accounting period corresponds to time needed to produce that unit of volume. However, it needs to be considered that this model **does not always match current industrial practices** (e.g. certain continuous processes), possibly leading to the need for current and more innovative industrial production techniques. Hence, the application of this model **may not always be the most favourable option**. On the other hand, when the allocation period is defined as the batch, controlled blending can be a straightforward and flexible model to adapt and vary the use of recycled content as an input across batches, also when delivered to different customers. For instance, CAM materials containing recycled content can be used in batch A to produce a battery of model X, destined for a customer located in the EU. In a second batch, CAM material not containing recycled content can be used in batch B to produce a battery of the same model X, but placed on the market outside the EU. In such case, no documentation on recycled content needs to be developed as the battery is not placed on the EU market, and the "premium" input material containing recycled content can be used in a flexible way based on customer demands.

Current practices and certification schemes for recycled content for other products are based on **mass balance models with flexible allocation mechanisms**, for different customers, across different geographical locations. This holds true for the final battery placed on the market as well as for intermediates and is due to different reasons:

- from a technical perspective it may not always be possible to determine the recycled content that is physically present in (a share of) the output material at any moment, due to the nature of the process (e.g. in a continuous process or in the case of temporally varying input materials in a batch reactor).
- from a logistical perspective the manufacturer may encounter short-term variations in supply of recycled content, requiring some flexibility and need to side-step from controlling inputs for every single batch, particularly for batch-processes with a short running time. In addition, unnecessary shipping of recycled materials between sites over very short periods of time can be avoided when each batch does not need to contain a certain amount of recycled material.

For such cases, **mass balance may represent a valid alternative to controlled blending**, as it allows for recycled materials to be allocated to the outputs without physically mixing them at every step of the production process and at every period in time. It also allows to reallocate volumes of recycled materials within a pre-defined accounting period. This model is suitable to any production process (whether in continuous or in batch) and provides a **higher level of flexibility**, while still ensuring the legal constraints laid down in Article 8 (declaration of recycled content for each battery model, per year and per manufacturing plant) are largely met. This, however, does not hold true for all types of mass balance and implementation methods.

Group-level mass balance allows, in fact, to reallocate recycled content volumes between different sites belonging to the same company, thus **not matching the requirement to declare recycled content at manufacturing plant level**. This type of mass balance is therefore not applicable to the battery manufacturer. There are no imposed restrictions for the preceding actors in Article 8, nonetheless the standard ISO 22095 specifies that each actor can apply either the same model as the previous one, or a model with a lower level of traceability (traceability and flexibility levels of CoC models have been defined in section 3.2.2.6). Consequently, **no other actor preceding the battery manufacturer shall be allowed to apply group-level mass balance**.

Batch-level and site-level mass balance models seem suitable to trace recycled content in the battery value chain, however it should be noted that, while site-level mass balance can still track the overall recycled content in the outputs, it does not provide accurate data of recycled content in specific batches, like batch-level mass balance. When comparing controlled blending applied at batch level and batch-level mass balance, it needs to be noted that only the latter allows to reconcile volumes within the accounting period, offering hence a higher level of flexibility.

As for the implementation methods, the **rolling average percentage method** allows to **allocate recycled content proportionally to the output produced within a specified time frame** (the accounting period), while the credit method assigns credits based on recycled content demands and without considering recycled content physically present in the outputs. The credit method is commonly used when multiple inputs are used, to enable allocation of recycled materials across different products. In the rolling average percentage methods recycled content is proportionally allocated to identical products produced e.g. within the same batch, ensuring a higher level of transparency.

In the **book and claim** model the **administrative record flow** of certified materials **does not directly connect to their physical flow**, resulting in loss of physical traceability of recycled content in the outputs. This model does not fulfil the principle “clear, accurate and verifiable rules to build trust” outlined in section 4.1. Thus we can conclude that it is **not a suitable approach to trace recycled content in batteries** and to support the reliability and accuracy of calculations.

Taking stock of these considerations and keeping in mind the **complexity of the battery supply chain** as well as the **specificities of the different production processes and steps**, it is recommended to keep a **flexible approach** to chain of custody models. This is also in line with the principle of “providing flexibility” outlined in section 4.1. In addition, as mentioned above, strict chain of custody models are not always favourable or sometimes not applicable to all supply chain actors.

It is therefore proposed that **all supply chain actors can apply three different chain of custody models: i) segregation, ii) controlled blending and iii) mass balance**. All actors should strive to use the chain of custody model with the highest level of traceability. The choice of the model to be applied will depend upon the specific requirements, constraints, and preferences of the production process and organisation. In particular, if the proportion of recycled material in the outputs is known for a specific volume (e.g. a batch), segregation or controlled blending can be applied. If those models cannot be applied, for instance because of the process characteristics, or because of administrative or logistical considerations (as outlined above), mass balance can be used. As for the **implementation method of mass balance**, it is proposed to allow only **rolling average percentage implementation** and to constrain the use of credit methods.

As mentioned above, in accordance to existing standards (cf. principle “building on existing standards”), in particular to ISO 22095, **a given actor in the supply chain shall apply either the same model as the previous actor or a model with a lower level of traceability**. Specifically, the International Standard indicates that “*the organization shall only use the same chain of custody model as its supplier or a model with lower physical presence of the specified characteristic in the output*”. The reason is that each chain of custody model is associated to a particular environmental claim and its wording. For instance, when volume reconciliation is used any part of the supply chain, standards may require that specific wording is added to the claim: “using allocation system”. Hence, once the level of traceability of recycled content is reduced (e.g. when applying mass balance), it is not possible to use downstream a model with a higher level of traceability (e.g. controlled blending). This should ensure consistency along the battery supply chain. This of course does not imply any impact on the on-the-ground production process that can actually be applied by other supply chain actors.

Rationale for point 1.3

In addition to outlining possible chain of custody models, it is essential to offer guidance on their appropriate application. The proposed requirements for segregation, controlled blending and mass balance are aligned with the general requirements for implementation of the chain of custody models given in the standard ISO 22095.

In particular, for **segregation and controlled blending** it shall be ensured that **compliant materials are kept separate from non-compliant and virgin materials**.

While for segregation, recycled content in the output shall exactly match the amount of recycled material used as input (taking into account possible conversion factors), for controlled blending it should be verified that recycled content in the output matches the amount of recycled materials used in the accounting period (not exceeding twelve months, in line with the requirement to declare recycled content per year).

When applying mass balance, an **accounting period** representative for the production volume shall be defined. The **maximum** accounting period allowed is **twelve months**, but it shall not necessarily fall within a calendar year. To ensure a higher level of traceability, it is proposed that all value chain actors can apply **reconciliation** of recycled content volumes **at batch level** within the accounting period. Nonetheless, in order to provide more flexibility to supply chain actors, **all actors preceding the battery manufacturers** are also allowed to apply **volume reconciliation at the production line level within a single production plant**. The **battery manufacturer** is allowed to reallocate volumes of recycled content **only between the same battery model** produced within the same manufacturing plant. This ensures the legal constraints of Article 8 are met.

The amount of recycled content claimed in the outputs shall be equal to (or lower than) the amount of recycled material in the input over the accounting period. For instance, once the accounting period carried out by a supply chain actor for a specific unit of volume is concluded, there could be a surplus of recycled material in stock that has not been used in the production process during that accounting period. This would imply that recycled materials in the inputs is higher than recycled content in the outputs over the accounting period, resulting in a positive balance. This positive balance can be transferred to the next accounting period, as long as recycled material is physically in stock. **No negative balances** can occur. Conversion factors can be used for the balance, to account e.g. for losses.

In case of multi-output processes (e.g. a battery manufacturer producing different battery models), the **rolling average implementation method** shall be used: recycling content shall be attributed proportionally to the different outputs (i.e. proportionally across the different battery models) within the accounting period. Virtual allocation of recycled content shall not be permitted, as it hinders traceability and it goes against the principle of "clear, accurate and verifiable rules".

Rationale for point 2

This point remains unchanged. The arguments described above in section 4.2.2.1.3 are therefore also valid for option 2.

4.2.3 Calculations

4.2.3.1 JRC draft recommendations for the calculation of recycled content in batteries

Recommended formula for the calculation of recycled content of lithium (Li), nickel (Ni) and cobalt (Co) in active materials of batteries

1. The share for recycled content of lithium, nickel or cobalt in the active materials of a battery is calculated as follows:

$$ReCo(X) = \frac{\sum m(X)_{rec,output}}{\sum m(X)_{total,output}} \times 100, \text{[mass \%]} \qquad (1)$$

where:

X = lithium (Li), nickel (Ni) or cobalt (Co) in the battery active materials or lead (Pb) in the battery as defined in Article 8(2) and Article 8(3) of the Regulation (EU) 2023/1542;

ReCo(X) = calculated *share for recycled content* of the material X in the total mass of material (X) per its referring system for the purpose of Article 8(2) and 8(3) of Regulation (EU) 2023/1542 [in mass %]. In case of lithium, nickel and cobalt the referring system is the active materials in the battery; in case of lead the referring system is the battery;

$\sum m(X)_{rec,output}$ = *mass of material X (Li, Ni, or Co), in the active material (or precursors thereof) recovered from battery manufacturing waste or post-consumer waste or the mass of material X (Pb) in batteries (or precursors thereof) recovered from waste and all accounting for the share for recycled content, summed over the accounting period,* [in tonnes];

$\sum m(X)_{total,output}$ = *total mass of material X (Li, Ni, or Co), in active materials (or precursors thereof) or the total mass of material X (Pb) in batteries (or precursors thereof)*, summed over the accounting period, [in tonnes].

2. The recycled content of a material X (Li, Ni, Co or Pb) is expressed in mass percentage, [mass %].

3. The calculation point of recycled content shall be at the output of each step of the battery supply chain.

4. The mass of recycled material, to be accounted for in the battery, shall be based on the following output data provided by the preceding supply chain actor(s):

- the recycled content of material X in the supplied material, ReCo(X);
- the total mass of supplied material, m_{tot};
- the chemical formula of the supplied material.

For each step, the $m(X)_{tot}$ is calculated from the m_{tot} via the chemical formula of the supplied material and the $m(X)_{rec}$ is calculated from the $m(X)_{tot}$ via the ReCo(X) as follows:

$$m(X)_{rec,output} = ReCo\,(X) * m(X)_{tot,output} \qquad (2)$$

5. The share of recycled content, if calculated per mass balance rolling average (4.2.1) shall take into account all the inputs and changes in stock to the step of the battery supply chain to which the calculation applies. Losses shall be calculated for each step of the battery supply chain and for any applied chain of custody model.

6. To account for losses of recycled material (X), the following formula shall be used:

$$m(X)_{rec,output} = m(X)_{rec,input} * cf \qquad (3)$$

where:

$m(X)_{rec,output}$ = as defined above.

$m(X)_{rec,input}$ = *mass of material X (Li, Ni, or Co), in the active material (or precursors thereof) recovered from battery manufacturing waste or post-consumer waste or the mass of material X (Pb) in batteries (or precursors thereof) recovered from waste; and used as input in a step of the supply chain,* [in tonnes];

cf = conversion factor, as defined in section 4.2.1

4.2.3.2 Rationale for the recommended formula for the recycled content of lithium (Li), nickel (Ni) and cobalt (Co) in battery active materials and for the recycled content of lead (Pb) in batteries

The recommended formula shall be used to calculate the recycled content of lithium, nickel or cobalt in battery active materials or of lead in batteries for the purpose of Articles 8(2) and 8(3) of the Regulation (EU) 2023/154. The recycled content is defined as the ratio of mass of a recycled material over the total mass of that material in a product. In the case of lithium, nickel and cobalt, and as per the abovementioned articles, the product shall be the total mass of active materials in a battery and not the battery itself. In case of lead, the product is the battery itself. Expressed in mathematical equations:

$$ReCo(Li, Ni\ or\ Co) = \frac{mass\ of\ recycled\ material\ \text{(Li,Ni,or Co)}\ in\ battery\ active\ materials}{total\ mass\ of\ material\ \text{(Li,Ni,or Co)}\ in\ battery\ active\ materials}$$

$$ReCo(Pb) = \frac{mass\ of\ recycled\ material\ \text{(Pb)}\ in\ battery}{total\ mass\ of\ material\ \text{(Pb)}\ in\ battery}$$

If one defines a referring system for the calculations as such:

- (Li, Ni, or Co) referring system = battery active materials
- (Pb) referring system = battery

The above formulae can be written in a concise way:

$$ReCo(X) = \frac{mass\ of\ recycled\ material\ \text{(X)}in\ the\ referring\ system}{total\ mass\ of\ material\ \text{(X)}in\ the\ referring\ system}$$

In any case, Article 8 of the (EU) 2023/1542 sets targets for the battery to be placed in the EU market, which is also the calculation of the recycled content. In other words, for lithium, nickel and cobalt, the recycled content is calculated for the active materials, but these values of calculated recycled content shall be compliant with the targets only at the final battery configuration. In fact, a battery may consist of a single cell or multiple cells configured in module or pack design: the total mass of active materials in a battery can only be determined at the final battery manufacturing. Expressed in a mathematical equation:

$$total\ mass\ of\ battery\ active\ materials = \Sigma\ (mass\ of\ cell\ active\ materials)$$

where the mass of cell active materials is the mass of active materials of each cell making up the final battery configuration and the sum includes the number of all cells in the battery to be placed in the EU market. Consequently, the total mass of a material X in the active materials of a battery can also be determined only at the final battery design and is expressed as:

$$total\ mass\ of\ material\ X\ in\ battery\ active\ materials = \Sigma\ (mass\ of\ material\ X\ in\ cell\ active\ materials)$$

As above, the sum includes the number of all cells in the battery to be placed in the EU market. The total mass of material X in cell active materials and the total mass of cell active materials are bijectively connected through the chemical formula of the active materials. Such chemical formula also defines, in commercial terms, the battery chemistry. Table 2 provides examples of mass of a material X, cobalt, per 100 g of active materials for different battery chemistries.

Table 2. Mass of cobalt in 100 g of active materials for different battery chemistries

Battery chemistry	Chemical formula of the active material	Cobalt in the active material per chemical formula [mass%]	Mass of cobalt in the battery chemistry [g]
NMC111	$LiNi_{0.33}Mn_{0.33}Co_{0.33}O_2$	20.28	20.28
NMC811	$LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$	6.06	6.06
NCA	$LiNi_{0.94}Co_{0.04}Al_{0.02}O_2$	2.43	2.43
LCO	$LiCoO_2$	60.21	60.21

Source: JRC own elaboration

The total mass of material X shall have a recycled content that is always known along the battery supply chain and that allows to calculate the mass of recycled material (X) as follows:

$$mass\ of\ recycled\ material\ X = total\ mass\ of\ material\ X * recycled\ content$$

For each step of the battery supply chain the mass of material (X) is preserved according to the conversion factor (cf) of the process(es) occurring at that step. This is, in another way, a measure of the losses of material (X) along the battery supply chain and is expressed as:

$$mass\ of\ material\ X\ in\ output = mass\ of\ material\ X\ in\ input * conversion\ factor$$

The conversion factor is expressed as a fraction between 0 and 1 so that the mass of material X in output and in input keeps the same unit of measurement. Each supply chain actor shall define the conversion factor for the corresponding step in order to calculate the losses for that step and possible changes on the mass of recycled material X in output to that step. In addition, the supply chain actor shall calculate the mass of material X in input, knowing the recycled content in the supplied material from the preceding supply chain actor, the total mass of material (X) and the chemical formula of the shipped material. With these data, the recycled content and the mass of recycled material at the output of each step of the battery supply chain can be calculated. In Table 3, an example is given for the calculation of recycled content at a single step of the battery supply chain where:

cobalt, Co = material (X);
active materials manufacturing = step of the battery supply chain;
metal refiners, MR = preceding supply chain actors;
cobalt sulphate, $CoSO_4$ = supplied material;
cathode active material NMC811 = material at the output of the step of the battery supply chain.

Table 3. Example for the calculation of recycled content at a single step of the battery supply chain

Chemical formula	m_{tot}	ReCo(Co)	Molar Mass of $CoSO_4$	Molar Mass of Co	$m(Co)_{tot,input}$	$m(Co)_{rec,input}$	cf	$m(Co)_{tot,output}$	$m(Co)_{rec,output}$	ReCo(Co) in NMC811
	[ton]	[%]	[g/mol]	[g/mol]	[ton]	[tons]	[-]	[tons]	[tons]	[%]
$CoSO_4$	18.0	20%	154.99	58.93	6.84	1.37	0.95	8.31	1.30	16%
$CoSO_4$	5.0	0%	154.99	58.93	1.90	0.00				

Source: JRC own elaboration

In the next step, e.g. of cell manufacturing, with the chemical formula of the NMC811 ($LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$), the calculations can be reiterated to know the mass of recycled cobalt in the shipped mass of material with ReCo(Co) = 16%. As indicated in Table 3, if more fractions with different mass of recycled material (X) or mixed fractions of material with recycled and primary cobalt are mixed together, all the contributions shall be taken into account in the calculations.

4.2.4 Verification

4.2.4.1 JRC draft recommendations for verification

1. Traceability system

Battery manufacturers shall ensure:

a) they develop a study supporting the recycled content share referred to in Article 8, as specified in the applicable conformity assessment modules (Annex VIII of the Regulation).
b) the reliability of data used for the calculation of the recycled content share referred to in Article 8 as well as the proper implementation of the relevant calculation methodology by having an established traceability system that:
   - ensures traceability across the entire chain of custody up to the finished battery model product;
   - ensures that all supply chain operators collect the necessary documentation as specified in point (2); and
   - provides the notified body access to the documentation that supports the data used for the calculation of the recycled content share, in an unrestrained manner across the entire chain of custody.

All supply chain actor in the chain of custody shall fulfill the requirements of the battery manufacturer, including the selected chain of custody model.

2. Documentation

To be compliant with the requirements described in the applicable conformity assessment modules (Annex VIII of the Regulation), battery manufacturers shall have at plant manufacturing level systematic, orderly and comprehensive documentation of at least:

a) a description of the production processes including chemical reactions of Li, Co, Ni and Pb containing materials, if material transformation or mixing takes place;
a) a description of the parts and characteristics of the relevant input and output materials containing recycled material at manufacturing plant level, if material transformation or mixing takes place;
b) information on the relationship between recycled content in the accounting periods and the percentage share of cobalt, lithium or nickel that is present in active materials and that has been recovered from battery manufacturing waste or post-consumer waste, and the percentage share of lead that is present in the battery and that has been recovered from waste, for each battery model per year and per manufacturing plant;
c) receiving records for contiguous accounting periods, including supplier name, supplier address, and supplier contact details, data of shipment, quantity of shipment specifying total mass and recycled content and product characteristics including chemical composition, and a unique identifier of the shipment. For inputs containing recycled material, also certificates of proof that inputs originate from eligible waste materials as specified in Article 8 of the Regulation, and information on the chain of custody model applied to trace and calculate their recycled content share in previous steps.

Upstream supply chain actors to the battery manufacturer shall have at production plant level systematic, orderly and comprehensive documentation of at least:

a) production process flowcharts and the production processes including chemical reactions of Li, Co, Ni and Pb containing materials, if material transformation or mixing takes place;
b) a description of the parts and characteristics of the relevant input and output materials containing recycled material at production plant level, if material transformation or mixing takes place;
c) a list of suppliers for and customers of recycled material;
d) receiving records for contiguous accounting periods, including supplier name, supplier address, and supplier contact details, data of shipment, quantity of shipment specifying total mass and recycled content and product characteristics including chemical composition, and a unique identifier of the shipment. For inputs containing recycled material, also certificates of proof that inputs originate from eligible waste materials as specified in Article 8 of the Regulation, and information on the chain of custody model applied to trace and calculate their recycled content share in previous steps;
e) shipping records for contiguous accounting periods, including customer name, customer address, customer contact details, shipping date, quantity of shipment specifying total mass and recycled

content and product characteristics including chemical composition, chain of custody model and its implementation details including accounting period of the shipped material, and a unique identifier of the shipment;

f) the calculations, if material transformation or mixing takes place;
g) the details of all the plant-specific data in relation to conversion factors and stocks, including underlying documentation needed to establish the reliability of the company-specific data on conversion factors and information on mathematical treatments applied to the data, if material transformation or mixing takes place;
h) any other data required for the calculations.

Supply chain actors shall keep the documentation for 10 years after the output leaves the production plant.

3. Verification

Notified bodies shall verify that:

a) calculations for the recycled content share in batteries referred to in Article 8 performed by the battery manufacturer are correct, reliable, appropriate, of acceptable accuracy, and performed in accordance with requirements laid down for traceability and calculation;
b) data and information used for the calculation of the documentation for the calculation of the recycled content share are accurate, complete, consistent, reliable and traceable;
c) all company-specific data used in the calculations are appropriate and in compliance with the requirements laid out in this Annex, addressing in the verification:
d) coverage, precision, completeness, representativeness, consistency, reproducibility, sources and uncertainty;
e) plausibility, quality and accuracy of the data;
f) quality and accuracy of the underlying documentation;
g) conversion of Li, Co, Ni and Pb mass in chemical reactions and measurement units are correctly applied; and
h) the output supplied to customers from production plants at each supply chain step does not exceed the percentage of input with containing recycled materials received at the production plant, taking into consideration plant-specific conversion factors for contiguous accounting periods.

The assessment shall include a review of the data used in the calculations. In addition to a required assessment visit to the premises of a manufacturer of batteries manufactured in series, it may include an assessment visit to:

a) the manufacturer's premises of batteries not manufactured in series;
b) the cell, anode, and cathode production premises;
c) the cathode active material production premises;
d) the anode active material production premises;
e) the metal refiner production premises;
f) the metal recycling premises; and
g) where considered important, the premises of one or more of any other production sites for which company-specific data were collected.

The notified body shall identify uncertainties that are higher than expected and assess the effect of the identified uncertainty on the total outcome of the documented recycled content.

4.2.4.2 Implications and rationale of the recommendations

The first point of the draft recommendations (**point 1**) sets out an obligation of the battery manufacturer in line with point 1 (description of the module) for Conformity Assessment Producers D1[29] and G[30], as per Annex VIII of the Batteries Regulation. It is the own responsibility, and without affecting the obligations of other economic operators, that the batteries in question comply with the relevant requirements. Battery manufacturers need to ensure that they receive accurate, precise, complete, reliable and verifiable data to underpin the documentation and calculation of the recycled content in a battery to be placed on the EU market. As outlined in section 3.2.1 of this report, a traceability system is a "*manual or electronic system that provides the ability to access any or all information relating to the material or product under consideration throughout their life cycle, by means of accessing documented information*". A challenge is that the chain of custody is not defined in advance, and that a specific supply chain actor may not be able to track all the different destinations of products. For instance, looking downstream, a manufacturer may not be able to track all the different destinations of products. Similarly, a manufacturer might be unaware of the identities of tier 2 suppliers (the suppliers to its suppliers) and those further upstream, amongst other because of confidentiality issues amongst supply chain operators. Hence, it is the responsibility of the manufacturer to set up a data collection system and/or contractual agreements, to ensure that traceable connections and information transfer (as specified in point (b)) exist between different supply chain operators with a view to secure traceability along the entire supply chain. Different models for sharing traceability data across organisations are available ("one step up, one step down", "centralised", "networked", "cumulative", "decentralised and replicated" ; see section 3.2.1 for details) to comply with this requirement. All supply chain actors shall fulfill the requirements that have been established by the battery manufacturer. The JRC draft recommendations also propose that the traceability system set up by the manufacturer grants notified body access to the documentation outlined in point (2) to ensure they can meet their obligations on verification as set out in point (3).

The proposal under point (1) directly builds on the guiding elements and principles outlined in section 4.1. In our view, it is a suitable way forward that builds on established practices from existing standards and certification schemes, and permits to ensure accurate and verifiable rules to build trust. For instance, many voluntary certification schemes rely on the principle of "end-to-end traceability" (defined and explained in more detail in section 3.2.1), and have mechanisms in place to verify that the complete supply chain is subject to control, often based on the involvement of third parties (cf. section 3.3.1 and Annex 2 for records of such requirements established in voluntary or mandatory certification schemes). At the same time, flexibility is permitted for the battery manufacturers to set up a traceability model of their choice, for instance to allow them to determine their own balance between confidentiality and transparency. For instance, the "one step up, one step down" models can depart from a need for contractual agreements that will ensure that every single supply chain operator shares at least minimum documentation that is essential for the requirements of Article 8, without risking uncovering of commercially sensitive information. Battery manufacturers and supply chain operators who would foster full transparency may benefit from, for instance, the "cumulative" system that can ensure that full information from each supply chain operator makes his way to the battery manufacturer. They may implement any system or their own control or with the involvement of a third-party organisation, on condition that the notified body has access to the documentation all necessary documentation in an uncontrolled manner across the entire chain of custody.

The proposed requirements under **point 2** represents the minimum documentation that the battery manufacturer and the different supply chain actor have to collect at the production plant level. A set of general requirements for the battery manufacturer are already in the description of the conformity assessment module they have to adhere to as per Annex VIII of the Regulation. To specify this, information is on specific production processes and products where recycled materials are involved are requested, and how the calculations performed for different accounting periods the obligations of the manufacturer spelled out in Article 8 of the

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[29] Module D1: 1. Description of the Module: Quality assurance of the production process is the conformity assessment procedure whereby **the manufacturer** fulfils the obligations set out in points 2, 4 and 7, and ensures and **declares on its sole responsibility, without prejudice to the obligations of other economic operators in accordance with this Regulation, that the batteries concerned meet the applicable requirements laid down in Articles** 7 and **8**, or, at the choice of the manufacturer, all applicable requirements laid down in Articles 6 to 10 and Articles 12, 13 and 14.

[30] Module G: 1. Description of the Module: Conformity based on unit verification is the conformity assessment procedure whereby **the manufacturer fulfils** the obligations set out in points 2, 3 and 5, and ensures and **declares on its sole responsibility, without prejudice to the obligations of other economic operators in accordance with this Regulation, that the battery** concerned, which has been subject to the provisions of point 4, **is in conformity with the applicable requirements laid down in Articles** 7 and **8**, or, at the choice of the manufacturer, all applicable requirements laid down in Articles 6 to 10 and Articles 12, 13 and 14.

Regulation (point a), b) and c)). Finally, information from downstream supply chain actors need to be collected requesting proof for the recycled materials received (point d)).

The documented that should be made available for the downstream supply actors will facilitate to (i) ensure traceability throughout the chain of custody, (ii) corroborate that the output supplied to customers from a specific production plant across the supply chain are in line with the input with specified characteristics received at the production plant (thus controlling for "mass balance fraud"), and (iii) perform the calculations to document and certify the recycled mass and content for every shipment to a downstream customer.

The production plant level is chosen in line with the traceability approach outlined in section 4.2.2. The selection of the production plant level is key to keep a similar aggregation level of documentation between supply chain actors and battery manufacturers. It is thus aligned to the requirements in Article 8 for the battery manufacturer to prepare documentation about the percentage share of recovered metals for each battery model per year and per manufacturing plant. By proposing to aggregate documentation at production plant level, there is no need for firms to set up complex material accounting and tracing systems at a higher level of aggregation, whilst allowing notified bodies to also set up effective verification systems to control for mass balance fraud when receiving inputs and outputs of recycled materials. The difficulties of such verification would significantly escalate if the scope were expanded to include group-level operations, with production plants situated in various countries and regions, and materials moving through these highly complex supply chains. This is in line with the "keep it simple" principle, outlined in section 4.1.3 of this report.

The data and documentation requirements in letters d) and e) of point (2) will be used as data input for the calculations (letter f)) to control for mass balance fraud, and to enable providing documentation on the mass of recycled material and accompany for every single shipment and customer. As a minimum to ensure traceability across the supply chain, information on the identity of suppliers and customers of input and output materials entering and leaving the production plant is required (letters c), d) and e) of this point (2)). This will enable to uncover the entire supply chain when required, providing opportunities to collect documentation from the different organisations in the chain of custody. Information on the identity of the direct upstream and downstream organisations in the supply chain is a necessary minimum for all traceability systems that a battery manufacturer can apply, in line with point (1). Clearly, standard data (e.g. supplier address, contact details, shipment dates, unique identifier of the shipment) as well as basic input data for the calculation (quantity of shipment specifying total and recycled mass, information on the chain of custody model applied) are also required for the calculations as set out in section 4.2.3.

Complementary information and (production) plant-specific data (letter g)) on material conversion losses and stocks are required to monitor input-output recycled material balances at the production plant level and thus to control for potential mass balance fraud.

To enable verification procedures, default technical information on the production process, description of the input and output materials and its components are required (letters a) and b) of point (2)). Note that contrary to the battery manufacturer, the requirement to collect such information is not yet specified in the description of the conformity assessment modules as per Annex VIII of the Regulation. The JRC recommendations propose a particular focus on Li, Co, Ni and Pb containing materials that are processed at the production plant, and a need to specify any chemical reactions that take place for such materials. This is the minimum essential information to properly trace and calculate mass of (recycled) Li, Co, Ni and Pb that undergoes a change in chemical composition, as commonly occurring at different stages of the supply chain. This documentation will enable notified bodies to verify if the conversions of Li, Co, Ni and Pb mass in chemical reactions are correctly applied for all calculations.

Some requirements (e.g. letters a), b), f) g)) are only applicable when material transformation takes place. The reason for specifying this is that some supply chain organisations (e.g. middlemen, traders) only transfer and trade materials in the supply chain, but do not have an active role in material transformations.

It is proposed that supply chain actors shall keep the documentation for 10 years after the output leaves the production plant. This period is aligned to the period of 10 years for the battery manufacturer for keeping technical documentation, including studies supporting the recycled content share referred to in Article 8, at the disposal of the national authorities after the battery has been placed on the market.

The responsibilities for the notified bodies are listed under **point 3**, and largely similar as the proposed procedures already developed for verification of the battery carbon footprint[31]. In simple terms, the proposal indicates that notified bodies have to review calculations and the completeness, consistency, reliability and traceability of the input data for these. This applies not only for the calculations of the recycled content share in the battery, but also for data containing information on (recycled) materials that are transferred between supply chain operators upstream. To do so, they can review and may perform an assessment visit at the premises of the battery manufacturer and other supply chain actors.

[31] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13877-Batteries-for-electric-vehicles-carbon-footprint-methodology_en

5 Conclusions and next steps

5.1 Technical background

The technical background reviewed in this report points to the complexity of the supply chain, extensive and global trade in battery precursor materials. Multi-input and multi-output processes are common steps in battery manufacturing processes, and span batch as well as continuous production methods. Current industry practices to claim recycled content often rely on mass balance approaches with flexible allocation rules and complex bookkeeping and credit systems to attribute recycled content to downstream products. The decoupling of physically present and claimed recycled content is perceived by certain industry actors as providing benefits. It enables a greater flexibility to meet recycled content requirements and demands and adopt flexible trade strategies as a function of claimed recycled content, whilst limiting recycled outputs claims to actually corresponding waste inputs in the larger system. It also reduces the need for supplementary logistical distribution of materials containing physically recycled content. On the other hand, certain customers of battery precursor materials and citizens may prefer an intimate connection between claimed and physically recycled content as they require knowledge of material characteristics (e.g. to ensure quality control systems and mechanisms of final products containing recycled precursors), and perceive a greater credibility and trust when such claims are made.

5.2 Traceability as a key basis for this report

Traceability is defined as the "*ability to trace the history, application, location or source(s) of a material or product throughout the supply chain*". Different traceability models exist that vary in their potential to ensure traceability and provide flexibility, with clear trade-offs across all chain of custody model. The models have differential impacts on the implementation of administrative, logistical, and organisational structures in the batteries supply chain recycled content in batteries. Hence, it is a key aspect of the JRC recommendations and this draft report. The selection of a suitable chain of custody model depends upon the desired benefits and quality sought by the stakeholders and, in case of the Batteries Regulation, the co-legislator.

Importantly, Article 8 of the Batteries Regulation has set strict boundary conditions that limit the room for manoeuvre in the upcoming JRC proposals and delegated act establishing the methodology for the calculation and verification of recycled content in batteries. Not only Article 8 indicates that documentation should be specific for each battery model per year and per manufacturing plant, it also signposts that a clear connection should be established between the recycled content present in the battery and the documentation. This was a deliberate choice of the co-legislator at the moment of adopting the Batteries Regulation, and coherence of the JRC proposal with the text of Article 8 of the Regulation is thus one of the guiding elements for this study. Hence, the application of certain, more flexible chain of custody models (e.g. book and claim, mass balance with a highly flexible credit system) are not recommended as incompatible with the traceability approach set out in the Regulation.

5.3 Current state of the report

Within those boundary conditions, the JRC has come forward with draft technical recommendations on traceability, and related calculations and verification procedures (section 4.2). The JRC has presented two different traceability options for discussion in this report. They largely build on existing standards and certification schemes that have already developed a vast landscape of guidance and expertise for sustainability claims, including recycled content. They aim at providing an avenue to calculating and declaring recycled content in batteries that accommodate, within the limits set out in section 5.2, existing production processes and procedures within the battery supply chain.

We have attempted to bring forward concrete recommendations for the calculation and verification rules, as well as arguments that support the choices of the preferred options for traceability, calculation and verification. We aimed to be specific rather than unflawed at this stage, to encourage further discussions based on a tangible text. At this stage, the JRC draft recommendations for the calculation and verification rules are per definition not finalised and classify as "work under development". First, it requires further improvements based on inputs and considerations from a broad set of stakeholders. Second, the wording and formulations currently applied in section 4.2 are not final and will surely benefit from a solid review by other experts and colleagues with complementary backgrounds and expertise.

5.4 Next steps of the study and stakeholder workshops

We are confident that the current draft version provides a concrete starting point to scale up the discussions and technical knowledge base to further develop the final JRC recommendations in the next step of our study. It will serve as a background document for a stakeholder meeting on 27 November. At this stage, the JRC is looking forward to receive critical feedback from experts in the field from industry, NGOs and Member States at a stakeholder workshop. We kindly request constructive feedback possibly including new suggestions that are viable within the framework and legislative settings of Article 8, and underpinned by clear, concrete, and technical argumentation.

The JRC will then further develop and adapt the report after a careful evaluation of feedback, and a consideration of the different stakeholder perspectives. The intention is to present an updated and pre-final version of this document for discussion at a final workshop, tentatively planned for Q2-2025. This timeline should permit JRC to finalise and publish the final report later in 2025.

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List of abbreviations and definitions

[to be developed for the final report]

Term	**Definition**

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Annex 1. Detailed information on value chains

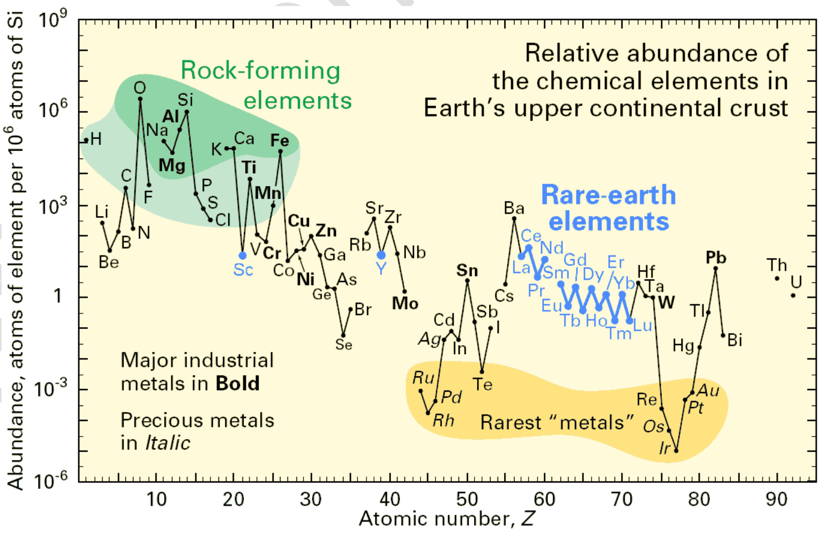
A1.1. Market and sources of primary materials

A1.1.1. Lithium

Lithium is an alkaline metal of the I group of the periodic table and, after hydrogen and helium (but first among the solids), the lightest element of the periodic table with an atomic weight of 6.9. These two characteristics make it a good electron exchanger for (lithium-based) batteries. Lithium is a relatively abundant element of the Earth crust (**Figure 12**) and it is present in three main sources: minerals of spodumene or petalite and salt-brines. While brines contain ~70% of the global reserves (and 50% of the global resources), hard-rocks of spodumene and petalite provide about 70% of produced primary lithium. The value chain is globalised with most of the world extraction occurring in Australia (minerals) and South America (brines) and refining in China. However, given the little price of lithium, the very first processing steps occur close to the extraction site to minimise the costs of a relatively cheap, not-yet valorised material. Both α-spodumene and petalite, two aluminium-silicate minerals are converted into β-spodumene then leached in sulphuric acid, H_2SO_4, and converted in lithium carbonate, Li_2CO_3 which is the most common commercial form of lithium compounds. In fact, also when the process starts from brines, the final result is Li_2CO_3. A challenge in lithium production is its partial replacement in the ore themselves by sodium or potassium; magnesium is also an impurity of lithium minerals. On the other hand, such affinity of lithium with more common sodium and magnesium paved the way to explore new battery chemistries, namely sodium- or magnesium-based.

Before lithium-based batteries, the demand of lithium was pulled by pharmaceuticals and glass and ceramics industry, with other applications being lubricants and greases, air treatment, aluminium alloys, polymers and continuous casting. Lithium volumes used for these sectors are stable, while the battery sector is largely expanding. Furthermore, many of these applications are dissipative (e.g. pharmaceuticals, polymers, lubricants and greases) and recycled in closed-loop (specialised glass) limiting the source of recycled content mainly to lithium-based batteries (section A1.2.1).

Figure 12. Relative abundance of the battery chemical elements in the Eath's upper continental crust. Some elements (N, O, Si, Au) have been included as reference of relative abundance.



Source: JRC own elaboration based on (Haxel et al., 2002)

A1.1.2. Nickel

Nickel is one of the transition metals – together with cobalt and iron – of the group of the periodic table historically known as 'VIII B' – and, as the other elements in this group, it is known for its high reactivity in redox processes and is, hence, a good candidate for all reactions based on exchange of electrons, also in batteries. Nickel also has the important property of improving the strength, toughness, and corrosion resistance of any metal it is alloyed to, e.g. iron or steel: the main application of nickel is, in fact, in stainless steel. Nickel occurs in ores of sulphide and oxide minerals, with sulphides being the most relevant for industrial production as they also contain significant quantities of copper and minor quantities of cobalt and precious metal. Due to this natural co-occurrence of nickel, copper and cobalt in the same ore, very good recovery yields of these materials have been developed in e.g. recycling processes of batteries. Resources of nickel are worldwide distributed with major volumes located in Indonesia, Russia, Australia, Philippines and Canada. Resources on the European territory are found in Finland, Sweden, Greece and Albania, and Finland is the first producer of EU primary nickel and second to Russia for EU refined nickel (RMIS, 2024).

For the properties mentioned above, nickel is used in a variety of products. First of all, a wide variety of products are made of or contain stainless steel which alone covers ~70% of nickel demand. Secondly, it is used in the super alloys and high-strength steel too, products of growing importance and application, which might compete e.g. with batteries in the demand of this metal. Nickel is also used in plating applications given its resistance to corrosion, in electric and electronic equipment, in catalysts and, as mentioned above, in batteries. In this specific technologies, the demand is pulled by Li-based batteries of NMC (nickel-manganese-cobalt) chemistries and, in minor quantity, of NCA (nickel-cobalt-aluminium) chemistry. Demand of nickel in NiCd (nickel-cadmium) and NiMH (nickel metal-hydride) batteries is decreasing in volumes up to become negligible in 2030. In particular for NMC batteries, nickel content in the active materials is expected to increase in parallel to the decreasing content of the (more expensive and similar in properties) cobalt. Finally, compared to the other targeted materials, nickel has the peculiarity to be present not only in the active materials but also in stainless steel possibly used for the casing of battery modules and packs. In other words, given its widespread presence in various battery chemistries and battery components, among the targeted materials in Article 8 of the (EU) 2023/1542, nickel is the most abundant material in batteries. In 2023, nickel of battery grade was defined a CRM (Carrara, S. et al., 2023), since the bottleneck in the EU supply was identified in the refining capacity of the EU itself for battery grade materials. In 2024, nickel has been listed in the SRMs (Strategic Raw Materials), and, hence, defined critical according to the CRM Act (EC, 2024), because of the economic relevance and growing demand of its applications listed above. Given the very large volumes of stainless steel, this flow can be considered constant compared to the flows of super-alloys and Li-based batteries. These two might compete for the demand of primary nickel, but unlikely for the demand of secondary nickel for recycled content purposes – as explained below.

A1.1.3. Cobalt

As mentioned above, cobalt has similar properties to nickel and is hence also a good candidate as active material in batteries. Its strength in alloys makes it also requested in hard metal alloys for cutting tools and its magnetic properties make it used for magnet manufacturing. It is the rarest of battery materials (see **Figure 12**); the main resources are located in the Democratic Republic of Congo, Australia and Zambia with the first country holding ≈ 70% of the global resources (Carrara, S. et al., 2023). China remains, as for nickel and lithium, the main producer of refined material (almost 80% of the world production). Cobalt is extracted from ores that mainly contain other materials as copper and nickel: such co-occurrence, somehow similar to that in batteries, turned to be an advantage in developing recycling processes, as there was already knowledge on separation processes of those materials. Global production has increased of about 100 kt in the past 20 years (Gregoir et al., 2022; RMIS, 2024).

Main demand of refined cobalt is for battery-grade chemicals for Li-based batteries. The Cobalt Institute pointed out that there is not an exact trend in reducing cobalt content in Li-based chemistries but rather fluctuations depending on the price volatility of the material. The Cobalt Institute stated that the cobalt at the time was relatively low with consequent preferred manufacturing of NMC622 batteries over NMC811.[32] While the energy density is similar for the two chemistries, the NMC622 are more stable and have higher power exactly because of the cobalt content. Cobalt also has very strong magnetic properties and, in particular, the highest Curie temperature of all materials: that is why cobalt is used in permanent magnets to increase their coercivity and, especially, to increase their thermal stability (samarium-cobalt magnets that contain up to 66 wt.% of cobalt are operative up to temperatures of ≈800 °C). For its strength and resistance to corrosion, ≈15% of cobalt demand is destined to super alloys and hard metals, such as cutting tools. The great capacity of cobalt as electron exchanger made it largely used for catalysts, before than for batteries, although this application is mainly related to fossil fuel sector and thus expected to shrink in the next years. Another significant application, at end-use, of cobalt is in electric and electronic devices, and particularly in hard-disk drivers, semiconductors and integrated circuits (Carrara, S. et al., 2023). However, the main demand of cobalt in electronics still relates

[32] Source: bilateral meeting held in September 2024

to Li-based batteries, as LCO (lithium-cobalt oxide) batteries. Minor applications of cobalt include dissipative use in chemicals, pigments, adhesives. Cobalt is listed as critical by the EU since the first CRM list in 2011 (EC, 2011), given both its high supply risk and, above all, economic importance. With exception for batteries, all applications of cobalt are expected to be stable in demand volumes in the short/medium term with a possible shrinking in demand for catalysts. Whereas battery volumes may increase in a future, the co-evaluation of Co demand is uncertain as a tendency exists to lower cobalt content in NMC batteries or potentially replace these by cobalt-free batteries, such as LFP first and Na-ion.

A1.1.4. Lead

Lead is a metal of the IV group of the periodic table and it is the heaviest non-radioactive after bismuth with an atomic weight of 207.2. For such characteristics, it has been historically used for weights and military applications. In modern times, the main application is for lead-acid batteries. Although from **Figure 12**, it looks like lead is less abundant than copper, but also than lithium, nickel and cobalt, lead reserves are not concentrated in just very few countries. On the contrary, ~40% of lead reserves are concentrated in Australia, China and United States and the rest is worldwide distributed with reserves in Europe too (namely Poland, Sweden and Spain). For this reason, lead is not a critical raw material but rather one with the lowest levels of supply risk, despite an economic value above the criticality threshold (EC, 2023). Lead occurs mainly in sulfidic lead concentrates (e.g. galena) and in ores containing also zinc and copper, oxide lead concentrates exist but are of minor importance. Lead is also classified as hazardous element with potential carcinogenic effects and the European Commission is restricting its use more and more, see for instance Annex I of the 2023/1542/EC on 'Restriction on Substances'. On this, the International Lead Association reported that of the primary lead used in EU 80% is imported and the EC RMIS (RMIS, 2024) indicates EU as the second largest importer of primary lead. Also, ILA points out how lead is also a by-product of zinc and phasing out lead demand might affect zinc market as primary extraction of zinc would unavoidably produce significant amounts (and additional costs) of hazardous lead (and cadmium) waste to be safely immobilised and disposed. As analysed in section A1.2.4, recycling of lead and as side effect of zinc, would positively contribute to limit primary extraction of lead.

As already mentioned, the main application of lead is in lead-acid batteries, with ~84% of its demand (RMIS, 2024) and it will remain a stable sector until 2035, i.e. until the EC will ban vehicles with internal combustion engines, while the restrictions in 2023/1542/EC do not apply to batteries in vehicles. Other sectors of lead applications are: weights, radiation shielding, ammunition (although the EC is working for phasing out lead ammunition in favour for other materials, e.g. copper or bismuth), chemicals and alloys, sound insulation (lead has no natural resonance frequencies), stained glasses, pipes and corrosion-shielding for high-voltage cablings. While most of these sectors, apart from batteries, represent small and shrinking volumes of application, only corrosion-shielding for high-voltage cablings is increasing. More specifically, such application is relevant to protect the cablings from water-sea corrosion and it is expanding together with the demand of green energy transportation at large distance. As a result, high-voltage cabling is the only application with a growing demand of lead and able, perhaps, to absorb important amounts of (secondary or by-product) lead which might instead be destined to safely immobilisation and disposal.

A1.2. Market and sources of secondary materials

Availability of secondary sources of a material depends, similarly to primary materials, on the technological and economic feasibility of exploitation and, for secondary sources, this also depends on the applications in which the material itself is found. A key aspect, and also a bottleneck of the material recovery, is the collection of the waste to treat and convert it in secondary raw material. Such collection is not always possible for instance because of dissipative use of the application, e.g. the material is consumed during its use, or obvious difficulties of collection, e.g. for space and defence applications; or it could be further improved compared to current state.

Hence, a valid secondary source shall be one that could be collected when it becomes waste. Further, such source should contain the targeted material in a concentration and a form that would make the extraction technological and economic worthy. The secondary source does not necessarily have to be the same application for which the recycled content is required – batteries in this case – but, as it will result from the analysis of this chapter the recovery of materials for the recycled content usually occurs in closed loop.

A1.2.1. Lithium

Following, the sources of secondary lithium for recycled content in batteries are quite limited to batteries themselves. In fact, many lithium applications – pharmaceuticals, lubricants and greases, polymers and chemicals – are dissipative and excluded due to their nature: in 2016, the volume of lithium lost in use dissipation was 1.6 kt over the 3.2 kt of lithium in finished products used in the EU (Matos et al., 2020).

Other products as special glasses or ceramics are usually not collected for recycling given the cheap value of the finished product and the low price of the primary material. However, whether they are recycled, especially special glasses, this occurs in closed loop because it is more convenient technologically and economically. Contrarily to the previous products, Al-Li alloys are collected for recycling, but similarly to previous products they are recycled in closed loop into aluminium alloys (not necessarily of the same grade).

It is expected that neither the requirement for recycled content of lithium in batteries would change the trends in the (lack of) recycling of glass, ceramics and alloys for the recovery of lithium since pyrometallurgical recycling of these products will more easily provide back the same materials and the economic return is optimised in this way. At the same time, dissipative use of other products is not expected to be altered in a future. In conclusion, waste batteries can be considered as the only source of recycled content of lithium by the time the targets will enter into force.

A1.2.2. Nickel

Nickel has an End-of-Life Recycling Input Rate (EoL-RIR)[33] of only 16%, meaning that recycling of post-consumer waste containing nickel only contributes to its demand in the EU. Nonetheless, different EU policies (Battery Regulation, CRM Act[34], ESPR[35], etc.) are expected to positively impact on this rate overall. In fact, the EoL-RIR should be divided in two contributes that do not necessarily support each other: nickel from and is recycled as back to alloys and nickel from compounds (in batteries, catalysts) that is used in the goes back to nickel industry for secondary production of nickel compounds but also of alloys. As a matter of fact, stainless steels and the other Ni-containing alloys are recycled conveniently in a pyrometallurgical process, i.e. smelting the input material and obtaining three phases: matte, slag and alloy. This alloy might need more or less refining afterwards according to the type of material in input, the process, and the customer requests on the type of alloy. The less refined product obtained is pig-iron. Waste streams, instead, where nickel is present as a compound and not an alloy, e.g. catalysts and batteries, are recycled depending on the composition of the catalyst or battery and so both in alloys, via the same pyrometallurgical process described above, both in nickel compounds, mainly $NiSO_4$, in a hydrometallurgical process – i.e. leaching the material in an acid more or less selectively and then purifying the different materials in the acid. Hence, recycling of nickel in alloys is always a (semi-)closed loop recycling, meaning that for instance high-strength steel (also containing niobium) would be recycled into stainless steel (losing the properties of the niobium). In case of the other products, closed-loop recycling occurs as well as open-loop recycling. In particularly for batteries, NiCd and NiMH are mostly recycled to obtain steel and stainless steel, since they contain good amounts of nickel and iron and are poor of other, more valuable, materials. Differently, Li-based batteries are recycled to mainly obtain $NiSO_4$ and $CoSO_4$ to recover both materials and avoid that cobalt would be mainly lost as impurity of the produced alloy.

The Nickel Institute expects a shift in the demand from pig-iron to battery grade nickel, implying that process changes may occur at middle stage and smelting stage and may not impact recycling processes of mixed nickel sources. As for the demand of recycled nickel, flows of (recycled) stainless steel are so large that they might be considered constant and not interfering with other flows. The main competing sectors might be identified in super-alloys (incl. high-strength steel) and batteries but, as explained, secondary nickel for these two applications comes from different processes they should not hamper each other. The critical challenge for recycled content of nickel is expected to be traceability of nickel, considering it is recycled from a wide range of sources, whereas availability of secondary nickel would be a smaller concern than for cobalt and lithium[36].

A1.2.3. Cobalt

The high cost of cobalt as a commodity is a key driver for waste batteries recycling, since it is currently the most expensive material in batteries. As also mentioned in section 3.1.3, neither cobalt separation from similar elements, such as nickel and copper, nor separating cobalt from lighter elements, as lithium or aluminium, is a technological challenge. Thus, cobalt recoverability from batteries or waste streams with comparable

[33] The End-of-Life Recycling Input Rate (EoL-RIR) reflects the total material input into the production system that comes from recycling of post-consumer scrap. It is a measure of recycling's contribution to meeting material demand (RMIS, 2024).

[34] Critical Raw Material Act, (EU) 2024/1252

[35] Ecodesign for Sustainable Products Regulation, (EU) 2024/1781

[36] Source: bilateral meeting with the Nickel Institute.

composition and behaviour to recycling, e.g. electronics, is high compared to other materials (similarly to nickel). In fact, the RMIS reports an EoL-RIR of 22% for cobalt, although this index does not distinguish between the recycling of alloys and other Co-containing products (RMIS, 2024). Alloys, including super-alloys, are reasonably recycled back into alloys for the technological and economic convenience of the process. Additionally, some waste streams originate from business to business applications as industrial catalysts or hard metal cutting tools and are recycled in a closed loop. Hence, post-consumer waste of cobalt that can potentially contribute to provide recycled cobalt mainly involves waste batteries and waste electronics.

A1.2.4. Lead

Lead has been historically one of the most recycled material, being nowadays the most recycled not only in Europe (EoL-RIR = 80% according to RMIS) but also worldwide. Most of lead is recycled from batteries and, particularly, ≈80% of lead for batteries comes from (closed-loop) recycling. This is particularly positive if one considers the increasing EU restriction in lead products (see section A1.1.4). In fact, lead occurs in ores with copper (a strategic raw material) or zinc (an element of high economic value). Hence, primary lead is extracted as a by-product of the other two metals. The EC RMIS reports that lead primary production has reduced of ≈50% since 2000, whereas the tonnages of refined production from primary and secondary lead has remained unchanged. Therefore, about 50% of lead refined in EU comes from secondary sources. As regards batteries, recycled content of lead should not raise particular concerns as collection and recycling efficiencies of waste batteries can reach up to 95% in some regions (ILA-Lead, 2015).

In contrast with its well established recycling, lead does not have specific traceability standards or certification systems for recycled content, but rather self-declarations and warranties from the producers. This should be attributed to the large distribution of lead worldwide and its very low supply risk as well as to the absence of particular obligations by the legislation so far. On the other hand, lead value chains seem to be less complex than those identified for cobalt, lithium and nickel and ILA also assumed that recycled content targets will mostly be met by secondary lead sourced in EU because of practices already in place in the industry, more economically viable, easier on a regulatory perspective, and less costs for transport.

Finally, whereas volumes of demand are shrinking for most applications (see section A1.1.4), waste streams of such applications seem to not really contribute to supply recycled content of lead in batteries for different reasons: i) dissipative use (chemicals); ii) contaminated material (radiation shielding); iii) not significant (weights) or not feasible (ammunition) collection.

A1.3. Battery active materials production

A1.3.1. Lithium production

As the EoL-RIR of lithium is so far 0% worldwide, description of production of lithium only considers primary sources as indicated in section A1.1.1. It is also difficult to assess whether and how lithium production might occur in the near future from mixed primary and secondary resources, and the most likely scenario is that secondary sources as waste batteries will be fed to nickel production rather than lithium (or cobalt) production. In addition, given the growing lithium demand, production technologies for this material are the most innovating of the four target materials for recycled content.

Historical process of lithium production is extraction from spodumene in hard-rocks. The first step is concentration of spodumene through mild techniques as flotation or optical separation (based on reflective properties). The spodumene ore can then be leached in acidic or alkaline media, with the acidic one being the most common. First, the α-spodumene into β-spodumene to increase its solubility in the lixiviant solution that is sulphuric acid. The leaching liquor is separated from unleached silicates and then the solution is purified through purification: the undesired elements but more abundant elements in solution than lithium (, magnesium, calcium, aluminium and iron), are precipitated using a solution of sodium carbonate, Na_2CO_3. After filtration, further addition of Na_2CO_3 makes also lithium precipitate as Li_2CO_3. This product can be purified to battery grade, as it is the starting material for pCAM production (see section A1.4.1.1), or can be converted to Li(OH) depending on the customer requirement and the next battery manufacturing process.

Extraction from brines has been mainly developed in China and Argentina, which have vast resources of lithium brines in their salt flats ("*salars")*. This process has the advantage to have lithium already dissolved in an aqueous saline solution and it can be conceptualised more as a concentration than an extraction process. In fact, the brine is pumped to a pond and brought to evaporation to enrich the lithium content. Then, undesired materials such as again elements of the secondary and third group (calcium, magnesium, boron) are precipitated and the remaining lithium chloride, LiCl, is refined into Li_2CO_3 or Li(OH) and purified to battery grade. Hence, lithium production from brines, just before the refining step, recalls the process for salt kitchen production, with the only difference that the high altitudes of South-America *salars* allowed to keep in solution also the lighter lithium, next to the sodium.

Nonetheless, and for different reasons, both treatment of spodumene hard rocks and of brines produce large volume of by-products without relevant market value. In case of spodumene, it depends on the fact that it is extracted in open-mining from veins extended more horizontally than vertically and for the brines because, being the lightest solid, lithium is the least concentrated. Recently, technologies for direct extraction are developing in different areas of the world (Razmjou, 2024) with the benefit to directly extract the lithium ions from the brine considerably reducing the carbon, water and land footprint compared to both spodumene extraction and brine treatment. Processes for direct extraction of lithium are still under exploration but, especially processes based on adsorption or ion-exchange, might be commercialised in the short/medium term with a further potential contribution to a greener lithium supply.

A1.3.2. Nickel production

Production of nickel from its different sources has been developed through processes, pyrometallurgical, hydrometallurgical and pyro-hydrometallurgical, depending on the desired final product. For instance, a pyro-metallurgical process is typically used if the objective is production of Fe-Ni alloys, while a hydrometallurgical step is always necessary to obtain (battery-grade) nickel salts. In fact, Fe-Ni alloys refined into steel can also be used to manufacture the battery casing, but this section focuses on the production of active materials and that is on the production of $NiSO_4$. In this case, whether a pyrometallurgical process precedes the salts production depends on the type of source (oxides concentrates would not need a pyrometallurgical treatment), but it is the most typical case and it is the one described in this section. As for lithium, the production includes processes of material extraction from its sources, ores or waste, and of refining.

After beneficiation of primary ores to concentrate the content of the metal(s) of interest, the nickel-bearing material is sent to a smelter to produce a nickel matte. If the process treats both primary and secondary, e.g. waste batteries, sources of metals those can be mixed already at the smelting stage. In particular, waste Ni-Cd and NiMH batteries can be fed directly to the smelter but, with regards to the waste Li-based batteries, the process is not optimised to recover lithium. It has not been a particular issue with the targets into force before the (EU) 2023/1542, but a technology shift might occur from 2025 onwards with entering into force of the targets in Article 71 of the Batteries Regulation. In any case, it has to be noted that nickel is present in batteries not only in the active materials but also in the steel casing and, hence, the input of nickel from waste batteries might come from batteries of any chemistry with a steel casing. The output of main interest at the smelter is the nickel matte that is then sent to hydrometallurgical treatment to bring the metals in solution and separate them through typical stages of leaching in hydrochloric or sulphuric acid (depending on the type of input) with consequent solvent extraction and/or precipitation to separate the metal fractions as desired. Next to nickel, also cobalt and copper are products of the process and precious metals if present. Cobalt and copper are fractions deriving largely also from waste batteries (see also section A1.2), whereas precious metals are present in the battery management system but this would be an output of the nickel production only if the whole waste battery is fed to the process. It is more common, instead, that such component is separated in advance and in particular that the black mass (intermediate fraction rich in lithium, cobalt and nickel (Orefice et al., 2024) is more commonly fed to the nickel production process rather than at the pyro- or hydro-metallurgical step. Nickel stream is sent then to the refining stage to remove impurities and bring it to battery grade purity. As the first producer, also refiners might mix nickel fractions from primary materials and materials to recycle. They would have, then, to calculate the ReCo(Ni) rate of the outputs sent (sold or transferred in-house) to pCAM and/or CAM production. If the first producer of nickel is a recycler supplying material to the refiner (or directly to a pCAM/CAM manufacturer), the ReCo(Ni) of the material will be 100%, but it has to be averaged with ReCo(Ni) in the next manufacturing stages.

A1.3.3. Cobalt production

Similarly to the nickel case, also production of cobalt can be carried out from primary and secondary sources. Nonetheless, since in waste batteries normally the nickel content exceeds that of cobalt, as it occurs with ores, this waste stream is more commonly fed to nickel production rather than cobalt production. Secondary sources might still include spent catalysts or other waste streams as listed in section A1.2.3.

After beneficiation to enrich the, however little (just up to few wt.%), cobalt content in the ore, this is sent to pyrometallurgical treatment (also depending on the desired product, as for nickel) or directly to hydrometallurgical treatment if they contain arsenic or are oxides. As for secondary sources, for instance, as catalysts are usually based on Co-oxides, they would go directly to hydrometallurgical leaching; on the contrary, super-alloys and hard metals are fed to a pyrometallurgical step. The pyrometallurgical step consists of a oxidising or sulfatising roasting that serves to optimise the stream in input to the next leaching process that happens in sulphuric acid. Afterwards, the leaching liquor is purified in all its fractions, most usually copper, nickel and cobalt. In fact, about 98% of cobalt production is mined as a by-product of the first two metals. Purification of cobalt consists in its precipitation as a hydroxide which is then electrowinned to Co metal or converted into other salts or oxides, according to its application. The product for battery manufacturing is $CoSO_4$. Secondary cobalt from waste batteries can rather be obtained directly as sulphate, sent together with primary $CoSO_4$ for refining up to battery grade or as oxide (CoO), or as chloride ($CoCl_2$), and mixed at previous steps of the refining stage.

A1.3.4. Lead production

In PbA (lead-acid) batteries, the active mass is the PbO paste added on the positive and negative grids. Nonetheless, the grids are made of lead and particularly of Pb alloys and the production of both materials, PbO and Pb alloys starts from the lead bullion which is sent to the refinery to produce refined lead ingots and alloys. The most common alloy for PbA batteries is the Pb-Sb alloy that contains, next to lead, also antimony (Sb) to increase hardness of the alloy; arsenic (As) to increase resistance to corrosion and tin (Sn) to increase fluidity. The intermediate product lead bullion can be produced starting from primary and secondary raw materials in separate process lines or by mixing fractions of waste PbA battery to the smelter of primary lead production. The refining stage is usually carried out by mixing primary and secondary materials for efficiency of the process given that there are no significant chemical or physical differences between primary and recycled material. As a result, the ReCo(Pb) in output to the refining can be higher, equal or lower to the ReCo(Pb) in input depending on the ReCo(Pb) in each input fraction and the volume of those fractions. Traceability of the materials is extremely important at these stages, whereas losses at this stage of production are not relevant, as concentration of primary and secondary materials are homogenised in the smelters and hence no loss of ReCo(Pb) can be claimed.

A1.4. Batteries production

The recycled content targets are not specific for chemistries and, e.g. the recycled content target of nickel equally applies for nickel present in active materials of in Li-based, NiCd and NiMH batteries. Nonetheless, in this section a closer look will be provided only to the manufacturing of the two largest battery chemistries per volume on the market: Li-based and PbA batteries. In fact, the scope of the section is not that of a literature review, but rather highlighting the stages where the active materials are added and to understand the nature of the on-the-ground manufacturing steps that take place and might impact the calculation of rates of recycled content.

A1.4.1. Li-based batteries

A1.4.1.1. pCAM and CAM manufacturing: example of a NMC chemistry

The pCAM (precursor of the cathode active material) is the mixed nickel-cobalt-manganese salt used as precursor of the CAM (cathode active material) oxide, which also contains lithium and is deposited at the cathode. The process of pCAM manufacturing starts by mixing $NiSO_4$, $CoSO_4$ and $MnSO_4$ with NaOH to precipitate the mixed salt in the reaction below, where the pH is adjusted via addition of NH_4OH:

$$(1\text{-}x\text{-}y)\ \mathrm{NiSO4} + x\ \mathrm{MnSO_4} + y\ \mathrm{CoSO_4} + 2\ \mathrm{NaOH} \rightarrow \mathrm{Na_2SO_4} + \mathrm{Ni}_{(1\text{-}x\text{-}y)}\mathrm{Mn}_x\mathrm{Co}_y(\mathrm{OH})_2$$

Noticeably, this is also the last step of processes for the ‘direct recycling’ of waste batteries which have exactly as their objective the production of pCAM material via the co-precipitation of nickel, manganese and cobalt from the waste batteries recycling. The sodium sulfate is a by-product of the process, eventually destined to the detergent industry. The pCAM salt is filtered, washed and dried to be ready for the next step of CAM production.

To prepare the CAM, the NMC salt is mixed with Li_2CO_3 (or LiOH for high-nickel chemistries) and calcinated to liberate the carbonate. The reaction occurs as follows:

$$\mathrm{Ni}_{(1\text{-}x\text{-}y)}\mathrm{Mn}_x\mathrm{Co}_y(\mathrm{OH})_2 + 0.5\ \mathrm{Li_2CO_3} + 0.25\ \mathrm{O_2} \rightarrow \mathrm{LiNi}_{(1\text{-}x\text{-}y)}\mathrm{Mn}_x\mathrm{Co}_y\mathrm{O_2} + 0.5\ \mathrm{CO_2} + \mathrm{H_2O}$$

Regarding the anode, it does not contain any of the ReCo targeted materials and the AAM production more simply consists of refined particles of (synthetic or natural) graphite ready for the electrode manufacturing. Finally, lithium is present also in the $LiPF_6$ salt of the electrolyte, added at a later stage, but as the target only applies to active materials, i.e. CAM in this case, investigating ReCo(Li) in the electrolyte is out of the scope of this report.

The pCAM and CAM production are processes that would occur in continuous but they might also occur in batch depending on the needs and settings of the manufacturer as well as of the customers. They are the key steps, at cell level, for the control of recycled content rates in the final battery since, in the next stages, there is no addition of active materials. In particular, the final concentration of recycled materials in the CAM shall be carefully controlled if mixing pCAM stocks at different recycled content rates. Losses at these steps are not relevant for the recycled content rates as the materials are produced with a homogenous concentration.

In two separate process lines, the CAM and AAM are mixed with inert carbon black and with the binder and possibly other additives. As for the cathode production, the CAM is mixed with a PVDF[37] binder and carbon black and the mixture is suspended in NMP[38] solvent. A similar slurry is obtained for the anode. Such slurries are pumped to the coating machines to be deposited on the current collector sheets: aluminium is used as current collector for the cathode and copper for the anode. The thickness of the coating depends on the battery design. Next steps are: multi-stage drying to remove the solvents, compression of the electrode sheets, rolling and cutting of the sheets. Losses might occur in the first three steps and cut-off are unavoidably in the last one, however as this scrap material would be eventually recollected and reprocessed in the process line, ultimately potentially leading to low or negligible process losses at plant level.

The cell assembly is very design-dependent and, thus, different for pouch, cylindrical and prismatic cells. In any case, the scope is to build the cell structure including its housing. As first, the separator is introduced to wound the anode and cathode and each of the electrode connected to the corresponding contact terminals. Electrolyte is then added in a very controlled way to ensure homogenous distribution and absence of inactive areas in the assembled cell. At this stage losses of active materials are relevant when a cathode roll has to be entirely substituted, e.g. because of damaging: the new cathode roll shall have the same share of recycled material as the replaced one. Partial discarding of the cathode roll is, instead, not relevant due to a homogenous concentration on the roll itself. Again, in case of mixing of cathode rolls from different suppliers, the final concentration and the traceability of all the relevant materials is controlled by the cell manufacturer.

In the last steps of cell formation, the cells are prepared for the market and go through tests of charging and discharging (with, non-relevant at this scope, partial loss and replacement of the electrolyte), aging, and end-of-life behaviour. Cells that do not pass any of these tests become battery manufacturing waste. No mixing of materials from different suppliers occurs at this step.

A1.4.1.2. Module and battery assembly

The module and battery assembly is carried out either by the battery manufacturer. Several battery manufacturers in the EU carry out only these last steps with cells supplied from different geographic origins, including deliveries from outside the EU. The two steps have the similar scope of connecting and assembling together first cells in modules and then different modules in the battery pack. However, different options are possible: cells assembled directly in the pack without the module configuration or the final product might be the cell itself or a module, without the pack configuration. A key factor is, instead, the mixing of cells from different suppliers not only of same chemistry but more importantly of different chemistries (NMC811, NMC622, LCO) in the same battery pack or module. Any loss at such steps will become battery manufacturing waste which might contribute after its recycling to the recycled content rates of next batteries.

A1.4.2. PbA batteries

Manufacturing of PbA batteries starts with lead in two forms. PbO and Pb alloys, respectively used for the active mass and for the positive and negative grids. The active material consists of a paste of PbO mixed with sulphuric acid (H_2SO_4), water and additives to a thick consistency. As active mass, the PbO paste determines the capacity and lifetime of the final PbA battery. Next to that, Pb alloys are melted to produce the positive and negative grids, but also terminals and connectors. Grids of ordinary of open batteries are made of Pb-Sb alloys, grids of

[37] Poly-vinyl-diethyl-fluoride
[38] N-Methyl-2-Pyrrolidone

free-maintenance batteries are made of Pb-Ca alloys (or low-Sb alloys) and grids of valve-regular batteries are made of Pb-Ca alloys. In both steps of paste preparation and alloys smelting, losses are not relevant for the calculation of recycled content targets as the materials are to be considered homogenous. The next step is the pasting of the active mass on the grids and it is perhaps the most crucial for the recycled content rate of a PbA battery.

The paste is transformed into a solid porous skeleton bound to the grid during the curing; afterwards, the battery is assembled and the H_2SO_4 electrolyte is inserted carefully to ensure homogenous distribution. The next formation step is similar to that described for the Li-based batteries with the main difference that, if battery manufacturing waste is eventually produced and recycled, the lead recovered from there would not account for the rate of ReCo(Pb) in other batteries. Hence, overall, neither relevant losses of materials in these steps, nor mixing of materials.

Annex 2. Standards and certifications schemes for environmental and social sustainability claims

A2.1. Voluntary certification and standards for environmental and social sustainability product claims for (intermediate) products other than batteries

The United Nations Global Compact (UNGC) identified a number of multi-stakeholder initiatives that have already set up traceability schemes and/or standards for different commodities (see **Table 4**). An important factor that enhances the effectiveness of traceability schemes is collaboration among the different actors in the value chain. It is common practice to assign governance of the collaborative scheme to an independent body, in charge of storing relevant data and sharing information as well as of providing certifications (UNGC, 2014).

Table 4. Existing initiatives to trace sustainability targets for different product categories (non-exhaustive list)

Initiatives	**CoC models**	**Commodities**
Better Cotton Initiative (BCI)	segregation, mass balance	cotton
Fairtrade International (FTI)	segregation, mass balance	cocoa, cotton, coffee, flowers, fruit, gold, honey, rice, nuts, spices and herbs, sugar, tea, wine, textiles
Forest Stewardship Council (FSC)	segregation, mass balance	timber
Responsible Jewellery Council	segregation	conflict minerals, gold
Roundtable for Sustainable Palm Oil (RSPO)	segregation, mass balance, book and claim	palm oil
Textile Exchange	segregation	textiles
Rainforest Alliance - UTZ Certified	segregation, mass balance, book and claim	cocoa, coffee, tea, hazelnut
Marine Stewardship Council (MSC)	segregation	fish
Bonsucro	mass balance, book and claim	sugar

Source: (UNGC, 2014)

These standards provide clear guidelines for companies to handle and track certified materials. Adherence to these standards helps build trust with consumers, as they can be confident that the certified products they purchase are sourced responsibly and sustainably. In the specific context of sustainability, traceability serves as a tool to prove or validate sustainability claims associated with products.

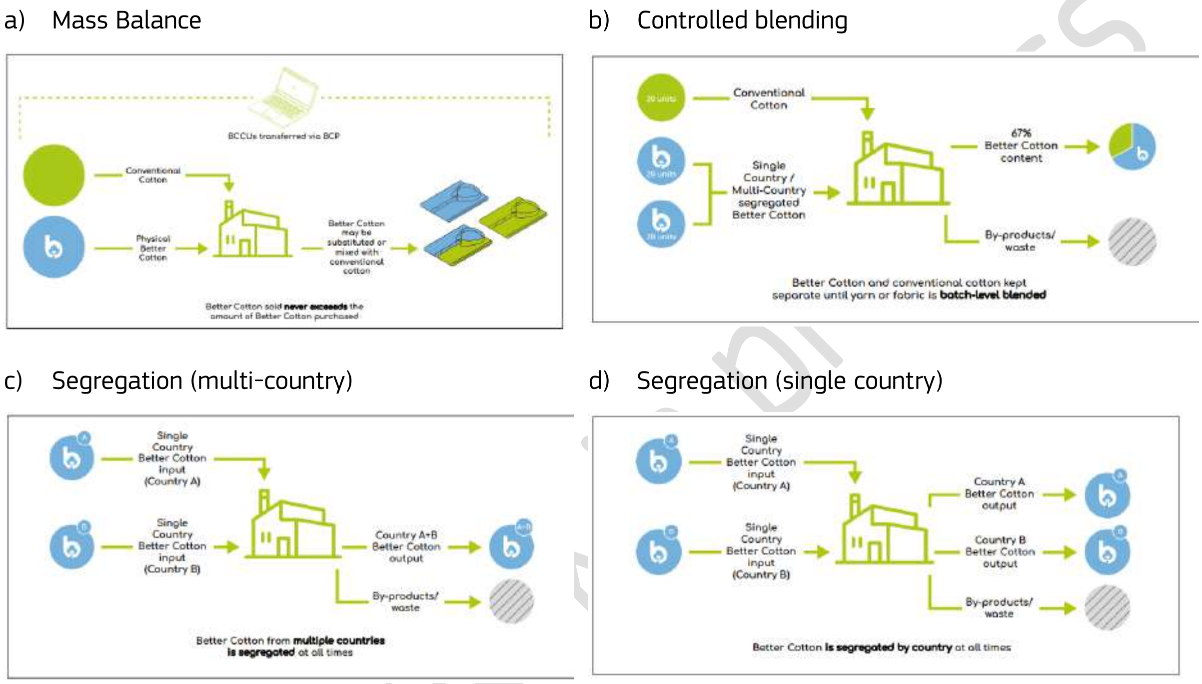
A2.1.1. Better Cotton Initiative

The Better Cotton Initiative was funded in 2005 and has more than 2500 members, including farmers, ginners, spinners, suppliers, manufacturers, brand owners and retailers, among other actors (BCI, 2024).

In 2023 BCI launched the Better Cotton Traceability[39], including a chain of custody standard, an enhanced digital platform for data collection (Better Cotton Platform) and a supply chain monitoring and assurance process.

The chain of custody standard lays down requirements applicable to all organisations involved in the Better Cotton supply chain, buying or selling virgin cotton produced in accordance with the Better Cotton Principles, the so-called Better Cotton (BC) (BCI, 2023).

Figure 13. Better Cotton chain of custody models



Source: (BCI, 2023)

The standard includes definitions of different types of chain of custody models (see **Figure 13**):

- **Mass balance**[40]: allows to transfer claims between BC products either through physical blending or virtually through the Better Cotton Claim Units. The mass of physical cotton sold cannot exceed the quantity of cotton purchased across the value chain. The organisations applying this model shall have procedures in place that control the identification of orders and inputs at material receipt.
- **Controlled blending**[41]: allows to mix BC with conventional cotton within a production batch. The claim corresponds to the proportion of physical BS used within the batch. This model can be used within a manufacturing activity from spinning mill onwards. The organisations using this model shall have procedures in place that control the identification of physical BC and conventional cotton inputs at material receipt. A specific formula shall be used to calculate the percentage of BC relative to the total volume of cotton within the production batch.
- **Segregation (multi-country)**[42]: does not allow mixing BC with conventional cotton at any stage of the supply chain. This model is to be applied when the physical BC originates from multiple countries. The organisations applying this model shall have procedures in place that control the identification of segregated inputs at all stages.

[39] Better Cotton Traceability: https://bettercotton.org/traceability/
[40] This model can be considered as a combination of the group-level mass balance and the book and claim described in section 3.2.
[41] This model corresponds to the batch-level blending model described in section 3.2.
[42] This model corresponds to the segregation model described in section 3.2.

— **Segregation (single country)**[43]: does not allow mixing neither BC from different sources nor BC with conventional cotton at any stage of the supply chain (segregation by origin or by country). The organisations applying this model shall have procedures in place that control the identification of segregated inputs at all stages.

The Better Cotton CoC Standard requirements apply globally to all supply chain organisations involved in buying or selling physical BC or fulfilling BC Mass Balance orders. This includes, but is not limited to, intermediaries and markets for raw seed cotton, ginners, merchants, lint traders, mills with spinning capabilities, mills or suppliers without spinning capabilities (such as fabric mills, dyeing mills, yarn and/or fabric traders, vertical mills), end-product manufacturers, sourcing agents, and retailers and brands with their own manufacturing capabilities. Organisations must include subcontracted (outsourced) activities within their verification scope where applicable. Amongst other requirements, subcontractors must agree to provide full access to their operations to enable both 2nd and 3rd party audits of the activity within the CoC Standard, if appropriate. Hence, this means that at each supply chain step can be subject to verification. The BC Initiative is able to trace value chains from finished products back to raw materials, navigating through various commercial boundaries (such as the sale of goods), logistics and process boundaries (like the manufacturing transformation of inputs into different outputs), ensuring that the sustainability claims of goods can be verified as the sum of their component parts ("end-to-end traceability").

All organisations applying a BCI chain of custody model shall maintain records of (BCI, 2023):

(a) date of supply / production;

(b) date of sale / delivery;

(c) identification of production batch, where applicable;

(d) physical/virtual BC input product;

(e) conventional cotton and non-cotton fibre input products, where applicable;

(f) output product, including countries of origin of physical BC, where applicable;

(g) quantities and characteristics of inputs and outputs;

(h) applicable conversion factors.

A2.1.2. Fairtrade International

Fairtrade International was founded in 1997 and is a non-profit, multi-stakeholder association of 22 members. It owns the Fairtrade Mark, a registered trademark that appears on more than 30000 products (FTI, 2024a).

FTI developed a series of standards[44] for different commodities. The Fairtrade Trader Standard applies to traders buying and selling Fairtrade products or handling the Fairtrade price and premium. It also defines requirements on traceability, to ensure that for each sale of Fairtrade product, an equivalent volume has been bought from Fairtrade producers and that Fairtrade products can be traced back to Fairtrade producers (FTI, 2024b).

All traders have to identify Fairtrade products in the documentation and must keep record of all entries, processing and sales of Fairtrade products. The documentation shall include (FTI, 2024b):

a) name and ID of the traders involved in Fairtrade transaction;

b) applicable dates of the transaction;

c) quantities and physical form of the product when transacted;

d) payment of Fairtrade price and premium and pre-financing.

Physical traceability aims to ensure that goods sold as Fairtrade products can be traced back to producers. It consists of **segregation** of Fairtrade product from non-Fairtrade products at all stages of the supply chain. It

[43] This model corresponds to the identity preservation model described in section 3.2.

[44] Fairtrade Standards: https://www.fairtrade.net/standard/fairtrade-standards

is mandatory for all traders, with the exception of those trading cocoa, cane sugar, fruit juice and tea, who can apply either segregation or mass balance (FTI, 2024b).

Mass balance is used to ensure that for each product sold as Fairtrade on the consumer market, an equivalent volume has been sold by producers under Fairtrade conditions. Each actor of the value chain shall ensure that the amount sold as Fairtrade does not exceed the amount of inputs sources as Fairtrade (taking into account processing yields and losses). All Fairtrade inputs shall be purchased before the sale of the Fairtrade outputs. Two types of mass balance models can be applied (FTI, 2024b):

— **Single site mass balance**[45]: Fairtrade inputs must be delivered to and processed at the same site where the Fairtrade output is processed.

— **Group mass balance**[46]: Fairtrade inputs do not need to be delivered to the same site that produces Fairtrade outputs. This model is allowed only for cocoa and cane sugar. All sites involved in group mass balance belong to the same group. One site needs to be designated as the central administration site, managing all information on purchases and sales for the whole group.

The verification procedure for this standard also involves 'end-to-end traceability'. It starts with supply chain actors involved in the production of Fairtrade eligible product and ends with consumer-ready products which are not transformed or repacked any further before sale to the consumer (FTI, 2024b). It requests all entities in the value chain to accept announced and unannounced audits of your premises, and the obligation to provide the certification body with all information it requests to verify compliance with this standard (FTI, 2024b). All value chain entities keep records of all entries, processing and sales of Fairtrade products. Records must enable the certification body to trace back from any given Fairtrade output to the Fairtrade inputs (FTI, 2024b). The central administration of the FSC standard delegates the function of inspection and certification to a certification body as an independent third party, who confirms that a value chain operator or specific lot of product(s) complies with the standard. When conducting audits, monitoring reports, and making certification and verification decisions, the certification body will adhere strictly to the precise wording of the requirements of the standard and their stated objectives. To achieve this, the certification body establishes technical compliance criteria for each requirement (FTI, 2024b).

A2.1.3. Forest Stewardship Council

FSC is an independent, non-profit organisation created in 1993. It is a leader in sustainable forestry and operates the most rigorous and trusted forest certification system (FSC, 2024).

FSC launched an online timber traceability platform, FSC Trace[47], to improve communication between certified members and to enable them to access and exchange relevant data. The platform is built on blockchain technology.

FSC developed the FSC chain of custody certification standard, laying down requirements and best practices for chain of custody management systems. The CoC includes all stages of the supply chain, from sourcing, processing, trading and distribution. Any change of ownership of FSC-certified products requires the establishment of a CoC management system (FSC, 2021).

It shall be ensured that only eligible inputs are used in FSC product groups, for instance:

— for outputs claimed as FSC 100%, only FSC 100% inputs can be used;

— for outputs claimed as FSC recycled x% or FSC recycled credit, only FSC recycled x%, FSC recycled credit, pre-/post-consumer reclaimed can be used as input.

Different FSC control systems can be used (see **Figure 14**):

— **Transfer system**: FSC claims of input materials are directly transferred to output materials. Segregation between eligible and non-eligible input materials is maintained at all stages of an organisation's processes.

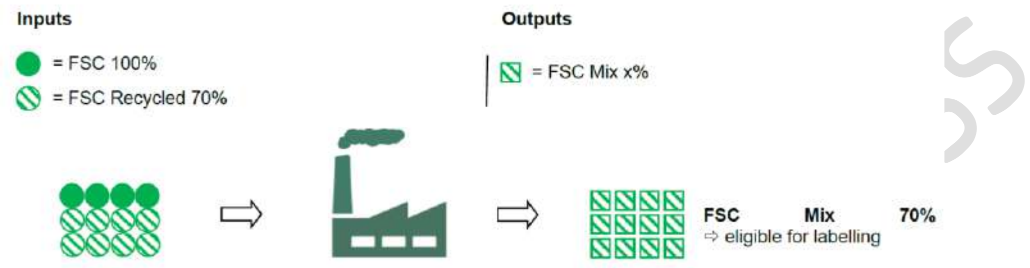
[45] This model corresponds to the site-level mass balance described in section 3.2.
[46] This model corresponds to the group-level mass balance described in section 3.2.
[47] FSC Trace: https://fsc.org/en/fsctrace

— **Percentage system**: allows all outputs to be sold with a percentage claim corresponding to the proportion of claim-contributing inputs over a specified claim period. This model is suitable for single or multiple physical sites.

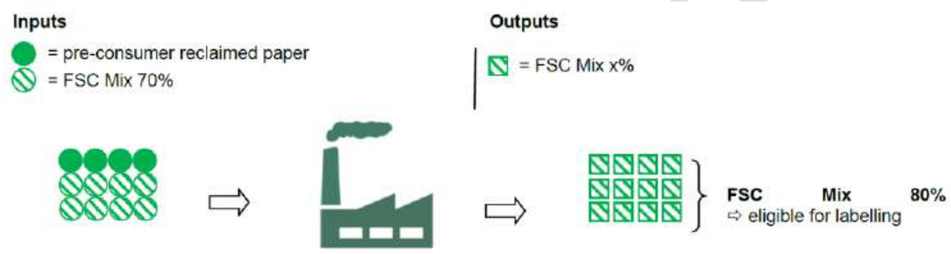
— **Credit system**: allows a proportion of outputs to be sold with a credit claim corresponding to the quantity of claim-contributing inputs and the applicable product group conversion factor. This model is suitable for single or multiple physical sites.

Figure 14. Examples of the application of the FSC control system

a) Transfer system



b) Percentage system



c) Credit system

Source: (FSC, 2021)

The credit system is an FSC control system which allows a proportion of outputs to be sold *with a credit claim corresponding to the quantity of claim-contributing inputs and the applicable product group conversion factor(s) (FSC, 2021). The credit system can be used for FSC Mix and FSC Recycled product groups at the level of a single or multiple physical sites (linked through common ownership).*

The organisation shall maintain material accounting records, including:

(a) inputs: supplier's sales document number, date, quantities and material category, including the percentage or credit claim;

(b) outputs: sales document number, date, production description, quantities, FSC claim and applicable claim period;

(c) FSC percentage calculations and FSC credit accounts.

For a product to be claimed as FSC certified, there must be an unbroken chain of organisations independently certified by FSC-accredited certification bodies covering every change in legal ownership of the product from the certified forest or point of reclamation up to the organisation selling it with an FSC claim on sales documents and/or to the point where the product is finished and FSC labelled (FSC, 2021). In order to confirm any changes that might affect the availability and authenticity of the supplied products, the organization shall regularly verify the validity and product groups scope of the certificates of their active FSC-certified suppliers through the **central FSC certificate database**. As such, the organisation shall ensure that only eligible inputs and the correct material categories are used. Organisations shall identify the main processing steps involving a change of material volume or weight and specify the conversion factor(s) for each processing step or, if not feasible, for the total processing steps. The organisation shall have a consistent methodology for calculating conversion factor(s) and shall keep them up to date. CoC certification is therefore required for all organizations in the supply chain of forest-based products that have legal ownership of certified products, but not for e.g. agents and auction houses arranging the trade of certified products between buyer and seller, or providers of logistics services (FSC, 2021).

Each organisation in the value chain shall complete the self-assessment in which the organisation describes how it applies the FSC core requirements to its operations. Verification involves a process by an independent FSC-accredited certification body. The certification body uses the self-assessment to guide the audit and verification of compliance with the standard. All single sites under the scope of the certificate shall be annually audited by the certification body.

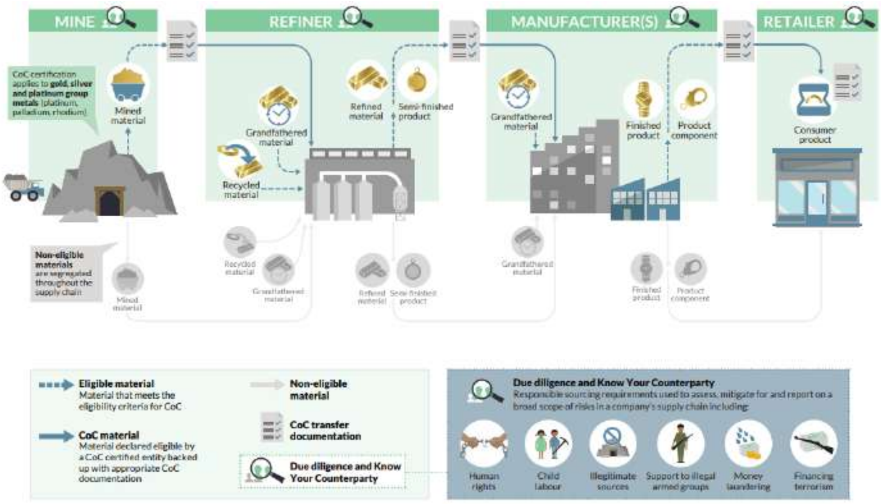
The FSC standard also elaborates specifically on the time and reporting periods of the declarations and their use in subsequent calculations (FSC, 2021). Organizations using the single percentage method may apply the calculated FSC% to the FSC claim of the output products produced either during the same claim period/ job order or in the following claim period. Organizations using the rolling average percentage method shall apply the calculated FSC% from the specified number of previous claim periods to the FSC claim of the output products produced in the following claim period. Organizations applying the FSC percentage in the following claim period shall ensure that fluctuations in the supply of input materials are not used to increase the amount of output products sold with FSC claims (FSC, 2021).

A2.1.4. Responsible Jewellery Council

The RJC is a not-for-profit organisation with 1900 members, founded in 2005. It is the world's leading standard-setting organisation for the jewellery and watch industry (RJC, 2024).

The RJC developed a chain of custody standard, along with guidance and self-assessment documents. The standard defines an approach for companies to handle and trade precious metals that is traceable and responsibly sourced. After carrying out a self-assessment any business handling gold, silver and platinum group metals can request an audit with a RJC accredited auditor. The auditor will share the findings and the company is granted certification in case of compliance with the RJC standard. Members are required to have a surveillance audit to monitor compliance (RJC, 2024). The Chain-of-Custody standard applies from mine to retail (see **Figure 15**).

Figure 15. RJC chain of custody standard – guidance



Source: *(RJC, 2019)*

The certificate requires third-party auditing at every stage of the supply chain. Certified companies must have a full understanding of their supply chain and identify their suppliers. That means (i) collecting different types of information and documents, depending on your position in the supply chain, and (ii) downstream companies (any company after the refiner up to and including the retailer) should ask their immediate suppliers for the identity of upstream refiners and obtain proof that the refiner has conducted due diligence in accordance with the recommendations of the OECD Guidance (RJC, 2024). Companies must also establish procedures for verifying incoming and outgoing shipments of chain of custody material, and for ensuring that each one has an accurate CoC transfer document. This document effectively records the material's sequence of custody as it moves along the supply chain. It provides the recipient with critical information that is used to prove the material's CoC status in subsequent transfers.

A2.1.5. Roundtable for Sustainable Palm Oil

RSPO is a global certification scheme founded in 2004 to set the standard for sustainable palm oil. It involves stakeholders from the whole industry, from oil palm producers, to processors/traders of palm oil, consumer goods manufacturers, retailers, banks and investors and NGOs (RSPO, 2024).

The RSPO developed a Supply Chain Certification Standard (SCCS), laying down requirements related to the control of RSPO certified oil palm products, including flows and associated claims. The standard is applicable to any actor in the supply chain taking legal ownership and physically handling RSPO certified sustainable oil palm products (RSPO, 2020). Different chain of custody models are defined (see **Figure 16**):

— **Identity preservation**[48]: it ensures that the RSPO certified oil palm products delivered to the end user can be linked to a single RSPO certified IP mill. Certified oil palm products shall be kept physically isolated from other oil palm sources throughout the supply chain, including other RSPO certified sources.

— **Segregation**[49]: it ensures that RSPO certified oil palm products delivered to the end user come only from IP certified mills. It allows mixing of different RSPO certified sources. RSPO certified oil palm products shall be kept separate from non-RSPO certified oil palm products throughout the supply chain.

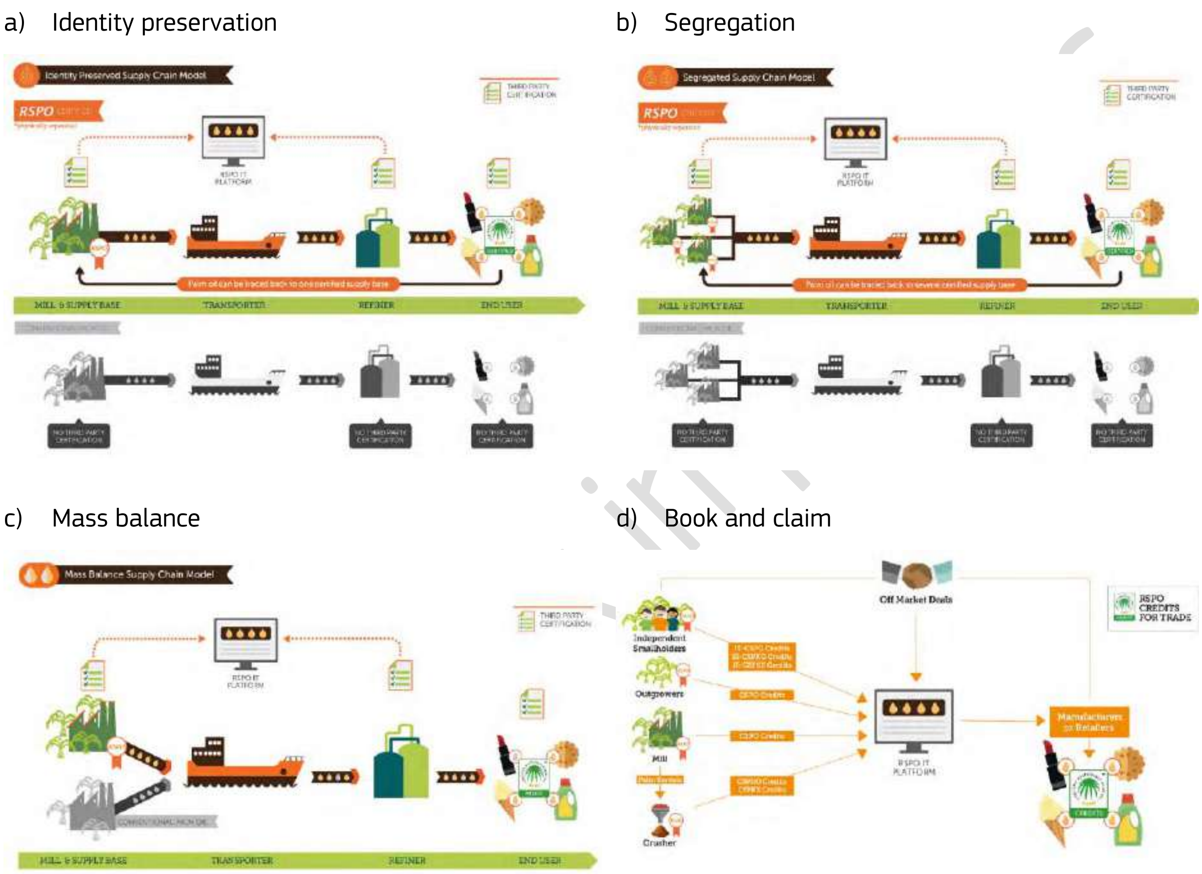
— **Mass balance**[50]: can only be operated at site level (no transfer of claims from site to site). It allows mixing RSPO certified and non-RSPO certified oil palm products, as long as quantities are controlled. The final product is linked to a list of RSPO certified mills. The quantities of RSPO certified oil products purchased

[48] This model corresponds to the identity preservation model described in section 3.2.
[49] This model corresponds to the segregation model described in section 3.2.
[50] This model corresponds to the group-level mass balance model described in section 3.2.

(inputs) and sold (outputs) shall be monitored and balanced within a fixed inventory period. Production losses are neglected in the mass balance calculation.

— **Book and claim**[51]: allows RSPO certified mills, crushers, independent outgrowers and independent smallholder groups to sell RSPO credits to the supply chain actors at the end of the supply chain, while selling the physical products as non-certified. The RSPO credits cannot be resold by the buyers.

Figure 16. CoC models covered by the RSPO SCCS



Source: (RSPO, 2020)

Only identity preservation, segregation and mass balance (or a combination thereof) can be used for the purpose of certification.

A **multi-site chain of custody system** can be used for multi-site certification, if the organisation defines the geographical area, the number and identity of sites and the types of operations covered. A central office is then in charge of the management and implementation of the RSPO chain of custody requirements.

A **group-level chain of custody system** can be used for supply chain certification, if members of the group are separate legal entities and use up to 500 MT of oil palm oil per year. The group manager shall define the geographical area (which can cover different countries), the number and identity of the group members and the type of operations covered.

The RSPO palm-trace platform[52] is an online platform developed to document the physical trading of certified palm oil in the supply chain.

[51] This model corresponds to the book and claim model described in section 3.2.
[52] RSPO palm-trace platform: https://palmtrace.rspo.org/web/rspo/welcome

The RSPO Supply Chain Certification Standard is presented as a series of auditable requirements, designed for use by organisations in the palm value chain to demonstrate implemented systems for control of RSPO certified oil palm products (RSPO, 2020). Downstream processors or users of RSPO certified sustainable oil palm products can claim the use of (or support of) RSPO certified oil palm products when they adhere to the requirements of the RSPO Supply Chain Certification Standard and the RSPO Rules on Market Communications and Claims document (RSPO, 2020). All actors in the supply chain shall ensure that the purchases of RSPO certified oil palm products are in compliance with the standards. In cases where an operation seeking or holding certification outsources its activities to independent third parties, the operation seeking or holding certification shall ensure that the independent third party complies with the requirements of the RSPO Supply Chain Certification Standard. Independent third parties engaged provide relevant access for duly accredited certification bodies to their respective operations, systems, and information. At least annual internal audits of each participating site shall be conducted to determine whether the supply chain certification system confirms the standard requirement, and is effectively implemented and maintained. Audits and all actions taken to correct non-conformities shall be available to independent certification bodies against the requirements of ISO/IEC Guide 17065:2012 upon request as part of the certification process (RSPO, 2020).

A2.1.6. Textile Exchange

Textile Exchange is a non-profit organisation founded in 2002 as Organic Exchange. In 2010 the focus was shifted from organic cotton to a variety of fibres and materials. The organisation developed the Climate+ strategy, aimed at reducing the emissions in the Tier 4 supply chain (farming, sourcing and extracting fibres from earth, plants and animals) (Textile Exchange, 2024).

Textile Exchange developed a series of standards[53].

The **Content Claim Standard (CCS)** is the reference chain of custody standard for textiles. The CCS provides industries with a tool to build trust with consumers about content claims. CCS certification applies to all supply chain sites that own the claimed material up to the brand of the final product, except traders (Textile Exchange, 2022).

The organisation shall carry out **volume reconciliation** per lot or batch production to balance claimed materials purchased, in stock and sold. The products sold as certified shall match the available CCS inputs.

The organisation shall maintain a system that controls volumes of input and output materials and shall keep record of:

(a) description, quantities, origins, destinations of all claimed materials purchased, sold, received or delivered;

(b) transaction certificates of any incoming claimed materials;

(c) volume reconciliations performed;

(d) List of suppliers of claimed materials, including license numbers.

If claimed materials are transferred between different sites within the same organisation, records of the initial claimed materials, the quantity, quality, blend and mix percentage, and description of the claimed materials being received shall be kept, to identify the incoming transaction certificate (Textile Exchange, 2022).

Chain of custody of physical materials is based on:

— **Segregation**[54]: the claimed material shall be separated from non-claimed material at all times. The claimed materials shall be clearly identified as they move through production.

— **Controlled blending**[55]: claimed materials and non-claimed materials can be blended at batch level. In case of blending, the organisation shall carry out calculations of the percentage of claimed content and content per raw material based on the weight and claim percentage of each input, considering loss factors per input material and product.

[53] Textile Exchange standards: https://textileexchange.org/standards/

[54] This model corresponds to the segregation model described in section 3.2.

[55] This model corresponds to the batch-level mass balance model described in section 3.2, although in this case volume reconciliation is allowed.

Each stage of production is required to be certified, beginning at the recycling stage and ending at the last seller in the final business-to-business transaction. The CSS is verified by accredited third-party certification bodies (Textile Exchange, 2022).

Beside the Content Claim Standard, Textile Exchange developed standard for traceability of recycled material.

The **Global Recycled Standard** (GRS)[56] is a voluntary product standard to track and verify the content of recycled materials in a final product. It covers manufacturing, packaging, labelling, trading and distribution of products with a minimum of 20% recycled content. It also sets requirements on chain of custody, in accordance with the Content Claim Standard.

The following requirements apply to organisations involved in the production or trade of GRS products (Textile Exchange, 2017a):

— all recycled materials entering the supply chain shall have a valid transaction certificate issued by an approved certification body;

— pre-consumer and post-consumer material content percentages must be documented individually for each batch at every certified location and included on the transaction certificate;

— traders with an annual sales volume of less than $10000 in GRS products, along with retailers exclusively selling to end consumers, are exempt from the certification requirement, as long as they do not repack or relabel GRS products;

— in cases where there is a potential for differing production losses between recycled and virgin inputs, certified organisations should account for these differences in their mass balance calculations;

The **Recycled Claim Standard** (RCS)[57] is an international chain of custody standard to track recycled materials through the supply chain. It is applicable to products that contain at least 5% recycled content. It is based on the chain of custody requirements of the Content Claim Standard.

The requirements listed above for GRS products apply also to RCS products (Textile Exchange, 2017b).

A2.1.7. Rainforest Alliance

The UTZ certification program (UTZ certified) is part of the Rainforest Alliance since 2018. Farms with UTZ certification are transitioning to the Rainforest Alliance 2020 certification program[58] since the merging (Rainforest Alliance, 2024).

The Rainforest Alliance sustainable agriculture standard lays down supply chain requirements on management, traceability, income and shared responsibility, as well as social aspects and environmental management (Rainforest Alliance, 2023).

Traceability requirements include (Rainforest Alliance, 2023):

— separation of certified and non-certified products at all stages (**segregation**), except for mass balance products;

— mapping of the product glow up to the final location of the certificate scope, including all intermediates and activities carried out on the product;

— shipments of certified products do not exceed the total production, purchase of certified products and remaining stock balance from the previous year;

— no double selling of volumes;

— volume summary of certified products for the previous 12 months, including inputs, volume purchased, in stock, processed, outputs, lost and sold.

Specific requirements apply to certificate holders using **mass balance** in the crops that permit traceability type mass balance (Rainforest Alliance, 2023):

[56] Global Recycled Standard: https://www.scsglobalservices.com/services/global-recycled-standard
[57] Recycled Claim Standard: https://www.scsglobalservices.com/services/recycled-claim-standard
[58] Rainforest Alliance 2022 Certification Program: https://www.rainforest-alliance.org/for-business/2020-certification-program/

— the volume of product sold as mass balance is 100% covered by volumes purchased as certified (negative balance not permitted);

— volumes sold as certified meet the minimum percentage requirements for origin information;

— purchase and sales documentation for volumes sold as certified include origin information to country level for incoming certified and non-certified volumes;

— movement of mass balance volumes from one certificate holder to another shall always be accompanied by a physical shipment of relevant product. Volume trading without a physical shipment can only take place between sites covered under the same certification scope.

A2.1.8. Marine Stewardship Council

MSC is an international non-profit organisation. It sets and maintains standards for wild-capture fisheries.

MSC developed the MSC Chain of Custody Standard[59] for Seafood Traceability. The certification ensures businesses and consumers that products sold with the blue MSC label originate from sustainable sources complying with the MSC Fisheries Standard.

The standard is built around four main principles:

— certified products are purchased from certified suppliers;

— certified and non-certified products are kept separate (**segregation**);

— certified products can be identified clearly;

— certified products are traceable and volumes are recorded.

Certification to the Chain of Custody Standard guarantees an unbroken value chain where that certified seafood is clearly marked, kept distinct from non-certified items, and can be traced back to another certified entity. Assessments are carried out by independent, third-party certifiers.

A2.1.9. Bonsucro

Bonsucro is the leading global sustainability platform and standard for sugarcane. It brings together over 300 members in the sugarcane sector, including sugarcane products and derivatives. It is a member of the ISEAL Alliance (Bonsucro, 2024).

They developed the Chain of Custody Standard aiming at providing assurance that sustainability claims can be tracked along the supply chain.

The chain of custody covers the entire supply chain from field to mill, through various steps of production, to warehousing, transportation and trade up to end product manufacturers. It is based on the **mass balance** model: the volume of Bonsucro certified output is balanced with a physical volume of Bonsucro certified input (Bonsucro, 2019).

There are two certification options:

— **Single site**: including a single functional part of an organisation's operations or a combination of parts situated at one location. Mills may only use single site certification.

— **Multi-site**: including a number of locations either within a single legal entity or across legal entities that are related via an ownerships structure. Sites may be within a single country or across international borders. One site is responsible for maintaining the central administration of the chain of custody requirements.

The organisation must conduct periodic inventories of the input/output balance for Bonsucro-certified products at each operation site, with a maximum interval of three months between each inventory. These inventories should cover mass balance and credit stock-keeping, considering relevant conversion rates.

[59] MSC Chain of Custody Standard: https://www.msc.org/standards-and-certification/chain-of-custody-standard/how-the-msc-chain-of-custody-standard-works

Fixed inventory periods should be continuous without gaps, and mass balances should be maintained during times with no movement of Bonsucro-certified material. Inventories should be performed at the certification unit level (single site, multi-site, or group).

The volume of Bonsucro-certified products received should be greater than or equal to the volume supplied to clients within a fixed inventory period. Positive balances at the end of an inventory period can be carried over to the next period (carry over) (Bonsucro, 2019).

The Bonsucro CoC standard applies to any organisation purchasing, handling and/or trading physical Bonsucro-compliant material who wishes to make any claim about the status of the material or representation of the material (Bonsucro, 2019). Any receiving organisation shall verify the current Bonsucro status of the supplier at the time of the purchase on the Bonsucro website. No incoming material certified under other schemes can be considered as Bonsucro compliant. In cases where a Bonsucro CoC certified organisation outsources activities to independent third parties (e.g. subcontractors for storage, transport or other outsourced activities), the certified organisation shall ensure that the independent third party complies with the requirements of the Bonsucro CoC Standard (Bonsucro, 2019). Only after certification (date when the certificate is issued and the organisation starts to be listed on the “certified members” list of Bonsucro’s webpage) are organisations allowed to make public claims about their purchase of Bonsucro certified products and/or sell Bonsucro certified products. Organizations can only make public claims about purchasing or selling Bonsucro certified products after they receive certification and are listed on Bonsucro’s “certified members” webpage. The required audits must be conducted by Bonsucro Licensed Certification Bodies, following the frequency specified in the Bonsucro Certification Protocol (Bonsucro, 2019).

A2.2. Traceability schemes at the general and supranational level

A2.2.1. International standards

The international standard **ISO 14021** (environmental labels and declarations)[60] sets requirements for self-declared environmental claims, including on recycled content. It also provides definitions for:

— recycled content “*the proportion, by mass, of recycled material in a product or packaging*”;

The standard also includes an evaluation methodology for recycled content, which specifies that it shall be expressed as a percentage and calculated as follows:

$$X(\%) = \frac{A}{P} \times 100 \tag{3}$$

where

X is the recycled content, expressed as percentage;

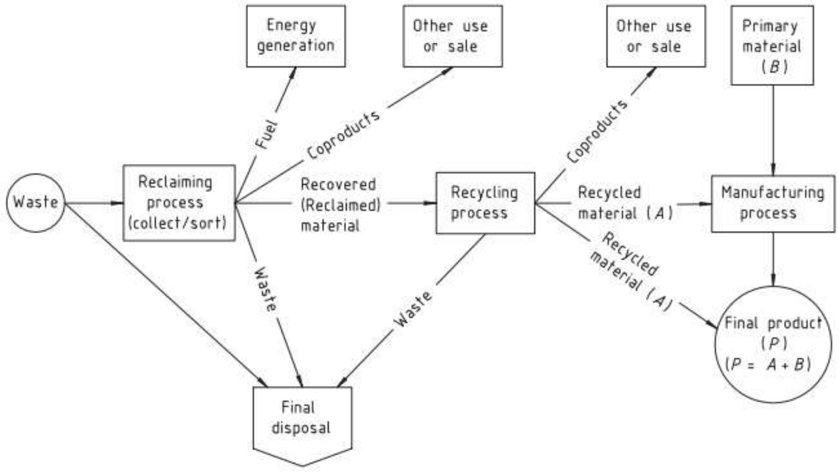
A is the mass of recycled material;

P is the mass of product.

Figure 17 depicts a simplified scheme of a recycling system to clarify the recycled content calculations.

[60] ISO 14021: https://www.iso.org/standard/66652.html

Figure 17. Simplified representation of a recycling system



Source: ISO 14021 – Annex A

Traceability schemes ensure that recycled materials are identified, documented and verified, making claims on recycled content more credible for consumers.

The standard **EN 15343** provides guidelines on plastics recycling traceability and assessment of conformity of recycled content. Collectors and sorters shall keep records on incoming and sorted products, in particular on the material or product type, the origin and the history of waste (e.g. contact with hazardous substances). The recyclers shall record the process variables, carry out quality control testing of the products delivered by the process and identify the output at batch level. Recycled content is to be calculated according to equation *(3)*.

Recently RecyClass[61] and EUCertPlast[62] reached an agreement for the development of a joint certification scheme for plastic recyclers, based on the standard EN 15343. The goal is to increase transparency within the plastics recycling industry and build trust in the recycling claims.

A2.2.2. Australian Government – A national framework for recycled content traceability

The Australian government developed a voluntary national framework for recycled content traceability. It also contains guidance on verification and certification.

The scope encompasses all supply chain activities, including material recovery (traceability entry point), reprocessing, manufacturing, distribution, retail or sale for final use (traceability exit point) (Australian Government, 2023).

According to the guidelines, interoperability, i.e. the ability of different IT or software systems to connect and communicate with each other to share information in a timely manner, is a key enabler of traceability. It is recommended to follow the traceability requirements of the **Global Traceability Standard** (see section 3.2.1).

Each value chain actor should implement at least 'one step forward, one step back' traceability, except at the entry point (material recovery stage) and the exit point (sale for final use stage). All actors should try, however, to extend traceability beyond the immediate trading partners (Australian Government, 2023).

The level of details on traceability required by each actor may vary. For instance a manufacturer may need information on the exact origin of recycled content, while a retailer may only need general information (e.g. national origin). Challenges arise in cases when the supply chains are spread across different countries, as foreign suppliers may not be willing to share data, or when the supply chains are very large and complex, involving intermediaries, subcontractors and suppliers (Australian Government, 2023).

The recycled content composition can be determined with mass balance, controlled blending or identity preservation chain of custody approaches, in line with **ISO 22095** (see section 3.2.2).

[61] RecyClass: https://recyclass.eu/
[62] EUCertPlast: https://www.eucertplast.eu/

The framework also defines minimum bass balance requirements, listed in **Table 5**.

Table 5. Minimum mass balance requirements

General requirements	• Allocation of claims based on known quantities of inputs/outputs, including losses, over defined balancing period. • Mass balance allocation supported by a material accounting system tracking input/outputs over the defined balancing period. • Mass balances should be kept material- and site-specific.
Balancing period	• The balancing period must be consistent. Recommended mass balance period is 3 months, up to a maximum of 12 months. • Mass balance periods should be continuous in time, clearly documented, and be kept even if no movement of recycled materials occurs.
Credit units	• The mass of material entering a mass balance system must be transformed into a single type of currency or credit unit. • Credits accrue in bookkeeping with each unit of material entering the system and decrease when recycled content materials or products are produced and sold.
Credit Transfers	• Surplus credits at the end of a mass balance period can only be transferred to the next mass balance period, if at least the equivalent amount of the recycled content material is physically in stock. • Transferring credits between materials or products only allowed for identical materials (or products) or identical product groups (or material groups).
Allocation	• Mass balance allocation determines how recycled input credits are assigned to specific outputs. Participants may use any allocation method but must share this information with trading partners. They must also ensure the resulting recycled content claim is consistent with the allocation method and not misleading.
Conversion factors	• A conversion factor describes the change in quantity of a specific material due to processing. • Conversion factors should be calculated on a site specific and product specific basis and should be based on actual data (e.g. processing or production data). • Conversion factors have to be provided by all the elements in the chain of custody where changes in quantities occur. They must be clearly documented and are subject to verification.

Source: (Australian Government, 2023)

Key data elements to be shared include (Australian Government, 2023):

— for basic traceability

(a) item identifier and item description

(b) quantity and unit of measure

(c) receipt/ship date

(d) sender/shipment/receiver identifier

— for recycled content provenance

(e) country of origin of recycled material

(f) feedstock source stream and type

(g) feedstock type (pre-consumer/post-consumer)

— for recycled content composition

(h) recycled content claim

(i) chain of custody approach

(j) mass balance period and allocation method

A2.2.3. EU legislation

A2.2.3.1. Single Use Plastics Directive

Directive (EU) 2019/904 on single use plastics (SUP) lays down targets for recycled plastics content in single-use plastic beverage bottles (cf. Article 6(5) of the Directive). It also empowers the Commission to develop rules for the calculation and verification of the attainment of the targets in implementing acts to the Directive.

The Commission Implementing Decision (EU) 2023/2683 lays down rules for the application of the SUP Directive as regards the calculation, verification and reporting of data on recycled plastic content in single-use plastic beverage bottles. This Decision applies to recycled plastic in beverage bottles obtained through a suitable recycling technology, as defined in Annex I Regulation (EU) 2022/1616, i.e. mechanical recycling. Recycling technologies changing the chemical structure of the polymer are not under scope.

Regulation (EU) 2022/1616 establishes a reporting chain for tracking recycled plastic content in food-contact beverage bottles, with recyclers and converters providing declarations of compliance to downstream economic operators. Economic operators placing beverage bottles on the market can calculate the weight of recycled plastic using the recycled content percentage provided in the declaration of compliance for each bottle component.

To minimise administrative burden, Decision (EU) 2023/2683 establishes that Member States should base their calculations of recycled plastic content in beverage bottles on data derived from Regulation (EU) 2022/1616. According to Annex I to the Implementing Decision the proportion of recycled content in beverage bottles and PET bottles shall be calculated as follows:

$$RC = \frac{R}{W} \times 100 \tag{4}$$

where

RC is the proportion of recycled plastic content in bottles placed on the market

R is the weight of recycled plastic used in bottles placed on the market

W is the weight of plastic used in bottles placed on the market

Plastic resulting from recycling technologies altering the chemical structure of the polymers (i.e. chemical recycling technologies, such as pyrolysis and gasification) is in scope of Regulation (EU) No 10/2011. As stated in Article 7 of (EU) 2023/2683 the Commission will adopt an amendment of the Decision to establish a methodology to calculate, verify and report recycled plastic content in beverage bottles resulting from recycling technologies other than mechanical recycling. The Commission is also empowered to further amend the Decision with provisions on the application of certain chain of custody models, as defined in ISO 22095, including controlled blending and mass balance.

(Hann et al., 2022) carried out a study commissioned by the Directorate-General for the Environment of the European Commission to support the preparation of the implementing act and possible future amendments. The study analyses different chain of custody models and allocation methods as well as their suitability for mechanical and chemical recycling.

The key findings of the study can be summarised in the following points (Hann et al., 2022):

— Definition:

- inputs must be waste (no by-products) and must have been recycled (no recovery and fuel products);
- the source material and outputs must be plastic.

— Calculation and measurement points:

- losses in the numerator may need to be accounted for to ensure coherence with denominator; inherent losses associated with recycled material in a given process should be included in the numerator; contaminations that are acceptable for the conversion process do not need to be deduced;
- the measurement point of the numerator should be set prior to entering the final conversion process or at the point of blending recycled/virgin materials;
- the measurement point of the denominator should be set after the conversion process; the scope is to be clarified.

— Chain of custody models and volume reconciliation:

- ISO 22095 should be used as basis for the definition of CoC models;
- for plastic recycling relevant models are segregation, controlled blending and mass balance, by order of preference; mass balance is to be used in cases where physical separation cannot be guaranteed;
- when using mass balance, an accounting period must be defined (up to 12-months); no negative balances can be carried out beyond the accounting period.

— Mass balance and allocation:

- thermal depolymerisation technologies require rules to determine co-product allocation, as co-products are produced as part of the process; different allocation methods are presented:
  - (a) proportional allocation – recycled content can only be allocated based on the content of recycled material theoretically present in the output product (e.g. according to the ratio of produced co-products);
  - (b) polymers only allocation – outputs that are directly linked to the production of polymers can be allocated freely;
  - (c) fuels excluded allocation – all outputs can be freely allocated, except fuel used within the process and co-products used as fuels;
  - (d) auto consumption excluded allocation – all outputs can be freely allocated, except fuel that is burned within the process to provide energy;
  - (e) free allocation – all outputs, including fuel, can be freely allocated.
- some thermal depolymerisation technologies benefit from multi-site restricted credit transfers;
- boundaries should be set to prevent intercontinental transfer of credits;
- credit transfers are only applicable to identical products and between actors belonging to the same company; each site shall maintain mass balance calculations and records.

A2.2.4. Voluntary certification and standards for recycled content in batteries

A2.2.4.1. UL Solutions – Recycled content validation

UL solutions was founded in 1894. They have more than 80000 customers worldwide and provide a wide range of services: certification, testing, verification, auditing and inspections, software, learning and development, field evaluation and advisory (UL, 2024).

UL developed the **Environmental Claim Validation Procedure** (ECVP)[63], which allows customers to validate their sustainability claims and obtain the UL Environmental Claim Validation Mark.

[63] UL Environmental Claim Validation Procedure: https://www.ul.com/services/environmental-claim-validation-ecv

UL 2809-1 establishes the **ECVP for Defined Source Content** and describes the methods for auditing chain of custody and calculating the content of materials with specified characteristics.

Depending on the nature of the value chain, it may be appropriate to apply different CoC models to different levels of the value chain.

All members of the value chain should comply with the documentation requirements for traceability, including:

(a) documentation on the design of the product;

(b) documentation demonstrating that finished products were manufactured according to the design specifications;

(c) documentation from the manufacturers supply chain ensuring material supplied has the prescribed Defined Source content;

(d) documentation from the manufacturer or manufacturer's supply chain describing the attributes and source of the validated material or product;

(e) documentation from the manufacturing process that demonstrates effective control of Defined Source content materials during production.

The manufacturer shall provide additional information on the process, in particular the product composition specifications along with the final content calculation, including the Bill of Materials[64], the process flowchart and material inputs/outputs, including material losses. When transferring the material to other sites, the manufacturer shall also provide documentation on its Tier 1 suppliers[65], including the supplier name, date of shipment and quantity of material received.

The standards also defines different chain of custody models and the related requirements, in accordance with ISO 22095 and with the definitions given in section 3.2.2. The manufacturer selects a CoC of choice, and UL certifies this model and issues a corresponding claim. Additional requirements on **mass balance** CoC that are worth highlighting are:

— Each organisation using a mass balance model shall define the system boundaries, i.e. where the materials flow into or out of the system. System boundaries can be set at the level of a single facility; at the level of multiple facilities, if there is a physical exchange of materials between them; at the level of a business unit including sites that are geographically distant, but they exchange feedstock.

— Materials entering the system boundary are converted to credits, while materials leaving the boundaries (debits) are converted to allocated recycled content. The mass of allocated recycled content shall take account of the efficiency factor, determined by subtracting the losses due to leakage, process efficiency, conversion efficiency or any other factors reducing the total amount of material available for allocation.

— Negative balances in the credit account are not allowed. If no credits are available, the outgoing material shipment cannot be allocated recycled content.

— Credit transfer, involving virtual exchange of materials, is allowed under certain circumstances if the sustainability or carbon benefits of the virtual transfer against the physical transfer can be demonstrated.

UL 2809-2 establishes the **ECVP for Recycled Content** and outlines the measurement of pre-consumer and post-consumer defined source material content in manufactured products and components. It also gives guidance on how to make recycled content claims.

[64] The Bill of Materials is a comprehensive list of raw materials, components and chemicals used to manufacture or assemble a product. It serves as a guide for the manufacturing process, identifying the quantities, specifications, and sources of each item needed. It is an essential document in inventory management, production planning, and quality control.

[65] Tier 1 suppliers are the primary level of suppliers in a supply chain, directly providing materials, components, or products to the original equipment manufacturer (OEM). Their role involves maintaining a direct contractual relationship with the OEM, ensuring timely delivery of high-quality goods or services, and managing lower-tier suppliers if necessary. These suppliers are crucial for the smooth operation of the manufacturing process and maintaining a strong partnership with the OEM.

A2.2.4.2. European Standard EN 45557

The European Standard **EN 45557** defines a general method for assessing the proportion of **recycled content in energy related products**.

Directive 2009/125/EC[66] on eco-design requirements for energy-related products defines energy-related products as "*any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently.*"

Batteries fall under the category of energy-related products, hence the standard EN 45557 can be used as a starting point for this work.

The standard provides guidance on how to make substantiated claims on recycled content in energy-related products, highlighting the importance of the chain of custody to trace secondary materials from different sources. It provides requirements for the assessment of recycled content, including:

— scope definition (product covered (whole product, a specified unit of a product, an intermediate product); origin of recycled material (pre-/post-consumer); value chain actor (e.g. supplier, manufacturer));

— assessment of materials composition;

— a management system to trace the type of inputs (primary/secondary);

— a mass balance accounting system.

Traceability of information is enhanced through the implementation of different CoC models. **Mass balance** is considered as the most appropriate CoC model to trace recycled content in energy-related products. The standard recommends that for post-consumer waste traceability should start at the point of treatment (recycling plant), while for pre-consumer waste it should start at the point of origin (producer).

The following formula can be used to balance the mass of production output over a given accounting period:

$$Output = Input + Change\ in\ stock + Internal\ conversion - Waste \tag{5}$$

Where

Output is the amount of material in finished products in the accounting period;

Input is the amount of material coming to the production in the accounting period;

Change in stock is the change of stock of material in materials and/or as materials in parts in the accounting period;

Internal conversions are the losses in material flows due to production technology in the accounting period;

Waste is the waste of materials from the production in the accounting period.

The accounting period can be defined by the manufacturer and shall not exceed one year. Material allocation shall be carried out only within the defined accounting period and can cover several production lines, sites and different product families, as long as it is in line with the scope definition.

The **pre-consumer recycled material content** of a complex multi-material part or product can be calculated as follows:

$$RC_{pre} = \left(\frac{\sum_k m_{pre,k} * rc_{pre,k}}{\sum_k m_{tot,k}}\right) * 100\% \tag{6}$$

Where

[66] Directive 2009/125/EC: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202401781

RC_{pre} is the pre-consumer recycled material content of a part or product;

rc_{pre} is the pre-consumer recycled material content of the kth material;

$m_{pre,k}$ is the mass of the kth pre-consumer material used to manufacture a material;

$mt_{ot,k}$ is the total mass of the kth material.

The **post-consumer recycled material content** of a complex multi-material part or product can be calculated as follows:

$$RC_{post} = \left(\frac{\sum_k m_{post,k} * rc_{post,k}}{\sum_k m_{tot,k}}\right) * 100\% \tag{7}$$

Where

RC_{post} is the pre-consumer recycled material content of a part or product;

rc_{post} is the pre-consumer recycled material content of the kth material;

$m_{post,k}$ is the mass of the kth pre-consumer material used to manufacture a material;

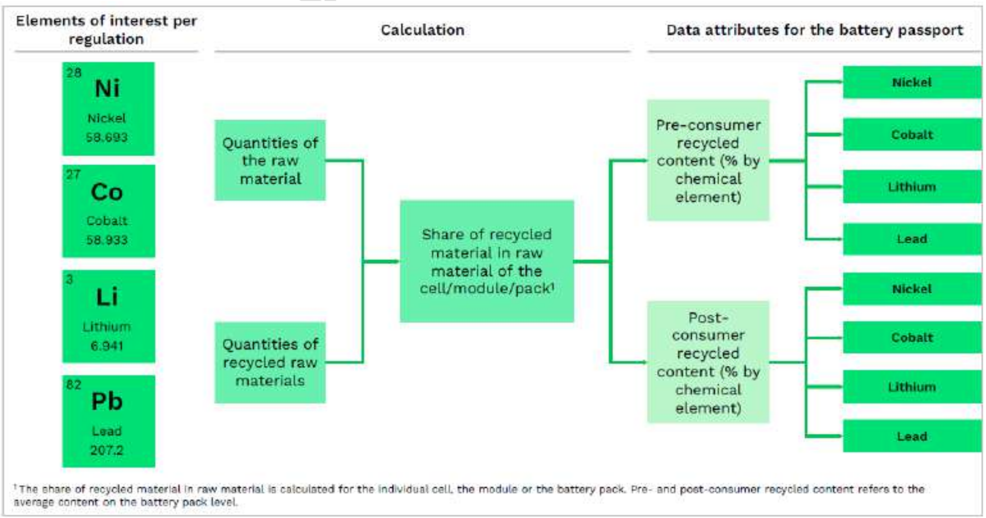
$mt_{ot,k}$ is the total mass of the kth material.

A2.2.4.3. Battery passport content guidance

Article 77 of the Battery Regulation lays down provisions on the digital battery passport. Information on recycled content shall be included in the battery passport, as defined in Annex XIII to the Regulation.

The Battery Pass Consortium[67] developed the battery passport content guidance targeted to organisations responsible for the implementation of the battery passport. It is recommended to calculate and declare the recycled content shares of nickel, cobalt, lithium and lead obtained form pre-consumer and from post-consumer waste separately. This would result in eight data attributes to be included in the battery passport (see **Figure 18**). The recycled content share of other elements can be reported on voluntary basis (Battery Pass, 2023).

Figure 18. Recommendations by the Battery Pass Consortium on recycled content calculation and declaration in the battery passport



Source: (Battery Pass, 2023)

[67] The battery pass: https://thebatterypass.eu/

A2.3. Verification

A2.3.1. Voluntary certification and standards for environmental and social sustainability product claims for (intermediate) products other than batteries

Standards for other product categories from have been reviewed for their specifications on verification mechanisms (UNGC, 2014) (section A2.1 with an overview of their traceability modalities).

Supply chain certification schemes validate claims and certify that a material or product has been managed and controlled across its supply chain to required standards. Shipments between supply chain operators are by default accompanied with basic information, including a least supplier/receiver name and contact address, an item (batch) identifier, item description, date of shipment/receipt, quantity of material shipped and its unit. For materials containing recycled content, additional information specific to the recycled content is made available. This includes e.g. recycled content claim and applied chain of custody method to calculate it.

Special requirements and conditions are commonly stipulated for outsourced activities and entities that act as intermediates without material transformation. For instance, the FSC and RSPO standard indicates that supply chain actors shall establish an outsourcing agreement with each non-certified contractor, specifying minimum requirements (e.g. conform to all applicable certification requirements, not further outsource any processing, accept the right of the organization's certification body to audit the contractor). The supply chain actor also shall maintain legal ownership of all materials during outsourcing. Traders, middlemen and distributors that do not modify the material may be included in the scheme, similar to any other supply chain actor (e.g. BCI), or simply shall pass on the certification number of the product manufacturer and the applicable supply chain model (e.g. RSPO). It may also be required that they have systems in place to ensure segregation of certified and non-certified materials.

Organisations that are organisations that adhere to different standards or schemes, and that have inputs and outputs that simultaneously carry claims from these schemes shall demonstrate that the quantities of products are not inappropriately counted multiple times to control for 'mass balance fraud'.

Current voluntary verification schemes mostly build on tracing value chains from raw materials to finished products ("end-to-end traceability"), and documentation available from value chain operators in the absence of reliable test methods for recycled content. This is typically achieved either (i) by integrating all supply chain actors in a common scheme, with a central database or technology where data is stored and made available to other supply chain actors, or (ii) by collecting information and certificates of upstream actors from manufacturers who wishes to certify its product.

Third party audits and assessments of manufacturing facilities and companies add trust in the verification process. Data requested for verification are dependent on the certification scheme or standard, but commonly involve information on the quality management system (e.g. ISO 9001 and ISO 14000), a description of the manufacturing specifications and processes (including e.g. flowcharts, and conversion factors to account for e.g. process losses), technical information on material/product attributes, and calculations underlying the selected chain of custody model applied to calculate recycled content. In addition, some certification schemes request the occurrence of internal audits, and may review such audit reports.

A2.3.2. Verification frameworks at the general and supranational level

A2.3.2.1. International standards

ISO/IEC 17000 sets out the terminology, vocabulary and general principles of conformity assessment procedures. It defines verification as the confirmation of truthfulness that specified requirements (e.g technical specifications, regulations) have been fulfilled through the provision objective evidence. Hence, only these requirements can be used as basis for the verification assessment.

ISO 14024 outlines principles and procedures for environmental labelling and declarations. It indicates that the assessment and demonstration of compliance should be documented with sufficient rigour to maintain confidence in the (labelling/declarations) programme. For a situation where testing of the requirement cannot be performed, it is also indicated that the minimum verification information requirements to be documented shall include the (i) identification of the standards and method used, (ii) documentary evidence, (iii) the name and address of any independent verifier outside the programme.

The standard **ISO 17029:2019** contains general principles and requirements for the competence, consistent operation and impartiality of bodies performing validation/verification as conformity assessment activities. It is applicable to validation/verification bodies in any sector, providing confirmation that claims are either plausible with regards to the intended future use (validation) or truthfully stated (verification). It is applicable to any sector, in conjunction with sector specific programmes (e.g. Greenhouse Gas verification and validation provided under ISO 14065:2013).

5.4.1.1 UNTP

The United Nations Transparency Protocol (UNTP)[68] aims to help governments and industries tackle greenwashing by encouraging practical measures for supply chain traceability and transparency. Unlike a platform, the UNTP is a standard protocol that ensures supply chain data remains with its original owners. It features a decentralized architecture with no central data repository. Supply chain participants can share relevant information about their products using a standardised digital protocol. Instead of mandating what must be shared, the UNTP offers a range of confidentiality measures, allowing each participant to balance confidentiality and transparency. When all actors in a value chain adopt the UNTP, it enables the tracing of product origins back to primary production. The UNTP does not require every product claim to be third-party verified or every certifier to be formally accredited, but it does make the chain of trust visible where it exists. Producers and manufacturers act as verifiers of any UNTP credentials linked to their upstream supply chain.

The UNTP solution to mass balance fraud[69] involves trusted third parties (certifiers or industry associations) to act as quota managers that issue "guarantee of origin" credentials (a type of conformity credential). In this model, the guarantee of origin certificate for 10 000 moles recycled lithium carbonate (for example) can only be issued when the third party (recycler) has evidence of the purchase of at least 10 000 molar units of waste lithium. The third party will also mark the input batch as consumed (in a similar way to the anti-counterfeiting protocol) so that it cannot be re-presented to a different third party.

5.4.1.2 Australian Government – A national framework for recycled content traceability

Supply chain participants should verify the traceability information they receive is accurate and adequate to support recycled content claims and enable tracing backward in the supply chain. Participants should verify that the traceability information they receive is accurate and adequate to support their recycled content claims. Information should be verified as often as necessary to provide the participant the assurance and confidence they need to substantiate recycled content claims. This may occur:

— for each shipment of recycled content materials or products;

— at regular intervals, such as monthly, quarterly or annually. Intervals may be determined based on the volume and frequency of transactions and the degree of trust between trading partners.

For example, information may need to be verified more frequently for suppliers found to have provided incorrect information in the past.

Participants may request suppliers to obtain independent third-party verification of information provided. Participants can engage the services of a third-party verification body to verify traceability information. Verification bodies should be accredited by an accreditation body that is a member of the International Accreditation Forum[70]. This Forum is a global association of accreditation and other bodies interested in conformity assessment in products, processes, validation and verification.

Participants can also conduct their own audits to verify traceability information, having regard to the principles and requirements set out in ISO/IEC 17029:2019[71] or ISO/IEC 17065:2020[72]. Participants are also encouraged to refer to Environmental and sustainability claims – Draft guidance for business[73] (as updated) published by

[68] United Nations Transparency Protocol: https://uncefact.github.io/spec-untp/

[69] Mass balance fraud refers to a fraudulent actor buying a small quantity of high integrity inputs (e.g. recycled metals) and mixes that input with lower quality alternatives (e.g. metals from primary sources) and then sells the full volume of manufactures product as containing recycled content, re-using the valid credentials from the niche supply.

[70] International Accreditation Forum: https://iaf.nu/en/home/

[71] ISO/IEC 17029:2019: Conformity assessment – general principles and requirements for validation and verification bodies

[72] ISO/IEC 17065:2020: Conformity assessment – requirements for bodies certifying products, processes and services.

[73] Environmental and sustainability claims – Draft guidance for business: https://www.accc.gov.au/about-us/publications/environmental-and-sustainability-claims-draft-guidance-for-business

the Australian Competition and Consumer Commission. It explains the obligations under the Australian Consumer Law that businesses must comply with when making environmental and sustainability claims.

Instead of collecting and sharing traceability information directly, supply chain participants can achieve traceability through suitable third-party certification schemes. These certification schemes validate claims and certify that materials or products have been managed and controlled throughout the supply chain according to required standards.

5.4.1.3 EU legislation

5.4.1.3.1 Green claims Directive

On March 22, 2023, the European Commission proposed a directive on green claims, mandating that companies substantiate their voluntary green claims in business-to-consumer practices. This proposal sets minimum requirements for substantiating and communicating environmental claims, which must undergo third-party verification as per Article 10. Furthermore, Article 11 sets out that the 'verifier' must be an officially accredited independent body, with no conflicts of interest to ensure independence of judgment and hold the highest degree of professional integrity. They must have the required expertise, equipment, and infrastructure to carry out the verifications as well as enough suitable personnel that observe professional (see standard ISO/IEC 17029:2019 Conformity assessment — General principles and requirements for validation and verification bodies[74]).

Article 5 details the information that shall be included together with the environmental claim, including:

— The environmental aspects/impacts covered by the claim

— Any calculations performed to quantify such impacts

— A proposal for improvement of the environmental performance

— The certificate of conformity referred to in Article 10

— The relevant legislation or the international standards (see section 5.2.2 b))

Member States would need to establish procedures for the pre-verification of these claims, ensuring they meet the directive's standards.

The proposal does not include the option of using a standard methodology or chain of custody model for recycled content to substantiate claims. Nonetheless, it is indicated that "the Commission may later propose legislative amendments to further harmonise provisions, including those related to recycled content, if deemed necessary".

5.4.1.3.2 Single Use Plastics Directive

The Single Use Plastics Directive (SUPD, Directive (EU) 2019/904[75]) requires that certain plastic materials shall contain a minimum content of recycled plastics. It is the obligation of Member States to ensure that those provisions are met. The verification and control system of the Directive have not yet been adopted, but drafts have been presented by the Commission[76]. Draft verification rules involves the review of the methodology used for the quality assurance and verification of the data, data reliability and accuracy, and calculations.

5.4.1.3.3 Carbon footprint in batteries

The draft delegated Regulation[77] for lays down the draft methodology for calculating and verifying their life-cycle carbon footprint. Verification and validation techniques for the carbon footprint study involve a role for notified bodies to assess whether the carbon footprint declared meets the requirements set out in this Annex. The assessment includes a review of the carbon footprint study, the public version of the carbon footprint study and the model used in the calculations. The general provisions indicated that the notified body shall verify that

[74] ISO/IEC 17029:2019 Conformity assessment: https://www.iso.org/standard/29352.html

[75] Directive (EU) 2019/904: https://eur-lex.europa.eu/eli/dir/2019/904/oj

[76] Drafts on verification and control system of the SUP-Directive: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302683

[77] Draft delegated Regulation on carbon footprint methodology: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13877-Batteries-for-electric-vehicles-carbon-footprint-methodology_en

(i) data and information used for the calculation of the carbon footprint are consistent, reliable and traceable; and (ii) calculations performed are correct.

For batteries manufactured in series, it shall also undertake an assessment visit to:

(a) the manufacturer's premises;

(b) the cell, anode, and cathode production premises;

(c) the cathode active material production premises;

(d) the anode active material production premises; and

(e) where considered important on the basis of the carbon footprint study, the premises of one or more of any other production sites for which company-specific data were collected.

The notified body shall identify uncertainties that are higher than expected and assess the effect of the identified uncertainty on the total carbon footprint.

5.4.2 Voluntary certification and standards for recycled content in batteries

UL solutions has expertise with certifying recycled content in batteries[78] with different chemistries (e.g. lithium ion batteries containing manganese oxide battery or cobalt). In the case of a supply chain with several actors, the UL documentation requirements (e.g. on acceptable waste materials used) are applicable to all members of the supply chain in the scope of the audit. The manufacturer shall provide documentation of the supply chain to the source of the defined content. Businesses have different access and control over value chains. Some firms are greatly aware of all their suppliers, up to raw material providers, whereas other are less. In case of requests, UL traces back the value chain based on supplier information from the previous actor ("N-1") and considering confidentiality requirements. Products validated by a desktop and on-site audit shall receive a recycled content claim. For closed loop claims, supplier sites shall also undergo a facility on-site audit to ensure compliance with the Chain of Custody requirements of the procedure. Although some clients also explicitly request to audit their suppliers in open loop systems, auditing is mostly only performed based on information collected by manufacturer who wishes to certify its product. UL then asks for a supplier declaration of actors upstream in the value chain.

Other voluntary solutions for batteries (e.g Circulor[79], CERA 4in1 performance standard[80]) are based on data and information from different value chain operators that are shared through a central platform or blockchain technology, respectively. In addition to building on on-site verification and auditing, these standards control and verification by triangulating data from different operators, enforcing as such sustainability and transparency.

Verification requirements for the recycled content in energy-related products set out in the International Standard **EN 45557** involve is based exclusively on documentation, and no testing requirements apply. The whole secondary material supply chain including suppliers of material with recycled material content shall provide information allowing traceability. Each economic operator in the chain of custody system is responsible for the data supplied in the material/product declarations submitted to the next actor in the value chain, and the validity of this information may be assessed by a third part. Alternatively, a supplier declaration may be used.

[78] UL solutions: https://www.ul.com/industries/products-and-components/batteries

[79] Circulor: https://www.circulor.com/

[80] CERA 4in1 performance standard: https://www.tuv-nord.com/fileadmin/Content/TUEV_NORD_DE/zertifizierung/Nachhaltigkeit/Brochure_Condensed_Version_-_TUEV_NORD_CERA_4in1_Performance_Standard__CPS_.pdf

Annex 3. Key takeaways from the first stakeholder consultation

In April 2024 the JRC hosted the first data inventory meeting with stakeholders, with the aim of presenting preliminary findings and launching the first stakeholder consultation. Key takeaways of the consultation are presented below.

— **Calculations**

- Concrete suggestions for recycled content calculation parameters were made.
- The majority of stakeholders affirmed that process losses are irrelevant and very difficult to measure. Losses are equal for primary and secondary materials, hence there is no need to account them in the calculation.
- The importance of boundary conditions (individual location of plant), functional unit (cell, module, pack level -> higher level of ambition, pack-level will provide more freedom) and reference timeframe for the calculation was highlighted.
- References to align to standards (international standards, but also commercial and industry initiatives).
- The main challenge is that the essential information is not always readily available to the actor in the value chain responsible for recycled content reporting. This is mainly due to confidentiality issues and to the complexity of the value chain.
- It is proposed that the starting point for recycled content calculation should be at the recycled plant, at the point at which secondary raw materials (Li, Co, Ni, Pb) are produced (not at black mass level[81]).
- The N-1 approach was proposed to ensure traceability along the value chain (upstream supplier provides the relevant information to the next actor).

— **Traceability and chain of custody**

- Most of the stakeholders suggested using the mass balance approach (it enables calculation and allocation), with B2B accounting and recycled content allocation to customers. A limited number of stakeholders provided suggestions for the book and claim chain of custody approach.
- Stakeholders did not consider identity-preservation and segregation favourable in the battery value chain: mixing of material from different sources is done to absorb fluctuations in the input materials. It is not possible to fully segregate batches within a given line, hence those methods would require building separate lines and would create inefficiencies.
- Some stakeholders highlighted that it is not always possible to identify the share of secondary materials in each production batch (often only per production volume). Allocation mechanisms may be needed.
- Stakeholders reported that at present, collaboration among actors is not fully optimal in the Li value chain. In the Pb value chain documentation procedures are working effectively and could be used as reference.

— **Verification and data sharing across the value chain**

- Stakeholders reported that at present no harmonised data transmission mechanism exists. The system is based on the trespassing of non-standardised certifications amongst value chain operator. It was proposed to implement an EU certification system with third-party verification.
- Some information (e.g. identity of suppliers) is sensitive and cannot be transferred along the value chain. Mechanisms should be in place to prevent disclosure of sensitive information and ensure business confidentiality.

81 The material origin is difficult to track when using black mass as feedstock. Granular data on the metal content at goods-in should be provided by the previous actor (mechanical recycler producing black mass) and accompanied by proof of origin.

- Commercial solutions exist to trace recycled throughout the value chain in a confidential manner.
- There is concern among stakeholders about EU calculation rules that will not be rigorously applied outside the EU. Extra-EU verification bodies may be needed, due to the global nature of the battery value chain.

— **Possible exemptions**

- Stakeholders suggested to establish minimum thresholds for the presence of materials subject to recycled content targets in active materials, to avoid disproportionate burden for materials present in small shares in the battery active mass (e.g. Co may be present in small amounts in future batteries).
- It was also proposed to exempt companies of a small size from compliance.

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