

Towards a practical method for measuring and improving the sustainability-impact of value chains

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Abstract

To take responsibility for issues such as climate change, biodiversity collapse and poor labor conditions, many organizations have formulated strategic sustainability goals. However, frequently firms find it difficult to operationalize such objectives in their value chain activities. To address this issue, a method coined as Sustainability Impact Value Added Accounting (sivaa) is introduced. Fundamentally, sivaa measures the sustainability impact per unit of products created by adding the impact of all value-adding activities in the value chain while considering the quality of the data available in doing so. As such, sivaa is a governance instrument focused on continuously improving the sustainability impact of the primary processes rather than on external reporting. The starting point for sivaa was a method developed in earlier research, which was subsequently enhanced through literature research, validation with business and controlling students and through interviews with experts. Additional research is needed to further integrate sivaa with existing sustainability reporting and risk management efforts.

Relevance to practice

The findings are that sivaa can be useful in many practical situations because it is fit for purpose and easy to use. Even in cases where only limited or incomplete data are available.

Keywords

Sustainability, controlling, value chain management, data quality, continuous improvement, management accounting

1. Introduction

One of the most pressing issues in contemporary business administration is the need to improve the environmental, social, and governance (ESG) performance of the firm. Whether driven by legal requirements (such as European Union laws like the CSRD and CSDDD), or by contractual obligations towards value chain partners, many organizations are increasingly focusing on sustainability and social responsibility. In other cases, this shift is driven by market demand from customers who seek sustainable and circular products, or by the intrinsic motivation of business leaders and employees to be stewards and contribute to a better world (Koning et al. 2023). As a result, many organizations

have formulated strategic ESG goals to reduce their footprint and demonstrate their commitment to higher social and ethical standards across their global value chains.

The need for sivaa

Unfortunately, despite their good intentions and stated strategic objectives, organizations often struggle with the implementation of initiatives that lead to improved ESG-impact (Mazur-Wierzbicka 2021; Sheehan et al. 2023). One of the reasons why organizations face such difficulties is the belief that these goals can be achieved by

creating an ‘add-on’ to the existing organization, such as a separate ESG department, or assigning specific responsibilities to staff members (Jebe 2019; López-Cabarcos et al. 2025). Examples of such efforts include appointing a sustainable officer, requiring suppliers to hold some ‘sustainability certificates’ or extending the yearly financial reports with sustainability statistics (Müller et al. 2025).

While any such actions can have strong positive effects, in practice these frequently turn out to be more focused on achieving compliance and/or improved risk management rather than fundamentally changing the organization’s sustainability performance as such (Li et al. 2024). Clearly, the objectives of compliance and risk management on the one hand and improvement on the other hand are rather reinforcing each other than contradictory. Nevertheless, it can be observed that making concrete steps towards improvement is not always given priority (Jiang and Han 2025). The starting point of this research therefore was that, to establish a true sustainability impact of value chains, an extra effort or approach would be needed. This approach can be summarized by the slogan “Sustainability is not a department; it is a mindset”.

To bring such a mindset to life, this paper proposes to connect the objectives of achieving a more sustainable organization directly to the work floor by providing the management and the value adding (primary) processes with a ‘common language’ (King and Cohen 2023). This paper introduces a practical method that can be used by operations, and process- or value chain managers to measure and improve the impact of sustainability efforts. This method has been coined ‘*Sustainability Impact Value Added Accounting*’ or *sivaa*.

Management accounting

Within *sivaa* the word ‘accounting’ relates to ‘to account for’; to measure and improve and to hold people ‘accountable’ for their behavior (Holmes et al. 2012). The *sivaa*-method is

designed as a managerial tool to steer sustainability impact across the entire value chain. While it builds on established carbon accounting standards – most notably the Greenhouse Gas Protocol and its Scope 1, 2, and 3 structure – it departs from their compliance-oriented logic.

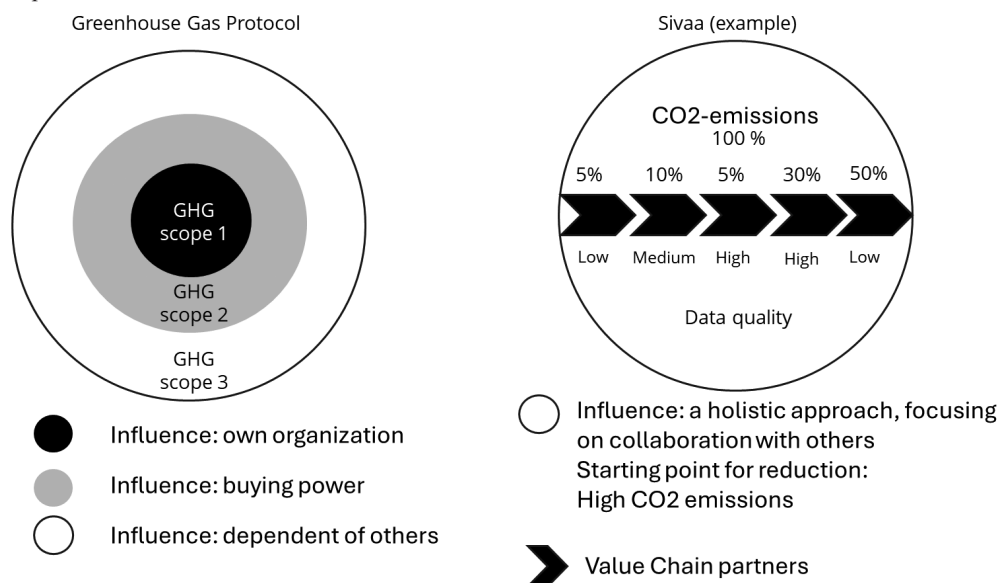
Rather than organizing emissions into reporting silos based on organizational boundaries, *sivaa* adopts a chain-oriented perspective. The central question is not which emissions fall under direct control, but where interventions in the value chain can generate the greatest and fastest impact. Although it uses existing emission factors and conversion methodologies, it does not seek disclosure-grade precision. Instead, it prioritizes decision relevance: identifying impact hotspots, directing improvement efforts, and strategically enhancing data quality where the largest reductions can be achieved, see Figure 1.

Compliance with CSRD, CSDDD and other directives is important and can be a major step for any firm towards ESG-related efforts. However, a practical instrument for continuous improvement seems to be lacking. Although the *sivaa*-method can fill this gap, it is important to understand that it primarily functions as a managerial steering instrument, not as an external reporting framework. It complements regulatory requirements such as the CSRD and the CSDDD, but its core purpose is to enable systemic improvement rather than compliance-driven disclosure.

ESG

In terms of ESG, *sivaa* can be considered as a governance tool. Under *sivaa*, data are collected to facilitate better decision making, i.e., it provides the necessary steering information for the organization and in fact the entire value chain to enhance the (ecological and social) sustainability performance. The tool has been presented as a means of support for improving the performance of the entire value chain with limited data. This supports the organization’s prioritization of focusing on issues that are

Figure 1. GHG protocol versus *sivaa*.



within its sphere of influence and on issues that are most important. Although reports can be used to supplement *sivaa* and inform the selection of appropriate CO₂ reduction actions, obtaining assurance is not the main goal of *sivaa*. Rather, *sivaa* can be seen as the starting point for collaboration in the value chain. It can expose the state of any chosen ESG-related datapoint in the value chain. Imperfect data is as relevant as perfect data, as it can shift the focus to action.

Leading principles

In designing the *sivaa*-method, several principles were leading:

- 1) following the flow of products through the end-to-end value chain and using a value-add approach for calculating sustainability performance;
- 2) allowing professionals to focus on their own value-adding steps so to jointly get insights in, and steering information for, managing the entire value chain;
- 3) finding improvement as a focus point next to, or in addition to, compliance and risk management; and
- 4) allowing for incomplete data as to ensure practical usability rather than exact reporting.

These principles will be further discussed in Section 3.

Paper structure

The remainder of this paper is organized as follows. The next section outlines the key drivers that motivate organizations to map their sustainability performance. Section 3 explains the *sivaa*-method, while section 4 discusses its validation based on discussions with several groups of potential users. The conclusions are presented in section 5.

2. Background – the need for sustainability performance measurement

In this section, a (literature) review is provided for the reasons for organizations (and value chains) to jointly map their sustainability data. Basically, there are three triggers for this, namely legal, value chain strategy and market demand. Below, the fundamentals of each of these three triggers are briefly reviewed.

2.1. Trigger 1: legal

The European Union is actively engaged in building an expansive and interconnected regulatory framework aimed at advancing sustainability, transparency, and accountability throughout value chains. This regulatory framework comprises multiple legislative pillars, spanning reporting (Corporate Sustainability Reporting Directive,

CSRD), due diligence (Corporate Sustainability Due Diligence Directive, CSDDD), market instruments (EU Emission Trade System, ETS), Carbon Border Adjustment Mechanism, CBAM), and product policy (Circular Economy Act, Eco-design requirements for sustainable products in the Ecodesign for Sustainable Products Regulation, ESPR, requirements for timber in the European Union Timber Regulation, EUTR) (Koning et al. 2023). Together, these instruments serve as major catalysts for increasing the availability of data within value chains.

While the CSRD imposes these requirements through reporting standards, their implications extend to governance structures and strategic planning, requiring a deep operationalization of ESG across the entire value chain (Vălcu and Spătaru-Negură 2025). The CSDDD (European Parliament & Council of the European Union 2024) and the CSRD partially overlap, as both instruments address broadly the same ESG components. However, the CSDDD focuses more specifically on identifying certain ESG-related risks, ensuring that these risks are mitigated, and that adverse impacts are effectively addressed. The CSDDD is strongly inspired by the OECD Guidelines for Multinational Enterprises (OECD 2023), although it differs in certain aspects of design and scope (Enneking 2022).

While ongoing geopolitical turbulence has exerted considerable pressure on the EU's sustainability policy and legislative initiatives, as demonstrated by the EU Omnibus proposal (European Commission 2024), which seeks to moderate both the scope and the implementation timeline of these regulations, the underlying rationale for data visibility in value chains remains fundamentally unchanged. Firstly, a number of companies remain subject to reporting requirements or will be in the near future, underscoring the urgency of preparing internal systems and value chain interfaces for compliance. In the wake of mitigating the consequences for small and medium sized companies (SME), the European Commission proposed Voluntary Sustainability Standards for SMEs, the VSME (EFRAG 2024).

Secondly, the climate crisis and broader sustainability concerns remain pressing, regardless of shifting political sentiment – a sentiment that could easily reverse. The EU Omnibus package, moreover, was not received without criticism (Bertram 2025; Business & Human Rights Resource Centre 2025) Thirdly, reputation, brand value, and the increasing scrutiny of investors and consumers have driven companies to incorporate contractual sustainability commitments (ESG clauses) into their operations (Olmos Giupponi and Figueroa 2024). In other words, many companies already operate within value chains governed by such contractual sustainability obligations, which remain binding regardless of temporary legislative delays.

2.2. Trigger 2: value chain strategy

Typically, any organization has a strategy to achieve its mission or purpose where the strategy is needed to get a clear focus (what value do I want to bring to which

type of customers), differentiation (how can I achieve a competitive advantage), alignment (creating a consistent pattern of decisions throughout the organization) and priority setting (what inevitable choices are needed), cf., Whittington et al. (2023). Within organizations, the business strategy is translated into functional strategies such as financial strategy, marketing strategy, and value chain strategy (Van der Veen and Van Buren 2021).

Key performance objectives

Value chain strategy evolves around six key performance objectives, namely:

- Cost
- Quality
- Dependability/Reliability
- Speed
- Flexibility/Agility
- Sustainability

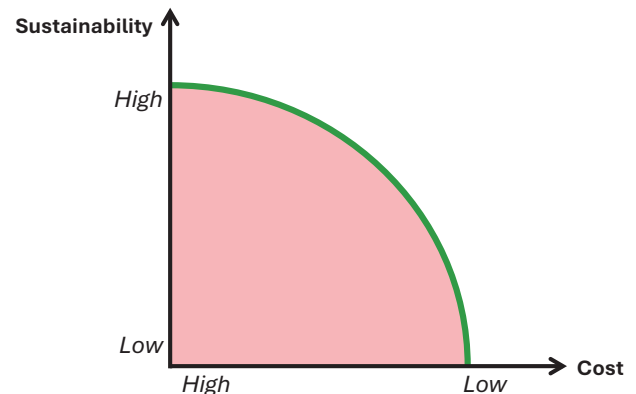
Where the first five of these have a long tradition (Slack et al. 2024), the sustainability performance objective is relatively new. The reason why these are considered as ‘key performance objectives’ is that in any firm, either in production or in service, either in private or in public governance and either in commercial or social enterprises, the six performance objectives are always of interest; no firm wants higher cost than necessary, everybody aims for good quality, serving customers just-in-time is always desirable, etc.

Unfortunately, the six key performance objectives cannot be achieved all together at the same time; there are inevitable trade-offs between each of these. A firm that wants to do particularly good on flexibility by offering customer-specific products at the time and place that the customer demands these, inevitably has higher Cost, and will have a harder time doing well on Reliability than a firm that offers standardized products at prespecified locations. A firm that wants to excel in Sustainability by reusing materials might face higher Cost and/or lower Quality. It is important to note that such trade-offs are not always needed; at some efforts there is a synergy between the objectives rather than a trade-off (Van der Veen and Venugopal 2013). For example, up to some point, Quality and Cost can be jointly achieved; if fewer mistakes are made then there is no cost to fix such mistakes so that the performance on both Cost and Quality is better. Likewise, if a transportation firm designs better routes for its vehicles, the travel distances might go down so that less fuel is needed which is good for both Cost and Sustainability.

To distinguish between where performance objectives can go hand-in-hand (synergy) and where these are conflicting (trade-offs), the concept of ‘effective frontier’ borrowed from Slack et al. (2024) can be used, see Figure 2. When the organization is positioned underneath the frontier then a synergy between the performance objectives is possible. It is therefore a key task of any firm to ensure

that they are not underneath the frontier (the red area); if so, they are performing ineffectively. The next, and more important, issue is to determine the desired place on the frontier (the green line); this choice is determined by the value chain strategy. Very simply put, the value chain strategy is determining how to make the trade-off on each of the six key performance objectives. Some firms aspire to always fulfill the latest customer-wishes and would set Flexibility high on their priority list. Others are price fighters, and these would focus on Cost. Social enterprises typically have Sustainability highly ranked.

Figure 2. Trade-off curve between cost and sustainability.



It is important to note that the value chain strategy drives decisions. For example, a firm might contemplate whether to replace its current supplier with one that can offer more sustainable products, yet for a higher price. Given the six key performance objectives, one decision is not superior to the other. It is the mutual priority and/or weighing of the six performance objectives, i.e., the value chain strategy, which determines what is best for the firm.

No matter what the value chain strategy is, firms need to have a clear understanding of the impacts of any of their decisions on their performance on each of the six key performance objectives and of the possible trade-offs between these performance objectives. In practice, all firms are well aware of their cost and have created key performance indicators (KPIs) for most of their other important performance objectives. However, as mentioned, sustainability has only recently been added to their strategic objectives so that value chain KPIs on this dimension are not quite common yet. It is here where *sivaa* can be useful. The insights gathered through *sivaa* data can be used within the firm's primary processes to make sure that decisions are in line with the formulated value chain strategy. In conclusion, through *sivaa* the organization may collect and use sustainability data in their operations so to be better able to fulfill their value chain strategy.

2.3. Trigger 3: market demand for sustainable products

One of the reasons to enhance sustainability in value chain processes is that consumers appreciate products and services that are produced in an ‘honest’ way without

leaving a substantial footprint (Camilleri et al. 2023). As companies aim to create customer value, offering sustainable products may be one way of competing in the marketplace (Oduro and Haylemariam 2025). Clearly, upon their purchasing decisions, consumers are not only looking for sustainability; many other factors are considered both in terms of the product-features such as quality, usability, availability, and brand as well as in terms of consumer characteristics including income, demographics, and social norms. To describe the added value of sustainable products compared to their traditional counterparts, the term willingness-to-pay (WTP) is frequently used. Although consumers typically have at least some WTP for sustainable products, the percentage varies largely between customer groups and between products/services, i.e., the WTP per product-market combination fluctuates heavily (Li and Kallas 2021; Sanghvi et al. 2025; Sindhu et al. 2025).

3. The sivaa-method

In the development of sivaa, a design science-methodology was used. In this form of research, a design is constructed based on literature, which is subsequently validated and adapted on the basis of the data collected about it (Wieringa 2014). Based on a design substantiated by literature, two rounds of practical validation were conducted in an educational setting with professionals from

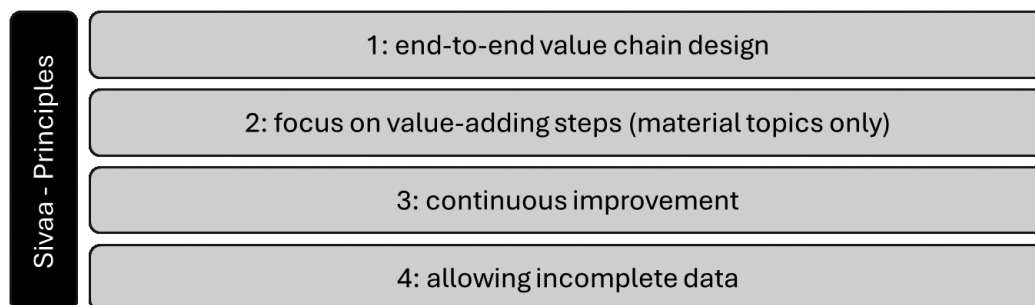
are not (yet) recorded in the organization's operational systems. In the past, various forms of data quality assessment have been experimented with. Given the need for practical support in creating insight, the first version of the model opted for a quite simple and pragmatic method of assessment (Cappiello et al. 2018).

The origin of what is now presented as sivaa was primarily developed to assess CO₂ emissions across the value chain, employing a stepwise approach and calculations weighted by data quality (Wagter et al. 2021). Next, a beta version (named 'carbon added accounting') was further developed through a trial conducted within a value chain for beer producers (Keetman et al. 2020). This beta version served as the starting point for our research. Subsequently, we generalized the original ideas – initially focused on carbon accounting – into a broader, generic approach, which was then refined through several iterative rounds.

Conceptually, sivaa can be regarded as complementary to the conventional accounting system: whereas financial accounting records transactions in monetary units, sivaa integrates steering information related to people (social value) and the planet (ecological value). Examples include remuneration, labor conditions, CO₂ emissions, and water consumption.

Figure 3 shows the four basic underlying design principles of sivaa, which were outlined at the outset, will be discussed in some detail after which the basic steps of the sivaa-method will be described through an example.

Figure 3. Sivaa principles.



the business community, followed by a validation round conducted with experts. After the first round of validation, the design was slightly modified to refine the model in the second round of validation. The sivaa-method is based on a combination of the supply chain methodology of a life cycle assessment and the approach of analyzing data quality. A product, process or human activity's overall environmental impacts are captured by an analytical tool known as Life Cycle Assessment, or LCA. This tool looks at every stage of a product's life, from the procurement of raw materials through to production, use and waste management (Curran 2013). The list of new regulations requires a large amount of additional non-financial information in order to gain insight into whether the organization is compliant or to be able to explain its performance to stakeholders. In many situations, these data

3.1. Principle 1: following the flow of products through the end-to-end value chain

The first principle stems from the aim to place the process of value creation at the core of sivaa's analytical framework. It seeks to identify which activities contribute to value generation and to assess the sustainability effects associated with these activities. These effects – referred to as 'impact' – may encompass both social and ecological dimensions.

It can be noted that this principle implies that the method enables greater transparency regarding the sustainability performance of any given product or service. Ideally, any end-user considering the purchase of a product or service would not only see its price but also the extent to which social and/or ecological standards are

met. For example, this could include information on how much water was used in producing the product, the CO₂ emissions generated throughout the value chain, and the degree of assurance that no forced labor participated in its creation. The term ‘(digital) product passport’ is frequently associated with this line of thinking (Zhang and Seuring 2024).

3.2. Principle 2: allowing professionals to focus on their own value-adding steps

The second principle aims to prioritize the process of determining which activities contribute to value generation and to assess the sustainability effects associated with these activities. In this, *sivaa* resembles the idea of VAT (Value Added Tax), where each entity in the value chain pays tax only on the value added. Similarly, *sivaa* determines the sustainability effects for their added value. To improve sustainability performance, ideally all entities across the end-to-end value chain should jointly monitor their key performance measures. However, in practice, such an approach is often not feasible. There are simply too many organizations involved, dispersed across the globe, and participating in a multitude of different value chains.

To counter this challenge, a value-adding approach is taken. The entire value chain is split up into ‘product + transport units’ (PTUs). Within each of these PTU-building blocks, the manager responsible can first obtain the information per product unit about the sustainability impact of the purchased materials (e.g., CO₂ emissions or water usage) obtained from the supplier and add to this the entity’s own sustainability impact from the transformation process. Added to this is the transportation of the products between the units. This information can be shared with the PTU’s customers so that these can do the same for their own PTU. By combining the information gathered in all PTUs, the sustainability impact of the final product can be distilled easily.

Figure 4 presents an example of a value chain for dairy desserts such as fruit yogurt. Next to energy, a manufacturer of such products relies primarily on three key inputs/

ingredients: milk (supplied by dairy farmers), fruit (by growers), and packaging materials (by a packaging producer). The manufacturers supply the finished products to a retailer, who subsequently sells them to consumers. In the figure, the yellow rectangles represent value-adding activities, while the red arrows indicate transport flows. The dashed boxes denote the PTUs. The blue arrows represent *hand-offs*, illustrating the flow of products throughout the value chain.

3.3. Principle 3: focus on continuous improvements

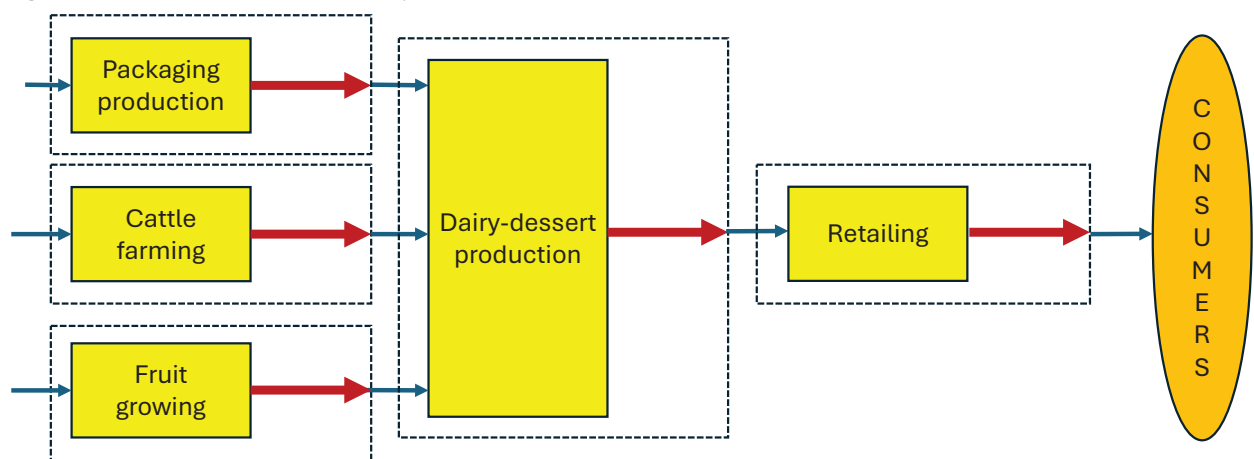
It is important to note that *sivaa* does not have the immediate goal of reporting to external bodies, i.e., it is not per se a financial accounting instrument. Rather, it is a tool that can be used on the work floor in the primary processes following the Plan-Do-Check-Act improvement cycle. Especially, the instrument provides the necessary data for ‘Check’ and can be instrumental in finding ways to ‘Act’, i.e., through *sivaa* the organization and in fact all value chain entities can get the necessary steering information to make informed decisions on where to focus the sustainability improvement efforts.

3.4. Principle 4: allowing for incomplete data

One of the more pressing issues in sustainability impact improvement is the lack of reliable data. Recognizing that impact data can vary significantly in reliability and completeness, a unique feature of *sivaa* is that it not only reports on the sustainability level achieved but, also provides an indicator of the quality of the data on which this outcome is based. *Sivaa* thereto, distinguishes between four different data quality labels:

- Bronze: based on estimates or assumptions (e.g., averages);
- Silver: combines verified data with assumptions;
- Gold: based primarily on empirical data, with limited uncertainty;
- Diamond: derived from robust, verifiable, preferably real-time data sources.

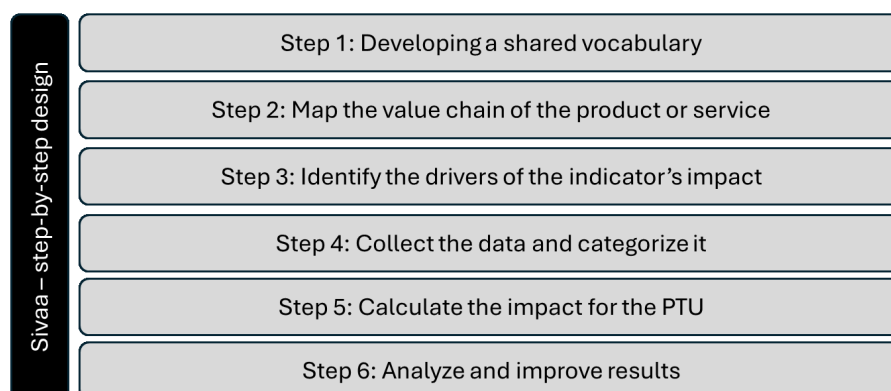
Figure 4. PTUs in the value chain of dairy desserts.



The richer the label, the more accurate and precise the sustainability data are. The underlying logic is that, on the one hand, using ‘poor’ data is better than not having any data at all, while on the other hand, before making radical improvement decisions, the sensitivity of the data should be considered. At the same time, this stratification in data quality labels brings transparency to the value chain regarding the robustness of information. It enables organizations to target improvements in data quality over time. The fact that any company in the value chain, regardless of its position, can begin to develop insight is essential.

Note that according to this principle, the data do not necessarily have to be measured directly. When drawing a comparison with the data categorization used in the Greenhouse Gas Protocol (GHG), it becomes clear that within siva, not all data are required to be ‘primary’ (data provided by suppliers or others that directly relate to specific activities in the reporting company’s value chain). The method is designed to allow organizations to start with secondary data (industry-average-data, e.g., from published databases, government statistics, literature studies, and industry associations, financial data, proxy data, and other generic data), (Greenhouse Gas Protocol 2013). In cases where the need is greatest, or when a company’s strategy calls for intervention, it can then be assessed whether a transition from secondary to primary data is feasible. In Figure 5 the process of applying siva will be explained in six steps.

Figure 5. Step-by-step siva design.



Siva step 1: developing a shared vocabulary

Developing a shared vocabulary is a critical first step. For some impact areas or KPIs, this is easier than for others. When comparing the different ESG parameters, establishing such a shared vocabulary (or achieving standardization) is generally more straightforward for the ‘hard’ KPIs (often found in the ‘E-category’) than for the less tangible performances in the ‘S-category’.

Within the E-component, for instance, CO₂ emissions represent one of the most widely recognized and standardized indicators. This prominence is well justified: CO₂ serves as a global common denominator for climate impact. As within several protocols, emissions are linked closely to energy consumption, transportation, production, and consumption-patterns, they provide a robust measure of

environmental burden. To this end, a well-established framework for CO₂ measurement has long existed: the Greenhouse Gas Protocol (GHG Protocol). This protocol offers a globally accepted standard for quantifying and reporting greenhouse gas emissions in a consistent and comparable manner.

The GHG Protocol delineates emissions across three categories, referred to as scopes:

- Scope 1: direct emissions, such as the combustion of fuel in company-owned facilities or vehicles.
- Scope 2: indirect emissions from purchased energy, such as electricity or district heating.
- Scope 3: other indirect emissions occurring along the value chain, including transport, purchased materials, and product use by end users.

The calculation method is straightforward: activity data (e.g., liters of fuel, kilometers driven, kilowatt-hours consumed) are multiplied by scientifically validated emission factors that quantify the CO₂ (or CO₂-equivalent gases such as methane or nitrous oxide) released per unit of activity. The result is a quantifiable tonnage of CO₂ that can be attributed to specific processes, products, or value chain segments.

The strength of CO₂ measurement lies in its well-established system, shared terminology, and reliable datasets. The GHG Protocol demonstrates how environmental impact can be quantified in a standardized manner. It

serves as an important conceptual precedent for frameworks such as siva, which seek to apply a similar degree of rigor to other non-financial domains, including human rights, living wages, and biodiversity.

A growing number of tools and standards have emerged to measure social and ecological impact. Examples include international human rights conventions, LTIR (Lost Time Injury Rate), LCA (Life Cycle Assessment), sustainability reporting frameworks, the OECD Guidelines, and recent European regulations such as the CSRD (ESRS), CSDDD, EUTR, and the EU Circular Economy Action Plan. These frameworks provide a valuable foundation for determining what should be measured with respect to social and environmental performance, and where within the value chain these measurements should occur.

Unlike CO₂ emissions, however, the quantification of social parameters – such as fair wages or safe working conditions – remains methodologically complex. This complexity arises primarily from the lack of universally accepted objective measures for such variables, comparable to financial accounting standards. Consequently, establishing shared definitions and metrics in collaboration with value chain partners is essential. Agreement must be reached on what constitutes a particular social value, which indicators are appropriate, and which reference standards or data sources are to be employed.

Once all actors within the value chain ascribe consistent meaning to terms such as ‘living wage’ or ‘decent working conditions,’ the exchange, comparison, and improvement of information become feasible. This collective effort lays the groundwork for rendering non-financial impacts visible and comparable – even in those domains that remain difficult to quantify today. Below, an example on CO₂ emissions will be provided. To demonstrate how other sustainability dimensions can be included, we refer to two worked-out examples in the appendix.

Sivaa step 2: map the value chain of the product or service

The value chain comprises all relevant organizations involved throughout the entire life cycle of a product – from raw material to end customer. The level of detail at which this mapping is conducted is at the discretion of the user and depends on the degree of insight the organizations in the value chain currently possess.

The chain is subsequently divided into PTUs, see Figure 4 and the appendix for examples. The primary process of each organization within the chain is to produce products and/or services that generate value for its direct customers. To do so, the organization procures various inputs such as raw materials, components, IT services, and facilities. The company then uses these inputs to create its products which are delivered to its customers.

The sivaa-method utilizes data from suppliers regarding the products they deliver to the organization. Using these data, combined with information on its own production and transport activities, the company calculates the impact per product and provides these results to its customer. When all actors in the value chain operate in this manner, it becomes possible to determine the overall impact of the final product delivered to the consumer.

Within each PTU, we aim to determine the impact based on the value chain up to and including that PTU. This means that all preceding links in the chain are considered. By starting upstream and then performing the calculation step by step for each PTU, it can then be ultimately determined what the impact of the combined efforts throughout the entire value chain is when the product reaches the consumer.

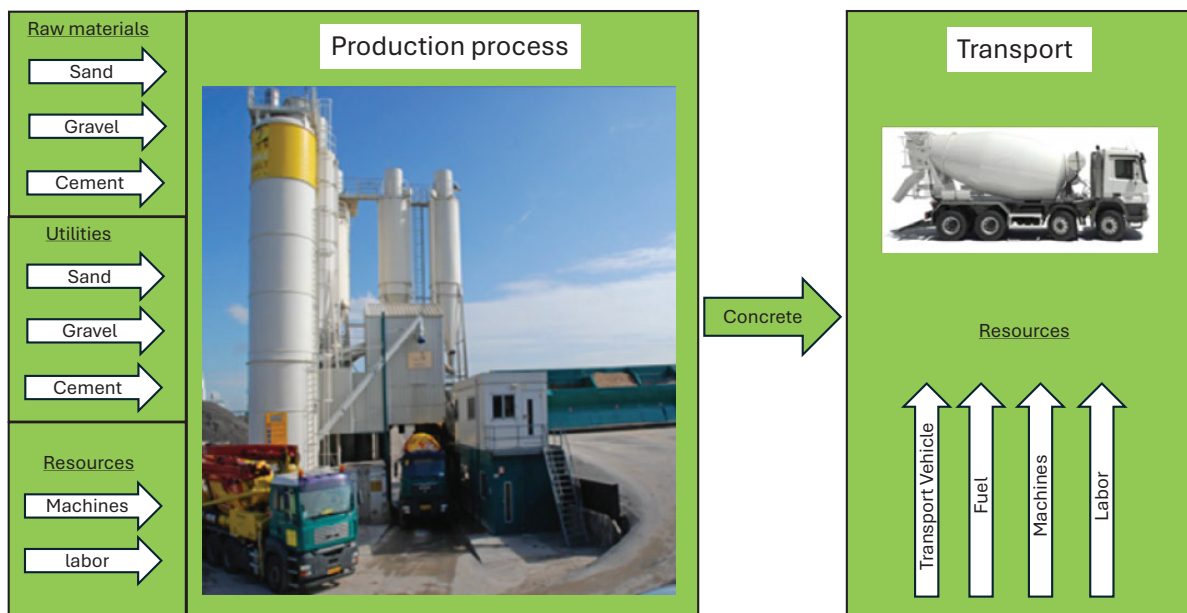
Sivaa step 3: identify the drivers of the indicator's impact

The main calculations take place within a PTU; it uses as input the impacts from all three scopes, including the impact values of all relevant suppliers. The output of this calculation consists of the impact value of the PTU (distributed across the four data quality categories), which then serves as input for the calculation of the PTU in the next link of the value chain.

The process explained above can be illustrated with an example. Suppose we want to determine the CO₂ emissions of a concrete manufacturer. More specifically, let us assume that the goal is to calculate the CO₂ impact of producing and transporting 1,750 kilograms of concrete by this producer to its customer.

Producing concrete requires several raw materials, such as sand, gravel, and cement. In addition, machinery, labor, and energy are required. These raw materials, energy, and other resources constitute the main drivers of CO₂ emissions in production. A similar logic applies to transport, where the primary drivers are fuel, trucks, and drivers. These drivers are illustrated in Figure 6.

Figure 6. Drivers of CO₂ emissions in a PTU for the production and transport of concrete.



Sivaa step 4: collect and organize the data

Once the main drivers have been identified, the relevant data must be collected. A sizable portion of these data must be provided by suppliers, while other data originate from the organization's own operations. Clearly, such data are not always immediately available, and not all information is equally dependable. Uncertainty may arise from unclear definitions or other sources of variability. For this reason, *sivaa* employs four data quality categories: the lower the category, the less dependable the data.

Table 1 (production) and Table 2 (transport) together provide an example related to concrete production.

In Table 1 and Table 2, the red numbers represent the collected sustainability data. For example, the production of one cubic meter of sand results in a total of 2,420 grams of CO₂ emissions, of which 1,900 grams are classified as bronze data quality and 520 grams as silver data quality.

It can be observed that it is not always possible to obtain all values directly. For instance, when transport is conducted by third parties, collecting accurate data can be challenging. In such cases, estimates may be used. Naturally, internally generated estimates are considered to have a lower level of data quality, but having some

information is better than none. Where necessary or desirable, more precise data can be obtained through further investigation at a later stage.

Sivaa step 5: calculate the impact for the PTU

Based on the collected information, the impact for the PTU can now be calculated. Again, this can be illustrated using the concrete manufacturer example. Tables 3, 4, and 5 show the calculated impact of concrete production and transport.

In the third column (red figures) of Table 3, the 'bill of materials' is shown – that is, the quantity of each driver required to produce a batch of 1,750 kilograms of concrete. For example, this batch requires half a cubic meter of sand and 100 kilowatt-hours of electricity. These quantities are multiplied by the CO₂ emissions per unit, as shown in Table 1, to calculate the emissions per ton of concrete; the resulting values are displayed in green in the last row of Table 3. A similar calculation can be performed for transport using the data from Table 2; see Table 4.

By summing the data from Tables 3, 4, the sustainability impact within the PTU per unit (in this case, CO₂ emissions per ton of concrete) can be determined; see Table 5.

Table 1. Drivers of CO₂ emissions in a PTU for the production of concrete.

Accounting Category	Specified	Per	CO ₂ (grams) per CF class				
			Bronze	Silver	Gold	Diamond	Total
Raw materials	Sand	m ³	1,900	520			2,420
Raw materials	Gravel	m ³	2,067	233			2,300
Raw materials	Cement	kg	583	168			751
Utilities	Water	m ³	260				260
Utilities	Gas	m ³				1,884	1,884
Utilities	Electricity	Kwh				405	405
Labor	Labor	hr			800		800
Machines & Materials	Machines	not specified					
Machines & Materials	Materials	not specified					

Table 2. Data on the transport of concrete.

Accounting Category	Specified	Per	CO ₂ (grams) per CF class				
			Bronze	Silver	Gold	Diamond	Total
Machines & Materials	Transport vehicle	not specified					
Machines & Materials	Fuel	liter				3.2	3.2

Table 3. CO₂ emissions from concrete production.

Specified	Per	Needed for 1750 kg	CO ₂ (grams) per CF class				
			Bronze	Silver	Gold	Diamond	Total
Sand	m ³	0.5	950	260	0	0	1,210
Gravel	m ³	0.75	1,550	175	0	0	1,725
Cement	kg	325	189,475	54,600	0	0	244,075
Water	m ³	0.16	42	0	0	0	42
Gas	m ³	1	0	0	0	1,884	1,884
Electricity	Kwh	100	0	0	0	40,500	40,500
Labor	hr	0.75	0	0	600	0	600
Machines	not specified	N/A					
Materials	not specified	N/A					
Total			192,017	55,035	600	42,384	290,036
Per ton concrete			109,724	31,448	343	24,219	165,735

Table 4. CO₂ emissions from the transport of concrete.

Specified	Per	Needed for 1000 kg	CO ₂ (grams) per CF class				Total
			Bronze	Silver	Gold	Diamond	
Transport vehicle	not specified		0	0	0	0	0
Fuel	liter	10	0	0	0	32	32
		Total	0	0	0	32	32
		Per ton concrete	0	0	0	32	32

Table 5. CO₂ emissions from the production and transport of concrete.

per ton concrete	CO ₂ (grams) per CF class				
	Needed for 1000 kg	Bronze	Silver	Gold	Diamond
Production	109,724	31,448	343	24,219	165,735
Transport	0	0	0	32	32
Total	109,724	31,448	343	24,251	165,767
Data quality					
Percentage	66%	19%	0%	15%	100%

From Table 5, the main conclusions of the calculation exercise can be drawn. First, the CO₂ emissions amount to 166.767 kilograms per ton of concrete. The sivaa-method additionally provides information on the reliability of this calculated outcome. For instance, some 66% (namely 109,724/165,767) of these CO₂ emissions are to be classified under the lowest data quality category (bronze), i.e., the number of almost 167 kg CO₂ should be taken with considerable caution. The data from Table 5 can then be passed on to the direct customer; the next link in the value chain. This transfer includes not only the total value of 166 kg CO₂ but also the breakdown across data quality categories. In this way, the next link in the chain gains insight into the reliability of the impact data.

Sivaa step 6: analyze and improve the results

The insights obtained from calculating the sustainability impact are only the starting point. The principle of ‘measure, understand, improve’ applies. Based on the information collected, it is possible to identify where improvements are feasible or desirable. It becomes clear where the greatest sustainability impacts occur and where the largest uncertainties in the data exist. This can serve as a starting point for improvements, both in the primary process itself and in enhancing data quality.

While the sivaa instrument was initially developed using a conceptual approach for measuring CO₂-impact and further developed through a case study for Beer production (Keetman et al. 2020), in this research it was further developed to create a governance instrument for sustainability impact throughout the value chain. Some examples are provided in the Appendix 1.

4. Validation of the sivaa model

The step-by-step sivaa-method was developed on the basis of literature research using various models. Two groups

of users were identified for the validation of the design: (1) management who have to evaluate and improve performance on the basis of data, and (2) controllers who collect data to support decision-making in organizations. These two groups of users were surveyed in an educational setting where 18 experienced management professionals who are also students in a modular MBA program, and 30 controllers, i.e., financial professionals who are doing an executive program at the university, were questioned about this in a presentation and exercise. This was followed by a discussion and a questionnaire. Prior to this, all participants were asked for their consent to include the discussion and questionnaires in this academic study. They had the option to withdraw from the discussion without consequences, and ethical consent was requested in advance for this method of data collection. A report was made of the findings per group which were submitted for feedback. First, the group of MBA students was questioned, after which a few adjustments were made to clarify the sivaa-method, and then the method was discussed with the controller students. The results of the data sources (discussion, questionnaires) were discussed and analyzed by the three researchers involved in this study. The outcomes of this analysis were presented to the participants for correct interpretation. The result is the design presented in this paper.

4.1. Validation from management perspective

Overall, participants expressed a positive view of applicability of the sivaa-method. However, they also noted that an underlying question is why companies would want to apply the method (is it financially motivated, driven by regulation, or intrinsically motivated?). It was observed that applying sivaa in practice can be a significant challenge, particularly for organizations that are not already actively engaged in sustainability. The method was described as ‘quick & dirty’: it does not need to be perfect, but it helps to get started, learn where the focus areas are, and initiate the conversation.

One participant remarked that the sivaa approach can be compared to more classical risk analysis, where it is often more effective to start efforts in high-risk areas. By doing so, a significant part of the impact can be mapped with relatively little effort, and this principle applies to the sivaa instrument as well.

Several participants noted that it can be difficult to determine where to begin with sivaa. Questions raised include: which party in the value chain should initiate this? How many FTEs will be required to map everything?

Is this suitable for small and medium-sized enterprises (SMEs) that have limited capacity and knowledge? Regarding the latter question, it was suggested that support from industry organizations could be helpful.

The general impression was that the sivaamethod provides organizations with the ability to better compare suppliers and identify where the greatest emissions occur. This can provide insight into potential improvement areas and serve as a basis for targeted actions. At the same time, some participants expressed concern that there is a risk the sivaamethod could be used as a checklist, emphasizing data collection over achieving actual improvements. It was stated that the strength of sivaamethod does not lie in data-precision but in the insights that lead to reduced environmental impact.

Participants noted that a key aspect of the method is collaboration with value chain partners. In their experience, some companies are pressured by their customers to become more sustainable, which in turn requires their suppliers to follow suit. This requires intensive coordination, especially since organizations often work with a large number of suppliers. It was noted that not all suppliers are ready to participate. A suggested solution to this issue was to not involve everyone immediately, but to start with the most important suppliers or the largest emitters.

Participants also found it challenging to be transparent. Some noted that there can be an unequal power dynamic, particularly upstream in the chain (where many smaller companies operate), which can create a sense of being pressured. It was further noted that the data provided by suppliers does not always reflect the underlying data. For that, one would need to look ‘under the hood’. It was also mentioned that companies must be willing to make choices and be ‘open’ for feedback (possibly on ‘poor’ performance) themselves. Participants stated that it is often ‘difficult’ to substantiate the data because there is a fear of being held accountable for these. Therefore, it must be clear what the method is used for: not for accountability, but rather for improvement purposes.

Several participants noted that determining the scope within the value chain is often challenging. It is not always clear where the chain begins or ends, for example, in the case of purchases through auctions where products are only registered by type and quantity. This results in a lack of detailed information and raises the question of who in the chain should take the initiative.

A frequently mentioned area for improvement is tooling and user guidance. The method should be combined with existing data insights or systems. Ideally, standards should be made centrally available.

4.2. Validation from controllers’ perspective

Overall, the participating controllers were fairly positive about the sivaamethod. A noted advantage of the method is that the sivaamethod appears logical and straightforward, making it easy to apply. Participants sometimes experienced a somewhat resistant reaction when dealing with

(particularly non-financial) reporting: the tendency to first discuss or define terms in considerable detail. The strength of this method is that such discussions are less necessary.

It was noted that sivaamethod can be a useful tool for conducting a cost-benefit analysis aimed at improving sustainability and serves to identify areas where data quality can be improved. The method can facilitate discussions both internally within an organization and across the entire value chain.

In the group of controllers, it emerged that participants currently involved in collecting ESG data referred to the application of sivaamethod in obtaining internal commitment and setting up internal processes and systems. Various data sources depend on off-balance sheet accounting registration, and the sivaamethod provides a place to connect such data with more robust data that does exist in systems. In addition to the supporting role of sivaamethod in registering non-financial data, the participant referred to the internal support for collecting these data and the still limited guidance on this within the organization. It is precisely in building this support, facilitating discussion, and working together to achieve improvement that the sivaamethod can be easily accessible. Small improvements can be made visible, and successes can be reported.

For companies that are already advanced in sustainability reporting, some participants noted that the method may be ‘too simple’. However, for companies just beginning to map ESG components in their value chain, the sivaamethod could be a suitable instrument.

Although participants described the method as useful, they also found it ‘challenging’. This challenge is threefold:

- 1) It relates to the transparency that the method provides in the value chain. The data could possibly reveal that the organization performs less well compared to its chain partners.
- 2) There may be uncertainty about what a request to apply the method means for the company itself (e.g., implications for oneself and colleagues).
- 3) There was a guidance issue because the data are not precise. If an imprecise outcome indicates a ‘good’ result, there is a risk that the ‘incorrect decision’ could be made to not act upon it.

Financial professionals within organizations reported that there is a challenge to ensure that the sivaamethod calculation itself is not seen as the ultimate goal; all stakeholders must understand that the purpose is to initiate discussions in the value chain based on the results of the calculation, not the calculation itself. For companies that are more advanced in sustainability reporting on CO₂, a connection to the European Reporting Standards (ESRS) is logical. Additionally, companies would benefit from further standardization of certain data or from tools to facilitate the application of the method.

Participants view sivaamethod as a good opportunity to map the value chain and build a common language for Scope 3. Obtaining data was identified as the main concern, followed by data quality.

Finding relevant data to support ESG-compliance and improvement is a challenging issue in practice. Financial professionals often want figures to be as precise as possible. Letting go of this need for precision may be the biggest challenge when applying *sivaa* within Finance; after all, the aim is not precise sustainability reporting, but a method focused on mapping the main trends to collaboratively work on improvements.

Several participants expressed concerns about data reliability. While it is possible to guide sustainability improvements based on broad trends, questions remain about whether the ‘correct’ direction is being pursued. Moreover, participants indicated that the method allows too much room for discussion. While the logic behind *sivaa* is generally understood, the collection and assessment of data must be harmonized to achieve a credible and widely supported outcome. This also prevents discussions from getting stuck in methodological debates rather than addressing the actual issues at hand. Clarity is required regarding how a specific data quality rating (bronze, silver, gold, diamond) is assigned; for example: when is data considered ‘silver’ versus ‘gold’?

Participants indicated that obtaining data is considered the most challenging aspect, even more so than data quality. It was noted that there can be a certain level of fear or embarrassment within the chain (figures can take on a life of their own, and relative outsiders may quickly form judgments). It remains important to use *sivaa* as a starting point for discussion, i.e., it serves a quite different function than finding out who can be blamed for what.

From an ESG perspective, participants felt the method is particularly well-suited to the environmental (E) component, and less so to the social (S) components; the latter component often includes ‘softer’ KPIs that require a more precise definition.

It was also noted that the method does not appear equally applicable to all types of value chains. For production chains, *sivaa* is more straightforward to use than for service-oriented chains.

Participants emphasized that mapping the value chain is not an endpoint. It is necessary to define where the endpoint lies; otherwise, the scope will continue to expand. This relates to defining materiality within sustainability reporting under CSRD and ESRS.

To make the *sivaa*-method more applicable across the value chain, it is important to keep explanations as simple and accessible as possible. A short guide or one-pager could help organizations and their chain partners quickly form a collective understanding of what is expected, facilitating discussions and coordinated actions.

It was also suggested that sector-specific templates would be useful. This would give organizations a more concrete idea of how to perform the assessment in their own context, simplifying the process and increasing the method’s usability and relevance.

Financial participants indicated that a logical next step is to link the results of CO₂ measurements to the financial performance of an organization. By integrating *sivaa* into

regular financial reporting, sustainable KPIs become part of standard business operations.

Finally, it was noted that it is crucial for the method to align with existing laws and regulations. When *sivaa* is integrated with applicable legal frameworks, it enhances credibility, applicability, and the likelihood that organizations will embed the method into their processes.

4.3. Validation from sustainability experts’ perspectives

A respondent noted that the current tool primarily focuses on mapping CO₂ emissions. However, according to the respondent, this is not where the greatest challenge lies. In the area of CO₂, many companies are already relatively advanced: there is considerable attention to this topic and a wide range of tools available. At the same time, progress in other risk domains lags behind; precisely in those areas the method could, according to the respondent, prove particularly valuable.

For measuring CO₂ emissions across the value chain, there is already extensive external tooling available, offered by dozens of providers (estimated at around fifty) each covering various aspects of measurement. Other aspects that could be incorporated include water usage, nitrogen and particulate matter emissions, and the use of chemical substances, among others. A key issue here, however, is that differences in definitions quickly arise, which does not benefit the consistent application of the method.

A further remark was that for CO₂ the CSRD and CSDDD are driving changes in the scope of reporting obligations. Companies that were previously intrinsically motivated to initiate sustainability reporting have, as a result of the so-called *Omnibus effect* (on EU Omnibus Package, see section 2 above), partially come to a standstill. This group, however, is particularly interesting to further support: they have already initiated the process, but the external pressure to comply with legislation has temporarily diminished. These are often companies that aim to manage their impact rather than focus solely on compliance. Typically, these are SMEs with 150 to 1,000 employees. The instrument aligns well with their needs.

With respect to the obligations under the CSDDD, companies are required to conduct a due diligence process – meaning, to exercise appropriate diligence. This aligns with the OECD Guiding Principles, which similarly emphasize that outcomes should be measurable and that so-called *priority risks* must be identified.

The vast majority of companies approaches sustainability primarily through the lens of compliance (meeting legal requirements) and risk management, often within the framework of double materiality; for example, assessing both how biodiversity loss affects the company and how the company’s activities impact biodiversity. A crucial point of attention in this regard is prioritization: determining what is truly material or relevant for the company. The respondent sees potential for the method precisely in this area. It can be particularly relevant for companies that have already started measuring and reporting their

impact but are not yet subject to current European regulatory requirements. In such cases, the emphasis lies more on managing within the value chain rather than on compliance with legal requirements. However, by linking the method to the CSRD (VSME), companies can achieve both compliance and value creation.

For softer KPIs (such as those addressed under the CSDDD or OECD Guidelines), a respondent expects that the emphasis will increasingly shift towards transparency and data visibility. This is important, as it would be undesirable for companies to refrain from reporting altogether out of concern that the available information is insufficiently dependable.

A respondent addressed the topic of compliance. It was discussed to what extent organizations risk becoming constrained by rigid definitions. The respondent notes that there is considerable debate focused on defining concepts, particularly among accountants and controllers, who tend to emphasize measurability and verifiability. Within ESG departments, however, the focus is different: it is centered on generating insights, acting, and fostering continuous improvement. This orientation aligns closely with the principles of the OECD Guidelines, which is focused on continuously improving the cycle of due diligence, which aligns well with the four principles of the *sivaa*-method.

A major challenge for implementing *sivaa* is that companies often lack a clear understanding of the structure of their value chains. The question arises as to how much effort and cost they are willing to invest in fully mapping them. One advantage of *sivaa* is that it is not always necessary to work exclusively with fully factual data; estimated data can also be valuable for generating insight.

According to a respondent, transparency within the value chain remains crucial. Ultimately, consumers should also be able to see the impact of a product. The *sivaa*-method enables such impact to be determined per product unit.

A respondent observed that retailers or companies that sell directly to consumers more frequently provide insight into impact than industrial enterprises. A digital product passport can support this effort. Currently, there is considerable attention for the digital product passport, though primarily for consumer products rather than industrial goods. For companies with their own production lines (such as some major brands) it is relatively easy to trace their value chains. For SMEs with dozens of tiers and multiple actors, however, this is nearly impossible. This is particularly true for raw material procurement, where inputs are often purchased in bulk on open markets, resulting in a wide variety of low-incentive supplier-buyer relationships and, consequently, highly opaque value chains.

A respondent noted that the topic is gaining broader attention, for example in the context of circular products such as batteries. In practice, estimations are still frequently used instead of measured data, though expectations are that this will become more professionalized in the coming years. The respondent considers it an

advantage that the instrument incorporates different data quality levels. Although there is also a clear push from a compliance perspective to ensure the highest possible level of data certainty, the advantage of this instrument is that it allows for a rapid estimation of the most significant risks. This approach is fully consistent with the OECD framework (particularly its emphasis on ‘risks that matter’) and aligns well with what organizations are seeking.

Transparency is crucial in the value chain, both internally and externally. Therefore, working towards a product passport that indicates the impact of a product for the end user is a valuable goal. This method could support this objective if it links to such a goal or tool.

5. Conclusions

In this paper an instrument coined *sivaa* was proposed with the aim of adding a product-based view to the practice of improving sustainability impact throughout the multiple organization value chains through offering a joint ‘language’ between all entities and departments involved. Through *sivaa*, end-to-end transparency is created which is instrumental in informing customers on the sustainability impact of their purchases. Through its design, *sivaa* offers flexibility in terms of data quality, is simple to use and can be directly applied within the primary processes of the organization.

Fit for purpose

From multiple discussions with potential users with different backgrounds, it became clear that the *sivaa* instrument not only services its purpose (identifying possible sustainability improvements in a value chain setting) but is also very intuitive, and easy to use because it fundamentally follows the value adding activities throughout the organization internally and through the external value chain. The potential users were also especially charmed by two *sivaa*-features, namely (1) the VAT-like approach of using the value-added activities for determining the sustainability impact, and (2) including several data quality levels, and the possibility to use this in calculations. The first feature helped users in providing the required steering information while the second feature resonated with their aims of approaching sustainability from a risk management perspective. As such, *sivaa* was seen as a method that could contribute to getting reliable sustainability information for improvement purposes which enables companies to make better choices towards their sustainability objectives.

Points for further development

Next to this highly positive reception on the instrument and its underlying features, there also remain some concerns and points for further research and development. First, although *sivaa* is found to be very usable for

measurable and relative ‘objective’ data such as greenhouse gas and other emissions or water usage and more in general for the ‘E’ variables, it is far less obvious how to apply this the same method for the ‘S’ dimension. The key issue is that in these areas the definitions, measurements, and ‘addibility’ of data are far less clear. Although some ideas have been discussed above (see section 3), further research and additional experiments might be needed to get a better grip on how to apply siva for all aspects of ESG.

Integrating with compliance requirements

Second, from the various discussions with potential users it became clear that many organizations dominantly use a so-called ‘compliance and risk-management approach’ towards sustainability, and that the urge to fulfill the legal and other reporting requirements has a dominant priority over actual sustainability improvement efforts within the primary processes. Obviously, nobody would claim that sustainability reporting is a goal in itself yet especially considering the recent National and European laws such as CSRD and CSDDD, it is only natural that companies want to ensure that the necessary steps towards sustainability reporting are taken, before engaging in further efforts. From this perspective, potential users of siva are looking for the integration of their sustainability efforts towards both reporting and improvement. Also, there is a demand for standardized data to use within the siva-method. Further research would be needed to see how siva can be integrated with reporting methods and standards. One recent example of this in the Netherlands is the “Uniforme kernset CO₂-e data”, see Topsector Logistiek (2025).

As a side-remark, it might be observed that the siva-method may be particularly relevant for SMEs (100–1,000 employees) that, due to the mitigation and postponement of European reporting requirements under the EU Omnibus Package, no longer face immediate legal CO₂-emission reporting obligations. Nevertheless, these companies remain motivated to strategically enhance the sustainability performance of their value chains.

Aligning with risk management

Third, as mentioned, when it comes to their sustainability efforts, many organizations focus not only on reporting but also on sustainability risk management. An important feature of siva is that it can be easily determined

which value chain activities will have the greatest impact on sustainability. This aligns well with the effort to identify and inventory the most significant sources of potential risk. However, at the same time siva allows working with sources that have a different data-quality; some of the data are highly dependable, as they are based on actual measurements, whereas other data may be little more than guesstimate. Some potential users have expressed their concern about this data quality differentiation. As there is broad acceptance that data quality is frequently imperfect, many improvements efforts are targeted in getting more accurate data as these are needed for both reporting and risk management purposes. In other words, companies, especially at the staff level, feel a strong natural need to decrease their uncertainty. However, despite that this is an understandable objective, the siva-method is designed for decision making under data-uncertainty, hence uses a different approach. Further research is needed to see how companies and value chains can deal with this. With this, it is also interesting to further research into how many different data-labels are needed. In the presented siva-instrument there are four levels (bronze, silver, gold, diamond). Although it seems logical to at least distinguish two levels (estimated vs. measured data), it might be that maybe three levels are needed.

Product or company perspective

Fourth, one of the appreciated features of siva is that it focusses on the sustainability aspects of the product rather than on the performance of a firm. This appeared to be particularly interesting for organizations that participate in value chains creating consumer products. In such value chains, increasingly the concept of a product passport is introduced and used, and the data gathered through siva corresponds well with such efforts. However, it can also be remarked that organizations that work predominately with industrial products and/or more upstream in the value chain might have less interest in this feature. For example, such organizations might purchase raw materials and commodities from ‘spot markets’ so that these do not even have clear relations with their suppliers. Conceptually speaking, each value chain would end at the consumer (unless of course, circular chains are considered), but this might not be the everyday reality of firms making industrial products. Therefore, a final interesting research direction listed here might be how to scope the value chain in which siva is used.

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Appendix 1: Applying sivaa for other sustainability dimensions

In the paper an example was provided on how sivaa could be used for determining the CO₂ emission impact. In this appendix two examples are provided which demonstrate how sivaa can also be applied for other sustainability dimensions.

Example 1: LTIR (Lost Time Injury Rate)

In order to measure the safety performance of companies, a Lost Time Injury Rate (LTIR) indicator is regularly requested in a customer-supplier relationship. The LTIR – also known as the Lost Time Injury Frequency Rate (LTI-FR); a safety indicator that shows how often accidents at work are resulting in lost time (i.e., injuries leading to at least one day of absence from work) occur within an organization relative to the number of hours worked. This indicator is calculated using the formula: (number of lost time injuries x 1,000,000) / total number of hours worked. For a company that has 3 accidents resulting in lost time and 900,000 hours worked, this leads to the calculation: $LTIR = (3 \times 1,000,000) / 900,000 = 3.33$. This means 3.33 accidents resulting in lost time per 1 million hours worked.

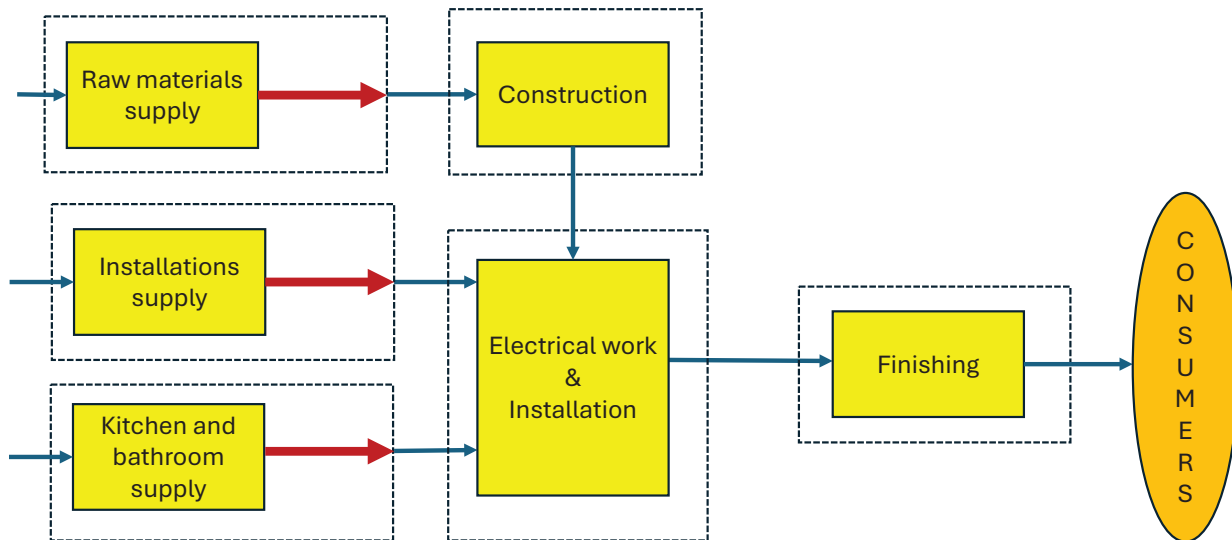
This works within the sivaa-method as follows. Each player in the value chain can calculate the LTIR for their own organization based on their hours worked. Translated into steps:

- *Step 1: agree on the definitions and calculation method.* It is important to consider how, for example, subcontractors working for the organization are included.
- *Step 2: map the value chain of the product or service.* Provide insight into which suppliers are included in

this ratio. What does the value chain that needs to be made transparent consist of?

- *Step 3: identify the drivers of the impact.* Two aspects need to be measured here: hours worked and the number of accidents resulting in absenteeism.
- *Step 4: collect data and categorize.* Hours worked can be recorded at various levels of detail. For example, actual hours or contractual hours. In the case of hours worked, is commuting time included as working time or as personal time? And how does this apply to travel time to a customer? Contract hours can be shown here with the label ‘silver’ and actual hours recorded as diamond. For incident reports and their level of detail, reference can be made to the process or system set up for this purpose. Is there a well-designed system in place that also records near misses? If so, the highest data category ‘diamond’ applies. Is there a monthly estimate based on less accurate data? Then ‘bronze’ or ‘silver’ applies. Is there no information available from chain partners? Then publicly available sector averages might be used. Depending on how representative such averages are considered for the supply chain at hand, such data can be classified in the suitable category (bronze, silver, gold, diamond).
- *Step 5: calculate the impact.* Based on the process steps and data quality, a calculation can then be made of the safety level throughout the chain.
- *Step 6: analyze and improve the results.* In consultation with chain partners, data can be analyzed and improvements initiated.

Figure A1. Value chain split-up in PTUs.



A numerical example for house construction would look as follows. Assume that a block of 40 houses is to be constructed. The value chain split-up in PTUs would then be something like given in the Figure A1.

For house construction, various raw materials are needed like concrete, bricks, drywalls, and roof tiles. Next to such raw materials also installations (for e.g., heating, ventilation, and water) and supplies for the bathrooms and kitchen are needed. Building a house is assumed to consist of three stages, namely Construction, Electrical work & Installation and Finishing. Note that there is no transportation involved in each of these three.

The data on LTIR can be collected as follows (note that the numbers used are merely for providing an example and do not necessarily represent a realistic situation).

Using siva, Table A2 can then be constructed (note that the column sums are subject to rounding).

From this analysis, it can be concluded that the high LTIR comes from multiple sources that require further attention. Clearly, the highest contribution is from Raw materials supply. However, this is a broad category with a wide variety of products and has the lowest data quality labels, i.e., further investigation into the underlying data is desired. The other main contributor is Construction. This comes with a relatively high data quality label (gold), so that the first concern would not be on the data gathering but rather on determining the causes of the observed LTIR at this activity and attacking these.

Table A2. Data on LTIR using siva.

	Bronze	Silver	Gold	Diamond	Lost time injuries	Hours	Weighted LTIR	LTIR factor	%
Raw materials supply	13,33	25,00			5	340,00	14,71	3,60	42%
Installations supply		0,00	6,67		1	170,00	5,88	0,72	8%
Kitchen & Bathroom supply		0,00		10,00	1	105,00	9,52	0,72	8%
Construction			8,00		4	500,00	8,00	2,88	33%
Electrical work & installation				10,00	1	100,00	10,00	0,72	8%
Finishing	0,00				0	175,00	0,00	0,00	0%
Total LTIR								8,63	100%

Table A1. Data on LTIR.

	Hours worked	Lost time injuries	LTIR	Category
Raw materials production	300,000	1	3.33	Bronze
Raw materials transportation	40,000	1	25.00	Silver
Installations production	150,000	1	6.67	Gold
Installations transportation	20,000	0	0.00	Silver
Kitchen and bathroom production	100,000	1	10.00	Diamond
Kitchen and bathroom transportation	5,000	0	0.00	Silver
Construction	500,000	6	12.00	Silver
Electrical work & Installation	100,000	1	10.00	Diamond
Finishing	175,000	0	0.00	Bronze

Example 2: water usage in the fashion industry

Consider the water usage (leading to considerable pollution) within a value chain producing T-shirts. The following value-adding steps, typically performed by separate firms, and their water-usage can be distinguished (also in this example the numbers used are merely used for illustration purposes and do not necessarily represent a realistic situation):

1. *Cotton farming* which uses water for irrigation; roughly estimated as 10,000 liters per kilogram of cotton;
2. *Textile processing* (ginning & spinning): recently measured as 500 liters per kg of cotton;

3. *Fabric manufacturing* (knitting & weaving): traditionally measured at 100 liters per kg of fabric;
4. *Dyeing & finishing*: estimated at 150 liters per T-shirt;
5. *Garment manufacturing* (cutting, sewing, packaging): roughly estimated at 10 liters per T-shirt.
6. *Retailing*: estimated as having virtually no water usage.

Although transportation would also have some water usage (for example for washing and cleaning trucks), these numbers are discarded as this would be minimal when compared to the water usage in the other parts of the value chain. Under the assumption that a T-shirt holds 250 grams of cotton, the following calculation applies for creating a batch of 100 T-shirts.

From Table A3, it can be determined that in order to create a batch of 100 T-shirts a total of 281.000 liters of water are used. Clearly, the main source of water-usage by far is cotton farming. At the same time, this number is also associated with the lowest data level. Based on such analysis, several actions might be in order. First, further investigations might be in order to determine the actual usage of water at cotton farming. Simultaneously,

Table A3. Data water usage for 100 T-shirts.

	Water usage (liters) for 100 T-shirts				Total
	Bronze	Silver	Gold	Diamond	
Cotton farming	250,000				250,000
Textile processing				12,500	12,500
Fabric manufacturing			2,500		2,500
Dyeing & finishing		15,000			15,000
Garment manufacturing	1,000				1,000
Retailing					0
Total	251,000	15,000	2,500	12,500	281,000
	89%	5%	1%	4%	100%

it might be investigated whether water usage at cotton farming could be substantially reduced. Alternatively, it might be considered whether T-shirts can be manufactured with less cotton and/or including other materials. It is important to note that whatever further action is taken; it is clear that the focus should be on this stage rather than starting with the other value chain activities; improvements there would most probably be neglectable when compared to improving cotton farming.