CHALLENGES & SOLUTIONS FOR ALLOCATING GREENHOUSE GAS MITIGATION OUTCOMES:

Contextualized in agricultural supply chain

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EDITORIAL INFORMATION

Challenges and Solutions for Allocating GHG Mitigation Outcomes: Contextualized in agricultural supply chain.
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TABLE OF CONTENT

EXECUTIVE SUMMARY

The significant investment that must be unlocked to achieve value chain decarbonization is subject to the continuous development of standards and guidance by the Science Based Targets initiative (SBTi) and the Greenhouse Gas Protocol (GHG-P).

This paper reflects on the need to balance incentivizing the scaling-up of value chain investment by delivering a robust return to companies investing in a non-liquid market while also, and most importantly, maintaining the credibility of the greenhouse gas (GHG) mitigation outcomes achieved by those investments. The proposals presented here have been developed by SustainCERT, with input from two market participants, Cargill and Soil Capital. Specifically, the paper focuses on agricultural systems that produce:

1. crops that are subsequently transformed into multiple other derivative products downstream ("co-products")
2. multiple crops in a crop rotation in a given year

The problem in the context of co-products can be understood as follows. To ensure the credibility of claims and to avoid double claiming today, the benefits to the climate achieved by an intervention at farm level (the "GHG mitigation outcomes") are attached to a specific quantity of crop impacted by that intervention. However, as the impacted crop travels downstream in the value chain, it is transformed into an array of multiple other derivative products ("co-products") leading to a dispersion of GHG mitigation outcomes across a large set of products.

As such, there is a significant gap between the amount of GHG mitigation outcomes generated by an intervention at farm-level and the amount that can be claimed on a specific co-product. If the investor seeking to make a claim, for example a downstream user seeking to decarbonize their supply chain, only uses one co-product, this acts as a significant deterrent to investment in the farm-level interventions in the first place.

Equally, when interventions involve crops within a crop rotation, the practice of attaching GHG mitigation outcomes to a specific quantity of individual crops can also disincentivize investment in those farm-level interventions. This is because, in most cases, the investing company seeking to make a claim is only sourcing a specific crop within the rotation, but since the intervention can involve all the crops within the rotation and the resulting GHG mitigation outcomes are allocated to each crop, only a fraction of the GHG mitigation outcomes is allocated to the crop of interest.

These problems are recurring issues experienced by value chains and production systems around the world. The allocation to co-products, for example, is already a significant problem for the world's most significant cereal commodity – wheat – as well as in many other major commodity value chains such as soybean, canola, palm fresh fruits and cocoa pods. Meanwhile, diversification of arable farming systems into crop rotations is common in many parts of the world.

The established emissions allocation as described by environmental accounting methodologies (life cycle assessments) were designed to credibly partition emissions and did not aim at considering GHG mitigation outcomes within its intended purpose. Following emissions allocation as described by ISO 14044 to allocate GHG mitigation outcomes leads to a proportional amount of GHG mitigation outcomes to be allocated to co-products or crops in a rotation that are not within the investor's Scope 3. From the perspective of the investor seeking to make a claim, re-purposing allocation methodologies to partition GHG mitigation outcomes therefore creates stranded assets and disincentivizes the investment toward decarbonized value chains.

The conceptually simplest solution to this problem would be for the original investor to find off-taker companies that are sourcing the other affected products and receive a return-on-investment for those products from offloading their associated GHG mitigation outcomes to those companies. However, momentum from companies to invest in Scope 3 reductions is still nascent so the market does not have sufficient liquidity to enable such a solution. This reality is compounded when considering complex sets of co-products or crop rotations, that would require large numbers of off-takers to be engaged simultaneously. Moreover, investor efforts should not be focused on finding additional off-takers to achieve a sufficient return on their original investment. Rather, they should be focused on maximizing investment in the decarbonization of value chains.

Another approach is to allow investors to re-allocate the GHG mitigation outcomes to the product of interest under certain conditions as to provide the necessary return and accelerate investment in value chain decarbonization. The work behind this paper investigated different re-allocation methodologies that allowed higher flexibility for claimant companies at the cost of varying degrees of credibility. The "supply shed re-allocation method" is highlighted as the approach that provides the best balance of credibility with an increased but controlled level of flexibility as to provide greater return for the investor to claim.

The supply shed re-allocation method improves the flexibility for investors seeking to make a claim by considering all the co-products of a system as interchangeable. As such, claimant companies can claim up to 100% of the GHG mitigation outcomes of an intervention on a single co-product as long as the claimant company can prove they are sourcing the appropriate amount of that co-product from the same supply shed.
This method enables the virtual exchange of co-products between producers in the same supply shed to re-allocate the GHG mitigation outcomes to the co-product of interest for the investor seeking to make a claim. The rationale for this is that other producers in the same supply shed are also producing products that are transformed into the co-products that are being used by the claimant company but are not subject to an intervention.

This method can also be applied to the context of crop rotations, by extending the concept of co-products to the crops in a rotation and considering that crops can be virtually interchanged with other farms of the same supply shed.

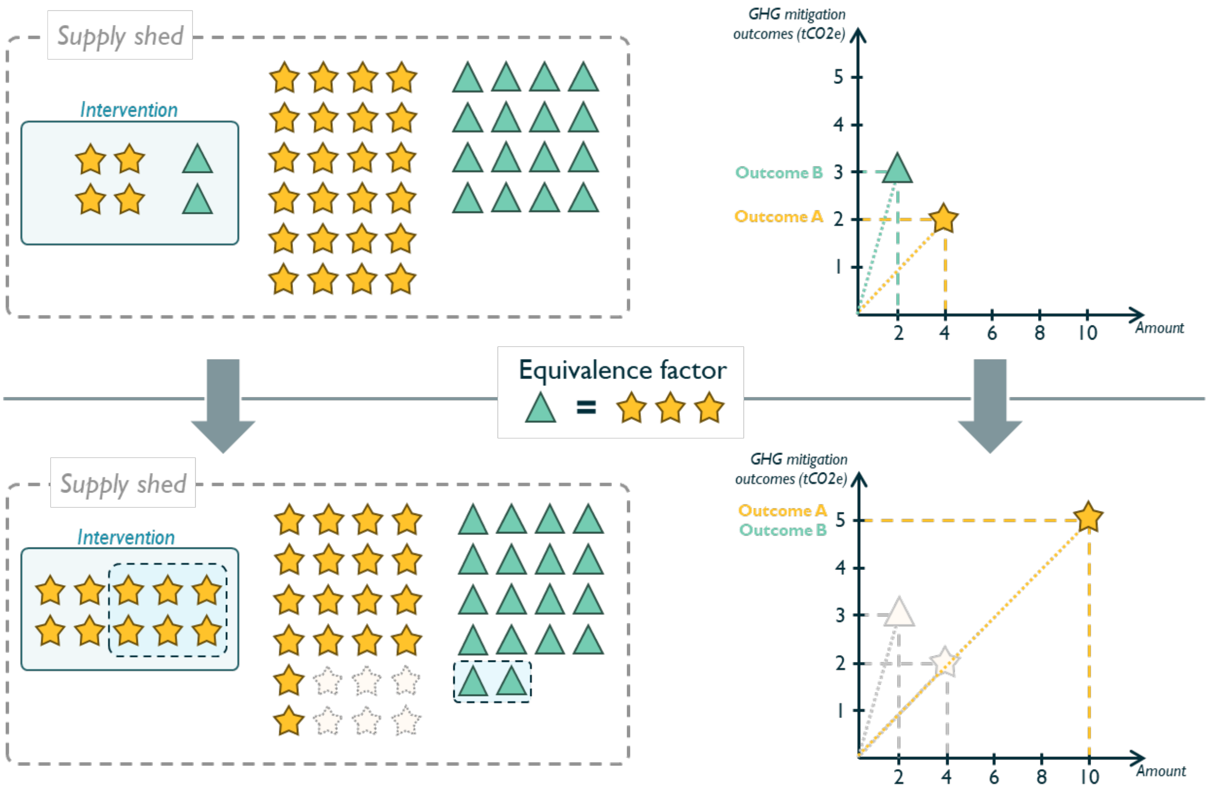


Figure 1: Visualization of the mechanism behind the supply shed re-allocation method.

Figure 1 above depicts the mechanism behind the supply shed re-allocation method using a simple example. We consider a system producing two co-products or two crops in rotation in different quantities: 4 units of yellow stars and 2 units of green triangles. The intervention has generated a GHG mitigation outcome of 5 tCO2e which is allocated 60% to the triangles and 40% to the stars, according to the default allocation.

If there is only an off-taker identified for the stars, the supply shed re-allocation method allows for the exchange of the two triangles for six stars from the supply shed. The equivalence factor of three stars per triangle is based on the same default allocation of GHG mitigation outcomes:

- Here, the ratio of GHG mitigation outcomes to amount of product for triangles is 3 tCO2e / 2 = 1.5, while the same for stars is 2 tCO2e / 4 = 0.5
- Hence 1 triangle is equivalent to 3 stars (1.5 triangles / 0.5 stars) after the virtual exchange.
- This equivalence factor therefore stipulates that in the context of supply shed re-allocation, claiming all GHG mitigation outcomes means that the claimant must be

sourcing 6 stars within the same supply shed (amount of triangles to be exchanged * equivalence factor = 2 * 3).

The charts on the right represent the GHG mitigation outcomes claimable by unit of product. They show that the slope of the line remains the same after the exchange, meaning that the quantity of GHG mitigation outcomes claimed per amount of product hasn't changed. The ability to claim all the GHG mitigation outcomes on the stars has been enabled by increasing the amount of stars on which the claim is made, via an exchange within the same supply shed.

With the right safeguards in place, this supply shed re-allocation method preserves the credibility of claims by ensuring that the mass balance of products is not disrupted at the supply shed level. Claimant companies must be able to prove that they are sourcing the total amount of product linked to the quantity of GHG mitigation outcomes they want to claim from the same supply shed. In that sense, the approach provides flexibility within the defined area of the supply shed, but this flexibility does not extend beyond those boundaries (i.e. it is not possible to re-allocate GHG mitigation outcomes to products that are not sourced from the target supply shed). This safeguard has the underlying assumption that supply sheds are appropriately selected. Additional safeguards to maintain a sufficient level of credibility are:

- Claims are capped to the total amount of product generated within the supply shed, preventing re-allocation of GHG mitigation outcomes beyond the mass balance of the supply shed,
- claims are capped to the total amount of GHG mitigation outcomes generated by the intervention,
- re-allocation of GHG mitigation outcomes is only allowed for a product impacted by the intervention, directly within the boundaries of the intervention or linked downstream products.

Furthermore, this approach was designed with a claim and intervention tracking mechanism in mind (e.g. VIVID impacts). This compatibility allows the protection against double counting and allows the previously mentioned safeguards to be automated. As claims are dictated by sourcing amounts, a supply shed where other claimant companies have been identified against known sourcing amounts (i.e. those active in the other value chains stemming from the supply shed) will provide reduced flexibility as each claimant company will have their known allocated GHG mitigation outcomes. As a result, the flexibility allowed by the method will evidently shrink as more value chains are participating in decarbonization efforts.

For the supply shed re-allocation method to function, the concept of a supply shed is further developed. The primary aspect is attaching GHG mitigation outcomes to products that are not included within the intervention scope – distributing GHG mitigation outcomes beyond affected farms and across the supply shed. The supply shed concept was created to simplify the issue of traceability of claimant companies to individual farms while the supply shed re-allocation method expands on this basis to generate flexibility of claims.

Moreover, the credibility of the supply shed re-allocation method relies on the supply shed being well defined at the outset. A supply shed that is too large would reduce the credibility of the claims as the GHG mitigation outcomes would be associated with farms that are not comparable. On the other hand, a supply shed that is too small would not provide sufficient flexibility for the claimant company in light of the increased burden of work that would be required (proof of sourcing, verification of supply shed) and would not help in mitigating stranded assets for highly complex products (e.g. feed). This paper recommends using the supply shed re-allocation method proposed above in the following circumstances:

- Other off-takers sourcing from a specific supply shed are either unknown or these off-takers have no interest in decarbonization efforts.
- The investing company seeking to make a claim is an early adopter of investing in value chain decarbonization within their supply shed.
- The products of interest are of a complex nature (either in terms of the number of associated co-products or crops in rotation) or with allocation & mass balance factors that would otherwise dissuade investments in decarbonization.

We do not recommend using the supply shed re-allocation method when:

- The supply shed has not been appropriately selected and is not in line with the definition provided in the "SustainCERT verification requirements for chain interventions" or another similar text.
- There is no possibility to implement or use a tracking mechanism that accounts for the total claims made.

This solution is not designed to be used as a staple method for all future Scope 3 accounting, but as a solution to a specific problem that exists given current market dynamics that can therefore provide a pathway towards fully decarbonized value chains. As such, we would welcome the future guidance of SBTi and GHG-P considering the supply shed re-allocation method in future iterations.

KEY TERMINOLOGY

The following are terms that are foundational to communicating and understanding the proposed solutions to allocation in both a crop rotation scenario and a derivative product scenario.

Allocation: Allocation is the method used in life cycle assessments (LCA) to allocate environmental impacts to the different co-products of a system. Allocation can be based on physical or economic criteria. By default, the GHG mitigation outcomes of an intervention are distributed across the product system of the product targeted by the intervention according to the LCA allocation of environmental impacts.

Causality: Demonstration that the investor has substantively contributed to or enabled the intervention and the resulting benefits (material role in the occurrence of the intervention).

Child product: Product that comes from the transformation of an upstream intermediate product, for example, wheat flour is a child product of wheat grain. Within one transformation stage, there may be multiple child product generated, these child products would then be considered co-products toward each other.

Co-claiming: Multiple entities claiming the same GHG mitigation outcomes that result from an intervention. Such entities must not co-exist within the same level of the value chain and must credibly demonstrate sourcing of the product from the defined supply shed. This approach aligns with the Greenhouse Gas Protocol (GHG-P) Scope 3 accounting rules and principles for co-claiming.

Co-products: Products that share the same production process. Co-products cannot be produced independently. If A and B are co-products, producing A would necessarily imply producing B. Example: Soybean oil and meal. Co-products are subject to allocation and have GHG mitigation outcomes associated to them, potentially leading to stranded assets for investors.

Competitive products: Products that emerge from different transformation technologies but have a common parent product. Competitive products are not subject to allocation.

GHG mitigation outcomes: The result of actions taken to reduce greenhouse gas (GHG) emissions, or to enhance carbon sinks that remove these gases from the atmosphere. Outcomes are expressed in tCO2e, a unit used to measure and compare emissions from different GHGs based on their global warming potential (GWP).

Intervention: An umbrella term for any action that introduces a change to a Scope 3 activity or activities. An Intervention may include changes to several activities that reduce or store emissions in different ways.

Investor (Co-investor): An entity (or several entities working together) that can prove active contribution towards an intervention via financial or in-kind resources necessary for implementing the intervention(s). Through the causality of their contribution, a portion of or all the GHG mitigation outcomes are owned by the investor (or co-investor). Ownership of GHG mitigation outcomes does not necessarily permit the (co-)investor(s) to claim the GHG mitigation outcomes – a proof of sourcing the products affected by the intervention would still need to be established.

Off-takers: Off-takers are entities that can acquire and claim GHG mitigation outcomes generated from an intervention as they can establish a sourcing to the products affected by the intervention. Off-takers are not the original investors in the intervention.

Product: Material good produced by an operation in the value chain that can be purchased by actors in the value chain and represented in a Scope 3 inventory.

Parent product: Opposite of Child product. Wheat grain is the parent product of wheat flour.

Re-allocation: The re-allocation (proposed alternative accounting procedures of this paper) of GHG mitigation outcomes to co-products or products of a system after an allocation has been done following conventional LCA (also highlighted in Chapter 8 of the Corporate Value Chain (Scope 3) Accounting and Reporting Standard).

Supply shed: Group of suppliers in a specifically defined market (e.g., at a national or sub-national level) providing similar products (i.e., goods and services) that can be demonstrated to be within the company's supply chain.

Stranded carbon assets: Situation where GHG mitigation outcomes are allocated to co-products or products that are not desirable by an investor. As GHG mitigation outcomes are bound to specific goods, the GHG mitigation outcomes cannot be claimed on other goods not relevant to the investor and thus the investment in the intervention causing such GHG mitigation outcomes is "stranded".

CONTEXT

The SustainCERT Verification Requirements for Value Chain Interventions, v0.9 ("SC VC" v0.9) define a set of auditable requirements that intend to ensure the credibility and transparency of the greenhouse gas (GHG) mitigation outcomes associated with a validated intervention or program of interventions. The SC VC Requirements aim at further defining how GHG mitigation outcomes can be allocated to goods and services produced in the context of the value chain where interventions take place.

These requirements are based on the Value Chain (Scope 3) Interventions Greenhouse Gas Accounting & Reporting Guidance, v1.1 (VC Guidance) which outlines the principles to enable value chain interventions by incorporating impacts in a GHG inventory and reporting progress towards quantitative GHG reduction targets. To underscore alignment with emerging protocols and standards, the VC Guidance is recognized in the latest SBTi FLAG guidance and is envisioned to be the backbone of many influential standards (both voluntary and normative) such as ISO 14069 and 14068, EU ESRS Climate and Biodiversity, and SBTi Net Zero.

Furthermore, the Value Change Initiative is a member of the GHG Protocol Land Sector and Removal Guidance (GHGP LSRG) Technical Working Group, contributed to pilots against the GHGP LSRG guidance draft V2 and intends to continue supporting until finalization. This paper aims to explore practical scenarios to arrive at a framework which balances the need to accelerate and facilitate industry investment in decarbonizing agriculture with the need for credibility of the impacts and claims that these investments can achieve.

PROBLEM STATEMENT

The delineation of a supply shed by product allows for credible claiming of GHG mitigation outcomes associated with the sourced product so long as the investor(s) or off-taker(s) along the value chain presents proof of the material flow and provide documented transparency surrounding assumptions made to reach that amount.

In agricultural contexts, the allocation of GHG mitigation outcomes arising from on field interventions to a particular product is mostly straightforward in cases where only one product is grown commercially. This scenario is somewhat dependent on geography, regional practices, and farm specific practices. In this case, all annually verified emission reductions and/or removals can be attributed to the volume, mass or any other commonly used physical metric of that single product grown. However, implementation of the conventional LCA approach can create investment barriers at multiple points of the value chain.
In an agricultural context characterized by the use of crop rotations, this presents a challenge for GHG mitigation outcomes allocation. This challenge is not caused by increased mathematic complexity due to more products within the system assessed, the issue lies in the rigidity in existing allocation accounting which disincentivises downstream investment. This is because, in most cases, downstream intervention investors only source a specific crop within the rotation, but the agronomic reality means that the intervention involves all the crops within the rotation.

With the existing allocation rules, GHG mitigation outcomes are allocated to each crop, resulting in only a fraction of the GHG mitigation outcomes allocated to the investor’s crop of interest. This can serve as a significant deterrent to investment in the required interventions as the real abatement cost associated with Land sector measures increase. Diversification of arable farming systems into crop rotations is common in many parts of the world, illustrating the prevalence of this challenge.

Furthermore, a second dilution can occur beyond the farm level where crops are often processed into several co-products. Individual co-products can often only use a small proportion of the parent product from which they were produced or have low economic value relative to that parent product and, within existing allocation rules, these co-products will only have a portion of the GHG mitigation outcomes generated at farm-level associated with them. In the case of a downstream investor seeking to decarbonize their supply chain, using one co-product, this acts as a significant deterrent to land sector mitigation investments. The allocation to co-products is already an important problem for the world's most significant cereal commodity – wheat – as well as in many other major commodity value chains such as soybean, canola, palm fresh fruits and cocoa pods.

The issue of stranded assets is complex but must be addressed whilst upholding the credibility of claims. Possible options include converting the stranded assets into Carbon credits which the investor can sell onwards to connected supply-chains of coproducts or even allocating all GHG mitigation outcomes to one single crop or product. Both these solutions have significant limitations that either impact on the principles of Scope 3 as an overarching framework (relinquishing rights to claim, incapacity to claim carbon credit and Scope3 emissions at the same time) or undermine the credibility of their accounting (yielding non-representation allocation and emission factor).

This paper examines the policy-science-business interface to determine how to better balance the scaling-up of value chain investment by delivering a robust return to companies investing in a non-liquid market while also, and most importantly, maintaining the credibility of the greenhouse gas (GHG) mitigation outcomes achieved by those investments. Solutions to the two scenarios, crop rotation and co-products, are presented in detail in Section 1 and 2. Section 1 focuses on the co-products scenario and Section 2 explores the crop rotation scenario.

DISCLAIMER

Section 1 and Section 2 present GHG mitigation outcome re-allocation methods in different contexts. The goal of these methods is not to change the allocation of environmental impacts attributable to each co-product or product of a system as they have been defined by LCA, but to decouple the allocation of absolute environmental impacts from the allocation of GHG mitigation outcomes.

Positive environmental impacts are consequences of biophysical mechanisms and even if their allocation to products or services follow scientifically robust protocol as laid out in IS14044. This positional paper calls for no flexibility in this allocation. GHG mitigation outcomes whilst contributing to GWP impact are direct consequences of investment. The allocation of this negative contribution to products or services should take into account the chain of causality and market mechanisms involved in such investments. Thus, there is a strong case for decoupling the allocation of GHG mitigation outcomes from the allocation of environmental impacts.

DESCRIPTION OF PROPOSED SOLUTIONS

The following two sections present unique solutions to stranded assets explore in the context of Crop rotations and processed co-products. These solutions are summarized as follows:

- **Supply shed re-allocation:** Increasing the amount of co-product or product on which a claim can be made by virtually exchanging undesired co-products or products with the product or co-product of interest elsewhere in the same supply shed.
- **Upper limit re-allocation:** Concentrating GHG mitigation outcomes on co-products or products. GHG Mitigation outcomes are awarded up to reaching the point of net-zero considering the baseline emissions profile of the product.
- **Investor re-allocation (derivative products only):** Allocation of GHG mitigation outcomes resulting from an intervention to the preferred co-product or product of the investor(s) based on the share of their investment in the intervention.

Whilst an appropriate level of rigor has been used to examine the case studies below, this document does not attempt to provide a detailed LCA of the explored value chains or the MRV standards of environmental impact accounting. The databases, tool and overall approach taken to present these case studies matches the intended purpose. These serve as illustrative purposes for the re-allocation of mitigative outcomes to investors.

SECTION 1: RE-ALLOCATION TO CO-PRODUCTS

CASE STUDY CONTEXT & MODELLING ASSUMPTIONS

Scenarios were created using the animal feed value chain as an illustrative example. Environmental impact data was based on secondary LCA databases and primary data from Cargill and Soil Capital. Specifically, two value chains connecting a crop, *wheat* and *rapeseed*, to downstream feed production were modelled to provide a network of exchange between products. Additionally, five interventions were modelled to generate GHG mitigation outcomes.

CROP TO FEED VALUE CHAINS

For both crops, the following two unit processes were selected from Agrifootprint for the first node of the value chain:

- Wheat grain, start material, at seed production {GB} Economic, U.
- Rapeseed, start material, at seed production {GB} Economic, U.

The potential value chains emerging from each commodity were traced through the connection to the downstream flows that connect to either of those unit processes and illustrate the effect of default mass and economic allocation factors provided in the secondary databases (see Figure 2). The branches containing a connection to feed were prioritized and the ones branching into other products were terminated. For wheat production, two layers of co-products exist:

- Wheat grain & wheat straw.
- Wheat bran, wheat starch slurry, wheat gluten meal, wheat gluten feed[1] & wheat starch.

For *rapeseed*, two layers of co-products. The second layer holds two possible technological options in the creation of oil which yield different co-products - *rapeseed meal (Solvent extraction)* or *rapeseed expeller (pressing)*:

- Rapeseed & rapeseed straw.
- Rapeseed oil, from solvent & rapeseed meal, from solvent; rapeseed oil, from pressing & rapeseed expeller.

To note, the Agrifootprint database models the transformation of wheat grain into its derivative products as a single process. Due to the lack of transparency in the model, starch slurry was omitted. The allocation was distributed across the remaining derivative products (wheat bran, wheat gluten meal, wheat gluten feed, wheat starch) to retain a consistent allocation of environmental impacts.

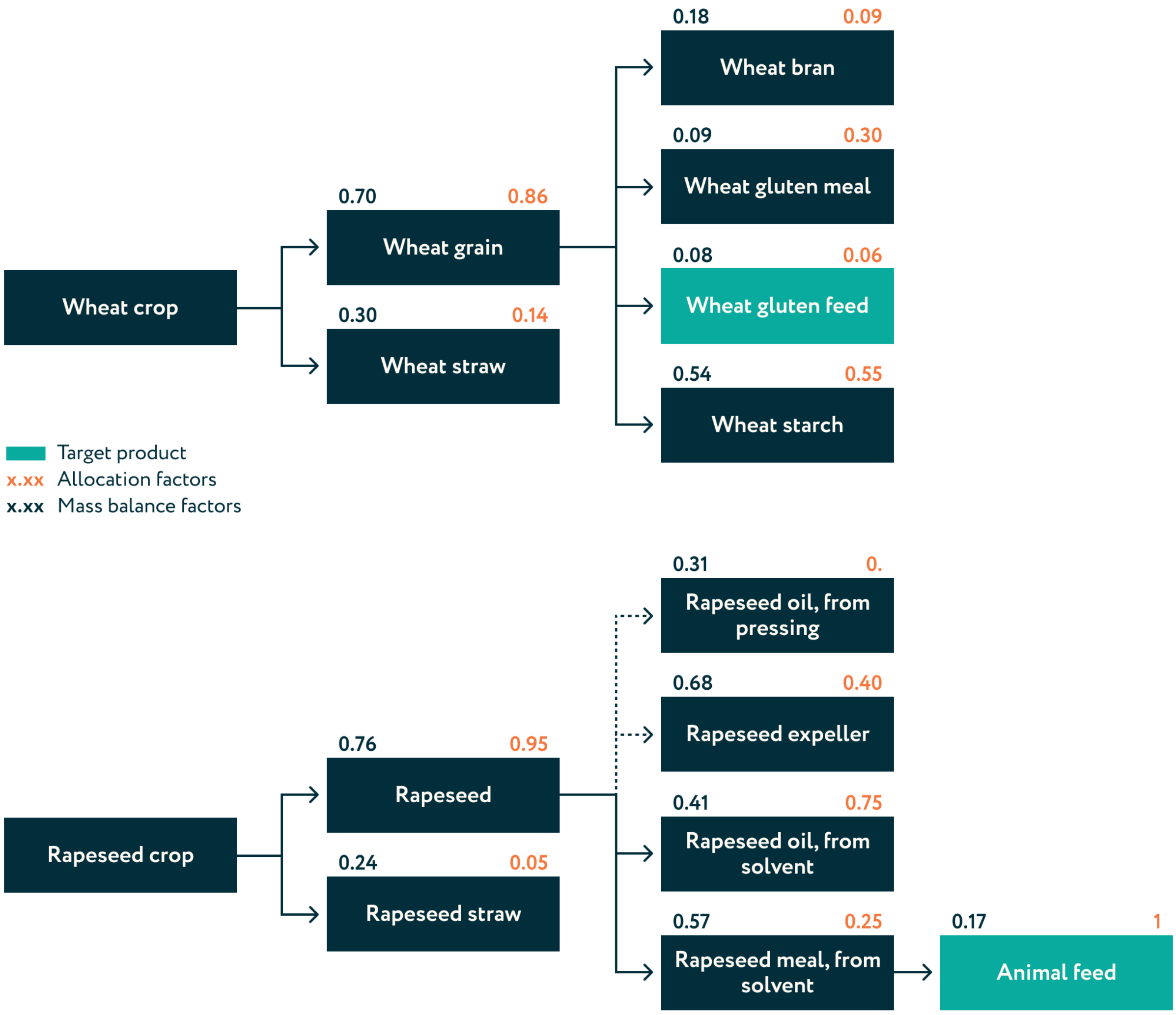


Figure 2: Product system of wheat (top) and rapeseed (bottom). The green box represents the product of interest, other boxes represent the different co-products generated along the way. In the rapeseed product system, competitive usage is present between two technological choices (solvent or pressing), represented by different types of arrows.

DATA INPUTS

Datapoints used to model the interventions are summarized in Table 1 and Table 2. The changes in emission factors (ΔEF) for each intervention were calculated using the Cool Farm Tool and are assumed to be directly linked to GHG mitigation outcomes generated at the farm (100% allocated to crop).

Table 1: Overview of commodities and key characteristics of the supply sheds.

Commodity	Variety & quality	Country, region	Amount produced (t)	Land occupied (ha)
Wheat	Feed, conventional	UK, England	8,227	1,088
Rapeseed	Conventional	UK, England	1,479	450

Table 2: Overview of interventions modelled and GHG mitigation outcomes generated from them.

Process	Affected commodity (area of field affected)	Description	ΔEF (tCO2e / ha)	GHG mitigation outcomes *(tCO2e)*
Variable rate nitrogen	Wheat (264 ha) Rapeseed (49 ha)	Variable rate of nitrogen fertilizer used on the field – reduction of total use of fertilizer	0.05	Wheat – 13.2 Rapeseed – 2.45
Urease inhibitor	Wheat (144 ha) Rapeseed (49 ha)	Application of urease inhibitor to reduce breakdown of nitrogen fertilizer causing loss of nitrates and nitrogenous emissions	0.05	Wheat – 7.2 Rapeseed – 2.45
Companion crops	Rapeseed (401.4 ha)	Use of companion crops in the field with the rapeseed to reduce the need for pesticide and fertilizer applications	0.11	Rapeseed – 44.15
Minimum tillage	Wheat (1008.8 ha) Rapeseed (450.4 ha)	Reduction of tillage from conventional practice to minimum	0.572	Wheat – 577 Rapeseed – 257
No tillage	Wheat (80 ha)	Reduction of tillage from conventional practice to no tillage	1.29	Wheat - 103

POSSIBLE SOLUTIONS

In this section, different options for re-allocation GHG mitigation outcomes are presented, each of which would allow investors to overcome some of the barriers to investment identified above. Additionally, risks and opportunities of those options from a business case and environmental integrity perspective are discussed. The proposed solutions further detailed in this section are the following:

- **Supply shed re-allocation:** Increasing the amount of co-product or product on which a claim can be made by virtually exchanging undesired co-products or products with the product of interest elsewhere in the same supply shed.
- **Upper limit re-allocation:** Concentrating GHG mitigation outcomes on co-products or products by applying them based on the emissions profile of that product up to reaching the point of net-zero for that product.
- **Investor re-allocation:** allocation of GHG mitigation outcomes resulting from an intervention to the preferred co-product or product of the investor(s) based on the share of their investment in the intervention.

Note that, while the accounting of Scope 3 emissions entails that multiple actors at different levels of a value chain can claim GHG mitigation outcomes in the emissions related to production, storage, processing or refining of a product that they all have in common, for simplification, the accounting of GHG mitigation outcomes in the examples below is limited to claiming GHG mitigation outcomes from the perspective of only one stage in the value chain.

In the subsequent tables, the GHG mitigation outcomes represent the re-allocated outcomes to each co-product but do not take into consideration claims made. In one stage of the value chain, it is possible to claim either parent or child product (e.g. make a claim on wheat grain & another on wheat bran). However, claims on child products at the same level of the product system must respect the need to avoid double counting. For example, in Table 3, the intervention yields a total of 577 tCO2e, but in the different re-allocation scenarios the column sum is 1,154 tCO2e. This is to reflect the possibility to claim any products at that specific stage of the value chain: claiming any of these impacts would lead to a re-calculation of GHG mitigation outcomes as to never allow any overclaiming above the threshold of 577 tCO2e.

SUPPLY SHED RE-ALLOCATION METHOD

Description

Supply shed re-allocation finds a solution to stranded assets by providing flexibility in the production amounts of a given co-product to which GHG mitigation outcomes can be applied to. This approach proposes expansion of the allocation boundaries to incorporate production of the same co-product elsewhere in the same supply shed where the intervention did not occur. The amount of the co-product of interest to the investor(s) is increased to allow for higher GHG mitigation outcomes to be re-allocated, while maintaining the same emission/GHG mitigation factor ratio on the co-product in question. This is done by exchanging different co-products in the system based on an *equivalence factor*. The total amount that can be exchanged is controlled by two safeguards:

(1) Total GHG mitigation outcomes generated by the intervention

(2) Total supply shed production amounts

The equivalence factor is uniquely defined by an intervention, allocation factors (either economic or physical) and mass balance. In the supply shed re-allocation method, it is used as a constant to re-allocate GHG mitigation outcomes to the co-product of interest as long as the supply shed is producing enough of this co-product. The main assumption of this method is that there is an equivalence between co-products that can be represented by a physical or economic attribute. In our analysis, price was used as an economic attribute, but physical attributes could also have been used (energy content, mass, volume…) to convert one co-product into another. Figure 3 depicts how the supply shed re-allocation method works alongside a detailed explanation of the steps.

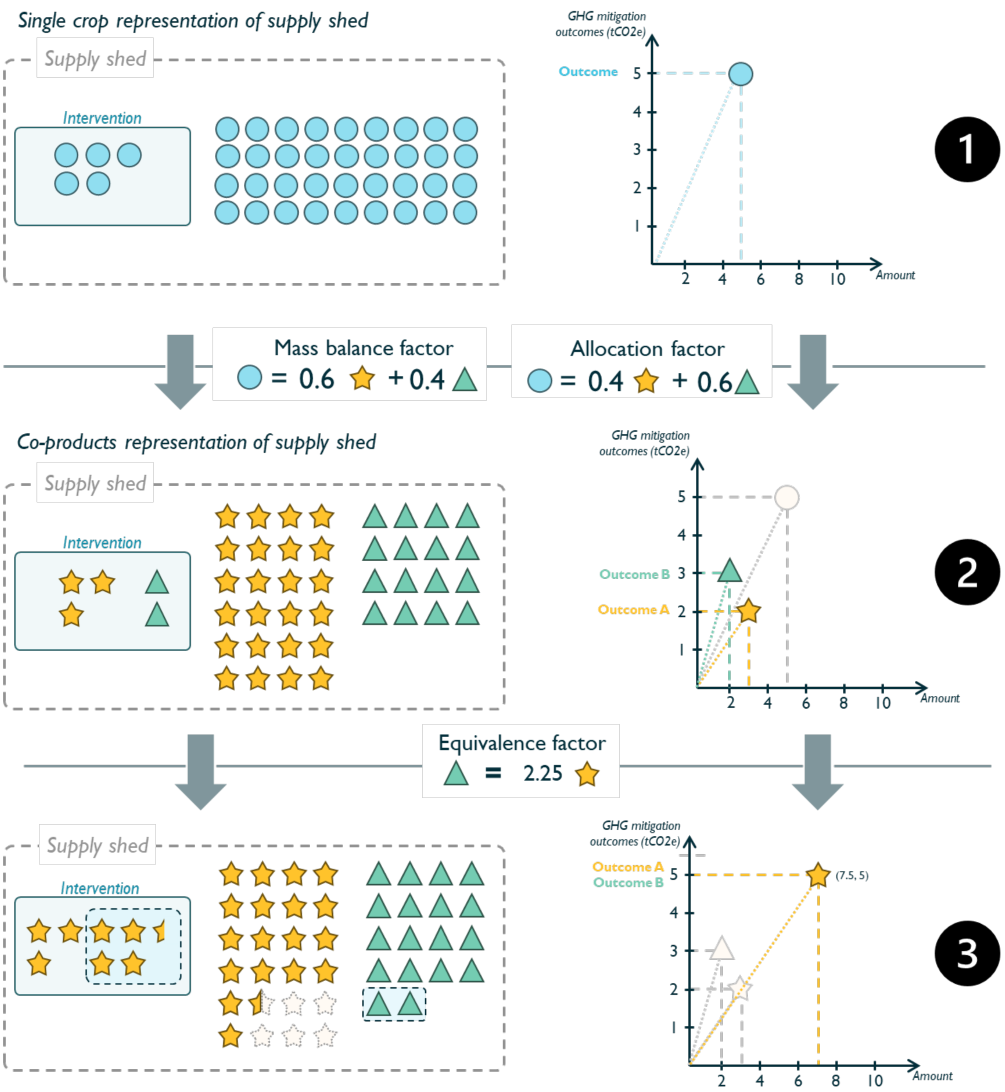


Figure 3: Example of applying the supply shed re-allocation to a crop with two co-products.

In this example, ○ is a crop with two child co-products (☆ & △) that have their mass established by the mass balance and the GHG mitigations outcomes allocated to them by the allocation factors described below graph ❶. The intervention that generated the GHG mitigation outcomes did not impact the whole supply shed but only a small subset.
Graph ❶ & ❷ portrays the same supply shed from the perspective of the parent good (graph ❶) or from the perspective of the child co-products (graph ❷). Assuming that the investor requires a re-allocation toward ☆, the method must establish how to exchange between ☆ and △ (How many ☆ is a △ worth?). The impact factor first describes the ratio of GHG mitigation outcomes associated to an amount of co-product.

△= 3 (tCO2e) / 2 (t) = 1.5 (tCO2e/t)
☆= 2 (tCO2e) / 3 (t) ≈ 0.667 (tCO2e/t)

The equivalence factor then assesses how to convert units of one co-product into another, using each of their impact factors.

Equivalence factor (△ / ☆) = 1.5 / 0.667 = 2.25

As such, in this example, 1 △ is equal to 2.25 ☆. This implies that if the investor would like to claim all the GHG mitigations outcomes generated by the intervention, they must be sourcing a total of 7.5 ☆: 3 ☆ from what was original allocated and 4.5 ☆ from the supply shed re-allocation – exemplified in ❸.

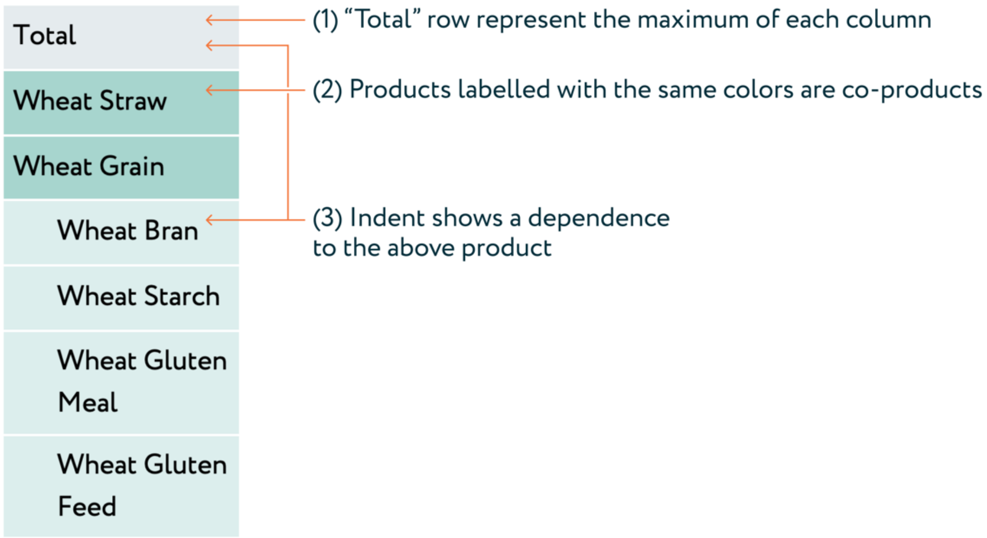
Examples

To show how this method works in practice, two examples were selected:

(1) Wheat using the data connected to a 'minimum tillage' intervention with a supply shed size of 15,000t. The product of interest is wheat gluten feed.
(2) Rapeseed using the data connected to a 'companion crops' intervention with a supply shed size of 5,000t. The product of interest is animal feed.

Table 3 & Table 4 outline the GHG mitigation outcomes claimable for each co-product in both wheat and rapeseed. With the supply shed re-allocation method, the GHG mitigation outcomes allocated to wheat gluten feed increased from 30 tCO2e to 59 tCO2e following an increase of the mass of claimable product from 267 t to 525 t. For animal feed, the claimable GHG mitigation outcomes increased from 10 tCO2e to 17 tCO2e with a corresponding product mass increase of 224t to 368t. To allow for any further re-allocation of GHG mitigation outcomes for either product, their supply sheds would need to be expanded to include additional production volumes.

Note 1: Reading the example tables for all re-allocation methods.



In the example tables for all re-allocation methods, the representation is static and does not take into consideration dynamics created by claims. In one stage of the value chain, GHG mitigation outcomes can be claimed on either parent, child product or competitive products up until reaching total amount of GHG mitigation outcomes generated in the impact layer. As such, these tables could imply that double counting is permitted while a dynamic system would reflect the 'claimable' GHG mitigation outcomes in line with each claim made. Furthermore, the example tables also possess key features to better encapsulate the realities of Scope 3 and intervention accounting, these features are described below:

(1) 'Total' is the maximum value that can be found in a column either informed by the intervention or product system boundaries, or the mathematical limit of the underlying equation.

(2) Co-products are represented by the same colours within the tables; the allocation of these co-products sum up to one. Two shades of the same colour represent the competitive branches.

(3) Indent shows the relation between parent and child goods. The indent between 'Total' and the first set of co-products shows the relationship between the crop on the field, and the crop harvested.

The result tables for supply shed re-allocation follow a structure that presents the total, the co-products and the relation between child and parents products. Here, the common columns are described (specific columns relevant to each method are presented alongside the tables):

- **Default Allocation factor**: guides the default assignment of GHG mitigation outcomes to each co-product within the product system. The allocation factor is expressed in respect to its parent product.

- **Mass balance factor**: guides the mass required from a parent product to generate a specific child product. The mass balance factor is expressed in relation to its parent product.
- **Allocated GHG mitigation outcomes**: GHG mitigation outcomes assigned by default to a co-product based on allocation factor and GHG mitigation outcomes yielded by intervention.
- **Amount impacted by intervention**: total quantity of co-product affected by the intervention, guided by mass balance factors from the crop to various child products.
- **Impact factor**: ratio of allocated GHG mitigation outcomes and amount in tCO2e / t.
- **Equivalence factor**: Factor used to translate a product into another. Equivalence factor is expressed in respect to one particular product (here wheat Gluten feed & Animal feed)
- **Amount needed to re-allocate GHG mitigation outcomes**: The amount of additional sourcing from the supply shed the claimant must prove to re-allocate GHG mitigation outcomes to the interested product. These amounts follow the equivalence factor described above.
- **Maximum claim based on supply shed limits**: Amount (t) and GHG mitigation outcomes (tCO2e) that are possible to claim based on the limits of the supply shed.

Table 3: Re-allocation of GHG mitigation outcomes following supply shed re-allocation for wheat considering a 15,000t supply shed and a 'minimum tillage' intervention.

	Mass balance factor	Amount impacted by intervention *(t)*	Default allocation factor	Allocated GHG mitigation outcomes *(t CO2e)*	Impact factor *(t CO2e / t)*	Equivalence factor for Wheat Gluten Feed	Amount needed for re-allocated GHG mitigation outcomes *(t Gluten feed)*	Maximum claim based on supply shed limits	
								t	*tCO2e*
Total	1.00	7,628	1.00	577	∞	-	5,174	-	-
Wheat Straw	0.30	2,288	0.14	81	0.04	0.32	724	-	-
Wheat Grain	0.70	5,339	0.86	496	0.09	0.83	4,450	-	-
Wheat Bran	0.12	641	0.09	45	0.07	0.64	400	-	-
Wheat Starch	0.29	1,549	0.55	273	0.18	1.64	2,447	-	-
Wheat Gluten Meal	0.07	374	0.30	149	0.40	3.64	1,335	-	-
Wheat Gluten Feed	0.05	267	0.06	30	0.11	1.00	267	**525**	**59**

Table 4: re-allocation of GHG mitigation following Supply shed re-allocation for Rapeseed considering a 5,000t supply shed and the intervention 'companion crops'. Amount needed for re-

allocated GHG mitigation outcomes: Amount of product needed to claim the re-allocated GHG mitigation outcomes.

	Mass balance factor	Amount impacted by intervention *(t)*	Default allocation factor	Allocated GHG mitigation outcomes *(t CO2e)*	Impact factor *(t CO2e / t)*	Equivalence factor for Wheat Gluten Feed	Amount needed for re-allocated GHG mitigation outcomes *(t Gluten feed)*	Maximum claim based on supply shed limits	
								t	*tCO2e*
Total	1.00	1,319	1.00	44	∞	-	944	-	-
Rapeseed straw	0.24	317	0.05	2	0.01	0.15	47	-	-
Rapeseed	0.76	1,003	0.95	42	0.04	0.89	897	-	-
Rapeseed oil, from pressing	0.31	311	0.60	25	0.06	-	-	-	-
Rapeseed Expeller	0.68	682	0.40	17	0.02	-	-	-	-
Rapeseed oil, from solvent	0.41	411	0.75	31	0.06	1.24	673	-	-
Rapeseed meal, from solvent	0.57	572	0.25	10	0.01	0.30	224	-	-
Animal Feed	0.17	224	1.00	10	0.05	1.00	224	**368**	**17**

Discussion – Risks and Opportunities

One of the fundamental risks of this approach is the capacity to trace additional product volumes to the supply shed and the need for the defined supply shed to produce a larger supply of a specific product as compared to the supply of the product impacted by the intervention.

Within Scope 3 accounting, the need for supply chain traceability to facilitate the linking of products procured to the interventions is a recurring topic. In the most ideal scenario, a company can provide evidence that they are sourcing from a production unit that could sit multiple tiers upstream in a value chain. As full traceability is often unattainable, the supply shed has been put forward as a mechanism to enable traceability up to a specific level but not to the individual points (i.e. individual farms) of production.

Under the supply shed re-allocation method, to claim GHG mitigation outcomes which would otherwise become stranded assets, a company would need to prove that they are sourcing additional quantities from that supply shed to allow for subsequent re-allocation of GHG mitigation outcomes. As such, the burden of work to prove sourcing from the supply shed would increase.

Furthermore, the size of the supply shed and the distance (in terms of value chain stages) the investor is from the supply shed play a critical role. Both aspects feed into the same underlying problem: establishing a connection to the supply shed. Varying sizes of supply shed (e.g. country level or sub country level) requires a different level of traceability and a significantly different amount that can be procured.

Varying distances (e.g. adjacent stage or last stage before consumer) also plays a role due to the multiplicative impact of mass balance & allocation factors. For example, combining a small supply shed and a high number of value chain stages leads to a marginal re-allocation of GHG mitigation outcomes, while a large supply shed and a low number of value chain stages would subsequently facilitate a full re-allocation.

The supply shed re-allocation method also assumes that the intervention scope is affecting a lower volume than the supply shed production volumes. In many cases, this assumption holds true as, for example, not all farms have integrated a no till activity within a supply shed at the time of the claim. However, as more and more farmers integrate interventions into their production, the intervention scope will grow, until it reaches the same scope as the supply shed hence limiting the re-allocation of GHG mitigation outcomes to products of interest.

In that case, the supply shed re-allocation method would follow an economic or physical allocation. Local context will determine if this aspect is either a risk or an opportunity. In supply sheds where interventions are being implemented by a large proportion of farmers, it is a risk in the sense that the method loses its flexibility.

The supply shed re-allocation method does not modify the emissions allocation described by the modelling of the value chain and the intervention. As such, within the bounds of the intervention, a particular product does not become net-zero or yield a negative emission factor other than if this is the direct result of the intervention(s). Rather, GHG mitigation outcomes associated with products not of interest to the investor(s) are dispersed to un-affected products elsewhere in the supply shed.

Another observation is that the re-allocation of GHG mitigation outcomes via this method does not guarantee that co-products comprising a small fraction of the output from the parent product are able to fully claim the GHG mitigation outcomes generated by an intervention. In the case of *animal feed*, for example, the amount of feed derived from either underlying wheat or rapeseed crop is relatively small and, as such, the intervention scope needs to be within a relatively larger supply shed to allow a high re-allocation of GHG mitigation outcomes to feed.

Overall, though, in value chains where one commodity acts as the parent product for a large set of child / co-products, this proposed approach can accommodate these multi-layered or complex production systems and provide an opportunity to claim at each step of production. The supply shed re-allocation method is designed to work in tandem with tracking platforms and registries to dynamically re-adjust itself if multiple claims on different co-products are sought.

The claimed GHG mitigation outcomes would be subtracted from the total amount of available GHG mitigation outcomes, allowing flexibility for claims on other co-products to be possible. Moreover, tracking platforms could provide a safeguard through keeping track of the volume within the supply shed, although as each claim must be backed by a proof of sourcing from the supply shed, a situation where more goods are claimed than what is produced by the supply shed is impossible. However, currently, this method was designed within an intervention specific context, and a risk emerges where multiple interventions (or programs) affect the same supply shed that are not directly linked to the intervention being re-allocated.

This risk is currently relatively small due to the limited number of (programs of) interventions but is expected to become a significant challenge with more interventions. Mitigation of this risk will come from the organisation of registries and could be addressed by interoperability between registries.

UPPER LIMIT RE-ALLOCATION METHOD

Description

The upper limit re-allocation method concentrates GHG mitigation outcomes on co-products by applying them based on the emissions profile of that product up to reaching the point of net-zero for that product. The re-allocation is therefore dependent on the emissions allocated to the interested product as an "upper limit" to what amount of GHG mitigation outcome can be claimed on that product. Three levels of aggregation have been identified and each have varying degrees of credibility, flexibility, and modelling requirements:

- **Activity** level – an activity describes a set of processes that are required for a specific operation to be performed at the level of the intervention. For example, the 'fertilization' activity includes processes involving the diesel consumption by tractor, the tractor creation, the direct and indirect emissions arising from the fertilizer application, the fertilizer application, the production of fertilizer, and other related processes.
- **Production level** – production describes all the operations used to generate the parent good; it is the aggregation of all activities. For example, to generate wheat grain or rapeseed, operations such as tillage, fertilization, transport, building/construction amongst others are needed.

- **Product level** – this level describes all operations within and beyond the production that are necessary to produce the child products. For example, to generate wheat gluten feed, there are additional allocated emissions from processing and refining that are not addressed by the intervention.

In Table 5 & Figure 4, the method describes a re-allocation of the GHG mitigation outcomes of an intervention yielding 20 tCO2e on a tillage activity. Figure 4 provides an overview of the emission profile of the parent product and its derivative products.

Table 5: The upper limit re-allocation method overview based on Figure 4 in tCO_2e. Values in parenthesis represent what the upper limit would be based on the selected level and product – these values are directly correlated to the emission profile for each product; values to the left of the parenthesis are the number of GHG mitigation outcomes that can be claimed for the co-products. Default allocation represents the GHG mitigation outcomes without re-allocation. In total, the sum of claims cannot exceed the total GHG mitigation outcomes generated by the intervention (20 tCO2e).

Levels	Parent Product *(tCO2e)*	Co-product A *(tCO2e)*	Co-product B *(tCO2e)*	Co-product C *(tCO2e)*
Default allocation	20	11	3	6
Activity level	20 (40)	20 (22)	6 (6)	12 (12)
Production Level	20 (100)	20 (55)	15 (15)	20 (30)
Product level	20 (100)	20 (88)	20 (24)	20 (48)

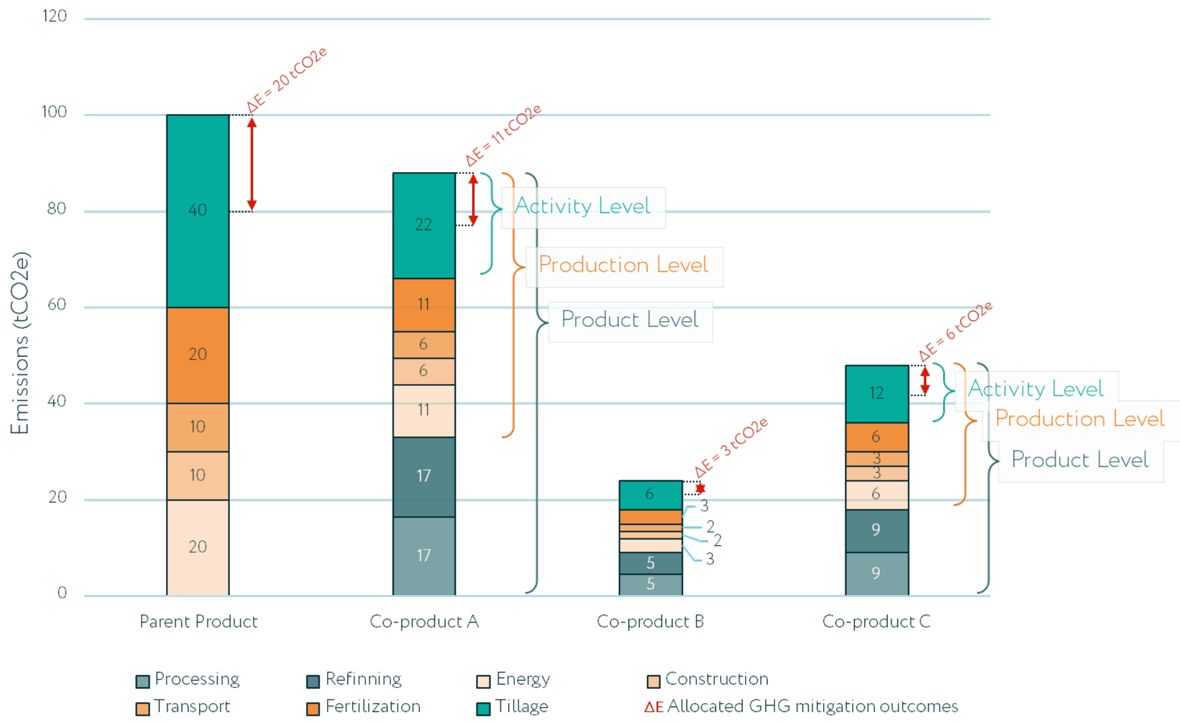


Figure 4: Breakdown of the emission profile by different level of aggregation for a parent product and the child co-products linked to it.

Examples:

In the example below, tables present the outcomes of the upper limit re-allocation method being applied (see Examples)

To show how this method works in practice, two examples were selected:

(1) Wheat using the data connected to a 'minimum tillage' intervention with a supply shed size of 15,000t. The product of interest is wheat gluten feed.

(2) Rapeseed using the data connected to a 'companion crops' intervention with a supply shed size of 5,000t. The product of interest is animal feed.

Table 3 & Table 4 outline the GHG mitigation outcomes claimable for each co-product in both wheat and rapeseed. With the supply shed re-allocation method, the GHG mitigation outcomes allocated to wheat gluten feed increased from 30 tCO2e to 59 tCO2e following an increase of the mass of claimable product from 267 t to 525 t. For animal feed, the claimable GHG mitigation outcomes increased from 10 tCO2e to 17 tCO2e with a corresponding product mass increase of 224t to 368t. To allow for any further re-allocation of GHG mitigation outcomes for either product, their supply sheds would need to be expanded to include additional production volumes.

(Note 1 for reading the table). All information is presented in respect to data provided by Cargill and Soil Capital or accessed through the Agrifootprint database. To note, the values within Table 7 and Table 8 represent the maximum claimable GHG mitigation outcomes and any claims on these co-products would result in a re-calculation of the maximum number of claimable GHG mitigation outcomes.

Table 6: Emission factors at different level in tCO2e /t. NOTE: the footprint emission factors are allocated using Agrifootprint allocation factors. Activity level emission factors are described by activity dictated by the intervention activity of "no Tillage" for Wheat & "Companion Crops" for Rapeseed.

Product	Activity	Production	Footprint
Wheat Gluten Feed	0.030	0.637	0.470
Animal Feed	0.249	1.05	0.652

Table 7: GHG mitigation outcomes re-allocated to co-products by level of aggregation. The commodity targeted is wheat using the intervention "No Tillage". These values are indicative of what the first claim would look like for each level. Default allocation of GHG mitigation outcomes is presented as reference.

	Default allocation *(tCO2e)*	Upper limit re-allocation method		
		Activity level *(tCO2e)*	Production level *(tCO2e)*	Product level *(tCO2e)*
Total	103	103	103	103
Wheat Straw	14	15	44	75
Wheat Grain	89	95	103	103
Wheat Bran	8	9	24	103
Wheat Starch	49	52	81	103
Wheat Gluten Meal	27	28	16	103
Wheat Gluten Feed	5	6	103	103

Table 8: GHG mitigation outcomes re-allocated to co-products by level used. The commodity targeted is Rapeseed using the intervention on "Companion crops". These values are indicative of what the first claim would look like for each level. Default allocation of GHG mitigation outcomes is presented as reference.

	Default allocation *(tCO2e)*	Upper limit re-allocation method		
		Activity level *(tCO2e)*	Production level *(tCO2e)*	Product level *(tCO2e)*
Total	44	44	44	44
Rapeseed straw	2	3	44	44
Rapeseed	42	44	44	44
Rapeseed oil, from pressing	25	44	44	44
Rapeseed Expeller	17	44	44	44
Rapeseed oil, from solvent	31	44	44	44
Rapeseed meal, from solvent	10	35	44	44
Animal Feed	10	35	44	44

Discussion – Risks & Opportunities

GHG mitigation outcomes are concentrated to one specific product/ co-product by associating the GHG mitigation outcomes to parts of the emission factor that are not targeted by the intervention. In that sense, the different levels of aggregation were explored to allow the investor to include GHG mitigation outcomes at a level of aggregation suited to their capacity and their credibility requirement. However, there is no direct incentive to disaggregate beyond a product level as fewer GHG mitigation outcomes would be allocated to the co-product of choice by detailing the emission factor to the activity level.

With data organized through the LCA framework, it is theoretically possible in some circumstances to achieve greater levels of granularity in emissions data, down to the activity level. However, some emissions quantification methodologies don't or cannot disaggregate emissions data to this degree, creating a methodological constraint on the ability to claim if this level of aggregation is chosen.

The upper limits used are derived from companies' emission factors and inventories. On the one hand, inventories composed of low emission factors would only be able to claim a limited amount of GHG mitigation outcomes due to the net-zero limit. On the other hand, a company with high emission factors would be able to claim a higher proportion of the GHG mitigation outcomes. As such, this methodology incentivizes early-stage value chain decarbonization but offers less of an incentive for later-stage progress towards net-zero, as envisaged by SBTi.

Another risk is the validity of claims related to uncertainty around the original inventory and/or emission factors. This may lead to additional costs for companies if they need to consolidate their inventory/emission factors or risk distrust in the market due to invalid or inaccurate inventory data being used. The upper limit re-allocation method allows flexibility in allocating GHG mitigation outcomes to all co-products, enabling investments to actively earn a return on their investment. As the upper limit re-allocation method does not lock GHG mitigation outcomes to products but pools them and implements an upper limit to safeguard against overclaiming, the search for off-takers is not based on a product (or co-product) but based on their connection to the commodity (and supply shed) addressed by the intervention. As such, this method embraces market-based mechanisms and co-investment opportunities as it incentives participation and entry into value chain decarbonization. Beyond the initial calculation, the upper limit re-allocation method is designed to dynamically re-adjust the upper limit if multiple claims on a variety of co-products is sought afterwards, however this requires the use of a tracking registry.

INVESTOR RE-ALLOCATION METHOD

Description

In the case of the investor re-allocation method, GHG mitigation outcomes are re-allocated to the preferred co-product(s) of the investor(s). The share of investment in the intervention is used as a factor linking the GHG mitigation outcomes to the interested co-product(s). As there might be multiple products between the interventions and the desired co-product(s), two methodological approaches are possible:

(1) **Re-allocation to specific chain segment** - Upstream GHG mitigation outcome allocation factors are also modified to direct all GHG mitigation outcomes to the chain segment of interest. As such, the GHG mitigation outcomes are directed to the upstream products or co-products that are transformed to create the product(s) of interest.

(2) **Re-allocation to specific co-products** - Upstream GHG mitigation outcome allocation factors are not modified, and GHG mitigation outcomes are distributed to other chain segments, reducing the total GHG mitigation outcomes re-allocated to selected co-product(s).

In Figure 5, the consequence of methodological choices is presented for wheat with an example intervention of minimum tillage. A summary of the GHG mitigation outcomes re-allocated to wheat gluten feed are presented in the table below:

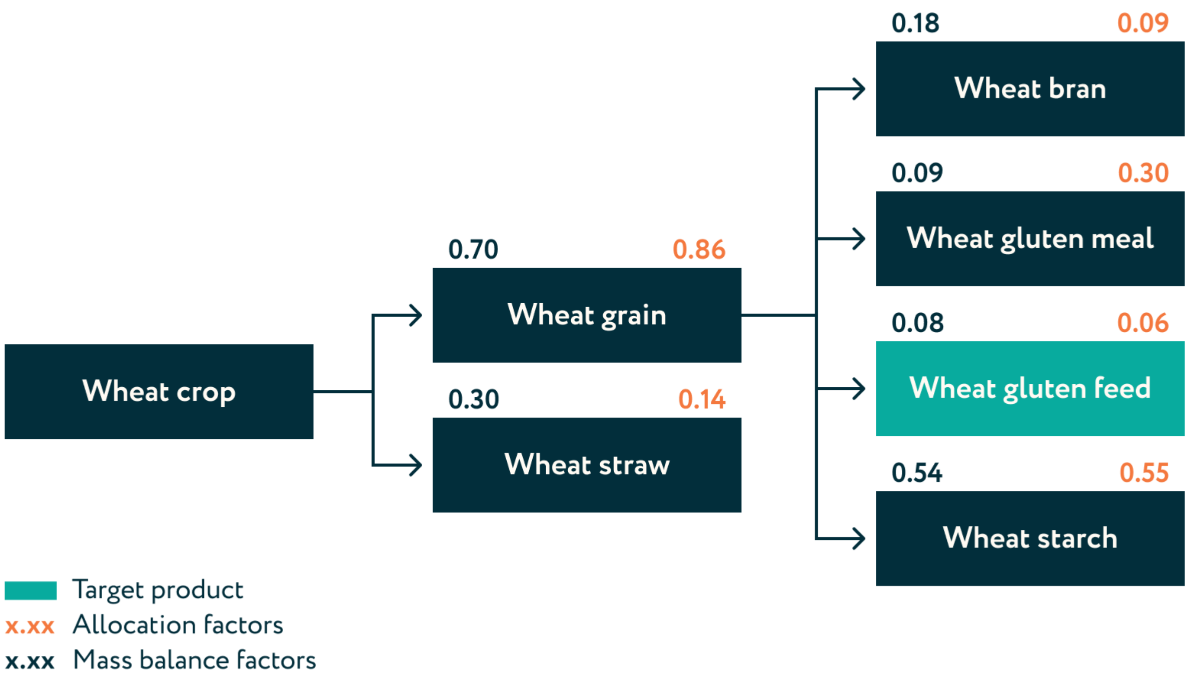


Figure 5: Default economic allocation and mass balance provided within Agrifootprint. For investor re-allocation to co-products, the allocation factors which are starred (*) are the allocation factors affected to direct the GHG mitigation outcomes to wheat gluten feed. For investor re-allocation to chain segment, all starred elements are affected (and **) to direct the GHG mitigation outcomes to wheat gluten feed.*

Table 9: Overview of investor re-allocation considering both methodological approaches on GHG mitigation outcomes allocation to Wheat gluten Feed. The numbers are taken from the intervention "minimum tillage" which yielded a reduction of 577 tCO2e (see Table 2 for Total Mitigation values).

Methodology	GHG mitigation outcomes re-allocated to *wheat gluten feed*
Default allocation	25 tCO2e
Investor re-allocation – Chain segment	577 tCO2e
Investor re-allocation – Co-products	496 tCO2e

Examples

To contextualize the risks and opportunities of the investor re-allocation, an example considering GHG mitigation outcomes based on the intervention 'minimum tillage' affecting *wheat* is explored. For simplicity, it is assumed that the investor(s) is interested in one co-product:

- One investor: only one investor is investing, and they are interested in the co-product used to generate feed: 100% wheat gluten feed.
- Two investors: two investors are sharing the cost and they are investing toward different co-products: 50% wheat gluten feed and 50% wheat bran
- Three investors: three investors are sharing the cost and they are investing toward different co-products: 50% wheat gluten feed, 20% wheat bran and 30% wheat gluten meal

Table 10: Re-allocation factors of investor re-allocation contextualized with wheat-based products based on investment scenarios. Default = Default allocation from Figure 5, Inv AL 1 = investor re-allocation Chain segments, Inv AL 2 = Investor re-allocation co-products.

		One investor		Two investors		Three investors	
	Default	Inv AL 1	Inv AL 2	Inv AL 1	Inv AL 2	Inv AL 1	Inv AL 2
Wheat Straw	0.14	-	0.14	-	0.14	-	0.14
Wheat Grain	0.86	1.00	0.86	1.00	0.86	1.00	0.86
Wheat Bran	0.09	-	-	0.50	0.50	0.20	0.20
Wheat Starch	0.55	-	-	-	-	-	-
Wheat Gluten Meal	0.30	-	-	-	-	0.30	0.30
Wheat Gluten Feed	0.06	1.00	1.00	0.50	0.50	0.50	0.50

Table 11: GHG mitigation outcomes re-allocated based of investor re-allocation contextualized with wheat-based products following Table 10 factors. Default = GHG mitigation outcomes allocated following default allocation, Inv AL 1 = GHG mitigation outcomes re-allocated following investor re-allocation Chain segments, Inv AL 2 = GHG mitigation outcomes re-allocated following investor re-allocation co-products.

		One investor		Two investors		Three investors	
	Default	Inv AL 1	Inv AL 2	Inv AL 1	Inv AL 2	Inv AL 1	Inv AL 2
Wheat Straw	81	-	81	-	81	-	81
Wheat Grain	496	577	496	577	496	577	496
Wheat Bran	45	-	-	289	248	115	99
Wheat Starch	273	-	-	-	-	-	-
Wheat Gluten Meal	149	-	-	-	-	173	149
Wheat Gluten Feed	30	577	496	289	248	289	248

Discussion – Risks & Opportunities

The investor re-allocation method leads to a concentration of the GHG mitigation outcomes previously distributed across co-products onto the desired co-product(s). The two different versions of the investor re-allocation method differ over how the GHG mitigation outcomes allocated to *wheat straw* are re-allocated to the child products of Wheat Grain.

Using investment as a metric to associate GHG mitigation outcomes to co-products could lead to disproportionate re-allocation of GHG mitigations outcomes to a specific product, creating a significant inequality between emissions allocated and GHG mitigation outcomes re-allocated. This in turn could lead to a reduction in the credibility of the claims by enabling potential negative emission factors. A solution to this would be to add safeguards limiting re-allocation of GHG mitigation outcomes up until reaching a net-zero product.

There is a risk that entities with a larger share of investment control a larger proportion of the GHG mitigation outcomes hence skewing the distribution of GHG mitigation outcomes in value chains in their favour. For example, in the three investors scenario, as the value chain approaches full traceability (who buys what from whom), 50% of the GHG mitigation outcomes would already be allocated to wheat gluten feed and animal feed. As such, newly linked chain actors are unable to make claims on the products they are sourcing as no GHG mitigation outcomes are re-allocated to those products.

On the other hand, the flexibility provided by the investor re-allocation method provides an incentive for investment to generate GHG mitigation outcomes to products that are of small economic value (either the product as a whole or the individually targeted portion of the product). In that sense, the investor re-allocation method would essentially provide more time to build market liquidity to find off-takers and obtain a return on investment over time. This opportunity relies on a pre-established assumption that the allocation of GHG mitigation outcomes should follow the same principle of allocation of product emissions in the long run.

SECTION 2: RE-ALLOCATION ACROSS CROP ROTATIONS

MODELLING CROP ROTATION & INTERVENTIONS

There are generally multiple cash crops in rotation on the targeted farms. To guide this section and present the re-allocation method comparatively, a scenario was imagined where a farm has four cash crops in rotation: wheat, sugar beet, rapeseed, and barley. Each crop occupies 25% of the farm area for each growing season. Each crop exists within its own supply shed, whereby additional farms are producing additional amounts of these crops beyond the boundaries of the interventions being made. The farm is being affected by two different interventions:

- Cover crop (CC) intervention - inclusion of nitrogen-fixing legumes as a cover crop that is inserted into the rotation prior to barley planting. This intervention is affecting the fertilization operation.
- Manure fertilizer (MF) intervention - the application of manure fertilizer that affects 75% of the farm. This intervention is affecting the fertilization operation.

CC intervention is linked to the rotation of barley, and each year moves from one plot within the farmland to another; this intervention is considered to be fertilization affecting activity. For simplicity, the effects of the intervention are considered additive, meaning that the effect of the intervention continues on the plot as the intervention moves around the whole farm, from affecting 25% to 100% of the farm area. In reality, a diminishing effect of the Nitrogen fixing ability is expected through time.

MF intervention is affecting 75% of the farm at all times, meaning that during the rotation one of the crop (across the years) is not being directly affected by the intervention. This choice is to have the ability to present the method in a more complex setting than an intervention affecting every parcel of the farm.

The farm was considered a multi output system that cannot be subdivided into the four aforementioned crops. As such, emissions and GHG mitigation outcomes are allocated using the price of each crop based on European August 2023 prices. Sugar beet price was determined by the average sugar content of a sugar beet multiplied by the price of white sugar. Economic allocation was selected for simplicity, and it is acknowledged that physical characteristics could have been selected for different allocation factors (energy content or other functional physical characteristic) as such this section does not argue for a particular allocation method to be used. Furthermore, due to the rotation from CC & MF interventions, some crops are not included in the default allocation as they are not impacted by the intervention within a specific year.

The intervention implemented was made possible from an investor who is only interested in wheat. Figure 6 is a representation of the example farm that has adopted these interventions across their varying crop rotation cycles over the course of four years.

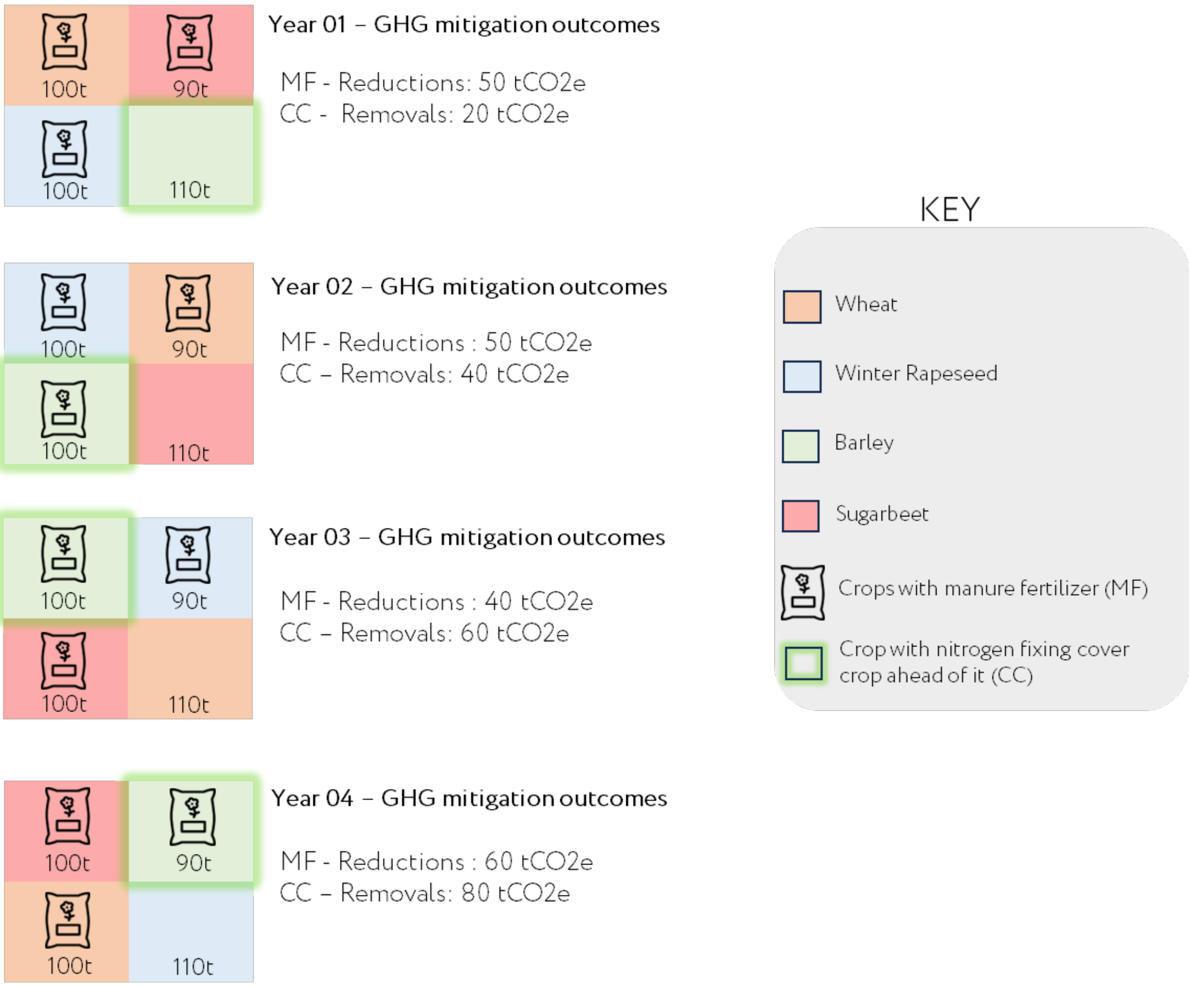


Figure 6: Case study example of one farm that is monitoring GHG mitigation outcomes over the course of four years and in which 4 different crops are grown.

Table 12: Mitigation outcomes and affected crops for both intervention across the 4 year of rotation.

Interventions			Year 1	Year 2	Year 3	Year 4
Maure Fertilizer (MF)	**GHG mitigation outcomes (tCO2e)**		**50**	**50**	**40**	**60**
	Affected crops (t)	Wheat	100	90	0	100
		Rapeseed	100	100	90	0
		Sugar beet	90	0	100	100
		Barley	0	100	100	90

	GHG mitigation outcomes (tCO2e)		20	40	60	80
Nitrogen Fixing Cover Crop (CC)	Affected crops (t)	Wheat	0	0	110	100
		Rapeseed	0	0	0	110
		Sugar beet	0	110	100	100
		Barley	110	100	100	90

Additionally, the emission factor of the farm was estimated using the Agrifootprint where the crop emission factors were retrieved:

- Sugar beet, at farm {GB} Economic, U - 0.05 tCO2e / t
- Rapeseed, at farm {GB} Economic, U - 0.79 tCO2e / t
- Wheat grain, start material, at seed production {GB} Economic U - 0.38 tCO2e / t
- Barley grain, at farm {GB} Economic, U - 0.34 tCO2e / t

For consistency with the system assumptions, the emission factor of the total rotation was calculated by aggregating all the emissions factors, totalling 0.388 tCO2e / t of product from the farm. With the assumption that the system cannot be subdivided and for simplicity, if partition is required, the allocation should follow the same principle as outlined previously in this document. All values used in the example are not meant to precisely reflect the emission realities of farms but provide simplified context to explain the re-allocation methods.
It was identified that detailing the inventory or emission factor of crops in a LCA fashion within the context of crop rotation is difficult. Activity /operation are thought out at a farm level rather than only a specific crop within a rotation as such, the focus is placed on the land affected (or the production as a whole) rather than the products emerging from it. Scope 3, in many of its categories, employs a life cycle thinking centralised on accounting products as they move through network of production. Here, an attempt at partitioning the emissions in categories of operation / activities were attempted in relation to the Upper limit re-allocation method. However, the partitioning does not take roots in any documents or previous realised studies rather, it acts as an example to simplify a highly complicated topic as to focus on the issue of Stranded assets.

POSSIBLE SOLUTIONS

This section proposes two GHG mitigation outcomes re-allocation methods, each of which are described below. Since these are the same methods as presented in Section 1, an overview of the proposed solutions and their limitations is provided in the conclusion alongside section 01.

SUPPLY SHED RE-ALLOCATION METHOD

Description

As in Section 1, the supply shed re-allocation method explores rights to claim greater amounts of GHG mitigation outcomes for the crop of interest to the investor by increasing the reportable quantity of products connected to the GHG mitigation outcomes.

This approach can be seen as an extension of the supply shed concept to multi-product systems. Here, the definition of the supply shed is extended to a pool of crops that serve the same market segment and can demonstrate functional and service equivalence. GHG mitigation outcomes generated by an intervention can be claimed by any company sourcing from this *functional* supply shed. As such, the supply shed re-allocation method allows the transfers of GHG mitigation outcomes to any crop present in the common pool.

All crops in the functional supply shed are considered interchangeable by using an equivalence factor, represented by the ratio of annually verified GHG mitigation outcomes to amount of each product. Using this equivalence factor, all the GHG mitigation outcomes generated by an intervention could be re-allocated to one crop by exchanging the crops produced on the affected farms with the crop of interest from other farms within the functional supply shed.

Examples

Table 13 & Figure 7 depicts this approach with a re-allocation orientated to wheat for the MF intervention in the first year. As part of the scenario described, the crop barley was not affected by the intervention during this period, hence no GHG mitigation outcomes can be re-allocated to it.

Table 13: Supply shed re-allocation in the first year of the farm rotation for the MF intervention. GHG mitigation outcomes are re-allocated to Wheat as it is the crop sought after by the investor.

Crops	Amount *(t Crop)*	Default Allocation	GHG mitigation outcomes *(tCO2e)*	Impact Ratio *(tCO2e / t)*	Equivalence factor for Wheat	Wheat Mass needed to claim GHG Mitigation outcomes *(t Wheat equivalence)*
Wheat	100	0.28	14	0.140	1.00	100
Rapeseed	100	0.55	28	0.276	1.96	196
Barley	110	0.00	0	0.000	-	0
Sugar beet	90	0.17	8	0.093	0.66	60
Total	**400**	**1**	**50**	**-**	**-**	**356**

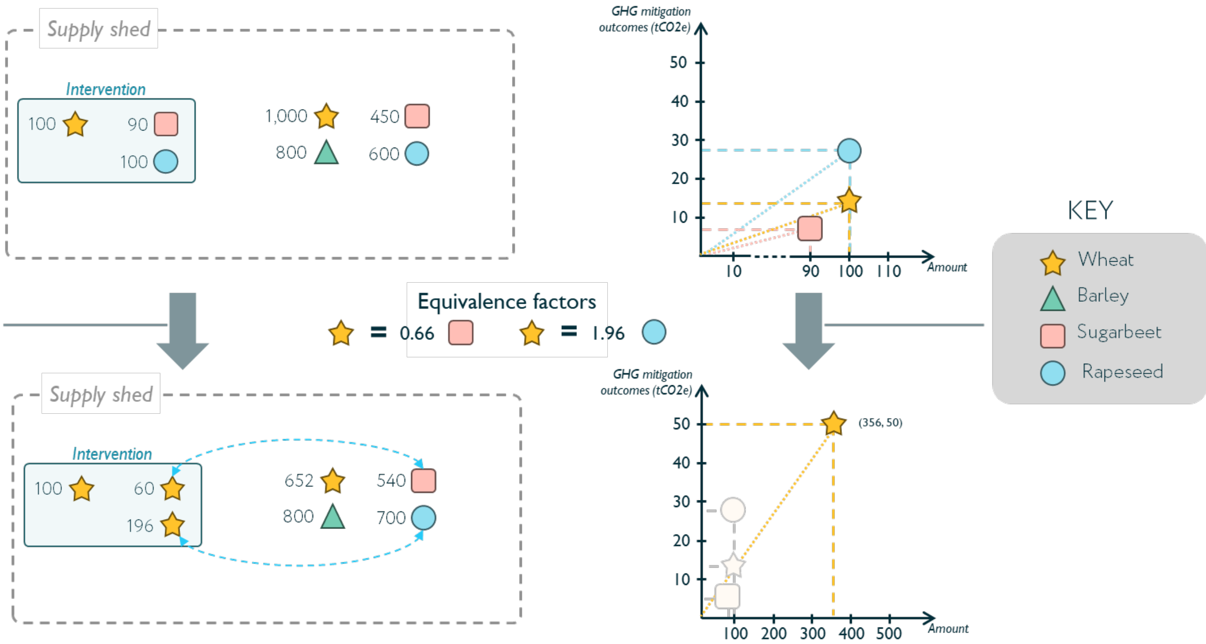


Figure 7: Diagram illustrating supply shed re-allocation method with reference to the MF intervention.

In this case, the investor will have to prove that they are sourcing a total 356t of wheat from the functional supply shed to be able to claim all the GHG mitigation outcomes generated by the intervention – 100t for default allocation + 60 from the virtual exchange with Sugar beet + 196 for the virtual exchange with Rapeseed.

Table 14 presents the supply shed re-allocation across the year based on the scenarios outlined in Figure 6. Each year a crop is not included within the intervention (as it is on the plot where the intervention is not occurring). During year 3, wheat is the crop excluded from the intervention and therefore, no GHG mitigation outcomes can be re-allocated to it. The 'total' row describes how much ton of wheat the investor would need to source to claim the associated GHG mitigation outcomes for each year.

Table 14: Supply shed re-allocation to claim all impacts on wheat. Mass needed represents the mass required to claim GHG mitigation outcomes associated with another crop to Wheat.

	Year 1		**Year 2**		**Year 3**		**Year 4**	
Crops	GHG mitigation outcomes *(tCO2e)*	Mass needed *(t Wheat)*	GHG mitigation outcomes *(t CO2e)*	Mass needed *(t wheat)*	GHG mitigation outcomes *(tCO2e)*	Mass needed *(t Wheat)*	GHG mitigation outcomes *(t CO2e)*	Mass needed *(t wheat)*

Wheat	14	100	13	90	-	-	20	100
Rapeseed	28	196	25	177	-	-	0	0
Barley	0	0	12	82	-	-	18	92
Sugar beet	8	60	0	0	-	-	12	60
Total	**50**	**356**	**50**	**349**	**-**	**-**	**50**	**251**

For the CC intervention, the first two years of the intervention does not affect wheat as the affected plots are not (yet) used to produce wheat. Table 15 & Table 16 represent year 3 & 4 where wheat has been affected by the intervention. The Default allocation between both tables differs as the first considers only three crops and the second considers four – default allocation is established based on the affected crops.

Table 15: Supply shed re-allocation for the CC intervention in the 3rd year of the crop rotation. Note that only three crops are affected by the intervention.

Crops	Amount *(t Crop)*	Default Allocation	GHG mitigation outcomes *(tCO2e)*	Impact Ratio *(tCO2e / t)*	Equivalence factor for Wheat	Wheat Mass needed to claim GHG Mitigation outcomes *(t Wheat equivalence)*
Wheat	110	0.24	14	0.129	1.00	110
Barley	100	0.26	15	0.155	1.2	120
Sugar beet	100	0.51	30	0.304	2.36	236
Total	**400**	**1.00**	**60**	**-**	**-**	**356**

Table 16: Supply shed re-allocation for the CC intervention in the 4th year of the crop rotation.

Crops	Amount *(t Crop)*	Default Allocation	GHG mitigation outcomes *(tCO2e)*	Impact Ratio *(tCO2e / t)*	Equivalence factor for Wheat	Wheat Mass needed to claim GHG Mitigation outcomes *(t Wheat equivalence)*
Wheat	100	0.20	16	0.164	1.00	100
Barley	90	0.22	18	0.199	1.21	109
Rapeseed	110	0.13	11	0.097	0.59	65
Sugar beet	100	0.44	35	0.351	2.14	214
Total	**400**	**1.00**	**80**	**-**	**-**	**489**

Discussion – Risks and Opportunities

The risks and opportunities for supply shed re-allocation discussed in Section 1 are also applicable to Section 2. Namely:

- Burden of work to prove sourcing to the functional supply shed.
- Distance and complexity of the chain from the functional supply shed.
- Size difference between Intervention scope and functional supply shed.
- Association of GHG mitigation outcomes to unaffected crops within the functional supply shed.

Similarly to co-products scenario, the supply shed re-allocation method associates GHG mitigation outcomes to a volume that was not affected by the intervention. However, the flexibility taken on this association are limited to the boundary of the functional supply shed. The virtual exchange of a crop for another is within the functional supply shed; no new crop is created. To exchange a given amount of a crop that is not of interest to the investor into an equivalent amount of the crop that is, there must be at least that equivalent amount of the crop of interest to the investor produced elsewhere in the supply shed.

It is not a guarantee that all the types of crops within the rotation are being affected by the intervention. In both examples above, there are years where the supply shed re-allocation to wheat is not possible as this type of crop is not within the plot where the interventions have an impact. As the equivalence factor is derived from the mass affected & allocated GHG mitigation outcomes, if a type of crop is not affected by the intervention, both those values become zero and hence, the investor would need to source an undefined (or infinite) amount of that type of crop from the functional supply shed. This is viewed as a safeguard as associating GHG mitigation outcomes to a *type* of crop that is not affected by the intervention would lead to credibility risks.

An uncertainty identified is the consequence of the re-allocation within a crop rotation system to the claims to derivative co-products further down the chain. Wheat, for example, is split between straw and grain during its harvest therefore, co-products allocation must be considered immediately. Theoretically, the supply shed re-allocation can be applied to a value chain with both crop rotation and co-products at the same time. However, this paper has not tested this hypothesis. Furthermore, the current market-based mechanism frameworks employed considers claims at each stage of the value chain to be accounted independently of other stages. This uncertainty can be considered a risk if it accentuates the current risks of double counting beyond the current issues faced by intervention accounting.

UPPER LIMIT RE-ALLOCATION METHOD:

Description

This method enables the re-allocation of GHG mitigation outcomes beyond the initial limit set by the default allocation. This approach follows the same reasoning described in Section 1 of this paper, and allows the GHG mitigation outcomes to be allocated to another crop within the rotation to a specific level. Here, an investor would be able to claim GHG mitigation outcomes generated by an intervention activity on several crops beyond what has been reduced on the production of the single crop of interest.

As opposed to Section 1, the upper limit re-allocation for crop rotation only has two levels: Activity & Production levels. The product level in derivative products consider the additive emissions as the transformed product travel down the value chains. As the crop does not have additional processes required, their product and production levels will be equivalent. Figure 8 provides a breakdown of the affected farm inventory with the MF intervention in year 1 being allocated to the relevant crops and Table 17 provides an overview of the re-allocation. The emissions are assigned through a price allocation.

Table 17: Overview of re-allocated GHG mitigation outcomes for the Activity & Production level using data from the MF intervention (year 1). Values in parentheses represent the upper limit while the accompanying value represents the GHG mitigation that can be claimed for the crop at a specific level.

Levels	Farm *(tCO2e)*	Wheat *(tCO2e)*	Rapeseed *(tCO2e)*	Barley *(tCO2e)*	Sugar Beet *(tCO2e)*
Default allocation	50	14	28	0	8
Activity level	50 (90)	20 (20)	39 (39)	0 (18)	12 (12)
Production Level	50 (290)	50 (65)	50 (127)	0 (59)	39 (39)

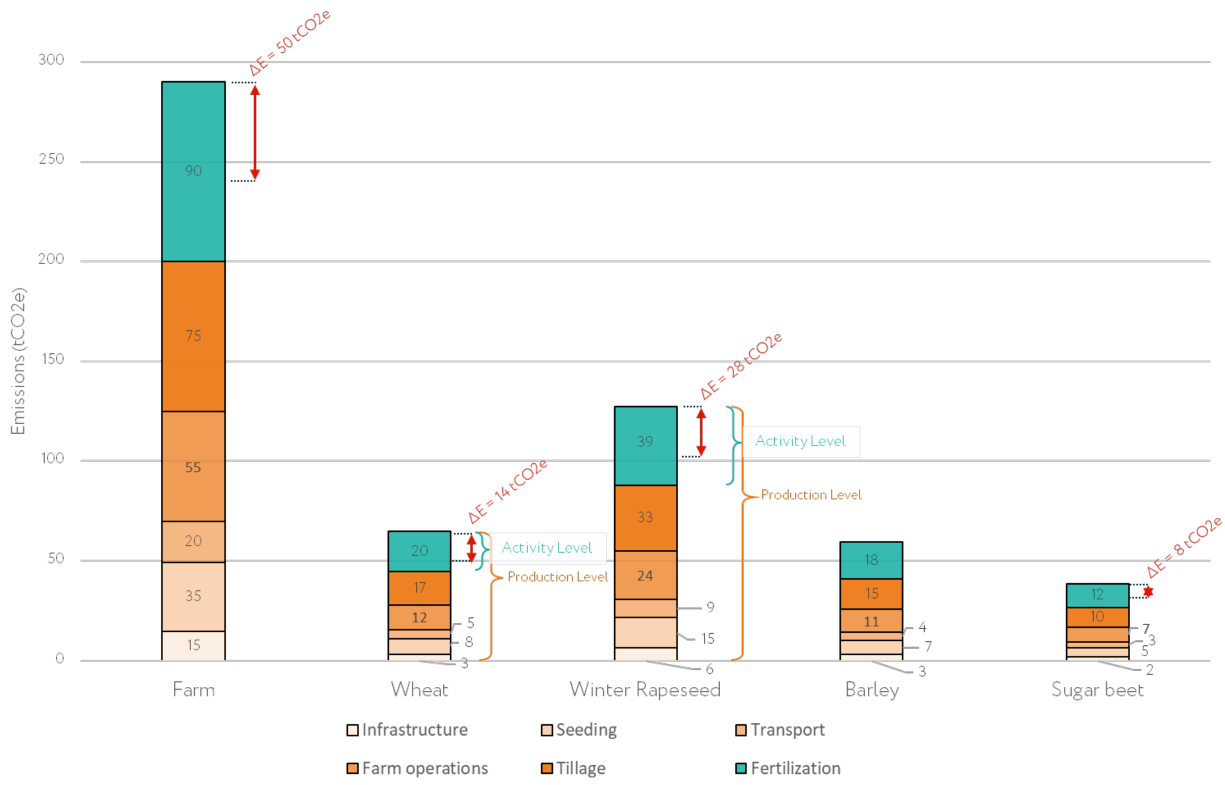


Figure 8: Farm emissions based on emission factor provided in "modelling crop rotation & intervention". Emission factor is broken down following allocation across the different crops present in the rotation. MF intervention for year 1 has also been added presenting to which crop GHG mitigation outcomes are being assigned to.

Examples

Table 18 & Table 19 showcase the application of the Upper limit re-allocation on both interventions outlined in the scenario of this section. The value presented in those tables reflect the GHG mitigation outcomes that could be claimed by the investor. However, these tables do not take into account the dynamism imagined when multiple claims are being processed in a registry. The "total" row represents the total amount of GHG mitigation outcomes that can be claim at most for these products; two consecutive claims cannot sum up to a value of more than what the total row is stating. Moreover, the default allocation is presented here to provide a point of comparison between how the allocation would assign GHG mitigation outcomes compared to the re-allocation method.

Table 18: MF intervention with re-allocated GHG mitigation outcomes throughout the years of the crop rotation. Results are broken down at the two levels outlined above. The emissions for the crops are taken from Figure 8.

	Year 1 – GHG mitigation outcomes (tCO2e)			Year 2 – GHG mitigation outcomes (tCO2e)			Year 3 – GHG mitigation outcomes (tCO2e)			Year 4 – GHG mitigation outcomes (tCO2e)		
Crops	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level
Wheat	14	20	50	13	20	50	0	0	0	24	20	60
Rapeseed	28	39	50	25	39	50	23	39	40	0	0	0
Barley	0	0	0	12	18	50	11	18	40	22	18	59
Sugar beet	8	12	39	0	0	0	7	12	39	14	12	39
Total	**50**	**50**	**50**	**50**	**50**	**50**	**40**	**40**	**40**	**60**	**60**	**60**

Table 19: CC intervention with re-allocated GHG mitigation outcomes throughout the years of the crop rotation. Results are broken down at the two levels outlined above. The emission factors for the crops are taken from Figure 8.

	Year 1 – GHG mitigation outcomes (tCO2e)			Year 2 – GHG mitigation outcomes (tCO2e)			Year 3 – GHG mitigation outcomes (tCO2e)			Year 4 – GHG mitigation outcomes (tCO2e)		
Crops	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level	Default Allocation	Activity level	Product Level
Wheat	0	0	0	0	0	0	14	20	60	16	20	60
Rapeseed	0	0	0	0	0	0	0	0	0	11	39	60
Barley	20	18	20	13	18	40	15	18	59	18	18	59
Sugar beet	0	0	0	27	12	39	30	12	39	35	12	39
Total	**20**	**20**	**20**	**40**	**40**	**40**	**60**	**60**	**60**	**80**	**80**	**80**

Discussion – Risks and Opportunities

The upper limit re-allocation method shares similar risks and opportunities as in section 1. These being:

- Lack of incentives to detail inventory beyond product level.
- Impossibility and/or difficulties to detail further than specific levels.
- Re-allocation is derived from claimant's inventory – uncertainty derived from what the emission factors / inventory is based on.
- Early decarbonization incentive, lower incentive for later stage decarbonization
- Flexibility of claims.

Additionally, in Table 19, there is a lower re-allocation of the GHG mitigation outcomes compared to the default allocation; the first three years sees a lower re-allocation of GHG mitigation outcomes for some crops compared to the default allocation used. Four explanations are offered to clarify the potential cause.

Firstly, this may be a consequence of the choices made for the modelling and the ranges selected for the breakdown of the inventory into activities. An accurate representation of the emissions through an activity level modelling may show that this discrepancy is only due to invalid or inaccurate data.

Secondly, the intervention is not only affecting the fertilization operation but further aspects of the production. As such, the upper limit selected does not consider the appropriate boundaries. Thirdly, the lowered GHG mitigation outcomes to a crop may be a consequence of the use of the same principles for Removals and Reduction. Reductions are intrinsically bound by the emissions generated from the production of a product while, removals may have additional effects that are beyond the boundaries considered to generate the inventory.

Lastly, this could be a direct consequence of the assumption that GHG mitigation outcomes and emissions can be decoupled. Accounting them separately leads to different allocation factors used for these two accounting streams leading to inevitable cases similar to this one.

CONCLUSION AND RECOMMENDATIONS

Re-allocating the GHG mitigation outcomes of an intervention from one co-product to another is possible using any of the solutions presented above. It is our view that the supply shed re-allocation method is of highest credibility. The primary reason for this is the set of safeguards that can control and prevent the over or wrongful use of the approach from either the derivative co-products or crop rotation perspective. Furthermore, it is our view that the set of assumptions that permit the use of this method are best aligned with other foundational approaches in Scope 3 accounting given the challenges presented by a lack of full traceability in most commodity value chains. Table 20 provides an overview of the relative merits and risks of all solutions in respect to both sections.

The methods have safeguards that could prevent from claiming all the GHG mitigation outcomes. The Upper Limit approach only allows investors to claim additional GHG mitigation outcomes until a net-zero threshold up to level selected. This threshold could be frequently hit before reallocating all the remaining GHG mitigation outcomes, only partially solving the stranded asset problem. The supply shed re-allocation necessitates two conditions for being able to reallocate all the GHG mitigation outcomes of an intervention to a single crop. Firstly, the supply shed (or functional supply shed) needs to be big enough to virtually exchange the other crops with the crop of interest. Secondly, the reporting company needs to be able to prove that it sources at least the amount necessary to claim all the GHG mitigation outcomes.

The challenge of stranded assets results from the application of conventional emissions accounting methodologies in a context of a fundamental lack of market liquidity that results from the early stage of development of investments in value chain decarbonization and Scope 3 reporting. This paper has proposed a set of accounting solutions that would incentivize the scaling-up of investments in value chain decarbonization.

We recommend using the supply shed re-allocation method proposed above in the following circumstances:

- Other off-takers sourcing from a specific supply shed (or functional supply shed) are either unknown or the off-takers have no interest in decarbonization efforts.
- The investing company seeking to make a claim is an early adopter of investing in value chain decarbonization within their supply shed.
- The products of interest are of a complex nature either in terms of the number of associated co-products or the number of crops in rotation, with allocation & mass balance factors that would otherwise dissuade investments in decarbonization.

This paper does not recommend using the supply shed re-allocation method when:

- The supply shed has not been appropriately selected and is not in line with the definition provided in the “SustainCERT verification requirements for chain interventions” or another similar text.
- There is no possibility to implement or use a tracking mechanism and registry that accounts for the total claims made.

Future work on the topic of stranded assets should try to explore how other ways of claiming GHG mitigation outcomes: Beyond Value Chain Mitigation (BVCM) could help in solving the problem of stranded assets without impeding the credibility of the claim as well as, understanding how these methods impact accounting when they are applied synchronically to a value chain where both a crop rotation and derivative products are present. These solutions are not designed to be used as a staple method for all future Scope 3 accounting, but as a solution to a specific problem that exists given current market dynamics that can therefore provide a pathway towards fully decarbonized value chains. As such, the authors of this paper would welcome the future guidance of SBTi and Greenhouse Gas Protocol considering the supply shed re-allocation method in future iterations.

Table 20: Summary of the three proposed solutions with respect to the opportunities and risks associated to them. Context specific opportunities or risks are outlined with preface S1 (section 1) or S2 (section 2) if they are only relevant to that context.

Method	Opportunities	Risks
Supply shed re-allocation	• Allows investors to claim up to 100% of GHG mitigation outcomes on a **single co-product or crop**. • Preserves both mass balance & equivalence factor constant at the supply shed & functional supply shed level. • S1 - Aligned on the way LCA treats **multifunctionality**. • **Emissions & GHG mitigation outcome allocation are respected** (increasing product quantity, not over-allocating) • **Flexibility of claims & fitting demand** • Works across multi-layered co-product systems and different crop rotation organization.	• Assumption that co-products or crops are **equivalent based on physical or economic characteristics**. • Dependance on (functional) supply shed size to be larger than the intervention scope to re-allocate otherwise, it follows allocation factors. • Potential problem of traceability, burden of additional documents or proof from **larger supply of product**. • GHG mitigation outcomes are attributed to **production that have not integrated the intervention.**
Upper limit re-allocation	• Simple and flexible • **Concentrates GHG mitigation outcomes** to one co-product • Strong incentive to invest in decarbonizing the value chain. • **Incentive for small scale investment** – Aligned with market-based approach & incentives co-investment opportunities for all types of products.	• Concentrating GHG mitigation outcomes can lead to **non-credible emission factors**. • **Decoupling between emissions and GHG mitigation outcomes** as they are not accounted for in the same way. • **Dependence on Inventory & Emission factors** leading to favor less detailed inventories as more GHG mitigation outcomes would be re-allocated. • Companies do not necessarily have the capacity, possibility, or incentive to **detail Emission factor to less aggregated levels** to use re-allocation.
Investor re-allocation (S1 specific)	• **Provide incentive for investors** to invest in GHG reductions through the possibility of GHG mitigation outcomes to be re-allocated to their products/crop of interest. • **Simple process** of re-allocation based on investor contribution and choice of co-products. • Allows to claim up to 100% of GHG mitigation outcomes on a **single co-product or crop**.	• **Re-allocation controlled by investors**, which can lead to negative emission factors for related products/crop without further safeguards. • When there are multiple investors, re-allocation of GHG mitigation outcomes is **primarily determined by the largest investor** • Mitigation outcomes re-allocated may be lower than mitigation outcomes allocated if multiple investors are present. • **Decoupling between emission and GHG mitigation outcomes** as they are not accounted for in the same way.

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