04/2024

BRIGHTWOLVES

Life Cycle Assessments: Allocation Methods

Whitepaper

Written by: **Arthur Van Dorpe**

www.brightwolves.com

CONTENTS

LCA Whitepaper Series

Foreword

Welcome to our LCA Whitepaper Series, each dedicated to a specific aspect of Life Cycle Assessment (LCA). As a critical tool in the field of sustainability, LCA provides a comprehensive view of the environmental impacts associated with all the stages of a product's life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. This series aims to delve into the intricate aspects of LCA, shedding light on the various methodologies, standards, and frameworks that guide its application.

In each whitepaper, we will focus on a specific topic, be it ISO standards that govern LCA, industry-specific standards such as Global Feed LCA Institute (GFLI), various allocation methods, ReCiPe method vs. Product Environmental Footprint (PEF), and many more. Our goal is to provide a clear, comprehensive, and accessible understanding of these complex topics, enabling you to apply this knowledge in your sustainability journey.

Whether you are a seasoned professional in the field of sustainability or a newcomer looking to understand the intricacies of LCA, these whitepapers will serve as a valuable resource. We invite you to join us in this exploration of LCA, as we strive to contribute to a more sustainable future.

LCA Methodology: Allocation Methods

Introduction

In the two previous papers of the series on Life Cycle Assessments, we guided you through the fundamentals of an LCA, introduced you to two well-known methodologies to perform such assessments, and presented you with a very relevant organization, GFLI, that could figure as an example for other industries to follow. In this paper, we will dive into a more technical aspect of LCAs, namely allocation. This phenomenon refers to the procedure used to allocate the environmental impacts in systems where multiple products or functions share common processes, i.e. when you have multiple output processes. We will discuss why allocation is so important in certain cases and what types of allocation exist to allocate certain burdens associated with a process among various outputs.

LCA Allocation Methods

In general, allocation, as defined by ISO, refers to the division of input and/or output that flows from a process into the product system being studied. This is important for multi-functional processes (i.e., processes or facilities providing more than one function), as all inputs and emissions associated with the process need to be partitioned between the multiple goods and/or services. Allocation methods in LCAs are critical tools used to address the distribution of environmental impacts in multi-output processes within a product's or service's life cycle.

Allocation itself is intricately linked to the structure and complexity of a supply chain, the specific industry in question, and the nature of the products or services involved. In complex supply chains with multiple intertwined processes and co-products, determining the most appropriate allocation method requires a nuanced understanding of the production processes and the interactions between them. For instance, in industries such as petrochemicals or agriculture, where by-products can serve as inputs for other processes, the allocation can become particularly challenging. The type of product also plays a crucial role; for durable goods, the use phase might dominate the environmental impact, whereas for consumables, the production and disposal phases might be more significant. Each industry also has its own set of norms and practices that can influence the choice of allocation method. For example, in the energy sector, allocation might be driven by the calorific value of the outputs, while in the pharmaceutical industry, economic allocation might be more appropriate due to the high value of active ingredients. Therefore, a deep understanding of the supply chain, industry practices, and product characteristics is essential to selecting an allocation method that accurately reflects the environmental impacts of a product's life cycle.

Allocation methods are essential for ensuring that the environmental burdens and benefits are attributed fairly and accurately to the respective outputs of a system. The choice of allocation strategy can significantly influence LCA results and, consequently, the environmental decision-making process. As such, selecting an appropriate allocation method must be grounded in a thorough understanding of the system under study, considering factors such as the physical relationships between co-products, the market dynamics influencing the value of outputs, and the overarching goals of the LCA. Because of its complexity, the ISO 14044 Standard recommends that the primary objective in an LCA should be to avoid allocation whenever possible, typically through system expansion or subdivision.

Before using a certain allocation method, it is important to start by determining a relevant allocation factor. The allocation factor serves as a pivotal starting point for selecting the most appropriate allocation method in an LCA. It is a quantifiable metric that determines how to allocate environmental impacts among different products or functions of a multi-output process. The choice of an allocation factor is guided by the principle of causality, aiming to reflect the way in which each co-product contributes to the overall environmental burden. For example, in a dairy production system where milk and cream are co-products, the allocation factor could be based on mass, assigning environmental impacts in proportion to the weight of each product. Alternatively, if the cream has a significantly higher economic value due to its use in premium products, an economic allocation factor might be more appropriate, distributing environmental impacts in line with the economic revenue generated by each co-product. The selection of the allocation factor is not merely a technical decision; it has profound implications for the LCA outcomes and can influence business decisions, policymaking, and stakeholder perceptions. Therefore, it is crucial to carefully consider the characteristics of the system and the goals of the LCA when determining the allocation factor, ensuring that it aligns with the most relevant aspects of the products' life cycle.

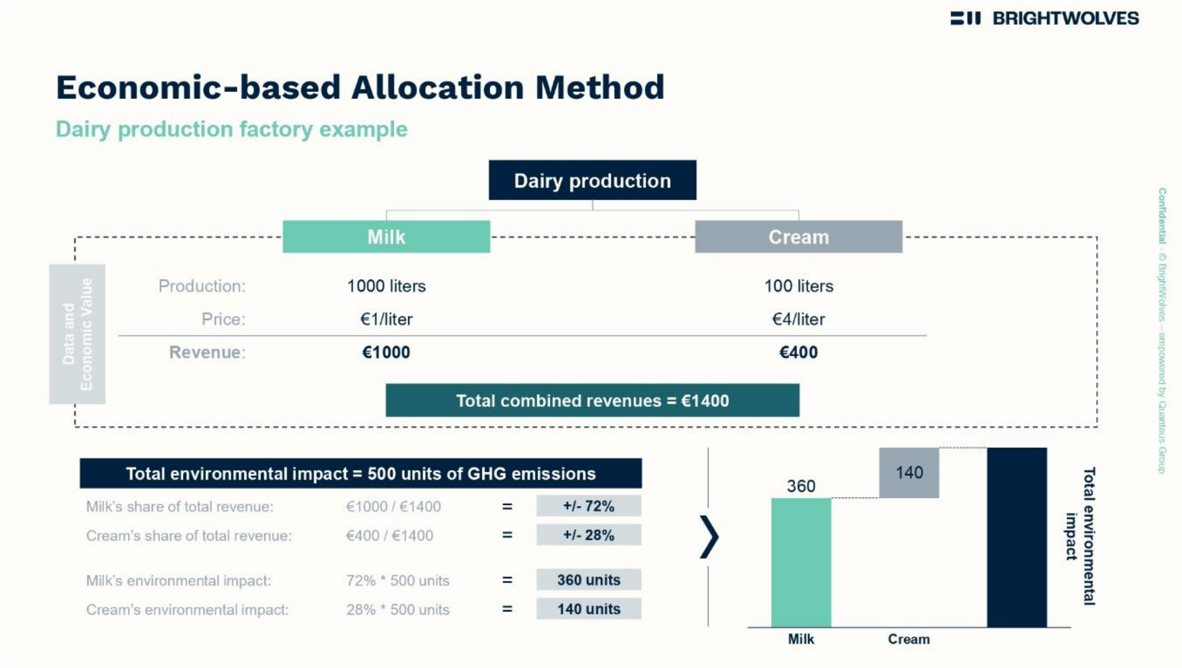
In what follows, we will dive into the different allocation methods, of which we will discuss three at length: the economic-based, the mass-based, and the energy-based allocation methods.

Economic-based Allocation Method

When the first guideline of ISO to avoid allocation is not feasible, the economic-based allocation method often becomes the most followed approach. This method assigns environmental impacts between co-products in proportion to their economic value, reflecting the rationale that economic worth is a surrogate for the product's overall environmental burden. The economic allocation method is particularly profound in its ability to capture the dynamic market conditions and the value-added aspect of co-products, which can be especially relevant in industries where product valuation significantly influences resource use and environmental emissions.

We assume the dairy production factory mentioned above produces both milk and cream. If the factory generates 1,000 liters of milk and 100 liters of cream, and the milk sells for €1 per liter while the cream commands a price of €4 per liter, the total revenue from these products is €1,400 (€1,000 from milk and €400 from cream). Now, if the environmental impact associated with processing these dairy products is assessed to be 500 units of greenhouse gas emissions, the economic allocation would assign these impacts based on the revenue contribution of each product. The milk, which contributes €1,000/€1,400 or approximately 72% of the revenue, would be allocated that relative amount of the environmental impact, equating to 360 units. Conversely, the cream, accounting for €400/€1,400 or about 28% of the revenue, would be allocated 28% of the impact, resulting in 140 units.

This approach not only aligns the LCA results with economic performance but also provides a versatile and adaptive framework that can accommodate fluctuations in market conditions over time. However, it is consequential to note that while economic allocation can offer a pragmatic solution, it may not always correspond to the actual physical relationships between the co-products and their environmental impacts. Thus, its application should be carefully justified within the context of each LCA study. Businesses often choose economic allocation first because while they do not always have data on the physical relation of their products, they do have corresponding financial data.

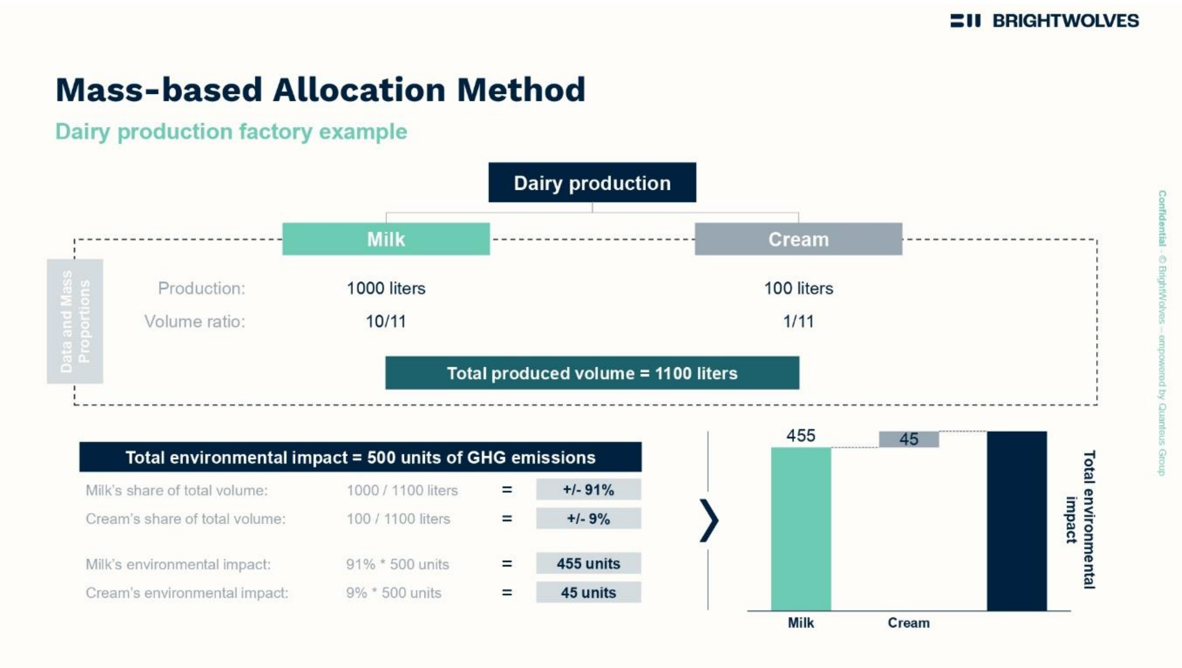


Mass-based Allocation Method

The mass-based allocation method is another commonly used method for allocation in an LCA. This method allocates environmental impacts between co-products in proportion to their mass, assuming that mass is a reasonable proxy for the environmental burden of each product.

Continuing with the dairy production factory example, we assume again that the factor produces 1,000 liters of milk and 100 liters of cream, and the environmental impact associated with processing these dairy products is quantified as 500 units of greenhouse gas emissions. Using mass-based allocation, the impacts would be distributed in proportion to the volume (assuming density is not significantly different for milk and cream such that volume can be a proxy for mass). Since the farm produces ten times more milk than cream, the milk would be allocated 10/11 of the environmental impacts, and the cream would be allocated 1/11, reflecting their respective shares of the total mass.

This method would result in the milk bearing approximately 454.55 units of the environmental impact (10/11 of 500 units), while the cream would be allocated approximately 45.45 units (1/11 of 500 units). This mass-based allocation is straightforward and does not fluctuate with market prices, making it a stable and often easily calculable method. However, it is essential to recognize that this method assumes that environmental impact is directly proportional to mass, which may not always be the case, especially if the environmental impacts of producing the co-products are not closely related to their mass. Consider the example of a production process that yields both a high-mass, low-environmental-impact product and a low-mass, high-environmental-impact product.

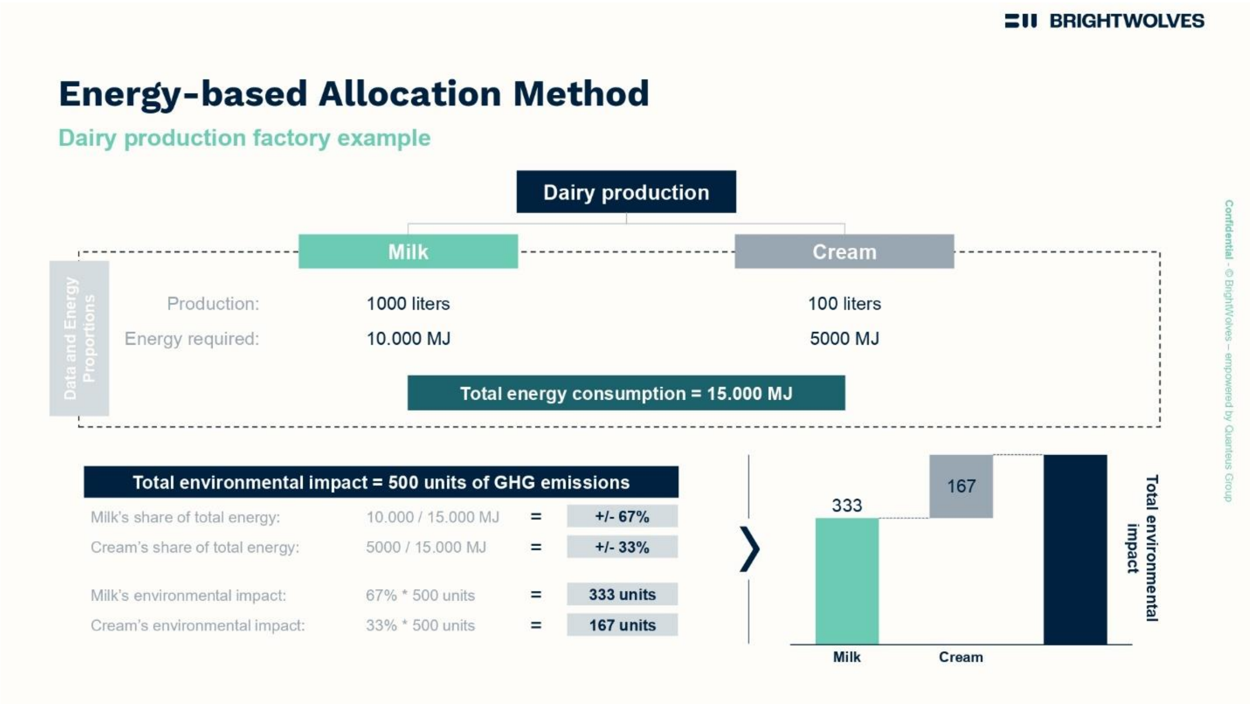


Energy-based Allocation Method

The third important allocation method is one where the energy content of the products is crucial to allocate the environmental burdens. The energy-based allocation method offers a sophisticated approach to distributing environmental impacts. This method allocates the burdens based on the energy content or energy demand associated with the production of each co-product, underpinning the notion that the energy embodied in, or required for, a product is a meaningful indicator of its environmental impact.

In the context of the dairy production factory, the energy-based allocation would consider the energy required to process each product. For instance, if producing 1,000 liters of milk consumes 10,000 MJ of energy, while the additional processing to obtain 100 liters of cream requires 5,000 MJ, the total energy involved is 15,000 MJ. Here, the milk would be allocated two-thirds of the environmental impact (10,000/15,000), resulting in approximately 333 units of the total 500 units of greenhouse gas emissions, while the cream would be allocated one-third (5,000/15,000), amounting to 167 units.

This energy-centric allocation captures the intensity of resource use and environmental stressors associated with the energy demands of production processes. However, it is imperative to acknowledge that this method also presumes a direct correlation between energy use and environmental impact, which may not account for other environmental aspects such as water use, land use, or toxicity. As such, while the energy-based allocation method provides a rigorous framework for impact distribution, it must be applied with discernment and in consideration of the broader environmental context of the product systems under study.



Other Considerations for Allocation Methods

The selection of an allocation method in LCAs can sometimes be subjective, as it often hinges on the perspective and judgment of the LCA practitioner. This subjectivity arises from the fact that there is no universally applicable rule for allocation; different methods may be more or less appropriate depending on the context of the study, the nature of the assessed system, and the goals of the LCA. Practitioners must make informed choices, drawing on their expertise and understanding of the system's intricacies. They must consider factors such as the relative importance of different environmental impacts, the physical and economic relationships between co-products, and the intended use of the LCA results. These decisions are inherently value-laden, as they involve weighing the merits and drawbacks of various allocation approaches, each with its own set of assumptions and implications. Consequently, the chosen allocation method reflects the practitioner's viewpoint on what constitutes the most reasonable and justifiable way to attribute environmental impacts, underscoring the importance of transparency and clear rationale in the LCA reporting process.

Other, lesser-known allocation methods may also be used by the LCA practitioner. We consider the example of “causal allocation”, a method that allocates impacts based on the underlying physical relationships that cause the environmental burdens. It attempts to reflect the actual causative factors behind the environmental impacts. Another method is “market-based allocation”. This method considers the influence of market dynamics and demand for co-products, allocating the impacts based on the market forces that drive the production of each co-product. The only drawback of these allocation methods is that they may not be comparable with the other methods or possible to include in databases. If we want to avoid allocation, as is primarily recommended, we can adopt “system expansion”. Instead of directly allocating impacts, system expansion involves expanding the system boundaries to include the additional functions related to the co-products. The environmental benefits or burdens the co-products displace are then subtracted from the overall impact.

Confronting or combining multiple allocation methods in LCAs can also be very relevant and beneficial in certain cases. Applying different allocation methods and comparing the outcomes can test the robustness of the LCA results. If the results are consistent across methods, this can increase confidence in the findings. Conversely, if the results vary significantly, it may indicate that the choice of allocation method is critical for the decision-making process and warrants further investigation. Furthermore, using multiple allocation methods can be part of a sensitivity analysis to understand how changing allocation methods can affect the overall environmental impact profile of the products. This analysis can help identify which stages of the product life cycle are most sensitive to allocation decisions and guide more focused improvements.

The combination of different allocation methods can also enforce stakeholder engagement. Different stakeholders may have different preferences or requirements for allocation methods based on their interests, policies, or regulatory frameworks. Combining or comparing methods can provide a more comprehensive view that accommodates diverse stakeholder perspectives. Presenting results based on different allocation methods enhances transparency and provides decision-makers with various scenarios. This approach can support more informed decision-making by illustrating how different assumptions influence the environmental assessment. As the field of LCA is continuously evolving, combining these allocation methods can contribute to methodological advancements. It can highlight the flaws of current methods and stimulate the development of new approaches that better capture the impacts of complex product systems.

Key takeaways

- Allocation in LCAs is essential for assigning environmental impacts to the outputs of multi-functional systems, with the method chosen being influenced by supply chain complexity, industry practices, and product types.
- The selection of an allocation factor is a critical initial step in the LCA allocation process, serving as a quantifiable metric that allocates environmental impacts among co-products based on their causal contributions. The choice of this factor can influence broader business and policy decisions.
- The primary objective of allocation in an LCA is to avoid it as much as possible. Allocation brings additional sensitivity to the model while avoiding it may ensure a more stable and reliable model.
- The economic-based allocation method assigns environmental impacts among co-products in proportion to their economic value. The mass-based allocation method distributes environmental impacts among co-products according to their mass, and the energy-based method allocates environmental burdens to co-products based on their energy content or the energy required for their production. Important to know is that the economic-based method does not always reflect the actual physical relationships between the co-products and their environmental impacts and that there is not always a direct correlation between the environmental impact and mass or energy for the mass-based method and the energy-based method, respectively.
- The selection of an allocation method in LCAs is inherently subjective and depends on the practitioner's judgment, as there is no one-size-fits-all rule for allocation. Practitioners must consider various factors, including the type of environmental impacts, relationships between the co-products, and the intended use of the results.
- Potentially combining different allocation methods can enhance the robustness and relevance of LCA results. While these methods may not always be directly comparable or easily integrated into existing databases, applying them can provide valuable insights, notably through sensitivity analyses and stakeholder engagement, and can drive methodological advancements in the field of LCA. However, one should be aware that going into analysis, comparing results based on different allocation methods is like comparing carrots and potatoes.

Are you inspired by the topic of LCAs or curious to know more about Digit Mint and its LCA tool? Stay tuned for our next paper of this LCA Whitepaper Series or do not hesitate to contact Peter-Jan Roose or Vincent Govaers!

References

- LCA Allocation Methods:

https://www.ecocostsvalue.com/lca/the-issue-of-allocation/

https://faculty.cnr.ncsu.edu/richardvenditti/wp-content/uploads/sites/24/2018/08/2016Lecture11Allocation.pdf

https://www.linkedin.com/advice/0/how-do-you-choose-allocation-method-waste

https://pre-sustainability.com/articles/finding-your-way-in-allocation-methods-multifunctional-processes-recycling/

- Economic-based Allocation Method:

Guinée, Jeroen & Heijungs, Reinout & Huppes, Gjalt. (2004). Economic Allocation: Examples and Derived Decision Tree. The International Journal of Life Cycle Assessment. 9. 23-33. 10.1007/BF02978533.

https://www.irbnet.de/daten/iconda/null_DC28103.pdf

- Mass-/Energy-based Allocation Method:

Kyttä, V., Roitto, M., Astaptsev, A. *et al.* Review and expert survey of allocation methods used in life cycle assessment of milk and beef. *Int J Life Cycle Assess* 27, 191–204 (2022). https://doi.org/10.1007/s11367-021-02019-4

Linkosalmi Lauri, Husgafvel Roope, Takano Atsushi, Valtonen Tuovi, Dahl Olli, Environmental product declaration of timber products: The impact of allocation method to the impact categories, Journal of Cleaner Production, Volume 256, 2020, 120386, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.120386.

- Other Considerations for Allocation Methods:

https://www.linkedin.com/advice/1/how-do-you-compare-integrate-different-allocation

BRIGHTWOLVES