MULTI-OUTPUT ALLOCATION **GUIDANCE**

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Catena-X
Your Automotive Network

Introduction

The purpose of this document is to provide practical guidance on solving multi-output allocations with the help of the Catena-X allocation hierarchy. It proceeds in six steps (see Figure 1). This document describes each of these steps by means of an example.

Allocation occurs in multi-output processes, which are processes yielding several functional outputs (co-products). For multi-output processes, the GHG emissions (as CO2e) associated with the respective process step must be partitioned between all process output products in a consistent way. Therefore, Catena-X prescribes a comprehensive allocation hierarchy in section 5.1.2 of the Product Carbon Footprint (PCF) Rulebook.

The rules as per Catena-X Rulebook (section 5.1.2) always apply. This document provides practical additional guidance and explanations. The examples shown are for illustrative purposes only.

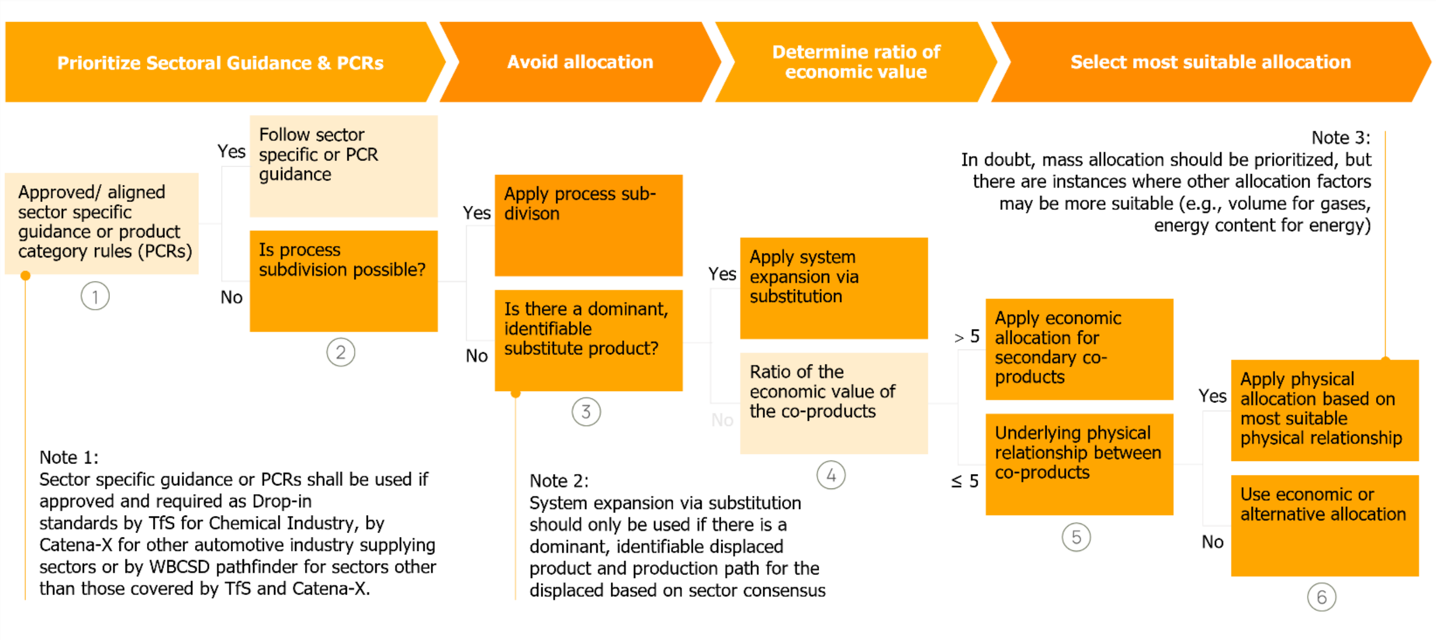

Figure 1: Multi-output allocation decision procedure

When do allocation problems occur?

The Catena-X rulebook is intended for attributional PCF. This means that the PCF is calculated focusing on the direct inputs (like materials and energy) and outputs (like products, direct emissions and waste) associated with the production process of a product. Consequently, multi-output allocation issues must be considered on production process level. Every unit process needs to be investigated for potential multiple outputs of a process under study (multi-functionality). This can be determined for each PCF study by identifying the output(s) of a process as either a product or a waste during the data collection. Figure 2**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the VDA generic data collection template with dummy input and output entries. In this case, two co-products (A and B) as well as waste are produced in the process. The distinction and criteria between co-product and waste can be found in Catena-X Rulebook section 5.2.2 and the Guidance on Waste treatment. Typically, waste is any material which is not deliberately produced as an integral part of a multi-output production process. A product (or co-product) in contrast is produced as an integral part of a multi-output process where its further use is certain.

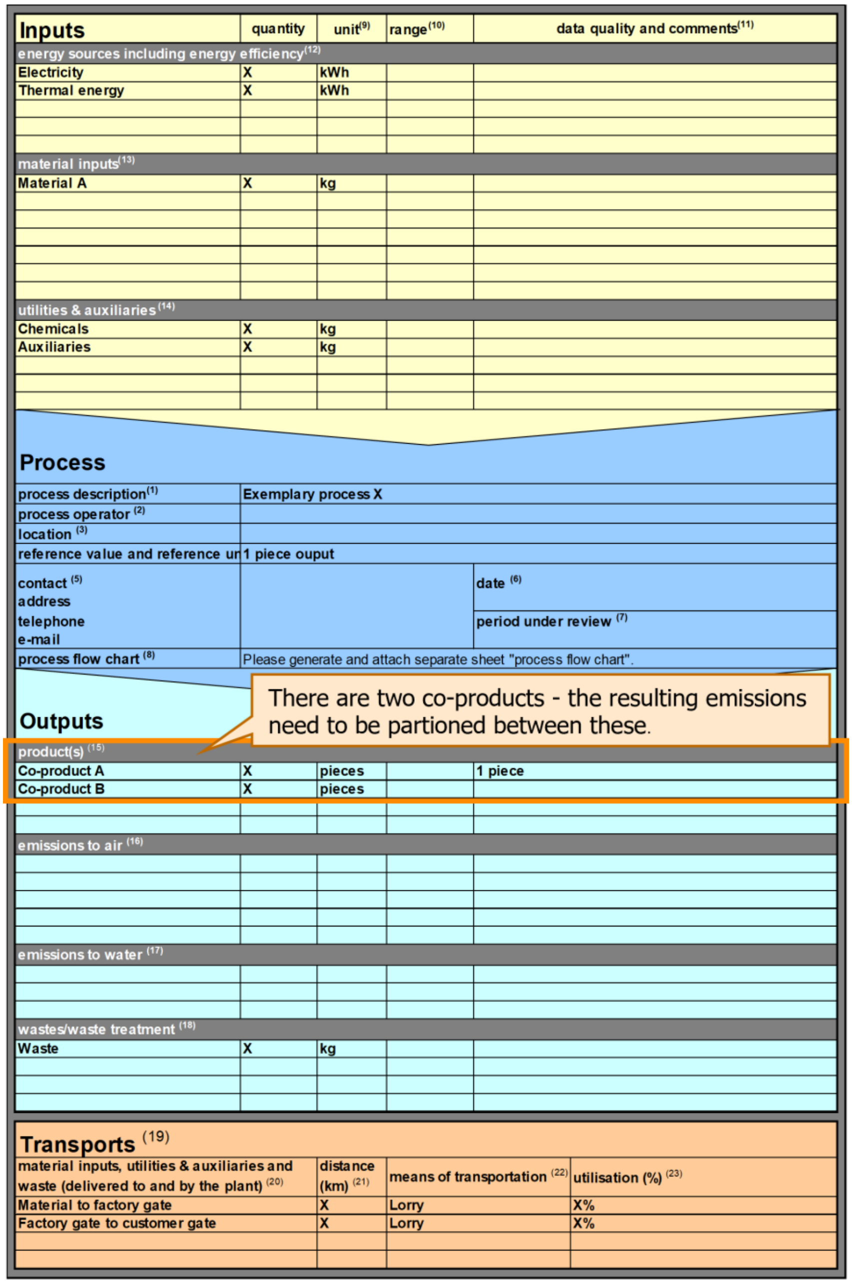

Figure 2: Generic data collection template from VDA (German Association of the Automotive Industry (Verband der Automobilindustrie - VDA), 2007)

If a process yields only one product and waste, no allocation is required, and the emissions associated with the waste need to be added to the PCF of the product (see Catena-X Guidance on Product Carbon Footprint (PCF) calculation).

If a process yields more than one product, multi-output allocation is required, and the 6-step allocation hierarchy must be applied. In general, it is important to ensure that all relevant GHG emissions are considered, and that double counting /omission of allocated emissions is avoided.

Info box: What is double counting and how can it be avoided?

Double counting means if a single emission reduction is counted more than once. This can occur in various stages of the LCA process of a product system, especially if multiple producers are involved that declare PCFs based on different accounting principles. As a consequence, total emissions across the value chain may be over- or underestimated causing potentially misleading conclusions about the environmental performance of a product. To avoid double counting in allocation, allocation methods need to be applied consistently within and across system boundaries.

Double counting when applying allocation occurs if the producer of the co-product applies a different allocation method than the recipient of the co-product. For example, if the recipient of the co-product receives emissions credits for the system expansion applied and the recipient of the co-product accounts for it as waste with no emissions.

Double counting is avoided when both producer and recipient apply consistent principles. This means in the system expansion example, that if the producer applies system expansion substitution, the recipient may not account for the co-product as waste (i.e. not with 0 CO2e.) The customer of the co-product can be provided with a PCF of the co-product. This enables the customer of the co-product to account for the co-product's correct footprint and prevents double counting of credits.

Guidance on using the Catena-X allocation hierarchy by means of an example: Allocation of multiple products from one production line

To illustrate multi-output allocation, we use the example of two different types of car grilles produced on one injection molding production line (see Figure 3). The injection molding process produces two types of intermediate co-products (A and B) on one machine at the same time. As these are deliberately produced as per the waste classification (Catena-X Rulebook section 5.2.2 and the Guidance on Waste treatment), the process results in two co-products. Therefore, the emissions associated with the inputs (polymer production, energy consumption, consumables) need to be portioned to the co-products in a consistent way.

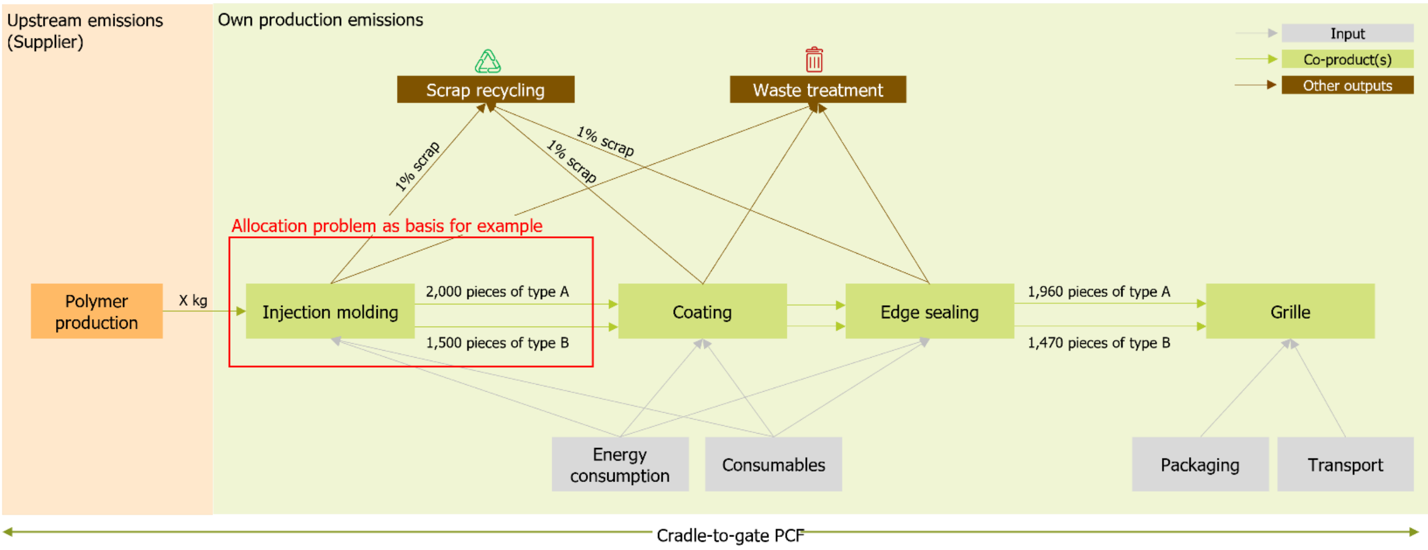

Figure 3: Exemplary illustration of multi-output allocation for the production of car grilles

Step-by-step guidance to solve the allocation problem

The Catena-X PCF rulebook prescribes a multi-output allocation hierarchy to solve allocation problems which proceeds in six steps.

1. Check if allocation rules of approved/aligned sector specific guidance or product category rules (PCR) are available

As a first step, check whether the allocation problem is covered by a sectoral PCF guidance which is accepted/aligned with Catena-X (see Annex A.2 and Annex A.3 of the Catena-X PCF Rulebook).

Since, in our example, the own production process is part of component production, the material-specific sector guidances accepted by/aligned with Catena-X (steel, aluminium, chemicals) do not apply. Therefore, the next step in the allocation hierarchy needs to be checked.

2. Check if process subdivision into more granular subprocesses is possible

As a second step, try to separate the process steps into sub-processes. This entails to investigate, whether data can be collected on a more granular level, e.g. for the time that only type B is produced in the injection molding process. If detailed data collection is possible, (electricity metering and data collection of other inputs (consumables) for the specific component) these component-specific input data can be used to separate the injection molding process into two sub-processes, i.e. (1) injection molding for product type A and (2) injection molding for product type B. Thus, no allocation is required as inputs can be calculated for both outputs separately.

If data collection on sub-process level is not possible, further subdivision cannot be applied. In our example, co-product-specific data collection is not possible as the co-products are produced on one machine simultaneously. This means, input data like electricity or auxiliary materials cannot be measured specifically for the two co-products. Therefore, the next step in the allocation hierarchy needs to be investigated.

If process subdivision is applicable for your purposes, please refer to Separate Example 1 for an illustrative example on process subdivision.

3. Check whether system expansion via substitution applies

As a third step, check whether system expansion applies. If there is a dominant identifiable product that is replaced by co-product type B and there is an alternative production path as LCI or emission factor available, it may be applied as long as additional criteria are met (see Catena-X Rulebook).

In the example above, the intermediate product is not sold and therefore it does not replace a product in another system boundary and system expansion may not be applied.

To identify whether system expansion can be applied, please see the info box below. If system expansion is applicable for you, please refer to the Separate Example 2 for an illustrative example.

Info box: investigation whether system expansion via substitution applies

(a) Is there a dominant identifiable substitute product?

To apply system expansion substitution, an equivalent product needs to be substituted by the produced co-product. Dominant means that the production process is the main process on the market. Hence, the LCI or CO2e emission factor of the substituted product must be available, representing the main process on the market. In the best case, the market average is used.

If yes, proceed to (b) in this info box. If no, proceed to step 4 in the allocation hierarchy.

(b) Are there positive lists of co-products and displaced products based on sector consensus?

A positive list of substitute production paths that should be used if available is, for example, presented in worldsteel LCI study 2020 data release Appendix 8, p. 66 et seq. These production paths should be used to calculate the system expansion substitution CO2e effect. Use primary data if available for the emissions data and only secondary (in accordance with Catena-X rulebook section 6.1.5), if primary data are not available. Positive lists should be based on sector consensus and part of aligned/accepted sector guidance methodologies.

(c) What to do, if no positive lists are available?

- Make sure the following requirements as per the Catena-X Rulebook (section 5.1.2) are fulfilled
- The production of the co-product is an integral part of the production process
- A dedicated, single-output process to produce the co-product via an alternative production process exists
- The alternative dataset must be representative of the dominant production route and comply with the requirements of chapter 6.2 (secondary data) of the Catena-X Rulebook.
- A clear description of the process for selecting the alternative product substituted by the co-product shall be internally documented

(d) What are market-mediated effects?

No market-mediated effects may occur, as the attributional LCA approach is used for the PCF. This means, the assumption that a co-product will automatically avoid a specific or the average product from the market is not enough. Instead, the substitution of a specific product ensures that the need for the primary product has decreased. This is to avoid claims of substitution that in the end are not real substitutions, but market extensions (simply more of the same product is produced).

4. Check if the difference in economic value of the co-products is significant

As a fourth step, calculate the economic value ratio to determine whether economic or physical allocation is applicable. The economic value ratio in this step is defined as the ratio of economic factors as required by the Catena-X Rulebook (in order of priority: 1) Global market prices, 2) Regional market prices, 3) Other economic allocation factors (i.e., production costs or sales prices)).

First, the most suitable economic factor needs to be determined consistently for each co-product:

(a) For the economic factor, it should be checked whether global market prices, regional market prices, or other economic factors (production costs or sales prices) are available for the respective co-products. In this order of priority, the economic factor shall be chosen consistency for all co-products based on availability. To smooth out fluctuations, average the economic factors over the last 3-5 years.

Since our example yields intermediate products, global and regional market prices as well as sales prices may not be available. Hence, production costs may be used. In our case, we assume the following unit cost:

Table 1: Unit costs of different car grilles over the course of 5 years

	2020	2021	2022	2023	2024	Average
Cost Type A	105€	120€	110€	105€	110€	110€
Cost Type B	215€	220€	230€	220€	215€	220€

Second, the ratio is calculated by dividing the highest economic value by the lowest economic value**:**

Equation 1: Calculating ratio of economic values

$$Ratio\ of\ econimic\ value(price\ or\ cost)\ = \frac{Highest\ price\ of\ co-product\ (€)}{Lowest\ price\ or\ cost\ of\ co-product}$$

In our case, the economic value of co-product Type B is divided by the economic value of co-product Type A:

Table 2: Ratio of economic value of different types of car grilles

	Average
Type A (lowest)	110€
Type B (highest)	220€
Ratio B/A	2

5. *Check whether economic allocation applies*

The resulting economic value differential is two. Only when this differential is equal or higher than five, economic allocation shall be applied. Therefore, in our case, physical allocation shall be applied and step 6) in the allocation hierarchy is evaluated. If economic allocation is applicable for you, please refer to Separate Example 3 for an example on how to perform the economic allocation.

6. *Check if there is an underlying physical relationship between the co-products and apply physical allocation*

If the calculated economic value ratio is equal or lower than five, the next step is to check if there is a physical relationship to partition inputs and outputs between the studied co-product(s). This type of allocation only makes sense for co-products which are similar in their nature. Different types of energetic gases could be compared using their energy content or different metals from one mining process could be allocated by their mass.

The relationships to choose from are based on what is most suitable to the specific case:

- produced masses
- produced pieces
- contained exergy
- contained energy

Equation 2: Calculating physical allocation factor (example pieces (or mass etc.))

$$Allocation\ factor\ (co-product\ n)\ = \frac{Pieces\ (or\ mass)\ of\ co-product\ (n)}{\sum_i^n Pieces\ (or\ mass)\ of\ all\ co-products}$$

In our example, we assume that 2,000 Type A and 1,500 Type B are produced. In case of components or products, "pieces" is the most suitable property as these are countable. In case of materials, mass would be more suitable. In case of gases, volumes.

Table 2: Physical allocation factor of different types of car grilles

	2024	Physical allocation factor
Output Type A	2000 pieces	57 %
Output Type B	1500 pieces	43 %

If no underlying physical relationship between the co-product(s) can be identified, economic allocation may still be used as the last option following the Separate Example 3 and Equation 5 to calculate allocation factors.

Finally, the resulting allocation factor has to be multiplied with the process-specific emissions (input activity data x emissions factors) to obtain the co-product-specific PCF.

REFERENCES

European Aluminium Initiative. 2023. Methodological guidance for the environmental assessment of aluminium intermediate and semi-finished products. [Online] May 23, 2023. https://www.carbon-transparency.org/resources/methodological-guidance-for-the-environmental-assessment-of-aluminium-intermediate-and-semi-finished-products.

German Association of the Automotive Industry (Verband der Automobilindustrie - VDA). 2007. Data Collection Format for Life Cycle Assessment. *Life Cycle Assessment.* [Online] October 07, 2007. https://www.vda.de/en/news/publications/publication/life-cycle-assessment.

ANNEX

Separate examples in addition to the overarching example

Separate Example 1: Alumina production process sub-division (adapted from European Aluminium 2023) (Illustrative example for step 2) process subdivision)

Bauxite has to be processed into pure aluminium oxide (alumina) before it can be converted to aluminium by electrolysis. This is achieved through the use of the Bayer chemical process in alumina refineries:

1) The aluminium oxide contained in bauxite is selectively leached from the other substances in an alkaline solution within a digester.
2) The solution is then filtered to remove all insoluble particles which constitute the bauxite residue (also called "red mud").
3) The aluminium hydroxide (AlOH) is then precipitated from the soda solution, washed and dried while the soda solution is recycled.
4) The aluminium hydroxide is then calcined to obtain the end-product, aluminium oxide (Al2O3, metallurgical alumina).

An allocation issue occurs for alumina refineries which sell both calcined metallurgical alumina (smelter-grade or non-smelter-grade) to aluminium smelters and non-calcined aluminium hydrate, as co-products, to other users.

All sub-processes of the Bayer process can be divided into single process steps with separate data collection. Aluminium hydroxide and aluminium oxide are not co-products of the same process but produced separately in sub-processes. Therefore, process-subdivision shall be applied.

To perform the process sub-division, data collection and PCF calculation shall be performed for each sub-process step (see Figure 4**Fehler! Verweisquelle konnte nicht gefunden werden.**). Thus, intermediary products are singled out for each sub-process step and no allocation is required any more.

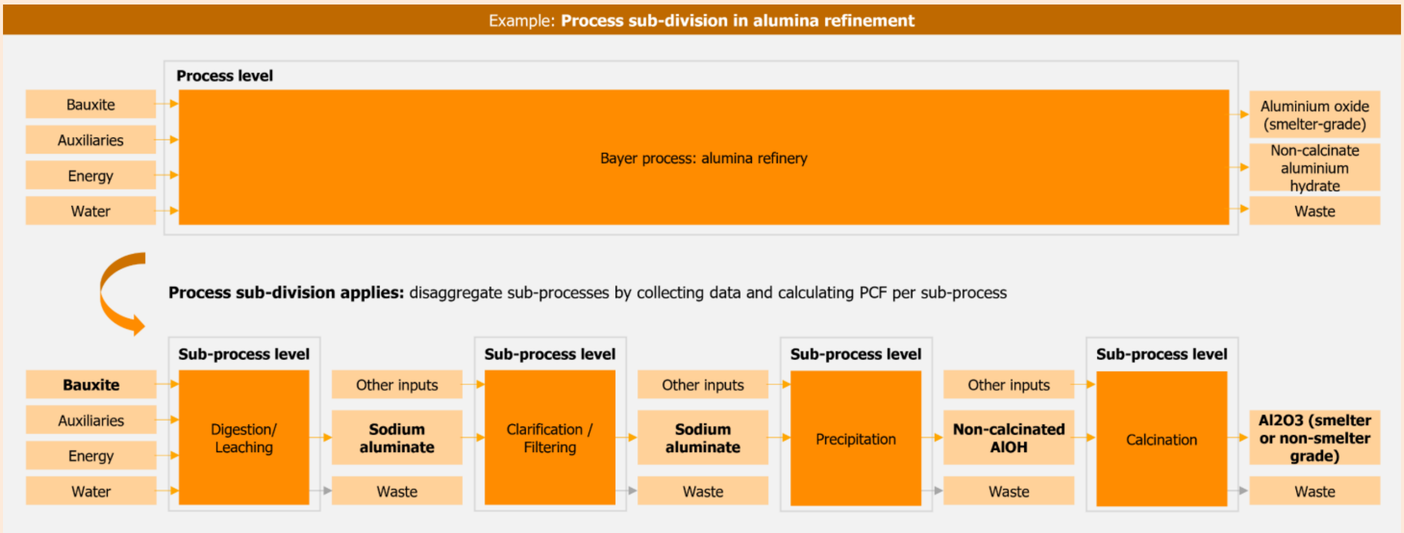

Figure 4: Exemplary process sub-division in alumina refinement (European Aluminium Initiative, 2023)

Separate Example 2: Coke making in steelmaking (illustrative example for step 1) following a sector guidance and 3) system expansion via substitution)

In integrated steelworks coke is used as a reducing agent and often produced on the steelmaking sites. Using a pyrolysis process, coke is produced from coking coal. Besides coke also tar, benzene and sulfur are produced as valuable co-products. For simplicity, this example focusses on the co-production of benzene and coke only.

Following the first step of the allocation hierarchy, it is checked if an accepted sector guidance exists. In this case this is the worldsteel methodology which is aligned with the Catena-X PCF rulebook.

The worldsteel methodology recommends using system expansion via substitution for the relevant co-products of the coke oven. In appendix 8 of the LCA study report a whitelist for applicable system expansion assumptions can be found. This whitelist gives information on the relevant co-products and the dominant identifiable substitute products.

As the steel producer has no primary data for the emission factors of benzene production via the alternative production path, secondary data needs to be used. The recommendations for appropriate data sets given in the worldsteel methodology shall be followed.

The recommended data set for the avoided primary production for benzene has a GWP of 2 kg CO2e/kg benzene[1]. In the coke production process 5 kg benzene per t of coke are produced. The total GWP for the coke making process is 1.1 t CO2e/t coke produced. The corresponding credit for the avoided primary production is calculated:

Equation 3: Calculation of the credit for the avoided primary production

$$Credit\ per\ 1t\ coke\ = \frac{kg\ CO2e}{kg\ benzene} \times\ 5\frac{kg\ benzne}{t\ coke} = 10\frac{kg\ CO2e}{t\ coke}$$

Using the system expansion via substitution approach, the 10 kg CO2e are attributed as a credit to the produced coke

Equation 4: Attribution of corresponding credit to produced coke

$$Total\ GWP\ per\ 1t\ coke\ = 1.1\frac{t\ CO2e}{t\ coke} - .01\ \frac{t\ CO2e}{t\ coke} = 1.09\frac{t\ CO2e}{t\ coke}$$

Thus, the total GWP to be used in the proceeding PCF calculation is 1.09 t CO2e/ t coke. As the benzene is sold to another industry a PCF statement for the co-product can be provided to the co-product customer.

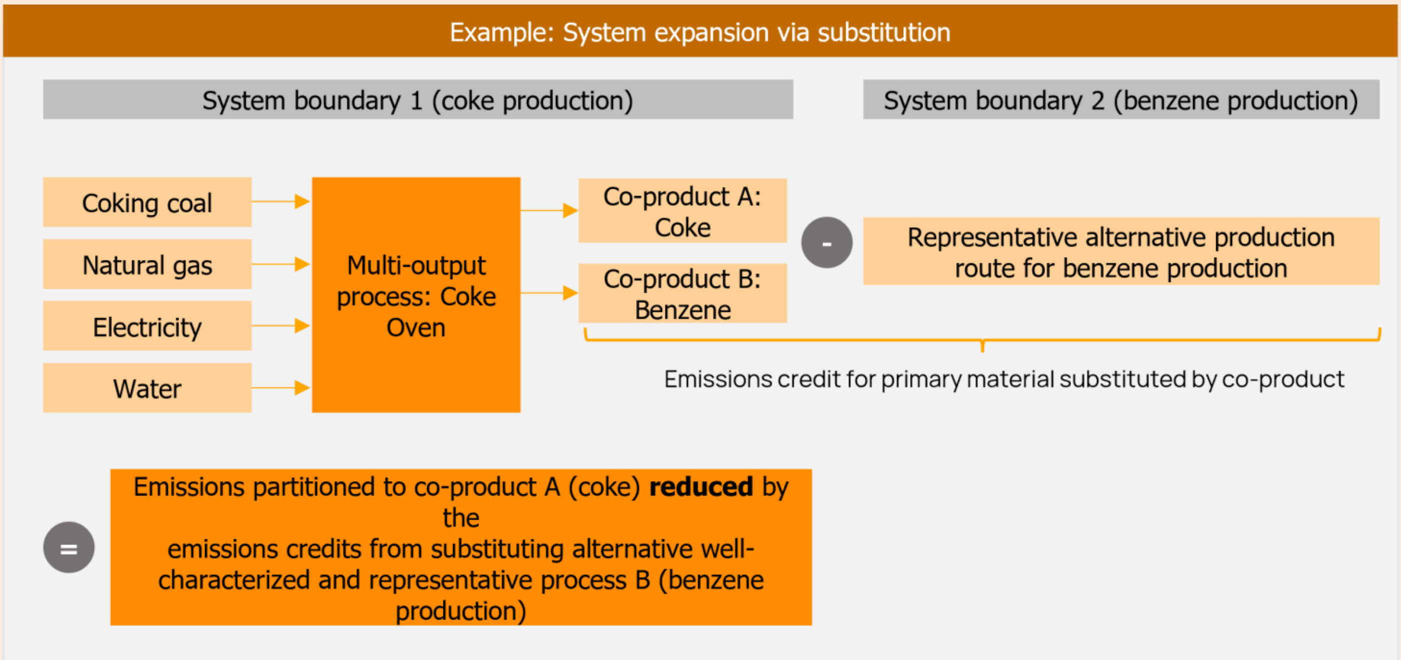

Figure 5: Exemplary system expansion via substitution

Separate Example 3: Battery recycling (hydrometallurgical treatment) (Illustrative example for step 4) & 5) Economic value ratio and economic allocation)

Through hydrometallurgical treatment, battery-grade materials are recovered from black mass (shredded battery cells). In the case of Lithium-ion Nickel-Cobalt-Manganese (NMC) cells, Lithium, Nickel, Cobalt, Manganese compounds can be recovered alongside other coproducts such as graphite, electrolyte, and/or sodium sulphate, depending on the process. Hence, hydrometallurgical battery recycling is a multi-output process, which usually cannot be further sub-divided as the process is continuous. Additionally, system expansion is not applicable as at least four co-products are recovered and sold without an dominant alternative production path.Thus, it has to be decided, whether economic or physical allocation are applied by calculating the economic value (price or cost) ratio.

As a first step, the market price for the respective commodities has to be chosen – if market prices are not available, sales prices or production cost can be used. With these, the ratio between the highest and lowest price or cost can be determined.

For the purpose of this example, global market prices are used and extracted from US Geological Survey (USGS) Mineral Commodity Summaries 2025. For the economic value ratio, sales prices shall be used. In all cases, the most functionally equivalent prices shall be used. All co-products then need to be compared based on the average economic factor (market prices). The highest price is divided by the lowest price to obtain the ratio (in this case 88).

Example: Economic value ratio

Search economic factors (prices) for functionally equivalent commodities/products and average over 5 years and calcuate ratio between highest and lowest economic value

	2020	2021	2022	2023	2024	**Avg 5 years**	**Economic value ratio highest vs. lowest**
Battery-grade lithium carbonate, USD/t	10,100	14,200	71,100	41,300	14,000	**30,140**	
Cobalt (cathode) USD/t	34,613	53,374	67,858	37,920	37,479	**46,249**	**88**
Manganese USD/t	458	527	597	480	580	**528**	
Nickel USD/t	13,772	18,476	25,815	21,495	17,000	**19,312**	
Copper (cathode) USD/t	6,321	9,531	9,057	8,715	9,480	**8,621**	
Aluminium ingot USD/t	1,490	1,870	2,050	1,820	1,600	**1,766**	

Figure 6: Exemplary economic value ratio for battery recycling

Since the economic value ratio is 88 and thus higher than five, economic allocation shall be applied. *See step 5) of this guidance.*

To apply economic allocation, the economic allocation factors need to be determined. To determine the economic allocation factors, first, the economic factors (market prices) shall be multiplied by the corresponding mass of the respective co-products to obtain the economic value (price x mass) per co-product. In our case, we assume the NMC111 inventory from Mohr et al (2020) for the mass of outputs. The example assumes that one ton of battery is recycled with the corresponding co-products.

[1] All values are just illustrative examples and should not be used in calculations

Cont'd:

Second, the economic value of each co-product shall be divided by the sum of all economic values. The resulting shares as displayed in the below example are the economic allocation factors. These have to be multiplied with the process-related CO2e emissions. Hence, as an example, the recycled lithium compound bears 16% of the hydrometallurgical process PCF.

Equation 5: Calculating economic value as basis for the allocation factors

$$Economic\ Value\ (€) = economic\ factor \frac{€}{piece\ ,kg,m^3} * output\ quantity\ (e.g.pieces, kg, m^3)$$

Example: Economic allocation factors

Multiply the economic factors (prices) with the output quantity of the respective co-product.
Divide each economic value (price x mass) by the sum of economic values of all co-products.

	Prices (avg 5 years) USD / t	Output quantity t / t battery	Economic value = price x mass USD	**Economic allocation factor**
Lithium compound	30,140	82	2,471,480	**16%**
Cobalt compound	46,249	173	8,001,010	**51%**
Manganese compound	528	168	88,771	**1%**
Nickel compound	19,312	172	3,321,595	**21%**
Copper	8,621	213	1,836,171	**12%**
Aluminium ingot	1,766	54	95,364	**1%**

Figure 7: Exemplary economic allocation factors

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