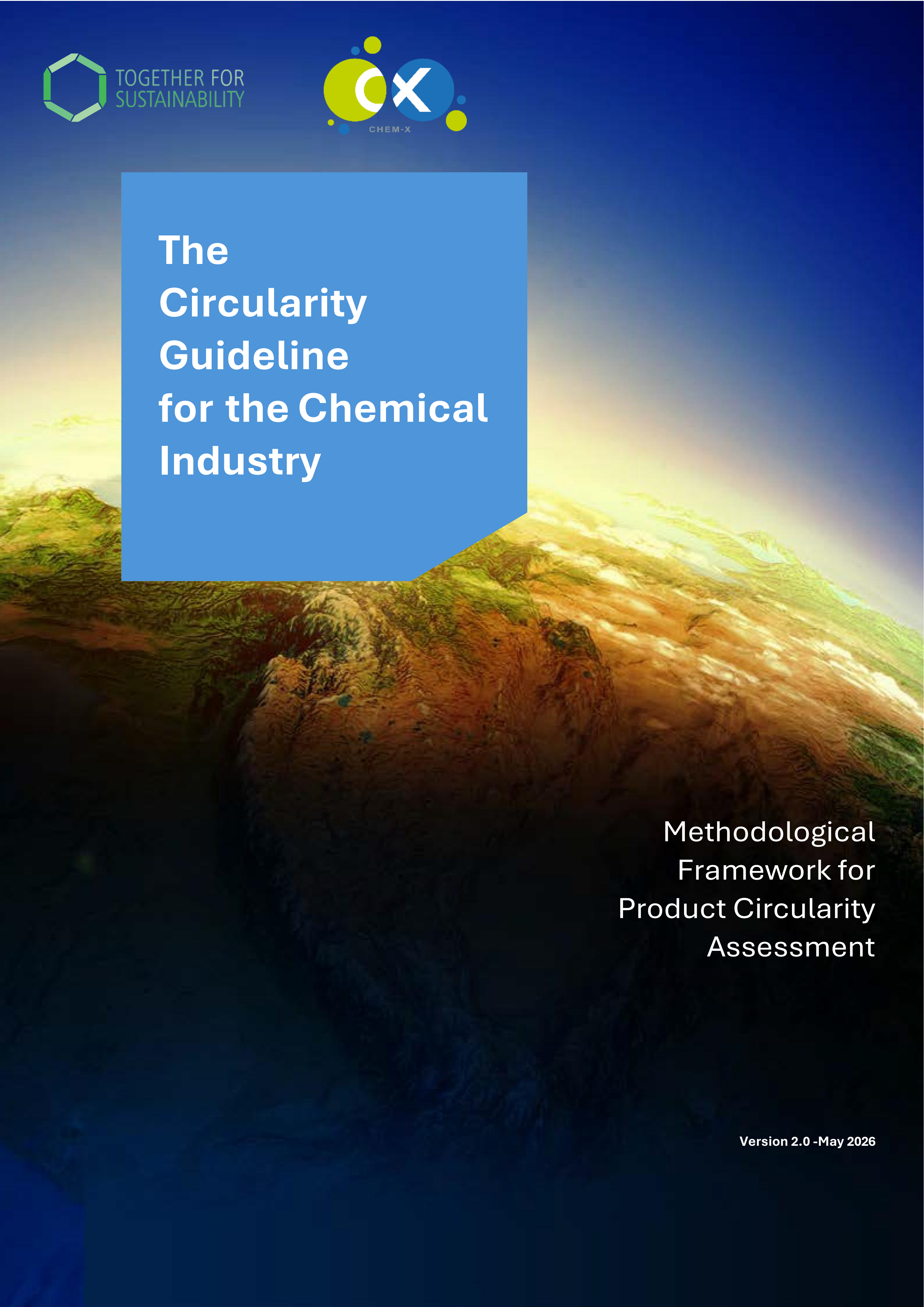


TOGETHER FOR SUSTAINABILITY

CHEM-X

The Circularity Guideline for the Chemical Industry

Methodological Framework for Product Circularity Assessment

Version 2.0 -May 2026

CHEM-X

Together for Sustainability
Chem-X consortium

The Circularity Guideline for the Chemical Industry

Methodological Framework for Product Circularity Assessment

Version 2.0 - May 2026

For more information,
please visit www.chem-x.de

Funded by the Federal Ministry of
Economic Affairs and Energy
BMWE

Funded by
the European Union
NextGenerationEU

Supported by:
Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

Participating partners

Chem-X participating partners:

- BASF SE
- coac GmbH
- Cofinity-X GmbH
- Covestro Deutschland AG
- DAW SE
- Henkel AG & Co. KGaA
- Merck KGaA
- SAP SE
- Siemens AG
- Spherity GmbH
- Wacker Chemie AG
- Catena-X e.V.
- Together for Sustainability (TfS) AiBSL
- Evonik Industries AG
- Sika Services AG

Together for Sustainability AISBL member companies (Status May 2026):

AdvanSix
AkzoNobel
allnex
ALTANA
ARCHROMA
ARKEMA
arxada
azelis
BASF
BAYER
BRENNTAG
CABB
CALDIC
Celanese
Chemours
CLARIANT
covestro
CRODA
Dow
dsm-firmenich
EASTMAN
eternis
EVONIK
Givaudan
HR GROUP
和创化学 HC Chemical
HEMPEL
Henkel
ICL
iff
IMCD
INDORAMA
JIAHUA
JM Johnson Matthey
KRATON
LANXESS
Lenzing
Lonza
LyondellBasell
Merck
MITSUI & CO.
MOMENTIVE
Nouryon
novonesis
OMV
P&G
PPG
sabic
SEMPERIT
Sennics
Sika
SOLVAY
SYENSQO
symrise
syngenta
synthomer
TAKASAGO
TRICON
Univar Solutions
UPM
WACKER
WANHUA
YARA

Note to the table of contents:

This document covers the "Module 1" and "Module 2" releases of "The Circularity Guideline for the Chemical Industry" as part of project Chem-X. The sections marked with an asterisk will be covered in future module releases.

Table of Contents

*Content chapters covered in future Guideline module releases.

List of Figures

List of Tables

1. Background & Context

The global chemical industry, a cornerstone of modern manufacturing, is at a pivotal juncture. As the world grapples with climate change, resource scarcity, and environmental degradation, the transition to a circular economy has emerged as a critical pathway for sustainable growth and resilience, particularly in the context of complex value chains and the global geopolitical uncertainties that affect supply chain stability.

A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use for as long as possible, closing the loop from end-of-life (EoL) to recycled input, and regenerating natural systems.

For the chemical sector, this means rethinking how raw materials are sourced, how products are designed and manufactured, and how EoL materials are recovered and reintegrated into the value chain. With over 95% (International Council of Chemical Associations (ICCA), 2020) of manufactured goods requiring chemical inputs, the sector is in fact marking both the beginning of most value chains and the “new beginning” of materials undergoing chemical recycling processes or making use of CO_2 as a feedstock.

In the European Union, the circular economy is a central pillar of the European Green Deal (European Commission, 2019). The EU’s circular economy monitoring framework includes 11 key indicators across five thematic areas, tracking progress in resource use, waste management, and secondary raw material flows (Eurostat, 2023).

The European Commission is also currently working on a Circular Economy Act (due for adoption in 2026) to establish a Single Market for secondary raw materials, increase the supply of high-quality recycled materials and stimulate demand for these materials in the EU. The goal is to boost the EU’s competitiveness and economic security, while advancing sustainable production, circular business models, and decarbonization. In this context, The European Commission also launched a public consultation and Call for Evidence for the upcoming Circular Economy Act (European Commission, 2025).

The economic potential of circular economy is equally compelling. A report by the Center for Global Commons and Systemiq estimates that embracing circular and low-carbon technologies in the chemical sector could create up to 29 million new jobs globally (Center for Global Commons, University of Tokyo, Systemiq, 2022). As outlined in a recent paper of the World Economic Forum (WEF), a more circular economy can foster deeper collaborations, transforming suppliers into partners and products into services that can be used again (World Economic Forum, 2023).

The chemical industry is rather unique, as it is currently doubly reliant on fossil raw materials, both for energy use and as a feedstock for the synthesis of the key chemical building blocks upon which chemical manufacturing is based on. In this context, the broad term of circularity, encompassing the shift from the use of primary feedstocks towards the adoption of recycled waste-based, renewable or CO_2-based raw materials, represents a key pathway towards the achievement of carbon neutrality (International Council of Chemical Associations (ICCA), 2023).

Circularity offers some key strategic benefits for the chemical sector, as well as for other downstream industries:

- Resource Security and Resilience: Circular practices reduce dependency on virgin fossil-based feedstocks by promoting the use of recycled and biogenic materials, enhancing supply chain resilience.
- Market Competitiveness: Offering circular products and services is a market differentiator and a requirement to remain competitive in a sustainability-driven global economy.
- Innovation and Collaboration: Circularity fosters innovation in materials science, process engineering, and digital technologies. It also encourages cross-sector collaboration, transforming traditional supplier relationships into strategic partnerships.
- Regulatory Compliance: With increasing regulatory pressure, especially in Europe, - such as the Packaging and Packaging Waste Regulation (PPWR), the Ecodesign for Sustainable Products Regulation (ESPR), or the upcoming mandatory Digital Product Passports (DPP) - circularity is becoming a compliance requirement on the path to reduce environmental impacts (European Parliament and the Council of the European Union, 2024a; European Parliament and the Council of the European Union, 2024b).

Therefore, the circular economy is not just an environmental initiative, it is a strategic transformation for the chemical industry. By embedding circular principles into own operations as well as up- and downstream value chains, chemical companies can unlock new value, reduce environmental impact, and lead the transition to a more sustainable and resilient global economy.

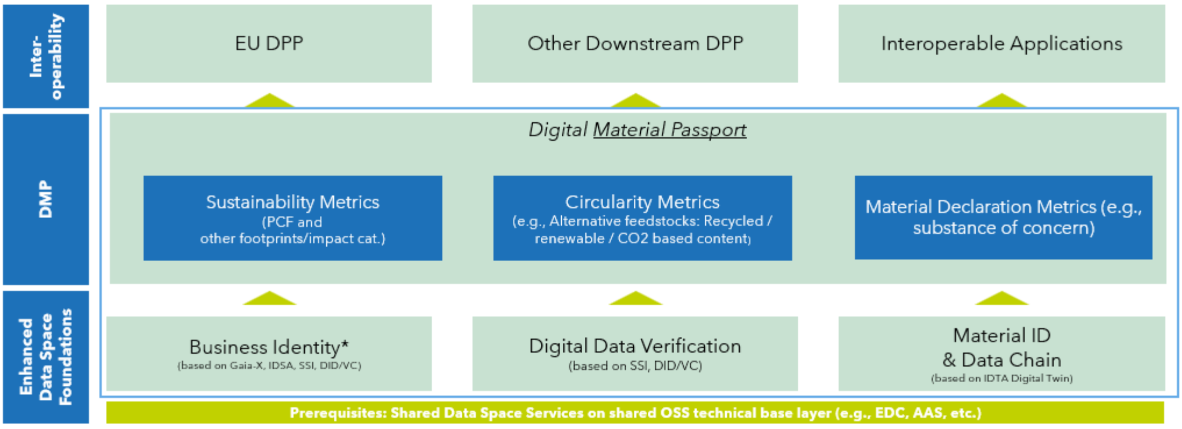
In 2024, only 6.9% of the global economy was circular, a slight decline since 2020, according to a study by the Circular Economy Foundation and Deloitte (Circle Economy & Deloitte, 2025).This highlights that the fundamental transformation from linear to circular supply chains still lies ahead of us.

A sustainable circular economy requires transparency regarding the impacts of processes and products, with the chemical industry playing a central role. This sector not only focuses on the responsible production of products with optimal ecological profiles but also lays the foundation for material recycling across all value chains. To enable effective and efficient material cycles, a regulated exchange of data on the relevant chemical and physical properties of all products is essential.

2. Objective & Scope

Since the chemical industry is integrated into nearly all value chains that produce physical products, it is necessary to develop a common language for the exchange of chemical input-related information. Digital Material Passports (DMPs) and Digital Product Passports (DPPs)(i.e., digital twins of their physical products have been identified as suitable tools for data transfer). The content definition of these passports for chemical materials remains unresolved and is the focus of the Chem-X project and of this guideline document, which aims at defining and describing the key metrics required to characterize circular flows.

The objective of this guideline is to provide a harmonized terminology, description and selection for the key circularity metrics relevant for chemical materials, ensuring transparency and clarity in communication, as well as interoperability in the provision of circularity data via DMPs through the complexity of chemical supply chains, enabling the fulfillment of regulatory requirements in DPPs (Figure 1).



* Includes positive list of supply chain due diligence and legal entity specific certificates

Figure 1: Chem-X DMP/DPP relations.

This document focuses on key circularity metrics which measure the circularity performance of resources entering (and leaving) the system boundary. Metrics which can only be accurately determined in the use phase of a product and depend on the type of application or end product design (e.g., durability, repairability) or are even dynamic in nature (e.g., state of health or state of charge in the case of batteries) are out of scope for this document, which aims at supporting the development of an interoperable data space for product information of chemicals and materials.

It is important to allow sufficient time for companies to build the necessary capabilities to implement, measure and act upon such metrics. Therefore, a staged roll-out approach, including a transition period with voluntary reporting ahead of any final mandatory enforcement, may be envisaged. This approach does not imply mandatory reporting on all possible items from the outset. Rather, it should be based on a minimum set of core information—such as a minimum viable passport—combined with a clear roadmap and overall direction for future requirements. The accompanying information model, once published, will provide a structured reference for what information may be included in the DMP and will support progressive alignment and refinement of the reporting of metrics over time. As circularity metrics often relate to complex global value chains, particular care should be taken to allow sufficient time for testing and methodological refinement.

3. Glossary

Term, Abbreviation	Definition	Source
Section related to DMP and DPP		
Digital Material Passport, DMP	A structured digital record for a material that contains detailed information about sustainability and circularity, as well as required and potentially optional declarations, certificates, and additional material information. It focuses on intermediate materials in the value chain which may not be subject to regulation, but whose data is required to enable the issue of regulated Digital Product Passports (DPPs). DMPs are designed to interoperate with one or more DPPs.	Chem-X Definition
Digital Product Passport, DPP	A structured digital record for a product that contains detailed information about sustainability and circularity, as well as required and potentially optional declarations, certificates and additional product information. It focuses on a regulated end product in the value chain. Both its information content and technical requirements follow regulatory requirements and/or standards delegated by the legislator to designated standardization bodies.	Chem-X Definition *Note 1: based on DPP definition in ESPR.*
Section related to chapters 4 and 5		
Backfilling	Any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must *substitute* non-waste materials, be suitable for the aforementioned purposes, and	EU Waste Framework Directive (2008/98/EC)

	be limited to the amount strictly necessary to achieve those purposes.	
Bio-based	Derived from biomass. *See "Biogenic", which will be used as leading term.*	EN 16575:2014
Biogenic	Derived from biomass.	ISO 14067:2018 *Note A: extracted from definition of biogenic carbon*
Biogenic carbon content	Fraction of carbon mass (out of total material mass) classified as biogenic. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095, where applicable by sector specific rules. Note 2: If analytically measurable via ^{14}C-analysis, it can be classified as "bio-based carbon content". Note 3: If not analytically measurable via ^{14}C-analysis (e.g., by applying mass balance chain-of-custody model), it can be classified as "bio-attributed carbon content". *"Biogenic carbon content" will be used as leading term in this document.*	Derived from ISO 59020:2024 *Note 1: based on ISO 59020:2024 section A.2.1 "Introduction to resource inflow circularity indicators", in analogy with "renewable content"*
Biogenic content	Fraction of material mass content classified as biogenic. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095, where applicable by sector specific rules. Note 2: This includes all molecules/atoms (carbon and non-carbon like nitrogen) derived from biomass and excluding added water.	Derived from ISO 59020:2024 *Note 1: based on ISO 59020:2024 section A.2.1 "Introduction to resource inflow circularity indicators". in analogy with "renewable content"*

Biomass	Material of biological origin, excluding material embedded in geological formations and material transformed to fossilized material. Note 1: Biomass includes organic material (both living and dead), e.g., trees, crops, grasses, tree litter, algae, animals, manure and waste of biological origin. Note 2: Excludes peat.	ISO 14067:2018
CO_2 Capture and Utilization, CCU	Process involving the separation and extraction of CO_2 from a CO_2-containing medium and using this CO_2 in a production process for the manufacture of a carbonaceous product or other use of the CO_2. Note 1: CCU is limited to CO_2 which would have otherwise been emitted. The CO_2 cannot be produced exclusively for the capturing process.	Derived from DIN SPEC 91508:2025-04
CO_2-based content	Fraction of material mass originating from CO_2 capture and utilization Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095, where applicable by sector specific rules.	Chem-X definition
CO_2-based carbon content	Fraction of carbon mass (out of total material mass) originating from CO_2 capture and utilization. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095, where applicable by sector specific rules.	Chem-X definition

Certified share	Fraction of material mass which has been certified by an accepted conformity assessment party regarding the traceable sustainable sourcing of the raw materials and/or manufacturing of the product, and the related determination of the share.	Chem-X definition
Circular Inflow	A resource inflow that is defined as circular, meaning it belongs to one or more of the following categories: a) reused content b) recycled content c) virgin renewable content d) virgin renewable energy-based content. Note 1: CO_2-based content for captured CO_2 is classified as recycled content.	Derived from ISO 59020:2024
Direct Air Capture, DAC	Technological process extracting CO_2 directly from the atmosphere, for CO_2 storage or utilization.	International Energy Agency (IEA), iea.org
End-of-Life, EoL	The end-of-life stage begins when the used product under study is ready for disposal, recycling, reuse for different purposes or energy recovery. Note 1: End-of-life processes may include: a) collection, packaging and transport of end-of-life products; b) preparation for recycling and reuse; c) dismantling of components from end-of-life products; d) shredding and sorting; e) material recycling; f) organic recovery (e.g., composting and anaerobic digestion); g) energy recovery or other recovery processes; h) incineration and sorting of bottom ash; i) landfilling, landfill maintenance and promoting emissions from decomposition, such as methane.	Derived from ISO 14067:2018

End-of-Waste	Waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste if it complies with the following conditions: (a) the substance or object is to be used for specific purposes; (b) a market or demand exists for such a substance or object; (c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and (d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.	EU Waste Framework Directive (2008/98/EC) | Article 6
Fossil carbon	Carbon that is contained in fossilized material. Note1: Examples of fossilized material are coal, oil, natural gas and peat.	ISO 14067:2018
Pre-consumer waste	Material or product which the holder discards or intends or is required to discard before it has been put in use. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it. Pre-consumer waste = post-industrial waste Note 1: Unsold goods shall not be classified as pre-consumer waste.	Derived from FprEN 18065 and ISO 14021
Primary material	*See "Virgin material" (synonym), which will be used as leading term.*	

Post-consumer waste	Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product, which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.	Derived from FprEN 18065 and ISO 14021
Post-industrial waste	*See "Pre-consumer waste" (synonym), "Post-industrial waste" will be used as leading term in this document.*	
Recovery	Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.	EU Waste Framework Directive (2008/98/EC) *Note 1: Annex 2 in EU Waste Framework Directive (2008/98/EC) provides a non-exhaustive list of recovery operations, which includes for example recycling*
Recovered material	Secondary resource that is obtained from one that has already been processed or used. Note 1: Other terminology used, depending on the context, includes "secondary material".	Derived from ISO 59004:2024
Recycled content	Fraction of material mass content classified as recycled. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095.	Derived from ISO 59020:2024 *Note 1: based on ISO 59020:2024 section A.2.1 "Introduction to resource inflow circularity indicators" .*

Recycling	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.	EU Waste Framework Directive (2008/98/EC)
recycling, closed-loop	A recycling process in which the output (e.g., recyclate) is used as content in a product or application of the same broad product category that it originated from. (e.g., Recycled packaging being used to make new packaging. EOL car component being used to make another car part. Polymer fabric being made into another polymer fabric).	Derived from Circular Transition Indicators, WBCSD (CTI)
recycling, open-loop	All other cases, which do not fall under the closed-loop definition can be seen as open-loop recycling (e.g., Recycled PET bottle being made into car seat fabric. PU foam from waste mattresses made into carpet underlay.).	Derived from Circular Transition Indicators, WBCSD (CTI) Note A: Not defined itself in CTI, complementary definition to closed-loop recycling.
Renewable energy	Energy from a renewable resource. Note 1: From energy sources that replenish (or renew) themselves naturally (e.g., solar energy, wind energy, biomass).	ISO 59004:2024
Renewable material	Material from a renewable resource. Note 1: Material that is composed of biomass (i.e., biogenic) and that can be continuously replenished or cleansed on a human timescale.	Derived from ISO 59004:2024, ISO 14021:2016 and ISO 6707-3:2022

	Note 2: Material that is not composed of biomass but is also replenished within a human timescale by processes found in nature (e.g., oxygen from air).	
Renewable energy-derived material	A material derived in the Technosphere from renewable energy and material resources that can be replenished on a human timescale (e.g., hydrogen from water electrolysis using renewable energy).	Chem-X definition
Renewable material content	Fraction of material mass content classified as renewable. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095, where applicable by sector specific rules.	Derived from ISO 59020:2024 *Note 1: Based on ISO 59020:2024 section A.2.1 "Introduction to resource inflow circularity indicators".*
Renewable resource	Resource that can be naturally or artificially grown or replenished within a foreseeable time frame by processes found in nature. Note 1: It refers to both renewable materials and renewable energy. Note 2: Some renewable resources are inexhaustible (e.g., the sun) while others are capable of being exhausted but can be regrown or replenished indefinitely with proper stewardship in line with sustainable development.	ISO 59004:2024
Reuse	Use of a product or its component parts after their initial use, for the same purpose for which they were originally designed.	Derived from ISO 59004:2024 and EN 15643:2021, and EUR-Lex 52007DC0059[1]

---

[1] Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on waste and by-products, 2007 (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52007DC0059)

	Note 1: Minor treatment (e.g., cleaning, removal of connection, trimming, stripping of coatings) of the product can be needed by the user to prepare and allow for reuse without any other reprocessing. Note 2: In some cases, resources such as water, are considered as a product, in which case the purpose of “original design” is not applicable. Note 3: Including the reutilization of rework, regrind or scrap materials generated within the process and capable of being fed back into the same process generating them or in other integrated productions where reuse is also certain, allowing waste to be reduced and materials to be kept in a loop.	
Reused content	Fraction of material mass content classified as reused. Note 1: Can be attributed by means of a mass balance chain of custody model as defined in ISO 22095 , where applicable by sector specific rules.	Derived from ISO 59020:2024 *Note A: based on ISO 59020:2024 description of “resource inflow circularity indicators”*
Secondary material | Secondary raw material | Secondary resource material	Material that has previously been processed or used (e.g., end-of-life material arrived as waste), has been captured by a recovery system and has completed all recovery process steps, and can be used as an input to produce new materials and products Note 1: Other terminology used, depending on the context, includes ‘’recovered material.” Note 2: Secondary material encompasses post- and pre-consumer recycled material, as well as reused material.	Derived from ISO 59014 and prEN 15897

System boundary	Boundary based on a set of criteria specifying which unit processes are part of the system under study.	ISO 14050:2020
Technosphere	Sphere or realm of human technological activity which results in a technologically modified environment.	ISO 59004:2024
Unit process	Smallest element considered in the life cycle inventory analysis for which input and output data are quantified.	ISO 14050:2020
Virgin material	Material that has not been subjected to use or processing other than that required for its manufacture and to which no reused or recycled material has been added.	Derived from ISO 21003-1:2008
Waste	Any substance or object which the holder discards or intends or is required to discard Note 1: A substance or object resulting from a production process the primary aim of which is not the production of that substance or object is considered not to be waste, but to be a by-product if the following conditions are met: (a) further use of the substance or object is certain; (b) the substance or object can be used directly without any further processing other than normal industrial practice; (c) the substance or object is produced as an integral part of a production process; and (d) further use is lawful (i.e., the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts).	EU Waste Framework Directive (2008/98/EC)

Section related to chapter 6		
Attribution	Assignment of specified characteristics to *outputs* or part of the outputs.	ISO 22095-2:2026
Balancing period	Time frame when the *inputs* and *outputs* with specified characteristics are balanced in the temporal boundaries of the system.	ISO 22095-2:2026
Chain of custody	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.	ISO 22095:2020
Claim	Declared information regarding the specified characteristics of a material or product. Note 1: Information can be any message or representation, including text, pictorial, graphic or symbolic representation in any form in the context of a commercial communication. Note 2: A claim can be made using various means or channels for example on the product or physically attached to the product or physical or virtual information about the product.	ISO 22095-2:2026
Claim period	Time frame when *claims* can be made on products.	ISO 22095-2:2026
Conformity assessment	Demonstration that specified requirements are fulfilled. Note 1: Conformity assessment can be performed as - first-party activity, if performed by the person or organization that provides or that is the object of conformity assessment;	ISO 22095:2020

	- second-party activity, if performed by a person or organization that has a user interest in the object of conformity assessment, or - third-party activity, if performed by a person or organization that is independent of the provider of the object and has no user interest in the object of conformity assessment.	
Credit	Representation of the quantity of attributable *units* with entitlement to claim the ownership of specified characteristics.	ISO 22095-2:2026
Conversion factor	Ratio which is used to determine the quantity of output or part of the output with specified characteristics that can be obtained from the quantity of the input with specified characteristics, taking into account any losses.	ISO 22095-2:2026
Evaluation period	Time frame when the performance of the chain of custody system is monitored, measured, analyzed and evaluated, by conducting audits to assess the performance of the chain of custody system procedures and the conformance with all applicable requirements.	ISO 22095-2:2026
Requirement setter	Person or organization that specifies the requirements for a particular chain of custody.	ISO 22095:2020
Similar in nature	Material, products, or concepts that share e.g., common characteristics, functionalities, qualities, compositions or attributes, making them alike in fundamental aspects.	ISO 22095-2:2026
Specified characteristics	Set of product characteristics and/or production characteristics that the chain of custody is designed to maintain.	ISO 22095:2020

System boundary of chain of custody (CoC)	Boundary based on a set of criteria specifying which processes or sites are part of the system under study.	ISO 22095-2:2026
Technically feasible	Following an existing and operable route to obtain the *output* or parts of the output from the *input(s)* with specified characteristics within the *system boundary of CoC*.	ISO 22095-2:2026

4. Circular Sources & Technologies

The transition towards a circular economy requires transparent, accessible information about material flows throughout product lifecycles, with the DPP/DMP as a key instrument enabling the assessment and sharing of those datapoints that are necessary across value chains. This chapter outlines the material flows in our economy, with particular focus on the way circularity can influence these flows and thereby reduce the impact on the environment and overall virgin resource consumption. Whether or not a product can be considered circular depends on the origin of its feedstock (Figure 2).

In today’s mostly linear economy, material flows follow the pathway highlighted in grey starting from virgin raw material extraction followed by manufacturing and use-phase to end-of-life materials or waste which ends up in landfill, incineration or composting. In a circular economy, non-renewable virgin materials such as fossil-fuels, metal ores and non-metallic minerals are being replaced with renewable resources like biomass or secondary material based on waste, as well as CO_2 as carbon source from captured incineration or process emissions (shown in green, blue and purple paths on Figure 2).The use of those alternative materials typically requires new strategies for waste management, recycling and product redesign. Therefore, this chapter also focuses on technological aspects of renewable materials, recycling and reuse aspects.

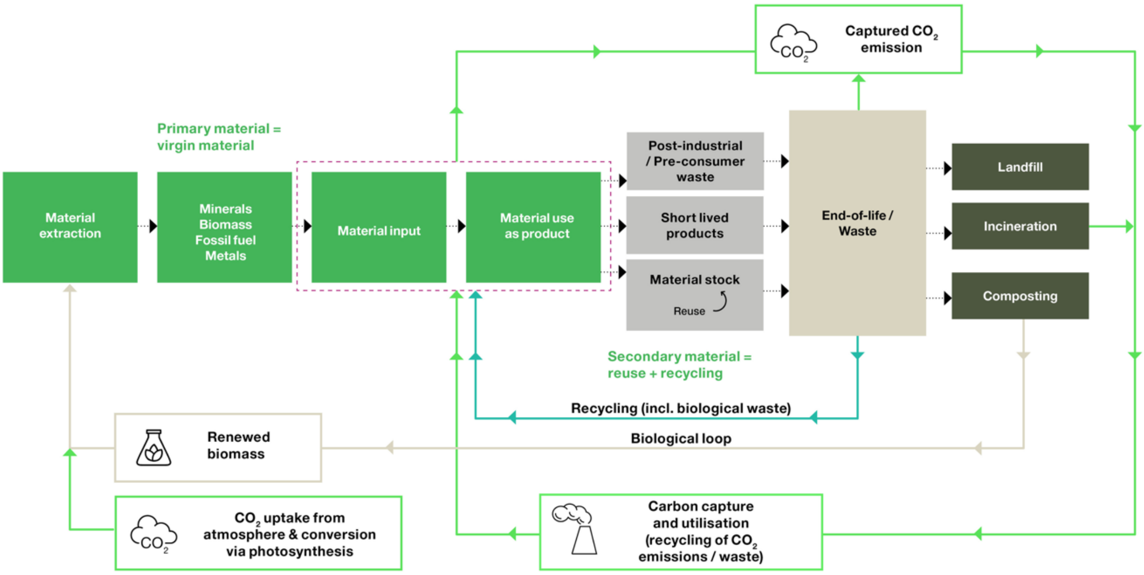


Figure 2: Schematic material flow chart along the material life cycle from virgin material extraction via material use as product to the different end-of-life / waste options and their potential contribution to circularity.

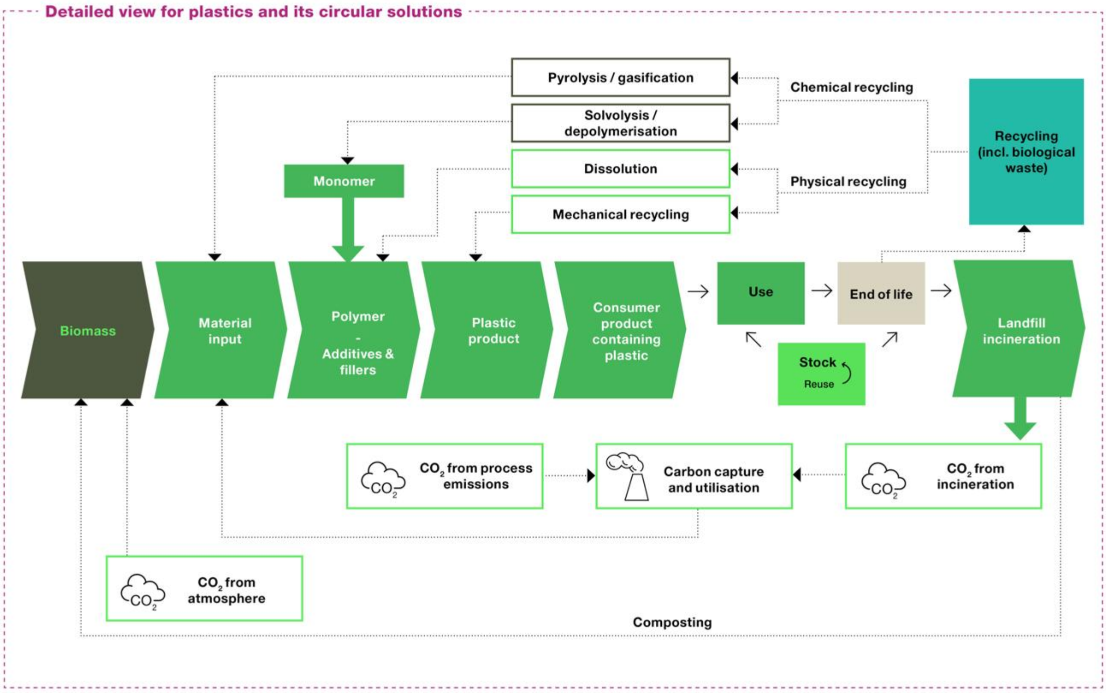


Figure 3: Visualization of detailed circularity options for plastics.

To demonstrate circularity, it is important to provide information on whether feedstock sources originate from reused material, waste, renewables, or are CO_2-based. The DMP/DPP provides the framework to share this information between value chain players such as waste generators, recycling facilities or secondary material users. For example, Figure 3 visualizes the detailed circularity options for plastics including reuse, the specific recycling options, composting and CO_2 uptake from the atmosphere within the biological loop, as well as CCU (carbon capture and utilization) from point sources like incineration or process emissions where CO_2 is an off-gas. Information needed to enable closing the loop from waste to a secondary material should follow the ‘need to know principle’ and be limited to a justified minimum for sustainability targets.

4.1. Renewable Resources

In the transition towards a low-carbon and circular economy, the role of renewable resources is becoming more relevant, also for the chemical industry, which is increasingly turning from linear to circular feedstocks. Renewable resources – both in the form of biogenic raw materials and renewable energy – support reducing the dependency on fossil-based inputs and lowering greenhouse gas (GHG) emissions.

Renewable materials are replenished within a foreseeable timeframe by processes found in nature. Typically, this means they are derived from biomass even though processes in nature do not only renew biomass (see Glossary, renewable materials definition, note 2). Alongside impactful levers such as waste-based feedstocks, electrification with an expanded use of renewable energy, renewable and biogenic materials pose a natural alternative to fossil-based economies for going circular and for mitigating climate change.

The use of biomass should be prioritized for the application most valuable to society, long-lasting applications and progressively move to lower value and shorter lasting uses before final disposal, creating a cascading use of biomass. The idea is that renewable materials are first processed into high-value-to-society products like pharmaceuticals, food, feed. After the initial use, the materials can then be repurposed for other material applications, further extending their value and lifespan. Only when biomass or its derived products can no longer be used for material purposes, is it considered for fuel and energy recovery.

Biogenic materials can be categorized in a couple of ways:

Primary and secondary feedstocks[2]:

- Primary feedstocks are materials directly harvested (e.g., maize, wheat, sugarcane, sugar beet, rapeseed, soybean and palm oil) and used in their original form or processed for use (e.g., crushed, milled). These feedstocks are often well-established in supply chains and offer high yields and processability, making them attractive for large-scale chemical production.
- Secondary feedstocks refer to by-products or residues generated during the processing of primary feedstock or from other industrial processes. They are derived from organic residuals and waste such as agricultural waste, manure, lignocellulosic biomass, or woody crops. They can substitute in certain applications with primary feedstocks thereby reducing waste generation.

1st, 2nd and 3rd generation feedstocks:

- 1st generation feedstocks refer to crops and plants that can be consumed by humans or animals as food/feed.
- 2nd generation feedstock refers to crops and plants not suitable for human or animal consumption as food/feed. They can be either non-food crops (i.e., cellulosic feedstock), for example derived from non-food biomass grown on marginal land unsuitable for food production, or waste materials from first generation feedstock (e.g., waste vegetable oil).
- 3rd generation feedstock refers to biomass not derived from arable land (e.g., algae).

To track and report from which biomass the biogenic content originates, because of market or regulatory requirements, it is useful to introduce the concept of “Biogenic origin indicator” to cover existing classifications. The concept will be illustrated in chapter 5.

Although, the division of biomass as per the above classifications (e.g., generations 1 to 3) is commonly referenced in literature, it is not detailed enough to account for the significant practical impacts arising from regional variations, species dependence, and other factors. The lack of a practical evaluation system has left industries and regulators without a pragmatic solution for expanding the bioeconomy for materials production. Sourcing sustainable biogenic materials is in reality very complex, with a challenging tracking situation and many parameters making up the impact on the planet. A more nuanced system should be implemented, making pragmatic use of biomaterials straightforward with clear rules that industry can adopt – possibly encompassing biomass-origin and related lifecycle assessment, food supply impact, etc. –, and that regulators can incentivize accordingly.

---

[2] Note: the definition of „primary“ and „secondary“ in this specific biogenic feedstock context differs from the definition of “primary” and “secondary” material in this document and in the Glossary.

As an interim measure, the DMP/DPP could incorporate, within and alongside its circularity metrics dataset for renewable and secondary materials, the certificates to proof the sustainable production or sourcing of such materials, as well as their traceability, supporting the claim of a "certified share" (see also chapters 5 for more details).

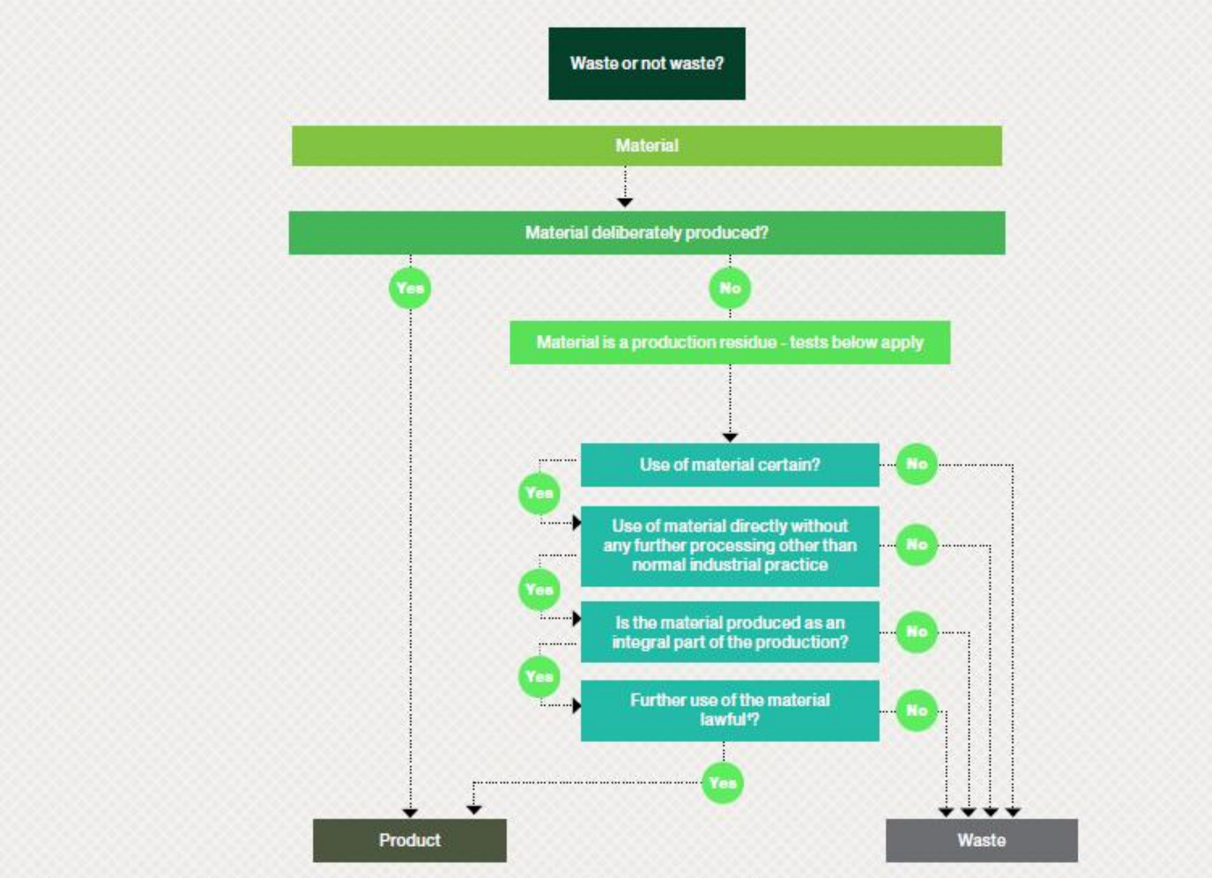
Renewable energy plays a complementary role in powering chemical processes with electricity from wind, solar, or biomass sources (e.g., biogas). This electrification of chemical production – such as through electric steam crackers or renewable-powered synthesis routes – further decouples industrial output from fossil carbon. Unlike fossil fuels, these sources do not deplete finite resources and typically emit little to no GHGs during operation. The integration of renewable energy is central to the chemical industry's net-zero transition by reducing Scope 1 emissions (from on-site fuel combustion), Scope 2 emissions (from purchased electricity), and indirectly supports Scope 3 reductions by enabling low-carbon products.

Materials which are resulting from processes in the Technosphere fully employing renewable energy and material resources that can be replenished on a human timescale are defined as "renewable energy derived".

4.2. Waste

In a linear economy, waste is the final lifecycle stage, typically when something without value for the holder is discarded (European Parliament and the Council of the European Union, 2024c).While in a circular economy, waste is an intermediate gaining back value as a resource for a recycling step.

The EU Waste Framework Directive (European Parliament and the Council of the European Union, 2024c) gives guidance on what type of materials should be considered as waste as opposed to (co-) products, as visualized in the following decision tree (Figure 4):



(1) If the use of materials is lawful needs to be checked specifically for the region, e.g. in Europe Article 5(1)(d) Waste Framework Directive (WFD).

Figure 4: Definition of product vs. waste (Together for Sustainability, 2024).

“Normal industrial practice” can include all steps which a producer would take for a product, such as the material being filtered, washed, or dried; or adding materials necessary for further use; or carrying out quality control. However, treatments usually considered as a recovery operation cannot, in principle, be considered as normal industrial practice in this sense.

Waste is generally defined by multi-level legislation (international, national, and local), with formal classification systems determining how materials must be managed. Once classified as waste, this status remains until formal end-of-waste procedures are completed according to criteria established by regulatory authorities.

Even though CCU from a point source like incineration and process emissions where CO_2 is an off-gas and therefore a waste, the topic of CO_2-based products has its own chapter within this guideline and is therefore elaborated in detail in chapter 4.5.

With the goal to establish a hierarchy of waste management options, prioritizing prevention, preparation for reuse, recycling, other recovery (e.g., energy recovery) over mere disposal, the European Waste Framework Directive (WFD) (European Parliament and the Council of the European Union, 2024c) introduced the so called "Waste Hierarchy" (Figure 5) ranking from top to bottom the possible strategies according to their environmental benefits.

Its aim is twofold:

- minimizing adverse impacts of the generation and management of waste; and
- improving resource efficiency.

Figure 5: Waste hierarchy illustration (European Parliament and the Council of the European Union, 2024c).

This approach encourages sustainable resource management by keeping materials in productive use for as long as possible and extracting maximum value before final disposal. It guides policy development, business practices, and individual behavior toward more environmentally responsible waste management.

Transforming waste back into a product - for example through a recycling process - entails bringing material from waste legislation back to the realm of product legislation when certain conditions are met. This transition is called "end-of-waste" and marks the beginning of a new material lifecycle. The end-of-waste criteria is defined in Glossary (Section 3) and in European Waste Framework Directive (European Parliament and the Council of the European Union, 2024c).

Because of regulatory or market requirements, it is important or at times even mandatory to track and report from which waste stream the recyclate originates. The following illustration (Figure 6) shows the three most common waste-origin indicator typologies based on position in the value chain: before or after use (A), on industry (B) or on geography (C). More details about this concept will be provided in chapter 5.

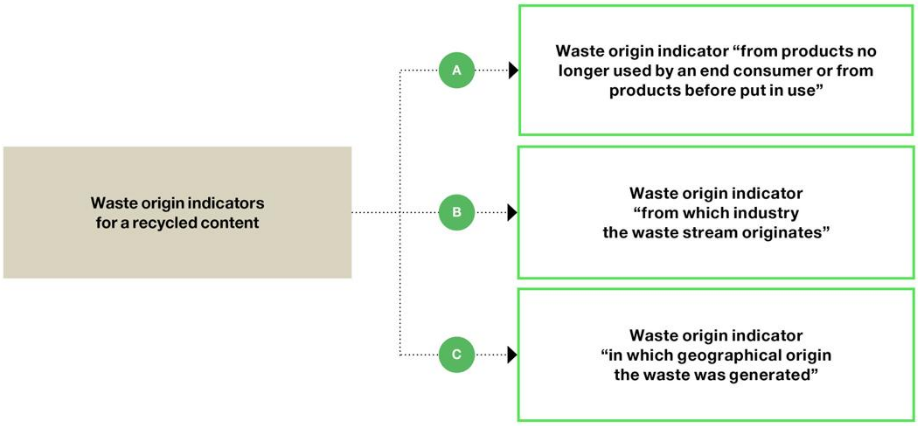


Figure 6: Typologies of waste-origin indicators.

Although keeping recycling loops short and contained within a given geography or industry may offer advantages in terms of economics, regional autonomy, environmental impact or efficacy of policy implementation, it must be emphasized that "open-loop" recycling does also represent an effective strategy to maximize circularity rates. As a matter of fact, open-loop recycling does not necessarily imply a downcycling but can also lead to upcycling into more valuable and durable applications, especially if versatile recycling technologies like chemical recycling are employed.

4.3. Recycling

Recycling is part of the waste hierarchy (Figure 5), and it is prioritized compared to energy recovery and disposal. In the WFD "recycling" is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Even though CCU from point sources like incineration and process emissions where CO_2 is an off-gas subsequently captured and used is recycling. Because that off-gas is waste utilized in a process that ends up in a CO_2-based product, or in other words, this off-gas is recycled. The topic of CO_2-based products has its own chapter within this guideline and is therefore elaborated in detail in chapter 4.5.

Numerous recycling technologies exist. The chart (Figure 7) and Table 1 below help provide an overarching classification for those. While a recycling technology indicator can be a valid data attribute to characterize a recyclate, as outlined in chapter 5, it must be emphasized that all listed recycling technologies have their benefits and drawbacks, so that they should all qualify as eligible for contributing to the total recycled content metric.

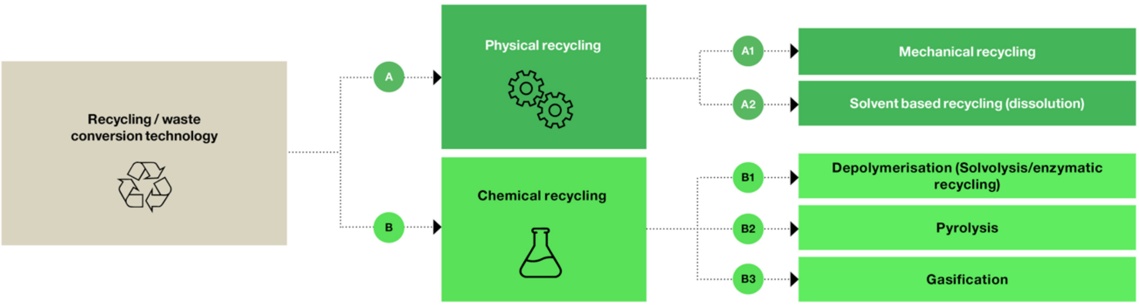


Figure 7: Overview recycling technologies.

Table 1: Recycling technologies.

Technology	**Description**
Common recycling technologies for chemical materials	
Physical recycling technologies	
Mechanical Recycling	Mechanical recycling is a process where materials (especially plastics) are physically processed without changing their chemical structure. It typically involves collecting, sorting, cleaning, shredding, melting, and remolding materials into new products. This method is commonly used for thermoplastics like PET, HDPE, and PP.
Solvent-based recycling (Dissolution)	Solvent-based recycling is a recycling process that uses selective dissolution and precipitation to separate target materials from waste streams using solvents, without breaking down the molecular structure of the materials. The process includes the dissolution of the target material in a suitable solvent, followed by a purification step to remove contaminants, and finally the recovery of the purified material through precipitation or other separation techniques.
Chemical recycling technologies Chemical recycling involves transforming waste streams such as polymers into chemical substances by changing the chemical structure of the waste stream. This is done through processes like the ones listed below. It does not include energy recovery, or the production of materials used as fuel or for backfilling.	
Depolymerization	Depolymerization is a chemical recycling process that breaks down plastic polymers into their original monomeric or oligomeric or polymeric building blocks[3] or other basic chemicals using heat,

---

[3] Note: In some cases, depolymerization can yield products that are themselves polymeric. For example, the depolymerization of polyurethanes yielding polyols, which may be polymeric compounds depending on their chemical structure.

	catalysts, or solvents. These monomers can then be purified and re-polymerized into new plastics. Established depolymerization technologies are e.g.: “Solvolysis” and “Enzymatic Recycling”. Solvolysis uses a solvent, like water, or alcohol, like methanol or glycol, to act as a reagent to break down chemical bonds in recovered materials, thereby enabling chemical recycling. In the solvolysis process. The most common types of solvolysis are methanolysis, glycolysis, hydrolysis and aminolysis. Enzymatic recycling, otherwise known as enzymolysis or enzymatic conversion, is a biochemical recycling process which uses enzymes to catalytically break down covalent bonds in polymers from recovered materials into intermediate or finished products which may then be further processed into a range of other products such as polymers and other chemicals. Some enzymes are bacterial, while others are synthetically derived.
Pyrolysis	Pyrolysis is a thermal decomposition process that breaks down waste streams into liquid, gas, and char by heating it in the absence of oxygen (typically between 300-700 °C). Pyrolysis is considered to be chemical recycling when these streams are used as feedstock for the production of new chemical products.
Gasification	Gasification is a thermochemical recycling process that converts organic or plastic waste into synthetic gas (syngas) – a mixture of carbon monoxide, hydrogen, and carbon dioxide – by heating it at high temperatures (typically >700°C) in a low-oxygen environment. Syngas can be used as an intermediate to produce a variety of products including plastics.
Other common recycling technologies for other materials	
Metallurgical Recycling (Metals)	Metallurgical recycling is the process of recovering and reprocessing metal waste into usable raw materials through mechanical and thermal methods, such as melting, refining, and alloying. This method helps conserve natural resources and energy.
Pulping Recycling (Paper)	Pulping recycling is a mechanical process used in paper recycling where paper waste is mixed with water and mechanically agitated to break it down into fibrous pulp. This pulp is then cleaned, de-inked, and reprocessed into new paper products.

Cullet-Based Recycling (Glass Recycling)	Cullet-based recycling is a method of recycling glass by crushing used glass into small pieces called cullet, which is then melted and reformed into new glass products. This process is energy-efficient and maintains the quality of the glass, allowing it to be recycled indefinitely without degradation.

4.4. Reuse

Reuse is an operation in which products or components, having reached their end-of-life stage, are used again without reprocessing, but including preparation for further use. Reuse is ranked as a high priority R-strategy, typically after waste prevention and reduction, and is a more favorable option than recycling. Reuse is defined as using a product or its component parts after their initial use, for the same purpose for which they were originally designed.

Key aspects of reuse include:

- Using products, materials, or components multiple times in their original form
- Extending the useful life of items
- Requiring minimal processing (typically just cleaning, minor repairs, or refurbishment)
- Preserving most of the embodied energy and resources that went into creating the original item
- Avoiding the environmental impacts associated with manufacturing new products.

This principle applies across diverse sectors through practices like returnable packaging systems, chemical recovery, equipment refurbishment, and material reclamation. These applications share the fundamental goal of extending resource utility and productive life before eventual recycling or disposal, though specific implementation varies by sector requirements and material properties.

Packaging:

The PPWR transforms reuse from a good practice to a binding requirement, detailing clear sector-specific targets for beverage, takeaway, retail, and transport packaging (European Parliament and the Council of the European Union, 2024b). It mandates infrastructural support, labeling, and container durability to embed reuse in the EU market - all aimed at reducing waste and supporting a circular economy.

For the chemical industry, the upcoming regulation will affect the following types of packaging:

- Transport packaging (e.g., pallets, crates, drums, IBCs)
- Grouped packaging used in logistics and distribution
- Packaging used only between businesses (B2B)

Mandatory reuse targets will be:

- 2030: 10-40% of certain B2B packaging must be reusable
- 2040: Up to 70% reuse requirement for some packaging categories (like transport and grouped packaging)

These obligations affect manufacturing, pharmaceutical, chemical, agri-food, and electronics sectors where B2B logistics is common.

To qualify as reusable under the PPWR (European Parliament and the Council of the European Union, 2024b) in B2B, industrial packaging must:

- Be designed for multiple trips or rotations
- Have a return system or pooling logistics in place (e.g., reusable IBCs, Euro pallets)
- Be traceable (via labeling, QR codes, barcodes)
- Undergo standardized cleaning and inspection

Table 2: Handling of Packaging reuse in different sectors.

Sector	Affected Packaging	Reuse Rule	Notes
Chemicals	IBCs, drums	Must be reusable	Track and pool containers
Food industry	Crates, pallets	% must be reusable	Closed-loop reuse encouraged
Electronics	Anti-static boxes	Must be reusable	Labeling + return system
Manufacturing	Pallets, cartons	% reuse targets	Phase-in by 2030–2040

Chemical materials:

Reuse is a relevant circularity strategy in the chemical industry also beyond industrial packaging. Some prominent examples are provided below.

Table 3: Examples of reuse in the chemical industry.

Chemical materials	Reused In	Notes
Sulfuric acid	pH control in wastewater	Common in industrial parks
Sulfuric/HCl acids	Ore leaching (mining)	Used as-is
Spent acids/bases	Internal pH neutralization	No treatment, just blending

Examples of direct reuse of spent chemicals (no processing involved):

1. Spent sulfuric acid as pH adjustment in wastewater treatment (U.S. Environmental Protection Agency, 2000):

- In some municipal and industrial wastewater treatment plants, spent sulfuric acid from unrelated processes is directly reused to lower pH in alkaline effluents.
- This is considered direct reuse because the acid is not purified, just transferred to another location and used in its existing state.

Example: Some pulp and paper mills and chemical plants have implemented this with waste acid from dye or metal finishing industries.

2. Spent acid for ore leaching (mining operations) (Kirk-Othmer, 1993)

- Spent acids from metal finishing or chemical production (e.g., sulfuric or hydrochloric acid) have been reused as-is for heap leaching of low-grade ores (copper, nickel).
- The acid, although impure, still functions as a lixiviant (leaching agent).
- No regeneration is done, direct use instead.

Example: Chile and South Africa have examples in copper recovery zones.

3. Spent chemicals as neutralization agents (internal reuse)

- Certain spent acids and bases are used as-is for acid-base neutralization during other steps of manufacturing (e.g., in polymer or fertilizer plants).
- This is done purely for pH balance and requires no additional processing.

4.5. CO_2 Capture & Utilization

CO_2 Capture and Utilization (CCU) refers to technologies that capture CO_2 emissions from technical (industrial) and biological processes and then use the captured CO_2. The captured emissions would have been emitted otherwise and shall not be exclusively produced for the capturing process. As an alternative CO_2 source, Direct Air Capturing (DAC) from the atmosphere could be used. For example, the captured CO_2 is utilized in the creation of carbon-based products such as basic chemicals, polymers, fuels etc. By capturing CO_2 and converting it to a secondary material, CCU can reduce reliance on fossil carbon.

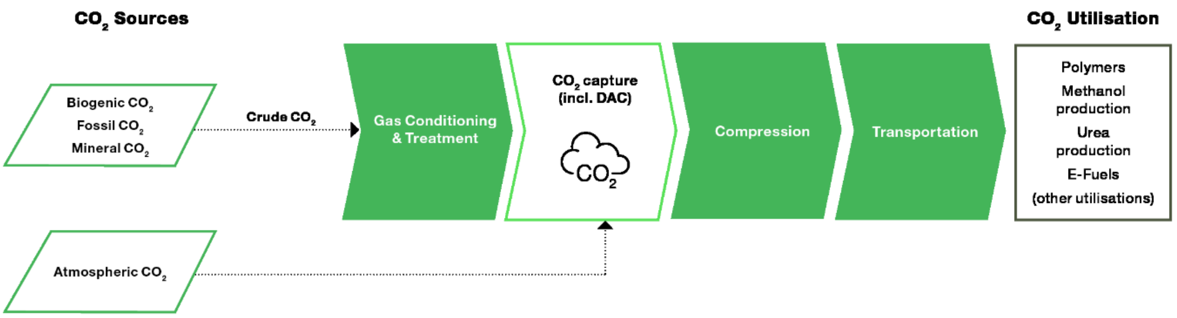


Figure 8: Description chart of the CCU Process.

In many CCU pathways, the captured carbon may be released back into the atmosphere when CCU products are used, consumed, or degraded. In contrast, CO_2 Capture and Storage (CCS) captures CO_2 and stores it long periods of time (for example, in deep geological formation) avoiding its re-emission. Notably, the stability, capacity, and CO_2 leakage from CCS systems is the subject of ongoing scientific research.

For this reason, CCU and CCS should not be treated as equivalent: while CCS is a form of long-term carbon storage, CCU keeps carbon in the loop and provides a potential pathway to a circular carbon economy. CO_2 captured through CCU may result in either permanent or non-permanent storage, depending on the final application, use phase, and end-of-life pathway of the material. Within the cradle-to-gate system boundary applied in this Guideline, information beyond the plant gate is generally unavailable and outside the control of the material manufacturer. Therefore, the permanence of CO_2 storage may not be determined at the material level alone. Only the manufacturer placing a product on the market and having knowledge of the intended application, may declare whether CCU results in permanent or non-permanent storage, on the basis of applying regulatory requirements or related international standards.

Post-combustion CO_2 capture, for example in coal- or gas-fired power plants, represents the most mature and widely deployed approach, involving the separation of CO_2 from flue gases after fuel combustion. Chemical absorption with amine-based solvents, particularly ethanolamine derivatives, is most common in commercial applications. CO_2 from a combustion off-gas stream is captured in an aqueous amine solution forming carbamate salts, which decompose at elevated temperatures (>100° C) to release concentrated, high-purity CO_2. Other advanced systems include carbonate-assisted capture with subsequent high-temperature CO_2 release or physical absorption in solvent-based capture processes. Biogenic CO_2 streams (e.g., from biomass combustion) that would otherwise be emitted to the atmosphere (either immediately at the point of generation or later at end-of-life) can be captured and used as a biogenic (non-fossil) CO_2 source for CCU.

Another point source is CO_2 formed directly in chemical reactions beyond combustion. These process-inherent CO_2 emissions are particularly challenging to abate, making CO_2 capture a crucial technology for achieving sustainability targets for the chemical industry. Prominent examples include CO_2 capture from chemical and cement production. In gasification-based syngas production, fossil carbon sources undergo gasification followed by a water-gas shift reaction, generating as a co-product high-purity CO_2 streams that are separated by physical absorption or membrane technologies. It must be iterated that CO_2 must not have been produced explicitly to be captured, in order to qualify as CO_2-based content. For example, conventional methanol manufacturing utilizes CO_2 generated internally from syngas and water-shift reactions or from coal gasification explicitly for methanol production. Thus, the CO_2 generated in this process cannot be considered for the captured CO_2-based content of the methanol.

In cement production CO_2 is generated both from fuel combustion (fossil CO_2) and the calcination of limestone (mineral CO_2), where approximately two-thirds of emissions are released by embedded carbon of raw materials (International Energy Agency , 2021). The resulting CO_2-rich off-gas can be captured using similar post-combustion technologies, though the higher CO_2 concentrations from calcination reactions offer improved capture efficiency compared to conventional combustion sources.

In contrast to point source capture, DAC technologies extract atmospheric CO_2 by passing ambient atmosphere through a capturing medium. Here, the same capture technologies described for point sources are employed. Given the atmospheric CO_2 concentration levels, DAC technologies face significant energy demand, therefore it is important to ensure that the capturing process has a net positive environmental benefit (e.g., by employing renewable energy).

Compression and transportation of captured CO_2 are essential downstream processes regardless of the capture technology employed. The captured CO_2 needs to be compressed to supercritical conditions for efficient pipeline transport or to high pressures for truck or ship transport to the intended point of utilization.

The utilization of CO_2 as an alternative circular feedstock for fossil carbon can be implemented through multiple pathways. In general, CO_2 conversion is thermodynamically challenging. This arises from its high molecular stability, which is a consequence of the highly oxidized state of carbon. Consequently, significant amounts of energy are usually required for these processes. Some of the most well-known strategies are based on the CO_2 reduction to C1 platform molecules such as methanol, formic acid, and carbon monoxide, which can serve as intermediates for downstream synthesis to a diverse range of polymers and fine chemicals. Beyond reductive routes, CO_2 can undergo insertion or coupling reactions to produce urea, organic carbonates (e.g., propylene carbonate, polycarbonate polyols), and mineral carbonates via carbonation processes. Additionally, CO_2 can be valorized via microbial or enzymatic pathways, for example via gas fermentation together with gasified waste streams to generate ethanol. In summary, CO_2 valorization is a rapidly evolving field, and more technologies are expected to emerge and scale up in the future.

5. Key Circularity Metrics

This document focuses on key circularity indicators which measure the circularity performance of resources entering (and leaving) the system boundary. These indicators focus on the origin of the resource and do not account for its end-of-life recoverability. While outflow indicators are essential for a comprehensive assessment of material or product circularity across the full life cycle, data pertaining to the use phase and end-of-life stage is frequently unavailable or incomplete and beyond the material manufacturer's control. Furthermore, remaining within the cradle-to-gate boundary ensures that circularity metrics are grounded on verifiable primary data. Therefore, circularity metrics beyond the plant gate – such as recyclability, repairability and durability metrics – are not considered in this chapter.

"Substances of Concern" (SoC) as defined in the Ecodesign for Sustainable Products Regulation (ESPR) includes Substances of Very High Concern (SVHC), substances regulated as Persistent Organic Pollutants (POP) and a large group of substances with certain hazard classifications as part of the CLP regulation (Classification, Labelling & Packaging). In addition, substances that negatively affect the reuse and recycling of materials will also be part of the SoC with the intention to support the scaling of the recycling industry. For the latter substances, an accurate and workable definition is so far missing. Recycling technologies are advancing rapidly, unlocking opportunities where recycling was previously limited. Whether a substance supports, impedes, or remains neutral to a recycling process depends on factors such as the technology used, sorting technique, end-use requirements (e.g., performance, durability), material innovation, and waste management. Emerging recycling technologies like solvent-based and various chemical recycling technologies (e.g., depolymerization, pyrolysis, gasification) are necessary developments for managing SoCs from waste streams, that are not suitable for the currently available mechanical recycling technologies. A substance which has been identified as problematic in one pathway may present no issue in another. As technologies evolve, substances that were identified to hinder recycling must thus be regularly updated.–Such substances are to be defined in accordance with the recycling technologies used, since they might not hinder all suitable recycling processes. The list of SoCs to be reported as per ESPR will be published in the respective delegated acts. Substance Declaration in a DMP/DPP will be managed in the Chem-X chemical composition information in the DMP model (see "Material Declaration Guideline").

All resource inflows (and outflows) can be categorized into three mutually exclusive types that together account for 100% of the total inflow (Figure 2):

1. **Reused content**
2. **Recycled content**
3. **Virgin content**

Relevant in the context of the chemical sector, the so-called CO_2-based content – consisting of CO_2 technologically captured from industrial waste process emissions and utilized for the manufacturing of other chemicals (i.e., Carbon Capture and Utilization, CCU) – is considered as a subcategory of recycled content[4].

---

[4] Excluding CO_2 deriving from the atmosphere (DAC).

Each of the resources above can be further categorized as:

a. **Renewable** (thereof **biogenic** is a subcategory, identifying material based on biomass)
b. **Renewable energy derived** (e.g., hydrogen produced through water electrolysis powered by renewable energy)
c. Fossil
d. Mineral

The delta between renewable and biogenic, as a sub-category, is renewable material which is not derived from biomass. Section 5.2.1 provides more details about the difference and the role played by heteroatoms replenished in human timescale from processes found in nature.

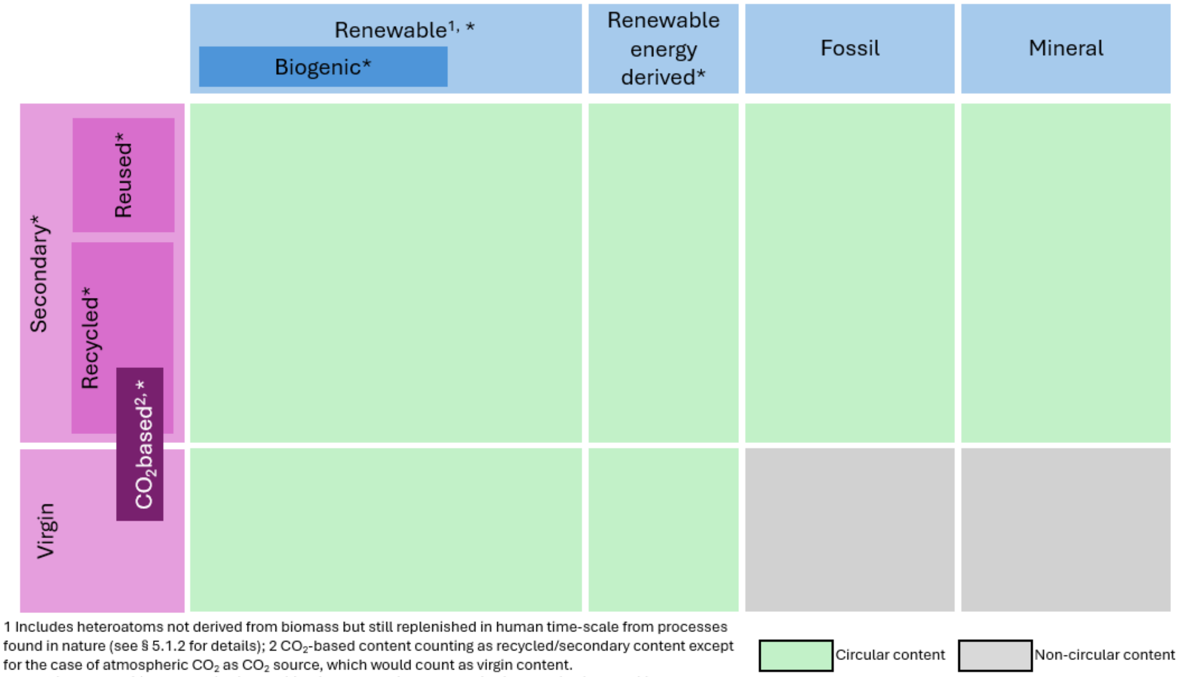
Recycled and reused content – sometimes also referred as "secondary material" content – are classified as circular content. **Virgin content** can be defined as circular, only if classified as *renewable* or *renewable energy derived*.

While content may be both biogenic/renewable and secondary (e.g., from biowaste), it must be noted that biogenic/renewable content and secondary content are not mutually exclusive and cannot be added up to determine a total circular content, to avoid double counting in such cases. Refer also to the formula and Figure 9 below for additional schematic clarity.

Circular content = **Recycled content** + **Reused content** + **Virgin Renewable content** + **Virgin renewable energy derived content**

As a safeguard that secondary content, renewable content, biogenic content and renewable energy derived content are correctly determined, have a traceable origin and are sustainably produced and sourced, circular materials should be subject to an accepted certification. With this regard regulators, industry and third party certification bodies should strive for standardization of definitions.

A "certified share" with the respective underlying chain of custody model shall be transparently communicated along the supply chain, with clear reference to the certification system adopted. The conformity assessment party may be first party (self-assessment), second party (peer assessment) or third party (independent body). The appointment process and the requirements for a conformity assessment party are out of scope of this document.



1 Includes heteroatoms not derived from biomass but still replenished in human time-scale from processes found in nature (see § 5.1.2 for details); 2 CO_2-based content counting as recycled/secondary content except for the case of atmospheric CO_2 as CO_2 source, which would count as virgin content.
* Counting as "certified share", if with certification of sustainable sourcing/production/traceability

Figure 9: Definition of circular content as sum of recycled, reused, virgin renewable content and virgin renewable energy derived content. Examples can be found in Annex II.

Both regulations and the need for transparency of business operators and consumers along the value chain require more granular metric reporting than at the aggregation level of *circular content*. For example, PPWR and upcoming ELVR set targets at recycled content level, with specific requirements for the origin of the underlying waste (e.g., post-consumer or closed-loop) and therefore demanding to report in a DMP/DPP on several metrics, such as (European Parliament and the Council of the European Union, 2023; European Parliament and the Council of the European Union, 2024b):

1. Biogenic carbon content
2. Biogenic content
3. Renewable content
4. Recycled content (including the various sub-categories referring to relevant waste-origin indicators)
5. CO_2-based content (counting also as recycled content, except for the case of atmospheric CO_2 origin)
6. Reused content
7. Secondary material content

As of today, the availability of primary data on such circularity metrics for raw material inflows is rather patchy. However, increasing regulatory pressure demanding verifiable circularity claims and the introduction of structured and harmonized data exchange via DMP/DPP is expected to improve the situation over time.

All the above-mentioned metrics are defined as a content ratio with the total mass as the denominator. It must be noted that water contained in the product shall be included in the total mass of the product. Water as a required reactant or product of a chemical reaction originating from circular raw materials (e.g., from the esterification reaction of biogenic ethanol and biogenic acetic acid to ethyl acetate and water) shall be counted as contributing to a circular content metric. This shall not apply to water resulting from a chemical reaction of non-circular raw materials (e.g., water from the combustion of fossil fuels) and especially water added in a dilution process or as a dispersing agent. Consequently, a dilution process would lead to a reduction of the value of the respective circularity metric.

As a further remark, the leading metric for water usage is elaborated in chapter 6 “Water scarcity" of The Environmental Sustainability Guideline for the Chemical Industry.

Each economic operator should determine and report the required circularity metrics to its customers, which, in turn, will be enabled to do the same allowing for metric propagation along the supply chain by means of the harmonized information model described in chapter 8. In absence of primary data provision from its suppliers (i.e., quantified value of a process or an activity obtained from a direct measurement, or a calculation based on direct measurements) the respective market operator should conservatively assume that the specific circularity metric is equal to zero.

In addition to the physical average method or proportional attribution, the above mentioned circularity metrics can be attributed by means of a mass balance chain of custody attribution model as defined in ISO 22095:2020 (International Organization for Standardization, 2020) and further outlined in Chapter 6. The data model shall clearly indicate whether and which specific chain of custody attribution models has been employed. Furthermore, the metric value shall be subject to a verification process, as foreseen in the respective chain-of-custody certification scheme employed.

Since certain sectors, customers or regulatory frameworks may not support all possible chain-of-custody models and their attribution methods, the economic operator shall transparently communicate about it via the information model. This enables the customer to choose the desired product offering.

As required by certain regulations such as PPWR, the circularity metrics shall be reported separately for the unpacked good and the packaging (i.e., the recycled content of the declared unit of unpacked product, and the recycled content for the packaging) (European Parliament and the Council of the European Union, 2024b).

5.1. Biogenic and Renewable Metrics

The following circularity metrics refer to the so-called biological loop and define the amount of circular material content in a product. The tracking of such metric may be motivated by carbon accounting – specifically for the case of biogenic carbon content –, regulatory requirements or marketing claims.

5.1.1. Biogenic Carbon content

Reporting biogenic carbon content ensures a harmonized approach for considering biogenic direct emissions and switching between the -1/+1 and 0/0 accounting for biogenic CO_2, in accordance with example to ISO 14067:2018 and the TfS PCF Guideline v3.0, §5.2.10.1 p82 (International Organization for Standardization, 2018; Together for Sustainability, 2024, p. 82). Information on biogenic carbon content shall be provided when performing cradle to gate product carbon footprint studies, as this information is relevant for the remaining value chain. Accordingly, it is mandatory in the PCF data models of numerous frameworks, such as TfS, PACT or Catena-X.

As a general rule, the declaration of the biogenic carbon content of the product should exclude the packaging, as outlined in the TfS PCF Guideline for the “product carbon footprint” and other sustainability metrics. The content metric of the packaging should be reported separately. The declarant shall clearly indicate whether the inclusion of packaging has taken place in an explicit data field provided in the data model (Together for Sustainability, 2024).

The biogenic carbon content is defined as the fraction of biogenic carbon mass (out of total material mass) classified as biogenic. For the sake of clarity, the total material mass shall include also water in the product.

When applying as chain of custody (CoC) the mass balance (MB) model, the biogenic carbon content could be attributed. If CoC – MB model is not used, the biogenic carbon content is physically present in the material and can be measured (see Figure 10).

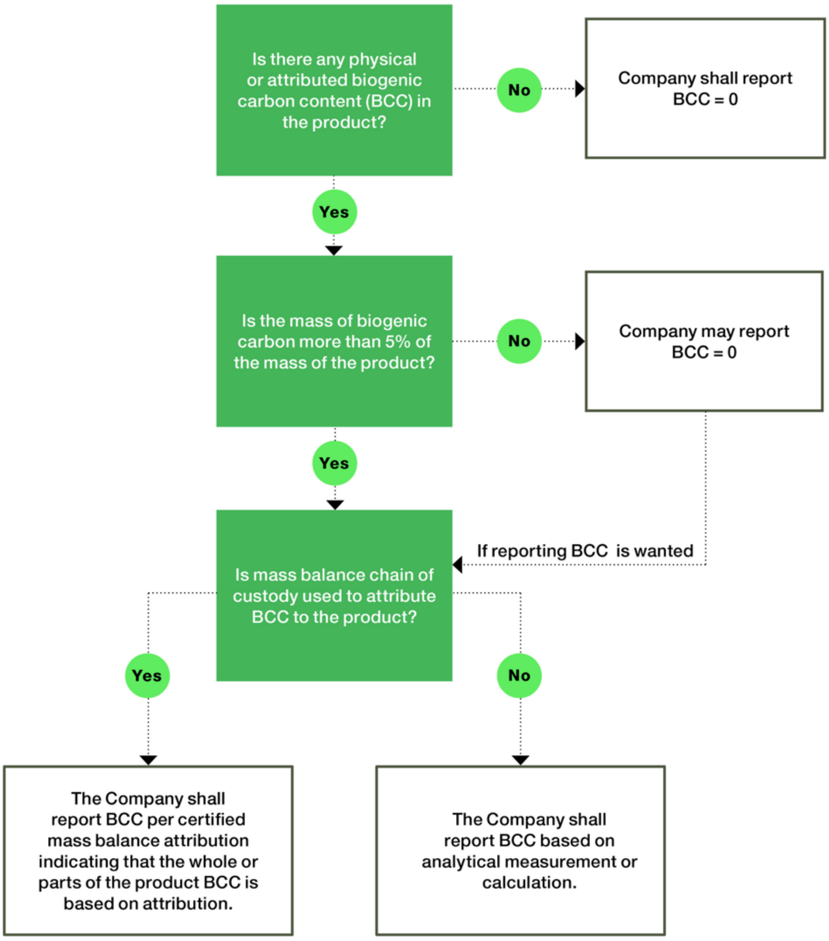


Figure 10: Decision Tree for Reporting of Biogenic Carbon Content (BCC) in a Product (Together for Sustainability, 2024).

In the case when biogenic carbon content is calculated, the following equation shall be applied to calculate it:

$$BCC_{(i)} = \frac{n_{(BC,i)} \cdot M_{(C.i)}}{M_{(i)}}\text{, where}$$

Formula 1: Calculation of "biogenic carbon content" for materials.

Where:

- $BCC_{(i)}$: biogenic carbon content
- $n_{(BC,i)}$: number of biogenic carbon atoms in product or attributed to the product
- $M_{(C.i)}$: carbon molar mass (12.011 kg C/kmol)
- $M_{(i)}$: molar mass of product (kg/kmol)
- *i*: unpacked good or packaging

If the mass of biogenic carbon containing materials in the product is less than 5% of the mass of the product, the declaration of biogenic carbon content may be omitted.

Example:

Let’s assume a 50 kg drum of bioethanol, with a 100% biogenic content. The drum is assumed to be single-use and made out of bio-polyethylene (HDPE), weighing 4 kg with a biogenic content of 90%.

Bioethanol:

The molecular formula for bioethanol is C_2H_5OH.

Table 4: Parameters of Bioethanol example.

Parameter	Value	Notes
Molar Mass of Carbon (C)	12.011 kg/kmol	2 C atoms per molecule
Molar Mass of Ethanol (C_2H_5OH)	46.068 kg/kmol	—

Carbon Mass Fraction in Ethanol:

$n_{(BC,unpacked)}$ 2.0 moles of C * 100%) = 2.0 $BCC_{(unpacked)}$ $\frac{2.0 \cdot 12.011\ kg\ C/kmol}{46.068\ kg\ ethanol\ /kmol}$ = 0.522 kg C/kg ethanol

HDPE Packaging:

HDPE (High-Density Polyethylene) is a polymer of ethylene (C_2H_4). The repeating unit contains two carbon atoms.

Table 5: Parameters of HDPE Packaging example.

Parameter	Value	Notes
Molar Mass of Carbon (C)	12.011 kg/kmol	2 C atoms per repeating unit
Molar Mass of Ethylene (C_2H_4)	28.054 kg/kmol	Monomer unit mass

Carbon Mass Fraction in HDPE:

$n_{(BC,packaging)}$= 2 moles of C *90%) = 1.80)

$BCC_{(packaging)}$: $\frac{1.80 \cdot 12.011 kg\ C/mol}{28.054\ kg\ ethylene/kmol}$= 0.770 kg C/kg HDPE

5.1.2. Renewable, Biogenic and Renewable Energy Derived content

The renewable content metric represents the fraction of material mass of a resource inflow that is classified as renewable, requiring that such material is made from a renewable resource that can be replenished continuously or cleansed on a human timescale. Biogenic materials derived from renewable biomass are an example of renewable material.

Renewable materials are not always strictly deriving from biomass. An example is the one of chemicals resulting from a reaction of biogenic – biomass derived – materials with oxygen from the air (e.g., renewable phenol, from biogenic raw materials oxidized with air in the Hock process): Phenol contains oxygen as a heteroatom, which is technically not derived from biomass but still replenished in a human time scale from processes found in nature. The oxygen heteroatom shall count as renewable content, yet not as biogenic content.

Another prominent example entailing heteroatoms which are not directly derived from biomass is renewable ammonia: ammonia is produced via the Haber-Bosch process from hydrogen and nitrogen. Hydrogen can be renewable, if renewably produced from biomethane (e.g., biomethane pyrolysis); nitrogen is obtained from the air separation process using 100% renewable energy. Also in this case, the nitrogen heteroatom shall count as renewable content, despite not directly originating from biomass. It must be noted that neither nitrogen nor hydrogen shall be accountable as renewable content if ammonia is manufactured from grey hydrogen (e.g., deriving from steam reforming of fossil natural gas).

It must be noted that water in the product shall be included in the total mass of the product for all the above-mentioned metrics.

While water used for dilution or as a solvent or as dispersing agent does not qualify as circular content, water used as a reactant or product of a chemical reaction originating from circular raw materials (e.g., from the esterification reaction of biogenic ethanol and biogenic acetic acid to ethyl acetate and water) shall be counted as contributing to a circular content metric. This shall not apply to water resulting from a chemical reaction of non-circular raw materials (e.g., water from the combustion of fossil fuels).

As renewable materials qualify as circular, it is recommended to track renewable content as leading metric. However, marketing claim may require tracking specifically the biogenic content or even the biogenic carbon content.

The renewable and biogenic contents of a resource inflow can be calculated using the following equation

$$RenC_{(i)} = \frac{m_{(Ren)i}}{m_i}$$

Formula 2: Calculation of "renewable content" for resource inflows.

Where:

- $\text{RenC}_{(I)}$: renewable content
- $\text{m}_{(Ren)}$: mass of renewable material in the product or attributed to the product
- $\text{m}_{(i)}$: total mass of the product
- i: unpacked good or packaging

$$BioC_{(i)} = \frac{m_{(Bio)i}}{m_i}$$

Formula 3: Calculation of "biogenic content" for resource inflows.

Where:

- $\text{BioC}_{(I)}$: biogenic content
- $\text{m}_{(Bio)i}$: mass of biogenic material in the product
- $\text{m}_{(i)}$: total mass of the product or of the packaging
- i: unpacked good or packaging

Example:

Consider a fictional plastic container with a mass of 1 kg. The container is made up of three products "P1" (250 grams), "P2" (360 grams), and "P3" (390 grams). Product "P1" has a declared renewable content of 90% (without indication how much of it be biogenic), product "P2" has a declared biogenic content of 75% and the product "P3" is made up of 100% fossil content. The renewable and biogenic contents of the container can be calculated as shown below

$$\text{RenC}_{\text{packaging (container)}} = \frac{250\ grams*90\%+360\ \text{grams}*75\%}{1000\ grams} = 0.495$$

$$\text{BioC}_{\text{packaging (container)}} = \frac{360\ \text{grams}*75\%}{1000\ \text{grams}} = 0.27$$

As described in Chapter 4, biogenic material can be characterized depending on the origin of the biomass material from which it is derived (Table 6).

Table 6: Indicators to characterize biogenic materials.

	Indicator type	**Examples:**
Biogenic-origin indicator	Feedstock generation	1st generation; 2nd generation; 3rd generation
	Other classification	Biowaste & Bioresidue[5]; Biowaste only

Renewable energy derived materials represent another emerging category of circular materials, which result from chemicals manufactured in the Technosphere leveraging renewable energy and resources which are abundant and replenishable with proper stewardship. The most prominent example is green hydrogen, obtained from 100% renewable energy powered water electrolysis. To achieve complete coverage of the demand, renewable energy certificates may be used. When purchasing renewable energy certificates, minimum reliability standards should be taken into account, ensuring the avoidance of double-counting and robust traceability measures. The guidance provided by ACLCA – "Quantifying Renewable Electricity Instruments in Environmental Product Declarations (EPDs)" – can be used (American Center for Life Cycle Assessment , 2023). In analogy to the case of renewable content, heteroatoms shall count as renewable energy derived content if resulting from resources that are replenishable via processes found in nature. The nitrogen reacting with green hydrogen in green ammonia shall also count as renewable energy derived content, under the assumption that 100% renewable energy has been used in the air separation process.

The renewable energy derived contents of a resource inflow can be calculated using the following equation

$$RenEDC_{(i)} = \frac{m_{(RenED)i}}{m_i}$$

Formula 4: Calculation of "renewable energy derived contents" for resource inflows.

Where:

- $RenEDC_{(I)}$: renewable energy derived content
- $m_{(RenED)}$: mass of renewable energy derived material in the product or attributed to the product
- $m_{(i)}$: total mass of the product
- i: unpacked good or packaging

Example:

Consider a 500 kg big bag of ammonium nitrate fertilizer (NH_4NO_3), assuming that ammonium nitrate has been manufactured from green ammonia (i.e., derived hydrogen from water electrolysis and nitrogen from air separation both powered through renewable energy) and fossil-

---

[5] waste and residues of biological origin from agriculture, forestry and related industries, including fisheries and aquaculture, and including the biodegradable fraction of industrial and municipal waste (e.g., used cooking oil, tall oil, food waste, etc.).

based nitric acid. Ammonia (NH_3) will count as 100% renewable energy derived content, while nitric acid (HNO_3) will be neither renewable nor renewable energy derived. Ammonium nitrate is produced according to the following chemical reaction:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

The molar mass of NH_3 is equal to 17.03 kg/kmol; the molar mass of HNO_3 is 63.02 kg/kmol.

$$\text{RenEDC}_{\text{unpacked}}\, NH_4NO_3 = \frac{17.03 \frac{\text{kg}}{\text{kmol}} * 100\%}{80.05\ \text{kg/kmol}} = 0.213$$

Example:

In case we have as described above green ammonia (100% renewable energy derived since hydrogen from water electrolysis and nitrogen from air separation, both utilizing 100% renewable electricity in the process) reacting with oxygen to nitric acid used to produce nitrobenzene, which in a follow up reaction gets converted again with green hydrogen to aniline.

$N_2 + 3H_2 \rightarrow 2NH_3$

$NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$

$C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$

$C_6H_5NO_2 + 4H_2 \rightarrow C_6H_5NH_2 + 2H_2O$

Then the final aniline contains nitrogen and hydrogen (i.e., the amino-group NH_2– attached to the benzene ring) based on renewable energy and therefore a 0.172 (16 g/mol / 93 g/mol) circular content (renewable energy derived content).

The above metrics should be determined and reported separately for the unpacked product and the packaging.

5.2. Secondary Material Metrics

The following metrics refer to the so-called “technical loop” in circularity, which define the amount of secondary material content in a product, displacing the need for primary (i.e., virgin) material. The tracking of such metrics may be motivated by regulatory requirements or marketing claims.

A material is defined as secondary if it is either recycled or reused. Consequently, the secondary content of a material can be calculated as the sum of the total recycled content (including CO_2-based content[6]) and the reused content.

---

[6] Excluding CO_2 deriving from the atmosphere (DAC)

5.2.1. Recycled content

$$RC_{(a,i)} = \frac{mr_{a,i}}{m_i}$$

Formula 5: Calculation of "recycled content" for materials.

Where:

- *i*: unpacked good or packaging
- *a*: waste-origin indicators or recycling technology indicators
- RC(*a,i*): recycled content with waste-origin/recycling technology indicator *a*
- mr(*a,i*): mass of recycled material with waste-origin/recycling technology indicator *a* in the product or attributed to the product
- m(*i*): total mass of the product or of the packaging

It must be noted that the total mass shall include water contained in the product.

As described in Chapter 4, recycled material can be characterized along four key dimensions, defining the type of waste-origin or recycling technology indicators (Table 7).

Table 7: Indicators to characterize recycled materials.

	Indicator type	**Examples:**
Waste-origin indicator	Value chain step	Post-consumer (PCR); Post-industrial (PIR)
	Industry	Automotive; Building & Construction; Electronics, Electrical & Appliances; Furniture; Healthcare; Packaging; Textiles & Apparel; Bioeconomy etc.
	Geography	Europe; EU27; Africa; Asia; North America; South America; [country], etc.
Recycling technology indicator	Recycling technology	Physical recycling; Chemical recycling; etc.

Regulatory requirements, such as industry closed-loop recycling quotas, or market claims will determine the typologies of recycled content to be tracked; in other cases, reporting of such indicators will be voluntary and optional. In general, an undeclared recycled content value type (e.g., no information on share of recycle content coming from a specific industry like automotive) will lead to the assumption that the related content is equal to 0% (e.g., 0% recycled content with waste-origin indicator “industry – automotive”).

Example:

Let’s assume a given 100 kg mixture “Mix1”, consisting of 40 kg of product “Rm1”, 50 kg product “Rm2”, and 10 kg product “Rm3”. The product “Rm1” has a declared recycled content of 30% with post-consumer automotive waste-origin, with undeclared geographical origin and recycling technology; the product "Rm2" has an unknown recycled content; the product "Rm3" comes with 90% recycled content from European, post-consumer, mechanically recycled, mixed packaging waste-origin. The unpacked good is packaged in a 7kg drum made of 50% recycled content out of post-industrial waste.

Mix1:

$$RC\ (Mix1)_{total,unpacked} = \frac{40kg*30\%+50kg*0\%+10kg*90\%}{100kg} = 0.21$$

$$RC\ (Mix1)_{PCR,unpacked} = \frac{40kg*30\%+50kg*0\%+10kg*90\%}{100kg} = 0.21$$

$$RC\ (Mix1)_{Auto,unpacked} = \frac{40kg*30\%+50kg*0\%+10kg*0\%}{100kg} = 0.12$$

$$RC\ (Mix1)_{MPW,unpacked} = \frac{40kg*0\%+50kg*0\%+10kg*90\%}{100kg} = 0.09$$

$$RC\ (Mix1)_{EU,unpacked} = \frac{40kg*0\%+50kg*0\%+10kg*90\%}{100kg} = 0.09$$

$$RC\ (Mix1)_{mech\text{-}recycled,unpacked} = \frac{40kg*0\%+50kg*0\%+10kg*90\%}{100kg} = 0.09$$

$$RC\ (Mix1)_{total,packaging} = \frac{7kg*50\%}{7kg} = 0.50$$

$$RC\ (Mix1)_{PIR,packaging} = \frac{7kg*50\%}{7kg} = 0.50$$

Table 8: Recycled content indicators of the different example materials.

	Rm1	Rm2	Rm3	Mix1
$RC_{total,unpacked}$	**0.30**	**0.0 (undeclared)**	**0.90**	**0.21**
$RC_{PCR,unpacked}$	0.30	0.0 (undeclared)	0.90	0.21
$RC_{auto,unpacked}$	0.30	0.0 (undeclared)	0.0 (undeclared)	0.12
$RC_{MPW,unpacked}$	0.0 (undeclared)	0.0 (undeclared)	0.90	0.09
$RC_{EU,unpacked}$	0.0 (undeclared)	0.0 (undeclared)	0.90	0.09
$RC_{France,unpacked}$	0.0 (undeclared)	0.0 (undeclared)	0.0 (undeclared)	0.0
$RC_{mech\text{-}recycled,unpacked}$	0.0 (undeclared)	0.0 (undeclared)	0.90	0.09
$RC_{total,packaging}$	**-**	**-**	**-**	**0.50**
$RC_{PIR,packaging}$	-	-	-	0.50
$RC_{MPW,packaging}$	-	-	-	0.0 (undeclared)

The example above is designed to explain only the calculation logic. The level of depth and breadth of data in a DMP/DPP will depend on the actual use-case, taking regulatory and market requirements into consideration. The total recycled content for the unpacked goods and for the respective packaging are valuable data attributes to be exchanged via DMP/DPP.

5.2.2. Reused content

$$RUC_{(\mathrm{a,i})} = \frac{mru_{\mathrm{a},i}}{m_i}$$

Formula 6: Calculation of "reused content" for materials.

Where:

- *i*: unpacked good or packaging
- *a*: reuse origin indicators
- RUC(*a,i*): reused content with reuse origin indicator *a*
- mru(*a,i*): mass of reused material with reuse origin indicator *a* in the product or attributed to the product
- m(*i*): total mass of the product or of the packaging

It must be noted that the total mass shall include water contained in the product.

Reuse of products is intended for the same purpose for which those products were originally designed. A relevant reuse origin indicator may be the geographic origin of the reuse material.

5.2.3. CO_2-based content and CO_2-based Carbon content

The CO_2-based content of resource inflow can be calculated using the following equation:

$$CC_{(a,i)} = \frac{mc_{(a,i)}}{m_{(i)}}$$

Formula 7: Calculation of "CO_2-based content" for materials.

Where:

- i: unpacked good or packaging
- a: CO_2-origin indicator
- $CC_{(a,i)}$: CO_2-based content with CO_2 origin indicator a
- $mc_{(a,i)}$: mass of the CO_2 portion incorporated into the CO_2-based product or attributed to the product, using the CO_2-origin indicator a
- $m_{(i)}$: total mass of the product or of the packaging

It must be noted that the total mass shall include water contained in the product.

As described in chapter 4, materials from CCU processes can be characterized depending on the origin of the CO_2 capturing step (table 7). To enable the PCF calculation for CO_2-based products from CCU of biogenic CO_2 (e.g., from bioethanol fermentation) or direct air capture (DAC), the CO_2-based carbon content stored in the product shall be reported separately (see formula 8). The impact of CO_2-based carbon content on PCF calculation is covered in the Chem-X Environmental Sustainability Guideline (referring to the TfS PCF Guideline v3.0) (Together for Sustainability, 2024).

If no information on CO2-origin is provided by a supplier providing a product with CO2-based content, the respective CO2-origin for the raw material shall be labeled as “Other CO2-CCU”.

Table 9: Indicators to characterize CO_2-based content.

	Indicator type	**Examples**
CO_2-origin indicator	CO_2 source	Atmospheric CO_2 (DAC)
		Biogenic CO_2 CCU
		Other[7] CO_2 CCU

It must be noted that CO_2-based content from atmospheric CO_2 source shall not count as recycled content or secondary content.

Furthermore it must be noted that biogenic content and CO_2 content from biogenic CO_2 CCU source are not mutually exclusive. Therefore they cannot be added to determine a total circular content.

Example 1:

Consider a 100 kg drum of methanol (CH_3OH) assuming a 100% production route via CCU from direct air capturing through CO_2 hydrogenation with green hydrogen according to the following net chemical reaction:

$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

The molar mass of methanol is 32.042 kg/kmol. Since both the carbon atom (12.011 kg/kmol) and the oxygen atom (15.999 kg/kmol) originate from captured CO_2, the total share of CO_2-based content is:

$$CC_{unpacked}\ CH_3OH = \frac{\left(12.011\frac{kg}{kmol}+15.999\frac{kg}{kmol}\right)}{32.042\frac{kg}{kmol}} = 0.874 \text{ kg } CO_2\text{-based content/kg methanol}$$

Example 2:

Consider a 100 kg drum of propylene carbonate ($C_4H_6O_3$) assuming a 100% production route via CCU from biogenic CO_2 through cycloaddition to propylene oxide (C_3H_6O) according to the following net chemical reaction:

$CO_2 + C_3H_6O \rightarrow C_4H_6O_3$

The molar mass of propylene carbonate is 102.09 kg/kmol. One carbon atom (12.011 kg/kmol) and two oxygen atoms (2 * 15.999 kg/kmol = 31.998 kg/kmol) in the product originate from CO_2. Consequently, the total share of CO_2-based content is:

$$CC_{unpacked}\ C_4H_6O_3 = \frac{\left(12.011\frac{kg}{kmol}+31.998\frac{kg}{kmol}\right)}{102.09\frac{kg}{kmol}} = 0.430 \text{ kg } CO_2\text{-based content/kg propylene carbonate}$$

---

[7] Intended as neither biogenic nor atmospheric CO_2 (DAC) origin (i.e., fossil, mineral or unspecified origin).

The CO_2-based carbon content of a resource inflow can be calculated using the following equation:

$$CCC_{(i)} = \frac{n_{(CC,i)}\, M_{(C,i)}}{M_{(i)}}$$

Formula 8: Calculation of "CO_2-based carbon content" for materials.

Where:

- i: unpacked good or packaging
- $CCC_{(i)}$: CO_2-based carbon content
- $n_{(CC,i)}$: number of CO_2-based carbon atoms in product or attributed to the product
- $M_{(C.i)}$: carbon molar mass (12.011 kg/kmol)
- $M_{(i)}$: molar mass of product (kg/kmol)

Example 1:

To calculate the CO_2-based carbon content of methanol, only the carbon atom originating from the CCU process is considered.

Table 10: Parameters of Methanol example.

Parameter	Value	Notes
Molar Mass of Carbon (C)	12.011 kg/kmol	1 C atom per methanol molecule
Molar Mass of Methanol (CH_3OH)	32.042 kg/kmol	—

As all carbon atoms in the example originate from CO_2 the following $n_{(CC,unpacked)}$ and CCC unpacked are obtained:

$n_{(CC,unpacked)}$= 1.0 mole of C * 100% = 1.0

$$CCC_{unpacked}CH_3OH = \frac{1 \cdot 12.011 \frac{kg\ C}{kmol}}{32.042 \frac{kg\ Methanol}{kmol}} = 0.375 \text{ kg } CO_2\text{-based C/kg methanol}$$

Example 2:

To calculate the CO_2-based carbon content of propylene carbonate, only the carbon atom originating from the CCU process is considered.

Table 11: Parameters of propylene carbonate example.

Parameter	Value	Notes
Molar Mass of Carbon (C)	12.011 kg/kmol	4 C atoms per propylene carbonate molecule
Molar Mass of propylene carbonate ($C_4H_6O_3$)	102.09 kg/kmol	—

As one of the four carbon atoms originates from CO_2 the following $n_{(CC,unpacked)}$ and CCC unpacked are obtained:

$n_{(CC,unpacked)}$= 4.0 mole of C * 25% = 1.0

$$CCC_{unpacked}\ C_4H_6O_3 = \frac{1 \cdot 12.011 \frac{kg\ C}{kmol}}{102.09 \frac{kg\ propylene\ carbonate}{kmol}} = 0.118\ \text{kg } CO_2\text{-based C/kg propylene carbonate}$$

5.3. Waste Disposal Metrics

Waste flows are included in the Life Cycle Inventory (LCI) as input/output flows that influence the assessment of impact categories (e.g., human toxicity, ecotoxicity, resource use), described in Chem-X's Environmental Sustainability Guideline (CHEM-X, 2026) and other LCA standards and frameworks (e.g., ISO 14067, EU-PEF).

Since modelling of waste metrics may be of relevance for the building and construction sector these requirements are described in detail, even if the provision of such data is not mandatory in the scope of the described guideline for DMP.

In this chapter we cover a set of three waste flow indicators[8] which are included in Environmental Product Declaration (EPD) frameworks and described in the European standard EN 15804:2012+A2:2019/AC:2021 (Sustainability of construction works, Environmental Product Declarations, Core rules for the product category of construction products) in the section “Environmental information describing waste categories“ (European Committee for Standardization (CEN), 2021):

- Hazardous Waste Disposed (HWD)
- Non-Hazardous Waste Disposed (NHWD)
- Radioactive Waste Disposed (RWD)

They are physical flow indicators that quantify waste outputs from the product system, and not impact indicators, like for example Global Warming Potential (GWP) or Ozone Depletion Potential (ODP); they are also accounting metrics, intended to describe how material flows are disposed at the end of each life-cycle stage, and not performance targets by themselves.

According to EN 15804:2012+A2:2019/AC:2021, such indicators are reported In the EPD frameworks for the respective life cycle stages “Product Stage” (A1-A3), “Construction Process Stage” (A4-A5), “Use Stage” (B1-B7) and “End of Life Stage” (C1-C4), as well as in the “module D” to quantify benefits or loads that occur beyond the construction work life cycle, should the waste reach end of waste and leave the product system to substitute materials or energy elsewhere (Figure 11).

---

[8] This chapter includes also – in addition – a related set of indicators dealing with output flows.

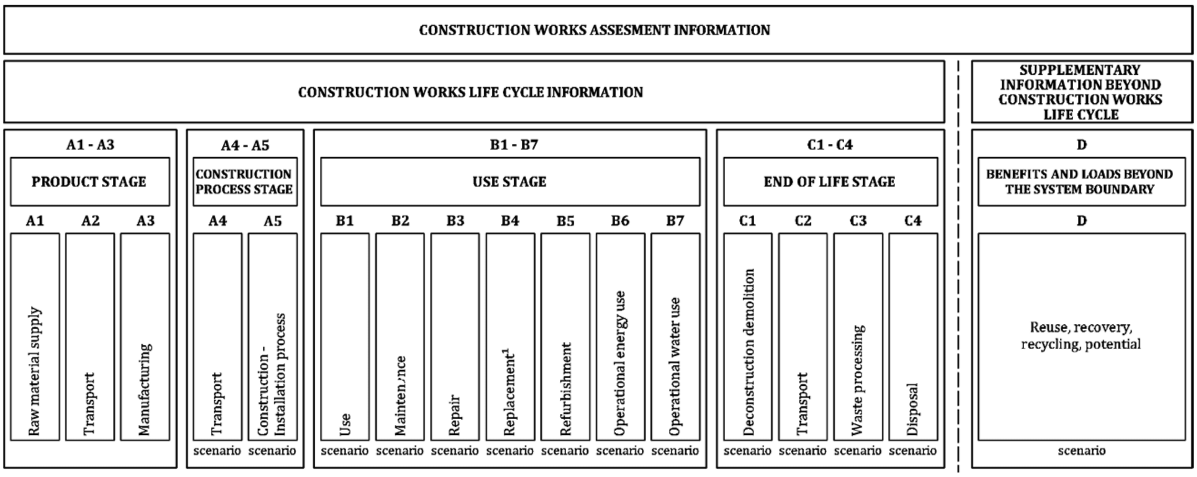


Figure 11: Life cycle stages and modules for the construction works assessment as in EN15804:2012+A2:2019/AC:2021.

With all the caveats and recommendations at the end of this chapter, the DMP reporting for chemicals used as raw materials in the construction sector should be limited to cradle-to-gate, as an aggregated value, in line with the system boundaries applying to the other circularity metrics described in this Guideline. This enables the following downstream manufacturer of construction products to use such cradle-to-gate data as an input for A1 (raw material supply) for their own EPD report.

As indicated in EN 15804:2012+A2:2019/AC:2021, the metrics HWD, NHWD, RWD refer to waste which has been disposed, intended as undergoing any material treatment that is not direct recovery, but as a subsequent consequence may include some recovery of material or energy (European Parliament and the Council of the European Union, 2024c). Treatments for disposal may include, *e. g.*, deposition by landfilling or land treatment, incineration, or any other operation mentioned in Annex I of the EU Waste Framework Directive (European Parliament and the Council of the European Union, 2024c).

"Hazardous waste" is waste that may have adverse effects on human health and/or the environment. A list of properties which classify waste as hazardous is given in the EU Waste Framework Directive (European Parliament and the Council of the European Union, 2024c) Annex III. It must be noted that the exact definition of hazardous waste is dependent on the country's jurisdiction. "Radioactive waste" does not fall into this category despite its potential adverse environmental and health impacts: it is covered by specific legislations and regulations (for example, (European Parliament and the Council of the European Union, 2011)). "Non-Hazardous waste" is any waste that is neither classified as "hazardous" nor as "radioactive".

Hazardous, non-hazardous, and radioactive waste is disposed of in different treatment facilities following the applicable legislations and regulations. These waste categories pertaining to the upstream supply chain may be extracted from the LCA modelling software in form of secondary data, if data is not obtained through a DMP or an EPD from the suppliers.

Alongside and related to the mentioned waste metrics HWD, NHWD and RWD, EN 15804:2012+A2:2019/AC:2021 (European Committee for Standardization (CEN), 2021) describes further output flows which are technical flows without a characterization factor and have a rather informative character. These flows are out of scope of this Guideline, even if briefly described in this chapter.

Output flow indicators:

- Components for Reuse (CRU)
- Materials for Recycling (MFR)
- Materials for Energy Recovery (MER)
- Exported Energy (EEE, EET)

CRU is most often applicable only to complex articles as it requires (product) components to be re-used again for the same purpose as they were originally produced for. These components may be subjected to inspection, cleaning or repairing operations before their final re-use (2008/98/EC – EU Waste Framework Directive). Chapter 4.4 in this Guideline provides further context and examples of Reuse for chemical materials.

MFR are waste materials that undergo some kind of recovery operation to reach the end-of-waste status and to be used in their product, material or substance form for the same or other processes (European Parliament and the Council of the European Union, 2024c).

MER are materials to be incinerated in incineration facilities with high energy efficiency of at least 60% (European Committee for Standardization (CEN), 2021). This is not typical waste disposal as waste incineration plants usually have a lower energy recovery efficiency than 60%. Waste incinerated in facilities with lower efficiency will be declared as a waste disposed (HWD, NHWD). Ashes from incineration will be accounted as waste disposed (HWD, NHWD). Materials classified as “MER” will enter the next product life cycle as Secondary Fuels (RSF/NRSF[9]) after they reached the End-of-Waste status (European Committee for Standardization (CEN), 2021).

“Exported Energy” is any energy recovered from incineration or landfilling operations leaving the declared system boundaries, irrespective of the energy efficiency of the incineration. As most incinerations yield thermal energy or, with conversion losses, electrical energy as well as thermal energy, this category is often divided into Exported Electrical Energy – EEE and Exported Thermal Energy – EET.

As CRU, MFR, MER, and Exported Energy are not directly related to elementary flows, these indicators should be traced based on the foreground data. They can only be declared if they leave the defined system boundary. As the chemical industry focusses on a cradle-to-gate declaration (A1-A3 in terms of EN 15804:2012+A2:2019/AC:2021), any material and energy recovery within the plant gates leads to a reduction of raw material and energy demand, therefore, shall not be declared as CRU, MFR, MER. However, recovered energy from incineration of process waste being utilized outside the plant gates (*e.g.*, by the local community or other companies in the vicinity) may be declared as Exported Energy.

An accurate determination of the metrics described in this chapter for dedicated products is often very challenging in chemical manufacturing. The required flows (e.g., waste disposals) are reported at site level, due to waste regulations, typically aggregated from plant-level data. Also, for this reason, waste is rarely included in the bill-of-material and therefore hard to track at scale at product level in automated fashion. In addition, waste generation in a plant varies typically from batch to batch in both quantity and composition, sometimes significantly (e.g., start-up and shut-down operations, product changes, unplanned events). In practice, this means that the amount of waste on product level will have to be calculated as an average based on an

---

[9] These indicators are covered in EN 15804:2012+A2:2019/AC:2021 as “indicators describing resource use” in section 7.2.4.2.

allocation[10] from the aggregation across a plant or site. While this is doable the result will depend on many plant dependent attributes which will not be meaningful at the product level and the result would hardly be comparable between sites and different suppliers at a reasonable quality. The difficulties mentioned compound with current lack of product-level primary data on waste disposal from the supply chain.

Taking all this into consideration it is recommended to treat such metrics as optional data objects in the DMP, or, if reporting is still desired, allow for the use of generic secondary datasets or proxies.

As for the other metrics described in Chem-X Guidelines, relevant secondary data are not uniformly available across LCA tools and databases, or are subject to access restrictions and licensing conditions. No generally applicable prescription can be given for this selection, however the chosen secondary data source should be transparently reported in the data model of the DMP.

---

[10] Refer to Environmental Sustainability Guideline for breakdown and allocation approaches.

6. Chain-of-Custody

Navigating the shift from a linear to a circular economy is a significant challenge for the chemical industry, demanding innovative methods to integrate sustainable raw materials into complex production processes. Central to this transition is a robust chain of custody (CoC), which is a structured system offering a transparent and verifiable record of a product's journey from origin to end-user. This can be applied to the use of alternative feedstocks, such as recycled or biogenic feedstocks. Such a framework supports verifiable sustainability claims as well as ensuring regulatory compliance.

A particular model of CoC, the mass balance (MB) approach, is an essential instrument for a sustainable transformation of the chemical sector. In this approach, a company tracks the total amount of sustainable raw material entering a production site and attributes it mathematically to a certain number of products within one organization. Thanks to the mass balance approach, the use of sustainable raw materials, such as biogenic and recycled feedstock, into existing production networks or new assets is possible without the need for costly and complex dedicated infrastructure. This enables the use of existing, large-scale chemical plants for the processing of new, sustainable feedstock. With an estimated global cumulative investment between US$1.5 trillion and US$3.3 trillion through 2050 for the chemical industry to achieve net-zero and sustainable product markets the transformation is still immature or developing (PwC, 2024) an efficient allocation of capital will be key to a socio-economically viable transition, making mass-balance a critical instrument for that.

The mass-balance approach is also a vital enabler for the advent of new technologies like carbon capturing and utilization, or chemical recycling processes, supporting the transition to a circular economy away from primary fossils towards alternative feedstocks.

6.1. Types of Chain of Custody

There are different chain-of-custody (CoC) models in place, which offer different expectations of physical presence of the specified characteristics described in Figure 12. ISO 22095:2020 differentiates between chain of custody models without mixing materials with specified characteristics (Identity preserved and segregated) and models with mixing (controlled blending and mass balance). Book and Claim is an additional model where the specified characteristics might be disconnected from the physical flow. Each of these CoC models are suitable for certain supply-chain and production settings. The identity preserved, segregated and controlled blending CoC models ensure a minimum determined amount of physical content, while mass balance and book and claim CoC models involve attributed content, where physical content is variable (mass balance) or cannot be guaranteed (book and claim) (International Organization for Standardization, 2020). The organization shall only make item-based claims on the same chain of custody as its supplier, or a model shown to the right of the chain of custody model, as illustrated in Figure 11 for each material or product with individual specified characteristics to make accurate item-based claims like described in ISO 22095:2020 (International Organization for Standardization, 2020).

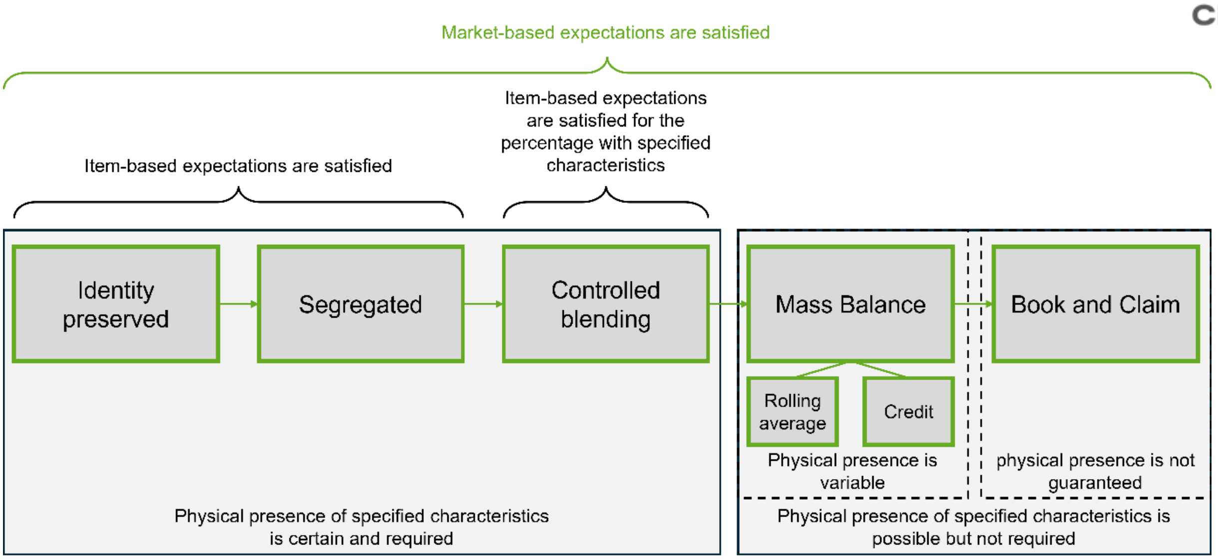


Figure 12: Indicative illustration of chain of custody models described according to the expectation of physical presence of specified characteristics (International Organization for Standardization, 2020).

6.1.1. Identity Preserved

The identity preserved (IP) CoC model is used for systems where the identity and integrity of a specific product or material are maintained throughout the supply chain in industries such as food, agriculture, and specialty products. In the example of food value chains, the material flow is followed from the specific farm or forest, where the raw materials were grown or harvested, through the processing and manufacturing stages, to the final product. This material flow is physically kept completely separated from other material flows keeping unique characteristics (e.g., not originating from other farms or forests).

6.1.2. Segregated

The concept of a Segregated CoC model generally refers to a system where materials or products with and without specified characteristics have to be kept separately. In case of certified palm oil that means that palm oil of different sources, but all certified have to be kept separately from non-certified palm oil throughout the whole supply chain, to maintain their characteristics and ensure traceability. For renewable and fossil raw materials the segregated CoC model requires complete separation throughout the linear value chain. E.g. the 100% renewable content claim can be used if renewable content is not mixed with fossil content at any point.

6.1.3. Controlled blending

In a controlled blending model input materials with and without specified characteristics are mixed in a controlled manner. As a result, the proportion of specified characteristics in the output is known for all products at any time. In this regard mixing covers not only physical mixing processes but also the mixture of more than two materials which undergo a chemical reaction. Depending on the type of specified characteristic it can be measured (e.g., biogenic carbon content) or only be calculated (e.g., recycled content). This concept is commonly used in industries such as forestry, agriculture, and manufacturing, where multiple materials or components are combined to create a final product (Figure 13).

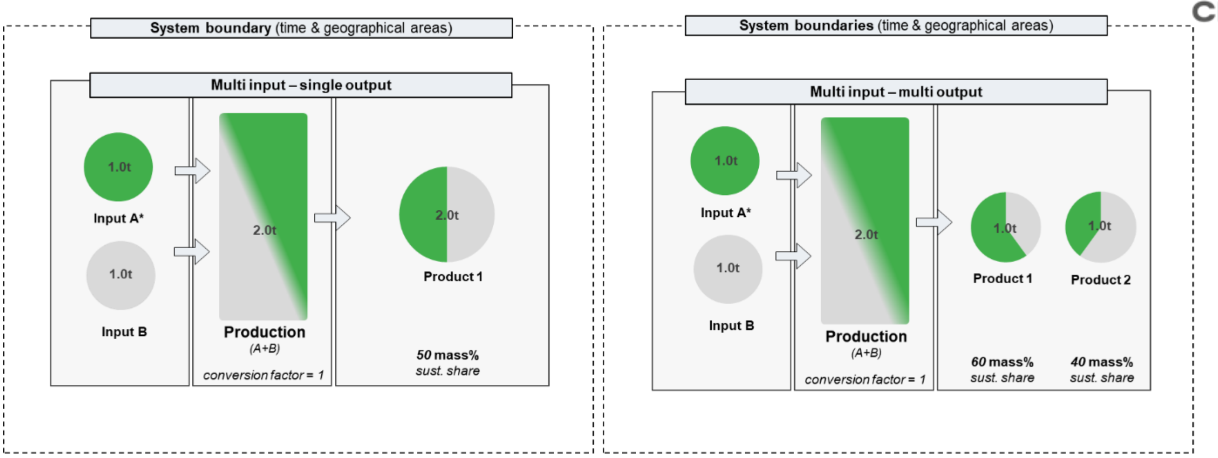


Figure 13: Controlled blending with multi-input: single and multi-output. Controlled blending with multi-input (A - sustainable raw material). Left: Multi Input - Single output The sustainable share is calculated by dividing the total mass of sustainable raw material (A*) by the total input (A* and B).; Right: Multi Input - Multi output. The sustainable share reflects the composition of products 1 and 2 and might therefore be different.*

6.1.4. Mass Balance Model

For materials, in a complex production environment (e.g. multi-input, multi-output production set-up), today the most relevant CoC model is the Mass Balance (MB) model. MB allows simultaneously the use of a mix of renewable, recycled and conventional materials and products[11], using the existing interlinked/integrated system of production plants, energy flows, and infrastructure. The use of renewable and recycled material can be scaled up effectively and rapidly without costly adaptation of production processes and value chains. A third-party certification ensures the credibility of the system by avoiding double counting.

In principle, there are two different implementation methods according to ISO 22095:2020: the rolling average method and the credit method, illustrated in Figure 14.

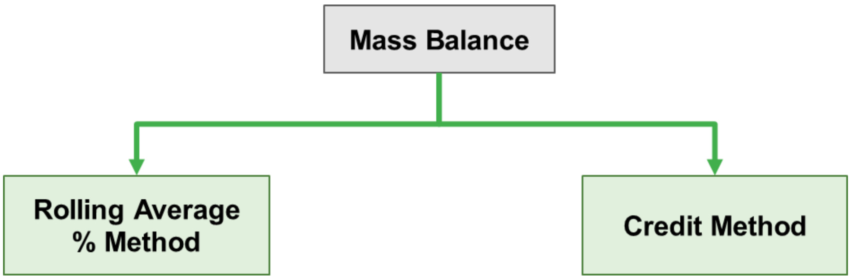


Figure 14: Two implementation methods according to ISO 22095:2020 (International Organization for Standardization, 2020).

6.1.4.1 Guiding Principles

When a mass balance model is applied to attribute specified characteristics from material and energy inputs to outputs requirements set by ISO 22095:2020 and ISO 22095-2:2026[12] (International Organization for Standardization, 2020; International Organization for Standardization, 2025b), as well as additional rules set forth below, which are especially relevant for the chemical industry, shall be followed.

---

[11] “Materials and products” and “feedstocks” are used interchangeably in this document.

[12] To be published as ISO 22095-2 in 2026.

A) Organizations shall ensure that there is no double counting. A reliable accounting system shall be established at each operating site to ensure that the total amount of specified characteristics or credits attributed to outputs during the balancing or claim period is equal to, or does not exceed, the total amount of specified characteristics or credits created by the inputs within the balancing or claim period, taking into account specified characteristics or credits carried over from the previous period and all losses considering the conversion factor.

B) The characteristics of creating mass balance model credits shall include:
   i. Real – A credit shall represent a real material, product or production characteristic defined as a specified characteristic.
   ii. Quantifiable – Credits shall be quantified.
   iii. Unique – A credit shall represent one unit of the specified characteristic for which it was created and shall not be duplicated or reused once retired to prevent double counting.
   iv. Immutable – A credit shall not be converted to represent a different specified characteristic once a credit has been created and has entered the system boundary of CoC even if the unit of measurement has been changed.
   v. Irreversible - Credits that represent specified characteristics shall be durable and lasting.

   NOTE: A credit's use period can expire, for example if the requirements setter or the issuer set specific duration limits, or if the certificate of an operator expires without being renewed. The credit does not disappear, so much as it can become inaccessible for use, effectively making it unusable.

C) The attribution of specified characteristics to outputs shall be technically feasible within the system boundary of CoC where the output is produced. The availability of technical infrastructure shall exist and be in use to produce the output or part(s) of output by processing the inputs with specified characteristics within the last evaluation period, yet no longer than 12 months.

D) For the credit mass balance method, the allowable attribution of credits to the output shall be defined by like-for-like principle. 'Like-for-like' means that credits shall only be attributed to the output or part of the output, which is 'similar in nature' to the input with specified characteristics. 'Similar in nature' shall be further specified and documented by the requirements setter considering aspects such as functionality, quality or composition. Attribution shall be safeguarded by requirements that the input shall have a chemical link with the respective output, thus the input shall be chemically convertible into the respective output (as an example: polyurethane insulation material is made of polyol and isocyanate. As there is no chemical link between a polyol and the isocyanate specified characteristic from polyol as input can be attributed to the part of polyol in the polyurethane only, but not to the part originating from isocyanate and vice versa).

E) Attribution may be done proportionally or non-proportionally in the case of multiple inputs or outputs.

F) A site-to-site credit transfer within system boundary of CoC can be applied in accordance with the conditions specified in ISO 13662:2025 and shall be made transparent, if applied. In particular, credit transfers should be allowed or restricted through technical requirements irrespective of the physical distance of the transfer.

G) The choice and implementation of mass balance model shall be transparent, clear, credible and verifiable. The key properties of the mass balance model shall be communicated to the next supply chain actor, covering the specified characteristics, the system boundaries (e.g., geographic area, physical link, balancing period), the implementation method (rolling average and credit method), and other properties like attribution rules (e.g., proportional, non-proportional) and the adoption of a site-to-site credit transfer (only for credit method).

H) Claim periods shall be clearly defined and justified by the requirements setter. A claim period shall be linked to one or more evaluation periods.

I) A conformity assessment system with regular audits shall be implemented according to the requirement setter. The organization shall be transparent about the type of assessment used (i.e., first-party (self-assessment), second-party (peer assessment) or third-party (independent body) conformity assessment activity).

6.1.4.2 Rolling Average mass balance

The rolling average mass balance method is a specific approach used in the mass balance system to account for fluctuating proportion of inputs with and without specified characteristics over a defined period. In the context of biogenic raw materials, the rolling average method allows to calculate an average percentage of biogenic and fossil raw materials as input over the defined claim period and make a claim for the related output. This shall be done for each material or product as shown in Figure 15.

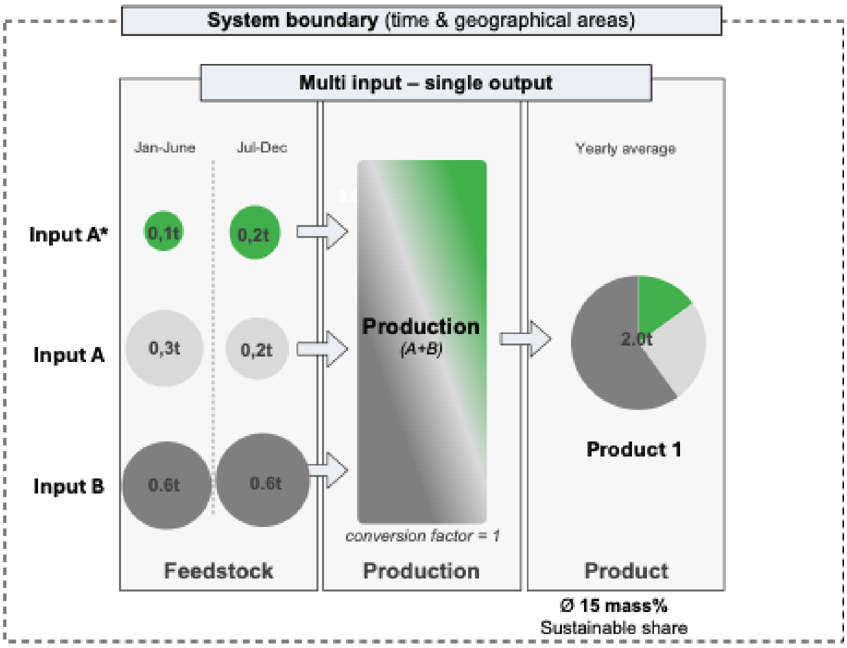


Figure 15: Rolling Average MB with multi-input (A - sustainable raw material) and single output. The sustainable share of 15% is calculated by dividing the total mass of sustainable raw material (A*; 0.3t) by the total input (A*, A, B; 2.0 t).*

6.1.4.3 Credit Method

The credit method mass balance is a specific approach within the mass balance system that involves generating credits based on specific characteristics of the input, such as the renewable or recycled attribute of a renewable or recycled feedstock. These credits are then stored in a credit account and can be used to balance the use of certain specified characteristics for the attribution to products. By utilizing the credit method organizations using mass balance can demonstrate the use of renewable, recycled or other desired attributes in their products.

According to the guiding principles described in chapter 6.1.4.1 the set-up of a credit mass balance system requires a transparent description of the key properties aligned with ISO 22095-2:2026 (International Organization for Standarization, 2026).

The key properties cover: specified characteristics, system boundaries (e.g. geographic area, physical link, balancing period), implementation method (rolling average and credit method), and other properties like attribution rules (e.g. proportional, non-proportional) and site-to-site credit transfer (only for credit method).

The following shall be considered (International Organization for Standarization, 2026):

- Definition of the specified characteristics (e.g., recycled, renewable)
- Description of the system boundary of CoC, which covers topics like the geographic area (e.g., process, site or multiple site), information about the possibility of physical presence and information about the balancing or claim period.
- Defining implementation method (rolling average or credit method)
- Definition of the attribution rules which are described in detail below
- Information whether site-to-site credit transfer within the same company was applied within the system boundary of CoC, as allowed under certain conditions described in ISO 22095-2:2026.

In the following the different attribution types are described in more detail to give a better understanding of credit mass balance. For the chemical industry a comprehensive classification of the product systems requires the description of attribution types in both directions, referring to the inputs of the production as well as to the outputs. As the categories proportional and non-proportional can be applied whenever more than one input and/or output is involved. It is not possible to apply it in case of single input or single output. ISO 22095-2:2026 distinguishes between proportional and non-proportional attribution and offers the category not applicable in case it is not possible to decide on both options. The latter concept shall be used for the case of single input and/or single output systems. Figure 16 visualizes the different possible combinations. In Annex I one can find detailed examples of all possible attribution types according to mass (International Organization for Standarization, 2026).

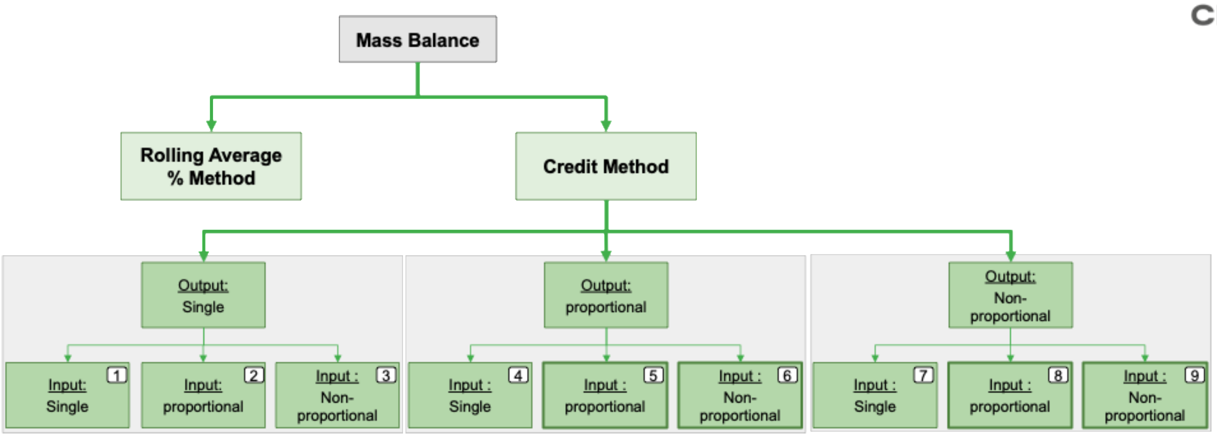


Figure 16: Description of the different mass balance implementation methods and the different attribution types in case of rolling average and credit mass balance.

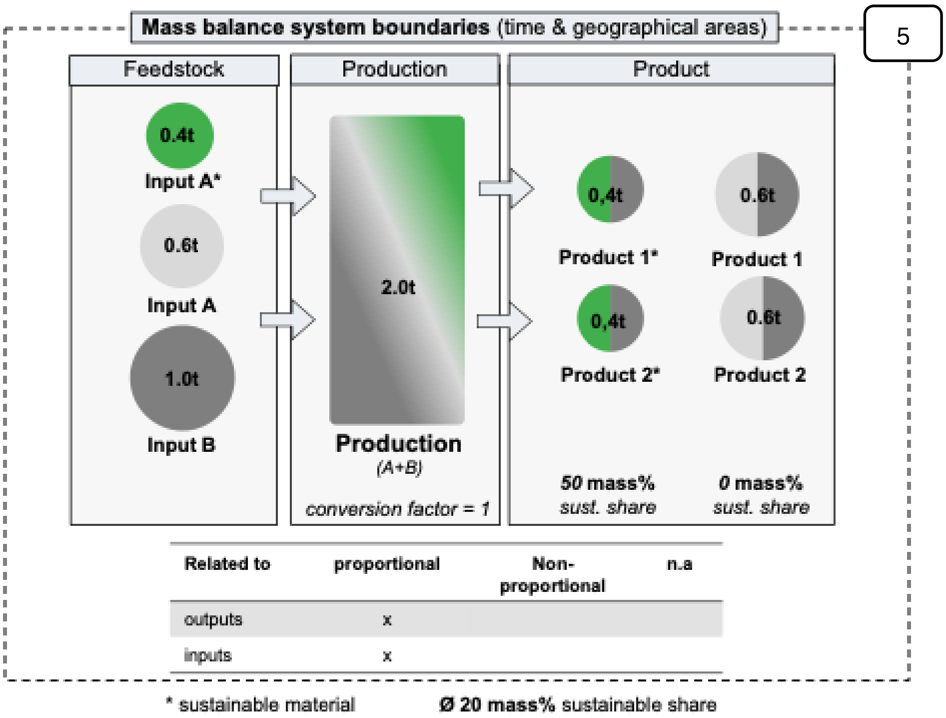
In a first step the user of a credit mass balance system shall determine whether the considered production process has a single output or several outputs (= multi-output system). The specified characteristics from the alternative feedstock may be attributed to the output(s) proportionally. It follows according to its individual proportion related to the total output. Alternatively, it may be attributed non-proportionally. In this case, the attribution follows rules irrespective of its individual proportion related to the total output. When attribution is done non-proportionally for inputs such as cases 3, 6, 9 in the figure 15, like-for-like principle shall be applied where inputs are similar in nature. In addition, inputs shall have a chemical link between the inputs and outputs as described in Section 6.1.4.1 Guiding Principles (principle D). As an example, polyurethane insulation material is made of polyol and isocyanate. As there is no chemical link between a polyol and the isocyanate specified characteristic from polyol as input can be attributed to the part of polyol in the polyurethane only, but not to the part originating from isocyanate and vice versa. Additional information can be provided how technical feasibility is maintained for non-proportional attribution together with fulfilling the like-for-like principle and the existence of a chemical link. Both principles apply independently if it is a single or multi-input system. After that the same decisions have to be taken regarding the input.

Below, cases for attribution of sustainable input are explained in detail. Annex I**.** Other cases can be found in Annex I.

All multi-input / multi-output system examples are set up in the same way:

Feedstock:	Different inputs (A and B) with 1t each
Input A-B:	0.4t sustainable input (A*) and 0.6t as non-sustainable input (A); 1 t non-sustainable input (B)
Production:	Mixing and/or reaction of A+B without losses (= conversion factor = 1)
Product:	Depending on the setting different outputs (product 1/1* and 2/2*) with different amounts and sustainable shares

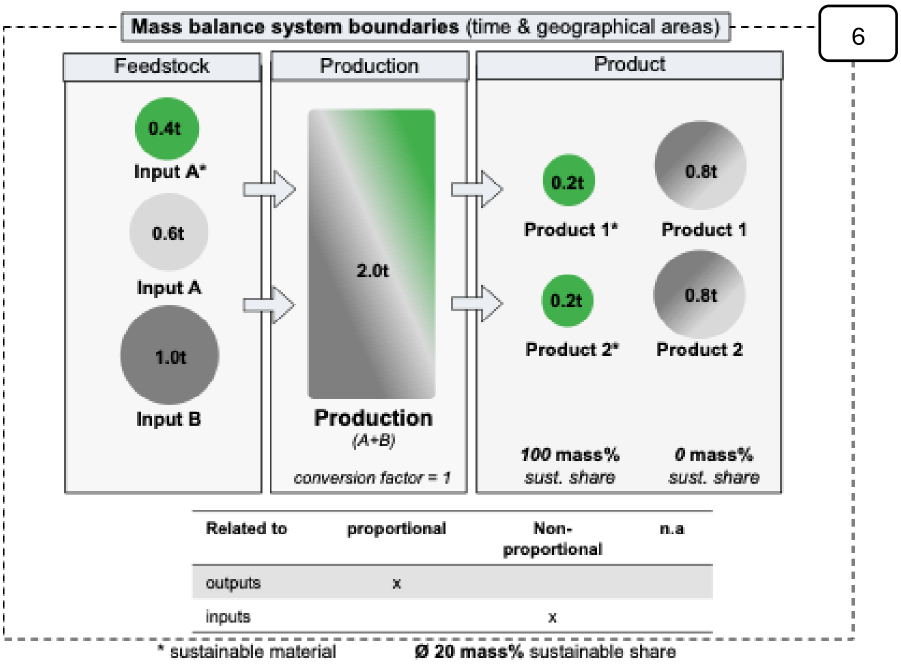
In Figure 17 the sustainable input A* is attributed to all products according to the individual proportion in the output. In addition, the input A* is attributed to each output proportionally to its individual share in the input. Therefore, it is a proportional attribution with respect to outputs and inputs.



Related to	proportional	Non-proportional	n.a
outputs	x		
inputs	x		

Figure 17: Example for proportional attribution of feedstock to outputs and inputs.

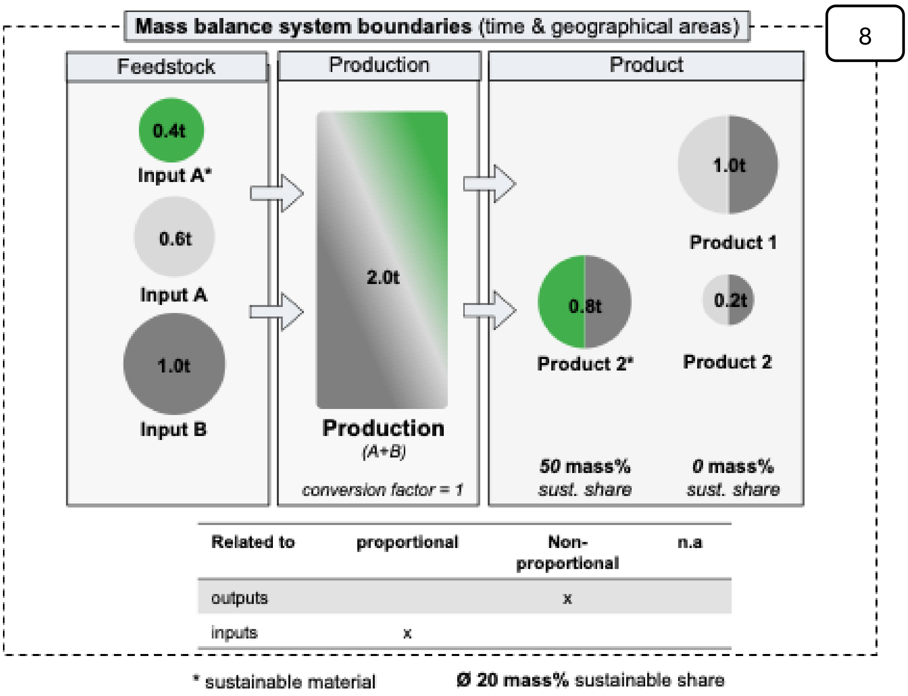
Figure 18 and Figure 19 show cases with a combination of non-proportional and proportional regarding the output and input. In Figure 18 Input A* is attributed to all outputs according to the individual proportion in the output but irrespective of the proportion of A* in the input. Therefore, it is a proportional attribution regarding the output and a non-proportional attribution regarding the input.



Related to	proportional	Non-proportional	n.a
outputs	x		
inputs		x	

Figure 18: Example for proportional output / non-proportional input.

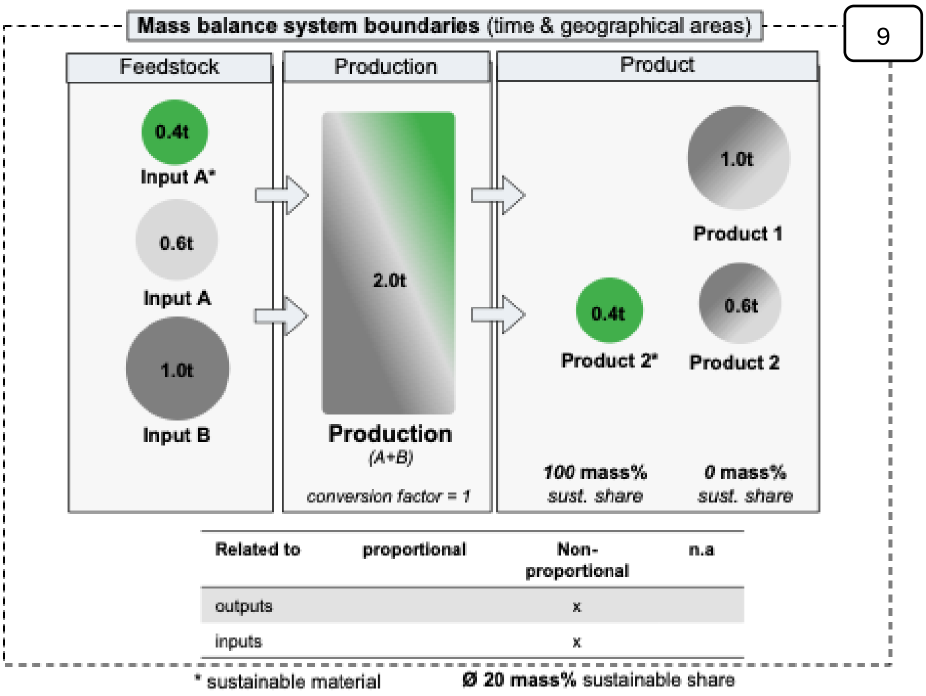
In Figure 19 Input A* is attributed to Product 2* only irrespective of the proportion of A in the output, whereas A* is attributed to Product 2* according to its ratio in the input. Therefore, it is non-proportional attribution regarding the output and proportional attribution regarding the input.



Related to	proportional	Non-proportional	n.a
outputs		x	
inputs	x		

Figure 19: Example for non-proportional output / proportional input.

In Figure 20 the sustainable input A* is attributed to product 2* only and not to all products according to their individual proportion. In addition, the input A* is attributed completely to one output only without considering the exact share of A in the total input. Therefore, it is non-proportional attribution with respect to outputs and inputs.



Related to	proportional	Non-proportional	n.a
outputs		x	
inputs		x	

Figure 20: Example for non-proportional to the output / non-proportional to the input.

6.1.5. Book & Claim

The Book and Claim (B&C) CoC model may be an option for transferring sustainability attributes between companies without physical transport of energy, or in case of materials without physical transport of products. B&C systems are the most applied method for tracking energy attributes because Energy Attribute Certificates (EAC), such as Guarantee of Origin (GO) can be transferred and traded separately from the physical flow of energy. Every unit of energy generated has certain characteristics, such as the source of energy (wind, solar, coal), where the energy was generated, and when the production device first came online. These characteristics can be documented into an EAC which is issued to the producer and can be traded or transferred to a user and even a consumer at the end of the supply chain. Because there is informational and economic value to EACs, they must be accurate and securely managed. Energy attribute tracking systems are often based on the B&C methodology and exist across the world.

6.2. Data attributes

For a credible CoC system it is important for the economic operator issuing a DMP/DPP to provide transparency about the CoC approach used. In order to achieve this, this document describes a minimum set of attributes designed to characterize the CoC approach adopted, taking inspiration from the designation system developed in ISO 22095-2:2026 and the current industry practice with the certification schemes listed in chapter 5 (International Organization for Standarization, 2026).

The DMP/DPP shall not only transport the CoC characterization attributes pertaining to the system boundary of CoC of the declarant economic operator but also provide – in aggregated form – relevant information about the CoC approach followed in the supply chain upstream.

For example, the adoption of a credit transfer between manufacturing sites in case of a mass balance credit method CoC model at any step in the supply chain upstream of the declarant economic operator shall be made transparent.

As is already the case for all reputable certification schemes, it shall not be possible to change along the supply chain from a less restrictive to a more restrictive CoC model (e.g., from segregated to identity preserved, or from mass-balance to controlled-blending, or from book & claim to mass-balance), while the opposite is allowed, at least in principle. As a consequence, at every step of the chain of custody, providing the information on the CoC model adopted by the last economic operator shall be sufficient.

Table 7 provides a list of attributes deemed sufficient to adequately characterize the CoC model adopted in a digital product and material passport.

Table 12. Attributes for characterizing CoC models.

Characterization attribute	**Value list**
Chain of custody model	1 – not applicable 2 – identity preserved 3 – segregated 4 – controlled blending 5 – mass balance (rolling average) 6 – mass balance (credit method) 7 – book & claim
[optional] System boundary of CoC information – existence of a physical link	1 – true 2 – false
Specific rules for mass balance credit method – attribution proportionality to output	1 – not applicable[13] 2 – proportional 3 – non-proportional
Specific rules for mass balance credit method – attribution proportionality to input	1 – not applicable[13] 2 – proportional 3 – non-proportional
Specific rules for mass balance credit method – credit transfer between different sites	1 – true[14] 2 – false

---

[13] In case of single-input or -output choose not applicable

[14] It's sufficient that at least one step in the chain-of-custody upstream has adopted a multi-site credit transfer, and this attribute shall be set as „TRUE“, even if the last step hasn't applied a multi-site credit transfer.

Certification system	Name of certification system adopted
Conformity assessment party	1 – 1st party 2 – 2nd party 3 – 3rd party
Additional attributes for upstream chain of custody characterization	
[optional[15]] Specific rules for mass balance credit method – non proportional attribution to the output adopted upstream	1 – true 2 – false
[optional[15]] Specific rules for mass balance credit method – non proportional attribution to the input adopted upstream	1 – true 2 – false
[optional] Certification systems used upstream	Name of additional certification system adopted upstream (in case deviating from the last step).

Additionally, to such attributes, the set of information will be underpinned and complemented by a link to a CoC certificate or set of certificates.

6.3. Impact on other metrics [link to Sustainability Metrics]

The methodology to determine the LCIA impact of CoC models is included in the scope of Chem-X Environmental Sustainability Guideline. Further standardization is under development within the ISO14077 process.

---

[15] Defined as optional because currently not yet conveyed as information in PoS certificates. Should this information become mandatory in PoS, the declarant economic operator shall provide such piece of data.

7. Material accounting*

[check in future Guideline module releases]

8. Information Model*

[A link to the respective DMP information model will be released soon]

9. Literature

American Center for Life Cycle Assessment , 2023. *ACLCA PCR Open Standard v1.0 | Guidance for Quantifying Renewable Electricity Instruments in EPDs,* s.l.: s.n.

Center for Global Commons, University of Tokyo, Systemiq, 2022. *Planet-Positive Chemicals - Pathways for the chemical industry to enable a sustainable global economy,* Tokio, Japan & London, UK: Center for Global Commons, University of Tokyo, & SYSTEMIQ.

CHEM-X, 2026. *The Environmental Sustainability Guideline for the Chemical Industry,* München: CHEM-X.

Circle Economy & Deloitte, 2025. *The Circularity Gap Report 2025,* Amsterdam: Circle Economy.

Deutsche Institut für Normung e. V., 2025. *DIN SPEC 91508:2025-04 - Requirements for the Life Cycle Assessment of CCU- and CCS-Technologies,* Berlin: DIN Media GmbH.

European Commission, 2019. *The European Green Deal COM(2019) 640 final,* Brussels: Publications Office of the European Union.

European Commission, 2025. *Call for Evidence - Circular Economy Act - Ares(2025)6250342,* Brussels: European Commission.

European Committee for Standardization (CEN), 2014. *EN 16575:2014 Bio-based products - Vocabulary,* Brussels: CEN.

European Committee for Standardization (CEN), 2021. *EN 15643:2021 Sustainability of construction works - Assessment of buildings and civil engineering works,* Brussels: CEN.

European Committee for Standardization (CEN), 2021. *EN 15804:2012+A2:2019/AC:2021 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products,* Brussels: CEN.

European Parliament and the Council of the European Union, 2011. *Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste,* Luxembourg: Publications Office of the European Union.

European Parliament and the Council of the European Union, 2023. *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on circularity requirements for vehicle design and on management of end-of-life vehicles (ELVR),* Luxemburg: Publications Office of the European Union.

European Parliament and the Council of the European Union, 2024a. *Regulation (EU) 2024/1781 on a framework for the setting of ecodesign requirements for sustainable products (ESPR),* Luxembourg: Publications Office of the European Union.

European Parliament and the Council of the European Union, 2024b. *Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste,* Luxembourg: Publications Office of the European Union.

European Parliament and the Council of the European Union, 2024c. *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives,* Luxembourg: Publications Office of the European Union.

Eurostat, 2023. *Information on data - Circular economy*. [Online]
Available at: https://ec.europa.eu/eurostat/web/circular-economy/information-data
[Accessed 25 09 2025].

International Council of Chemical Associations (ICCA), 2020. *Catalyzing Growth and Addressing Our World's Sustainability Challenges,* Washington: International Council of Chemical Associations (ICCA).

International Council of Chemical Associations (ICCA), 2023. *Pathways for the Global Chemical Industry to Climate Neutrality,* s.l.: s.n.

International Energy Agency , 2021. *Net Zero by 2050 - A Roadmap for the Global Energy Sector ,* Paris: IEA Publications.

International Energy Agency ,2022. *Direct Air Capture 2022*, IEA, Paris
https://www.iea.org/reports/direct-air-capture-2022, Licence: CC BY 4.0

International Organization for Standardization, 2016. *ISO 14021:2016 Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling),* Geneva: ISO.

International Organization for Standardization, 2018. *ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification,* Geneva: ISO.

International Organization for Standardization, 2020. *ISO 22095:2020 Chain of custody — General terminology and models,* Geneva: ISO.

International Organization for Standardization, 2022a. *ISO 21003-3:2022 Multilayer piping systems for hot and cold water installations inside buildings — Part 3: Fittings,* Geneva: ISO.

International Organization for Standardization, 2022b. *ISO 6707-3:2022 Buildings and civil engineering works — Vocabulary — Part 3: Sustainability terms,* Geneva: ISO.

International Organization for Standardization, 2024a. *ISO 59004:2024 Circular economy — Terminology, principles and guidance for implementation,* Geneva: ISO.

International Organization for Standardization, 2024b. *ISO 59020:2024 Measuring and assessing circularity performance,* Geneva: ISO.

International Organization for Standardization, 2025b. *ISO/FDIS 13662:2025 Chain of custody — Mass balance — Requirements and guidelines*. Geneva: ISO.

International Organization for Standarization, 2026. *ISO/FDIS 13662:2025,* Geneva: ISO.

Kirk-Othmer, 1993. Copper. In: H. F. Mark, D. F. Othmer, C. G. Overberger & G. T. Seaborg, eds. *Kirk-Othmer Encyclopedia of Chemical Technology.* 4th ed. New York: Wiley-Interscience, p. 381.

Polykretis, A. et al., 2021. Towards a cascading strategy for the valorisation of agricultural biomass: a Crete case study. *Journal of Environmental Management*, Volume 290.

PwC, 2024. *Net-zero chemicals industry transformation: A sectoral approach to deep decarbonization*. [Online]
Available at: https://www.pwc.com/gx/en/issues/business-model-reinvention/how-we-fuel-and-power/net-zero-chemicals-industry-transformation.html
[Accessed 25 September 2025].

Together for Sustainability, 2024. *The Product Carbon Footprint Guideline for the Chemical Industrty V3,* Brussels: Together for Sustainability AISBL.

U.S. Environmental Protection Agency, 2000. *Sulfuric Acid Recycling in the Semiconductor Industry,* Washington: UNITED STATES ENVIRONMENTAL PROTECTION AGENCY.

World Economic Forum, 2023. *How the chemicals industry can help build a low-carbon economy*. [Online]
Available at: https://www.weforum.org/stories/2023/03/chemicals-industry-low-carbon-economy/
[Accessed 25 09 2025].

10. Annex I

Figure 21 shows an example for single input / single output. Input A* is attributed to a certain amount of output, leading to Product 1* with 100% sustainable share and Product 1 with 0% sustainable share.

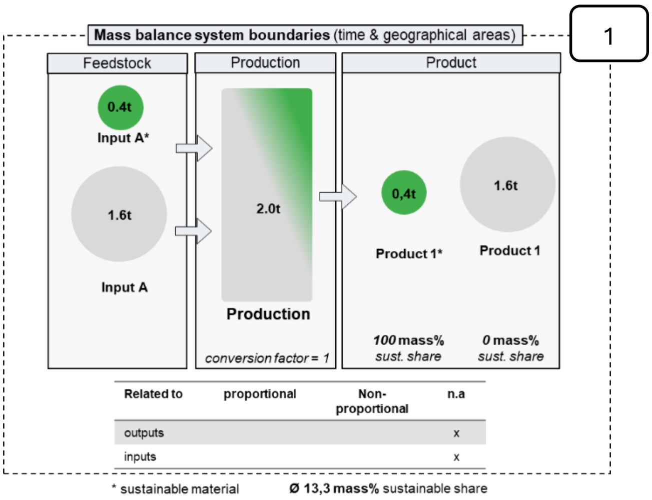


Figure 21: Example for single output and single input.

Figure 22 is an example for single input and multi output. Input A* is attributed proportionally to both products, leading to same amounts of Product 1* and 2* with 100% sustainable share and Product 1 and 2 each with 0% sustainable share. Therefore, it is a proportional attribution regarding the output.

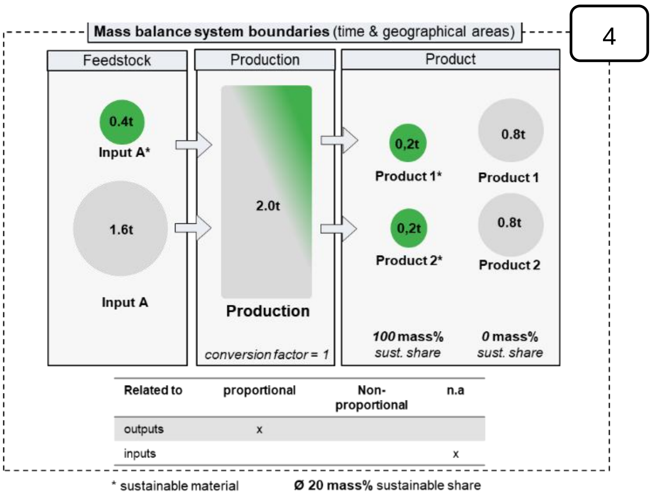


Figure 22: Example for single input and proportional output.

Figure 23 is an example for single input and multi output. Input A* is attributed non-proportionally to Product 1*, leading to Product 1* with 100% sustainable share and Product 1 and 2 each with 0% sustainable share. Therefore, it is a non-proportional attribution regarding the output.

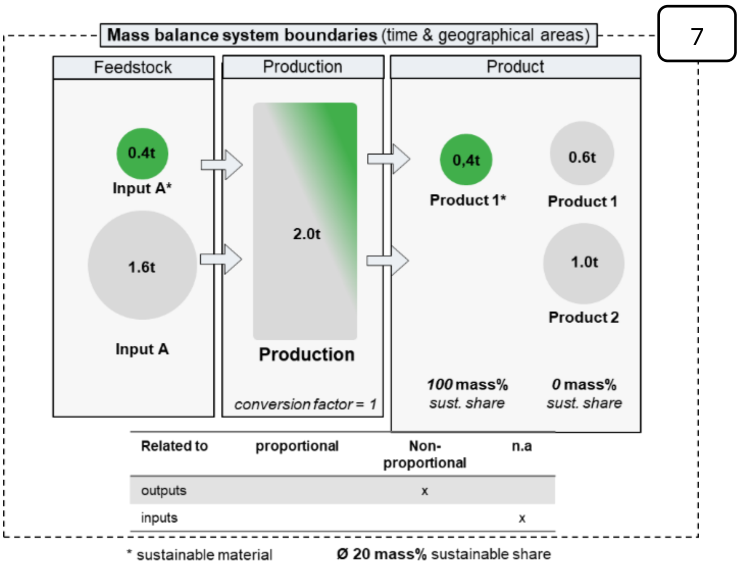


Figure 23: Example for non-proportional to the output / single input.

Figure 24 is an example for multi-input and single output. Input A* is attributed to product 1* according to its ratio in the input. Therefore, it is a proportional attribution regarding the input.

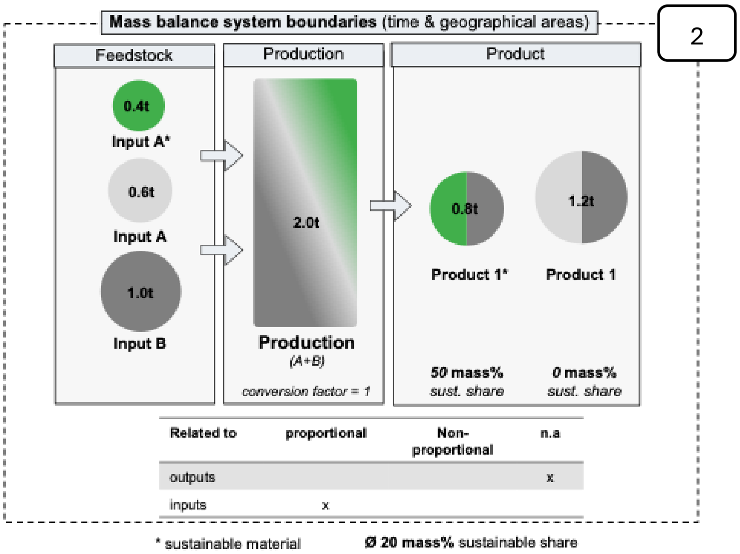
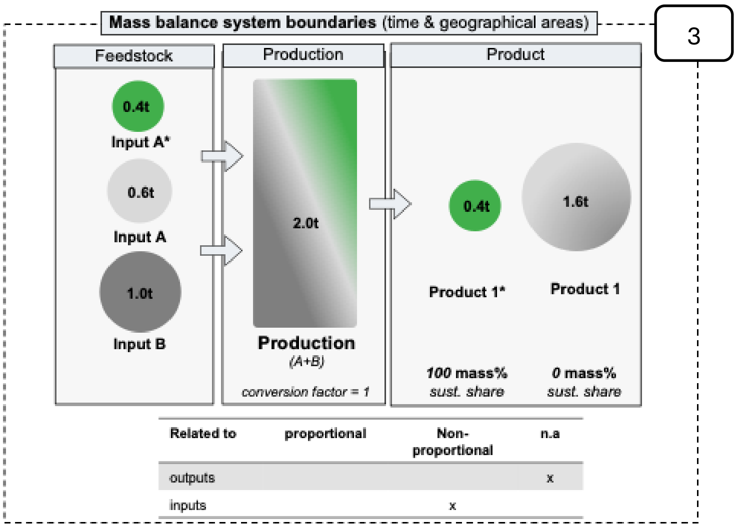


Figure 24: Example for single output / proportional to the input.

In Figure 25 Input A* is attributed to Product 1* irrespective of the proportion of A* in the input. Therefore, it is a non-proportional attribution regarding the input.



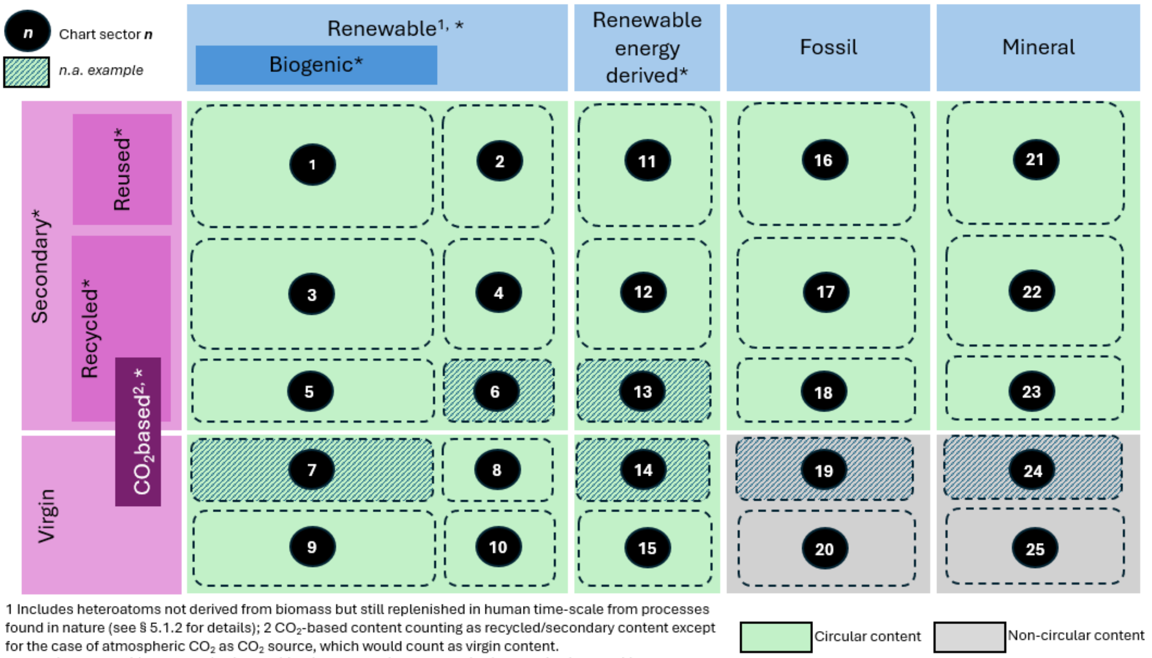
Related to	proportional	Non-proportional	n.a
outputs			x
inputs		x	

* sustainable material **Ø 20 mass%** sustainable share

Figure 25: Example for single output / non-proportional to the input.

11. Annex II

This Annex provides in Figure 26 and Table 13 a non-exhaustive list of examples of circular and non-circular content in chemical materials and is intended as an orientation to familiarize and further enhance the framework illustrated in Figure 9 of Chapter 5 of this Guideline. Chapter 5 provides details and guidance on the respective classifications.



1 Includes heteroatoms not derived from biomass but still replenished in human time-scale from processes found in nature (see § 5.1.2 for details); 2 CO_2-based content counting as recycled/secondary content except for the case of atmospheric CO_2 as CO_2 source, which would count as virgin content.
* Counting as "certified share", if with certification of sustainable sourcing/production/traceability

Figure 26: Subdivision into sectors of the chart displayed in Figure 9 of Chapter 5 of this Guideline.

Table 13: Examples for subdivision into sectors of the chart.

Sector	Examples
1	Reused spent acetic acid produced from fermentation of biomass
2	Reused spent nitric acid (pH correction) based on renewable ammonia
3	Biogenic content derived from biowaste; Biogas from anaerobic digestion of biowaste
4	Recycled polycarbonate from renewable phenol
5	CO_2-based content in CCU-derived methanol with biogenic CO_2 source
6	*n.a.*
7	*n.a.*
8	CO_2-based content in DAC-derived methanol with atmospheric CO_2 source
9	Renewable sustainable palm oil
10	Phenol from Hock-process with renewable cumene
11	Reused spent nitic acid (pH correction) based on renewable energy derived ammonia
12	Recycled polyoxymethylene (POM), originally manufactured from e-methanol-based formaldehyde
13	*n.a.*
14	*n.a.*
15	Hydrogen from 100% renewable energy-powered water electrolysis (green hydrogen); Ammonia from the reaction of green hydrogen with nitrogen from 100% renewable energy-powered air separation
16	Reused spent acetic acid produced from fossil methanol
17	Recycled fossil-based polyethylene
18	CO_2-based content in CCU-derived methanol with fossil CO_2 source
19	*n.a.*
20	Blue ammonia; grey ammonia; Propylene from steam cracking of virgin naphtha
21	Spent sulfuric acid re-used in water treatment
22	Recycled precious metal catalyst; Phosphorous fertilizer from industrial wastewater; Recycled silicon metal into silane and siloxane
23	CO_2-based content in CCU-derived methanol with mineral CO_2 source
24	*n.a.*
25	Phosphorous fertilizer from phosphate rock

tfs-initiative.com

chem-x.de

Funded by the European Union – NextGeneration EU. The views and opinions expressed are solely those of the authors and do not necessarily reflect the views of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Funded by the Federal Ministry of Economic Affairs and Energy BMWE

Funded by the European Union
NextGenerationEU

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag