



# How material flow cost accounting contributes to the SDGs through improving management decision-making

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## Abstract

The purpose of this study is to clarify how material flow cost accounting (MFCA) can contribute to the SDGs and indicate how to introduce it into a company. First, we undertake a literature review to examine which SDGs MFCA can potentially contribute to. We then analyse the interplay between MFCA and management decision-making on the SDGs using an MFCA-LCA integrated model. Finally, we discuss how to introduce MFCA into a company to integrate the SDGs into management decision-making with reference to the SDG Compass. The main contributions are as follows: First, we revealed that MFCA could potentially contribute to multiple goals in the SDGs. Second, we clarified that MFCA could integrate the SDGs into actual management decision-making. Third, we suggested appropriate steps for implementation, regarding how managers should introduce MFCA into the management process on the condition that it does not prioritise economic benefit over social and environmental benefits in contributing to the SDGs. Therefore, this study provides evidence that MFCA can contribute to the SDGs by integrating them into management decision-making, and suggests appropriate implementation steps for promoting the pursuance of SDGs in any company.

**Keywords** Sustainable development goals · Material flow cost accounting · Management decision-making · Life-cycle assessment · Environmental management accounting

## Introduction

The United Nations Sustainable Development Goals (SDGs) are an intergovernmental initiative and agreement declaring that whilst government commitment to these goals is

more important than that of individuals and companies, the role of the private sector remains key in their achievement [73, para 41]. According to PricewaterhouseCoopers [61], 72% of more than 700 global companies included SDGs-related information in their reports, and many agreed on their social significance. However, only 25% of these companies explicitly indicated the relationship between their strategies and the SDGs. In this sense, efforts to contribute to the SDGs remain superficial in many companies. This could be because it is not well understood how companies' environmentally and socially responsible actions directly affect their profits [76].

As a guideline for companies to address the SDGs, the SDG Compass is used worldwide [21]. It states that technological development and innovations are necessary to resolve social issues. Therefore, companies need to link the SDGs with their core business strategies, with impact assessment and goal setting required to implement these strategies. However, it is a complicated process for companies to amend their management mechanisms to contribute to sustainable development. The SDG Compass also proposes the use of specific methods, such as value chain mapping and life-cycle assessment (LCA), as methods to advance corporate

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initiatives relating to the SDGs. The SDG Compass shows the importance of integrating sustainable development challenges into everyday business decision-making; however, it does not address how to integrate them. Management research has shown the possibility of using informal controls [16] and performance measurement systems [23] to resolve the tension between sustainability and business activities. In practice, however, it is extremely difficult for management to pursue the SDGs as far as they do not know the impact of their sustainable development efforts on their financial performance. This will require an analysis of the impact of activities for the SDGs on the company's revenues or costs.

To this end, this study aims to clarify how material flow cost accounting (MFCA) can contribute to the SDGs by improving management decision-making. We intend to show that this is technically possible, but it is beyond the scope of this study to provide practical evidence of this. MFCA is a 'tool for quantifying the flows and stocks of materials in processes or production lines in both physical and monetary units' (ISO 14051:2011, para 3.15 [29]). MFCA calculates the cost of material losses that a company disposes, which, if reduced, would benefit the company. Thus, if waste reduction contributes to the objectives of the SDGs, the introduction of MFCA can improve management decision-making. Material losses visualised by MFCA encourage managers to simultaneously seek to generate financial benefits and reduce adverse environmental impacts by improving resource productivity [29, 56]. MFCA information can support the decision-making of companies including capital investment, product design, raw material changes, etc. through on-site improvement activities [40].

The original idea of MFCA, which adds cost data to eco-balance, was developed in Germany in the late-twentieth century [77]. Since 2000, the Japanese Ministry of Economy, Trade and Industry (METI) has played a major role in the development of this tool, supporting the diffusion of MFCA to Japanese companies for approximately a decade [38]. In 2007, the Japanese Industrial Standard Committee (JISC) proposed a new work item on MFCA to the International Organization for Standardization (ISO). The following three standards on MFCA were subsequently issued: ISO 14051:2011, *Environmental management—Material flow cost accounting—General framework*; ISO 14052:2017, *Environmental management—Material flow cost accounting—Practical implementation in a supply chain*; and ISO 14053:2021, *Environmental management—Guidance for phased implementation in organizations*. As these international standards have been developed for MFCA, it would be extremely effective for companies actively trying to promote SDG initiatives in the international context if it is clarified that MFCA contributes to the SDGs.

We adopt a practical approach to achieve the above research objectives. We aim to enhance the technical applicability of MFCA by integrating it with LCA, and examine how the technique can be used within the SDGs context. First, we review the literature on MFCA and explain which SDGs MFCA can potentially contribute to. Second, we examine the interplay between MFCA and management decision-making on the SDGs using an MFCA–LCA integrated model. Through this analysis, we identify how MFCA can ensure the cost-effectiveness of sustainability activities in their decision-making. Third, to introduce MFCA into a company for supporting the SDGs, we evaluate where to introduce it in the five implementation steps illustrated in the SDG Compass [21]. Even if the effectiveness of MFCA in improving management decision-making is clarified, it cannot be effectively used in practice unless it is evident in which phases of the management process MFCA should be applied. This analysis clarifies the processes in which MFCA should be utilised, referring to the five steps of the SDG Compass. We conduct the above analyses in the three subsequent sections, and conclude in the final section.

## Potential contribution of MFCA to the SDGs

In this section, we review previous MFCA studies to examine which SDGs MFCA can potentially contribute to. MFCA's primary objective is to improve resource efficiency, and in doing so, it could directly contribute to SDG 12 (sustainable consumption and production: SCP), especially 12.2 (natural resources), 12.3 (food loss), 12.4 (chemicals), and 12.5 (waste generation), as well as SDGs 8.4, 9.4, and 11.7 (including resource use efficiency). Additionally, MFCA could target energy and water, and thus, also contribute to SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), and SDG 13 (climate action).

Therefore, we focus on SDGs 6, 7, 12.2, 12.3, 12.4, 12.5, and 13 as they relate to MFCA. We searched for 'material flow cost accounting' as a keyword and collected 50 papers concerning MFCA in journals published by major academic publishers (i.e. Elsevier, Springer, Wiley-Blackwell, Taylor & Francis, Sage, and Emerald) out of 73 papers published listed on the Web of Science (as of 24 September, 2021). Moreover, because the study of MFCA has advanced the most in Japan, we collected 158 papers (in Japanese) from ten major Japanese accounting and environmental management journals as a supplementary purpose (as of 15 November, 2021).

In the following subsections, we review the key MFCA literature for each relevant goal or target in the SDGs.

### Waste generation (SDG 12.5)

As MFCA calculates the cost of material loss, most research relates to waste reduction. Therefore, many of the studies discuss waste generation, and most aim to improve conventional MFCA concerning the measurement of waste generation. For example, Takakuwa et al. [69] apply MFCA in a simulation model to examine the amount of waste generated in determining production lot size. Zhou et al. [79] combine the current MFCA model with the ‘3R’ (reuse, reduce, and recycle) principle of a circular economy.

Furthermore, many case studies targeting waste reduction are conducted especially in Asia, including in Thailand [11, 31, 34], Malaysia [78], China [46, 79, 80], India [63, 71], and Sri Lanka [13–15]. For example, Thanki and Thakkar [71] demonstrate an application of their proposed approach using MFCA for an Indian manufacturing SME. Elsewhere, Li et al. [46] highlight a resource value flow analysis in the paper industry from the circular economy perspective by extending MFCA.

Some studies discuss waste reduction in the supply chain. For example, Kokubu and Shimogaki [41] and Higashida [25] discuss sharing information in the supply chain. Okada and Kokubu [57] examine the effects of MFCA on waste reduction in a supply chain compared to MFCA implementation in a single company, identifying that the effects of the former are significantly larger.

### Natural resources (SDG 12.2)

There are few studies of MFCA with natural resources, possibly because natural resource efficiency results indirectly from waste minimisation [17, 72]. Nonetheless, some studies attempt to improve the resource efficiency of certain natural resources by applying MFCA. For example, Dunuwila et al. [13–15] analyse the natural rubber industry; Li et al. [46] explore the paper industry; and Shizuka [68] studies the lime mining industry. All of these studies discuss how MFCA responds to industry-specific requirements. Additionally, MFCA is also effective in forestry management by public forest service and other forestry organisations [33, 59].

In general, it is necessary to modify the original MFCA method to apply natural resources because they require a special cost calculation due to, for example, no initial material costs. Indeed, the above studies deal with this problem, and indicate the contribution of MFCA towards sustainable natural resource management and its efficient use, as prescribed by SDG 12.2.

### Food loss (SDG 12.3)

Food loss is not only a problem for SCP, but also relates to the problem of poverty raised by SDG 1. Given that many food companies, including restaurants, are small in size and lack sufficient resources, it is difficult for society to overcome this problem. However, MFCA can support small food companies by providing solutions to simultaneously reduce food losses and costs. For example, Fakoya and van der Poll [19] extend the MFCA system to provide waste information in a brewery, and Fakoya [18] reports findings from a pilot study conducted in a microbrewery adopting MFCA to capture adequate waste cost information. Likewise, Wan et al. [78] apply MFCA to the sago starch processing case and Jakrawatana et al. [31] introduce MFCA to the starch and ethanol industries.

Elsewhere, Anjo [2] and Manda [48] examine MFCA in a confectionery maker and a meat processing company, respectively. Christ and Burritt [8] focus on restaurant management and suggest that it is possible to raise efficiency by developing a model linking MFCA to a restaurant’s food loss management. Additionally, Kato and Yamada [35] focus on the cost information of food loss and develop new products made from food loss. All these studies demonstrate the actual and potential contributions of MFCA for reducing food losses in SMEs.

### Chemicals (SDG 12.4)

We can divide the application of MFCA to chemicals into two segments: applications to factories generating chemical substances and applications focussing on a process using specified chemicals as indirect materials. As an example of the former, Schmidt [65] develops a mathematical algorithm for MFCA and assess the environmental impacts, including greenhouse gas (GHG) emissions and chemicals. As examples of the latter, Motosawa et al. [50] conduct an MFCA analysis of an organic compound production process, and Tennojiya et al. [70] focus on the metal plating process in SME and its efforts to reduce losses during the plating process—a matter not previously the subject of improvement.

In many manufacturing units, because chemicals are indirect materials, managers often do not attempt to reduce their use with the same effort they apply to primary materials. However, these studies suggest that MFCA can provide some awareness to managers in controlling and reducing chemical use.

### Water (SDG 6)

The cost of using water is very low compared to that of using other materials and energy in some countries such as Japan, which implies that water may not be a primary target

for the reduction in use in these countries. In this sense, there is limited contribution to the efficiency of water use through MFCA. Indeed, some studies, including Christ [6] and Christ and Burritt [9, 10], suggest that water management accounting specifically designed to support corporate water management decisions could be more appropriate than traditional environmental management accounting tools. However, MFCA should be more effective in the management of wastewater because it focuses on the output flows. Thus, MFCA can complement water management accounting in wastewater management situations.

For example, Mahmoudi et al. [47] show that by applying MFCA to refining companies, MFCA can be effective in reducing wastewater contamination. As SDG 6 requires clean water and sanitation, this is a critical area of contribution for MFCA. Furthermore, Dunuwila et al. [13–15] conclude that the combined use of material flow accounting (MFA), MFCA, and LCA is useful for reducing water use in natural rubber processing. Behnami et al. [3] use the case of a petrochemical wastewater treatment plant to establish a new methodology improving the accuracy and certainty of measurements for MFCA. Ho et al. [28] develop a wastewater treatment process by adapting the concept of MFCA in the case of a sago mill plant. In other works, Amano [1] applies the MFCA method to a water purification plant. Haraguchi et al. [24] find that including water in MFCA provides a new awareness of a previously overlooked inefficiency. Overall, these studies support the view that MFCA is also effective for the management of water use efficiency.

### Energy (SDG 7)

As energy is one of the main cost components of MFCA, most MFCA studies include energy in their scope. For example, Schmidt et al. [66] propose an extended MFCA method that measures the energy flow. Because ISO 14051 focuses on material flows instead of energy flows, slight modification of the method is necessary to measure the energy flow more precisely and improve practice. Regarding the work in this area, Fakoya [18] identifies that MFCA can calculate the energy cost assigned to wastewater and solid waste in a microbrewery, whereas Wan et al. [78] incorporate energy as a hidden cost when formulating their MFCA-based approach. Additionally, Schmidt et al. [66] attempt to extend the scope of MFCA through methodical refinements by modelling energy flows, divergent flow system outputs, and long-term monetary effects.

Elsewhere, Dekamin and Barmaki [12] conduct an economic and energy consumption analysis of a soybean company using MFCA. Shimogaki [67] proposes sophisticated methods to reduce energy use by visualising the energy loss for each machine, whereas Nakajima [52] introduces MFCA into a power-plant company, identifying energy loss in the

generation as well as delivery processes. Rather than treating the energy cost as a system cost, Oki and Nakai [58] propose treating it as a material cost to visualise the energy loss more directly.

In general, the measurement of energy flow and its loss is more difficult than that of material flow because energy has no substantial body. However, the above studies suggest that even if the measurement of MFCA is imperfect, information on energy loss can motivate managers to use energy more efficiently. Indeed, as Shimogaki [67] argues, a precise measurement can lead to more effective actions for reducing energy loss. However, the degree of information preciseness calculated by a company depends on the measurement cost.

### CO<sub>2</sub> (SDG 13)

As MFCA is a method for reducing material loss, it does not calculate the amount of carbon dioxide (CO<sub>2</sub>) created in the production process, for which the introduction of carbon management accounting specifically designed for this purpose has been advocated [5]. However, the internal (to the company) concerns of carbon accounting have thus far been rarely investigated [20]. Nevertheless, if we multiply the amount of material measured by MFCA by the emission factor of CO<sub>2</sub> based on LCA, it is easy to obtain information on CO<sub>2</sub> emissions. Therefore, the systematic integration of MFCA and LCA is a potentially important academic topic for both MFCA and LCA researchers. Accordingly, Rieckhof and Guenther [62] develop a model to integrate quantity-based LCA into value-based MFCA, and May and Guenther [49] measure the global warming potential in black currant juice production using MFCA in combination with carbon footprinting.

Meanwhile, Kokubu et al. [37] and Kokubu and Shimogaki [42, 43] introduce information on CO<sub>2</sub> emissions into their MFCA calculations. These analyses provide an important suggestion that when integrating CO<sub>2</sub> information into MFCA through LCA, CO<sub>2</sub> should not be in monetary terms because its monetary value is much smaller than its actual cost. They are particularly concerned that this information makes managers undervalue the impact of CO<sub>2</sub> and argue that management should instead use physical data on CO<sub>2</sub>.

### Further issues

Whereas the SDGs are global in scope, MFCA focuses only on internal matters in an organisation, not the wider environmental impact. Zhou et al. [79] state that, ‘...the accounting content is limited to materials for internal resource loss but does not relate the load on the external environment’ (p. 111). However, a global approach has appeared in the supply chain, and MFCA can apply where material wastage in one organisation is occasionally sourced from suppliers [44, 45, 53, 55].

Thus, the extension to the supply chain is an important aspect of MFCA [26, 53, 60, 65], and the number of studies demonstrating its applicability to supply chains is increasing (e.g. [7, 44, 53, 60, 65, 75]; see also the last paragraph of "Waste generation (SDG 12.5)" section). Moreover, the supply chain data provided by MFCA can also be used for LCA [8, 32, 54]. With the publishing of ISO 14052 as guidance to apply MFCA to supply chains in 2017 [30], it is possible that MFCA will penetrate supply chains more actively. Thus, MFCA could promote SDG initiatives beyond the organisational level.

Furthermore, although the SDGs are long-term goals until 2030, Schmidt et al. [66] point out that the limitations of MFCA lie in the fact that its calculation biases towards only materials and inputs and has a short-term orientation. Nevertheless, this challenge to MFCA is not insurmountable, and its scope and duration can always be extended. As Schaltegger and Zvezdov [64] recommend, MFCA should extend to future-oriented and long-term perspectives to contribute to the SDGs more proactively. Additionally, previous studies have identified some more limitations related to the diffusion of MFCA, which includes that MFCA tends to discontinue its use in the short term [36], and that MFCA is not often taught in business schools [22].

## Summary

These studies clarify the relationship between MFCA and the SDGs. Previous research has shown that amongst the various SDGs, MFCA has the potential to contribute to waste generation (SDG 12.2), natural resources (SDG 12.3), food loss (SDG 12.4), chemicals (SDG 12.5), water (SDG 6), energy (SDG 7), and CO<sub>2</sub> (SDG 13). When a company intends to conserve the resources targeted by the SDGs, MFCA can support its initiatives. Many case studies, using actual data, report that increasing resource efficiency (or reducing material losses) also financially benefits a company. When an organisation starts an initiative for the SDGs, its economic effects are usually unknown. Therefore, if MFCA could provide such information to managers, it would promote those SDG initiatives. However, it is not clear from a literature review alone how MFCA could integrate the SDGs into business operations by improving management decision-making. Thus, in the following section, we use an MFCA-LCA integrated model to examine how MFCA can improve management decision-making on the SDGs in business.

## How can MFCA improve management decision-making on the SDGs?

The literature review in the previous section provides evidence that MFCA is effective for many SDG targets. However, in order to apply MFCA to business processes in

practice, there is a need to understand how it can improve management decision-making. MFCA can be used together with LCA information to improve management decision-making. This is because activities for sustainability have to consider both economic and environmental effects, and LCA assesses environmental effects. LCA is recognised as a tool to support the SDGs in the SDG Compass, but the relationship between LCA and management decision-making is still unclear. To address this problem, we explain how MFCA can improve management decision-making on the SDGs in business, based on the MFCA-LCA integrated model developed by Kokubu et al. [39].

The relationship between MFCA and LCA has been examined by several studies [4, 74]; integration of both methods is also recognised as an important issue [62]. However, very few studies integrate both methods using actual LCA and MFCA data. The MFCA-LCA integrated model of Kokubu et al. [39] adopts carbon footprint of products (CFP) as a LCA method and successfully makes costs and CO<sub>2</sub> emissions comparable. Therefore, we adopt the framework of this model to explain how MFCA improves management decision-making.

Figure 1 illustrates the scope of the model using a fictional example. The scope of MFCA in ISO 14051 is limited within a company, but the scope of the MFCA-LCA integrated model should be extended to its whole product life cycle. If the system boundaries of CFP and MFCA are different, additional calculations would be required to include that part in the scope. The scope can be divided into the stages according to the LCA Standard: ISO 14040. The use stage is omitted for simplicity in this figure.

LCA calculates total CO<sub>2</sub> emissions in each material and stage, but LCA does not separate material losses from products. However, we can separate products and material losses if we integrate MFCA data into the LCA calculation, as illustrated in Fig. 2. Data is fictional and graphed for ease of understanding. The black bar is products' CO<sub>2</sub> emissions and the grey bar is material losses' emissions. This separation has no implication for the environmental impact. If the only goal is to reduce CO<sub>2</sub> emissions, there is no difference between reducing production and reducing material losses. However, the impact of the two on management is completely different. If a company lowers product sales to reduce CO<sub>2</sub>, profits also decrease. Of course, this is a difficult decision for managers to accept. By contrast, if a company reduces material losses to reduce CO<sub>2</sub>, material procurement costs fall accordingly, which is better in terms of profitability. Therefore, managers can prioritise their policies to reduce CO<sub>2</sub> emissions by MFCA information. This is the effect that MFCA improves management decision-making. LCA cannot provide such information. Thus, reducing material losses would have a positive effect on meeting SDG 13 on climate impacts in addition to SDG 12. In this

Fig. 1 Scope of material flow

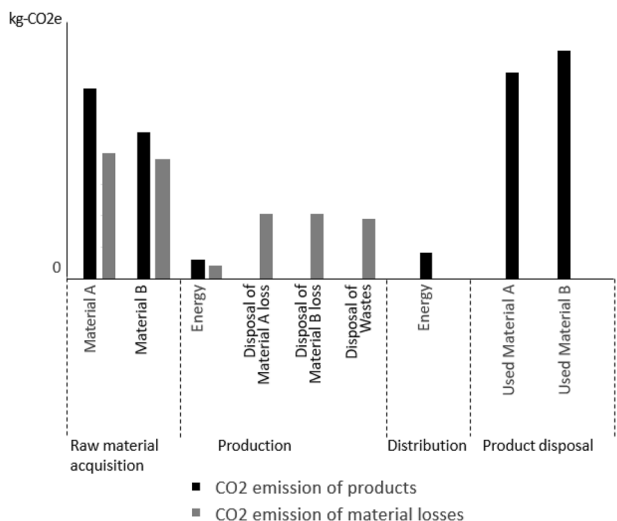
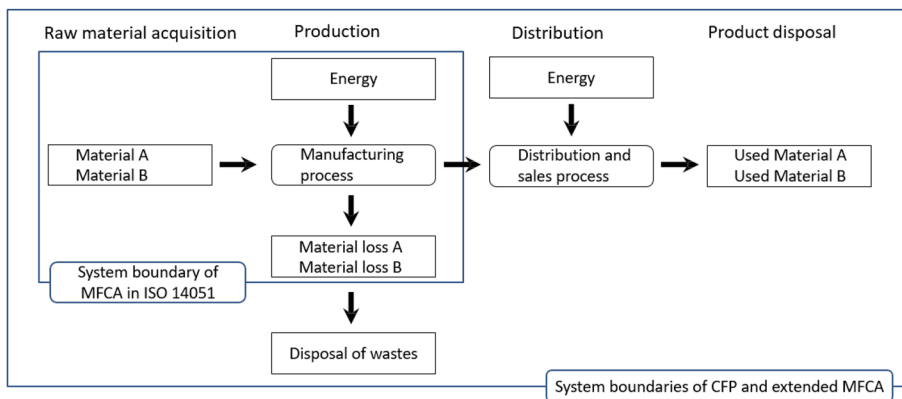


Fig. 2 CO<sub>2</sub> emissions of products and material losses

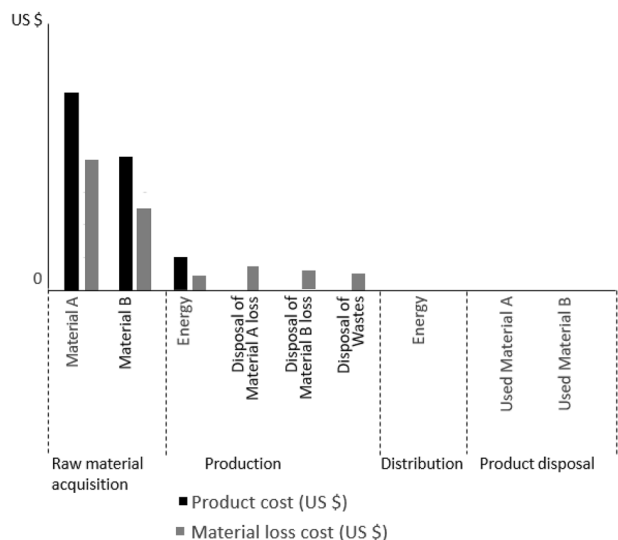


Fig. 3 Cost information of products and material losses

manner, MFCA can improve management decision-making regarding multiple SDGs.

Furthermore, MFCA can provide cost information about products and material losses with which managers can conduct more precise decision-making. Figure 3 illustrates fictional cost information for products and material losses. As the cost calculated here is only company cost, it ignores costs in the distribution and the disposal of product stages. Looking at CO<sub>2</sub> only, the product disposal stage emits high CO<sub>2</sub> emissions; however, there is no cost to a company incurred in this stage. On the contrary, for managers, the raw material acquisition stage is the most important. In other words, reducing CO<sub>2</sub> in this stage is the most cost-effective route for a company in this example. MFCA might, therefore, enable managers to analyse management priorities related to the SDGs more effectively using this information.

In this case, MFCA could contribute to SDG 12 (resource efficiency) and SDG 13 (climate change). However, to do so, it would be necessary for managers to

incorporate both targets into its strategy. Many companies have broad objectives to reduce CO<sub>2</sub> and increase resource efficiency, but dividing these objectives into detailed business operations such as product development is another problem. To overcome this, it would be useful to indicate how such environmental initiatives would affect economic performance given the concerns of top management. It should be noted, however, that utilizing MFCA information does not mean only implementing cost-effective sustainability measures. In terms of Fig. 3, it should not lead to a decision that reducing CO<sub>2</sub> in the product disposal stage should not be undertaken because there is no cost return for the company. Therefore, it is necessary to consider which management decision-making stage MFCA should be applied to. Managers should properly position MFCA in their operation. In the following section, we discuss this issue with reference to the SDG Compass.

## Positioning MFCA in the management process for the SDGs

Although the SDGs are primarily commitments made by national governments, some guidelines are available for the private sector. The SDG Compass, jointly published by the Global Reporting Initiative (GRI), United Nations Global Compact (UNGC), and World Business Council for Sustainable Development (WBCSD) in 2016 [21], is one of the most influential guidelines available to companies that can explain how to align their business strategies with the SDGs [51]. The guidelines provide effective ways for companies to work on the SDGs. Thereafter, the GRI and UNGC launched the ‘Business Reporting on the SDGs’ project and in 2018, published a report titled ‘Integrating the SDGs into Corporate Reporting: A Practical Guide’. The guidelines instruct on reporting SDGs-related issues in a company. However, as these guidelines have no accounting tools and techniques, managers cannot evaluate how their SDGs-related initiatives affect their financial performance. These risks undermine effective decision-making on the SDGs.

Companies as profit-making organisations may limit the expansion of the SDGs in their operations if the economic benefit to them is unclear. Evaluating solely the costs and benefits of the SDGs may discourage their initiatives, as many sustainability activities are less cost-effective than other business plans. Therefore, for companies to decide to address the SDGs, it is effective to use accounting tools to deal with this problem. Although it would be possible to implement SDGs-related initiatives without accounting, those actions could not be long-lasting because the contribution to profit made by the project is not evident. As discussed in the previous section, MFCA can be effective in addressing these problems. However, when applying accounting methods such as MFCA to a company's SDGs-related efforts, it is necessary to consider at what stage of the company's management process it should be applied. This is because the application of accounting methods at inappropriate stages may hinder their SDGs-related initiatives.

To consider this issue, we draw on the five steps for companies to address the SDGs, as outlined by the SDG Compass. The SDG Compass delineates the following five steps:

Step 1 Understanding the SDGs.

Step 2 Defining priorities.

Step 3 Setting goals.

Step 4 Integrating.

Step 5 Reporting and communicating.

In Step 1 (Understanding the SDGs), ‘companies are assisted in familiarizing themselves with the SDGs’ [21, p.5]. In this stage, no special management skills are necessary. In Step 2 (Defining priorities), the SDG Compass requires companies to ‘(t)o seize the most important business opportunities presented by the SDGs and reduce risks, companies are encouraged to define their priorities based on an assessment of their positive and negative, current and potential impact on the SDGs across their value chains’ [21, p.5]. LCA is then a representative technique for evaluating the environmental impact. Other assessment tools, such as GHG Protocol Scope 3 and the WBCSD Global Water Tool, are also available. The SDG Compass requires companies to evaluate their social and environmental impact regarding the SDGs, engage with shareholders, and thereafter, prioritise the SDGs-related issues addressed.

On the other hand, the SDG Compass does not require companies to evaluate economic aspects of the initiatives. However, it would be controversial to do it in Step 2. In principle, economic evaluation is indispensable when prioritising a company's strategic issues. As activities that pursue excessive profit may threaten the sustainability of the planet, evaluating SDGs priorities based on their economic effects on the company could be problematic. Higashida et al. [27] indicates that a company's use of MFCA tends to emphasise economic rather than environmental purposes based on their case study. Therefore, for the purpose of addressing the SDGs, it is not appropriate to use accounting methods to evaluate their economic effects in the defining priorities step.

The same argument applies to Step 3 (Setting goals). The SDG Compass explains that ‘(g)oa setting builds directly on the outcomes from the impact assessment and prioritization covered in Step 2, and is essential to driving good performance’ [21, p.16]. This step is divided into four stages: define the scope of goals and select key performance indicators; define the baseline and select the goal type; set the level of ambition; and announce the commitment to the SDGs. In this step, the SDG Compass recommends that companies employ an ‘outside-in approach’ instead of an ‘inside-out approach’. According to the former, ‘(b)y looking at what is needed externally from a global perspective and setting goals accordingly, business will bridge the gap between current performance and required performance’ [21, p.19]. Step 3 is paired with Step 2 and aims to set a goal for the priority activities determined in the previous step. Therefore, if accounting methods to evaluate financial aspects of the initiatives are not applied to Step 2, they should not be applied to Step 3 either.

However, in Step 4 (Integrating), managers face difficulties adjusting the goals from the SDG initiative to their

own business. In this step, the SDG Compass explains ‘(i) ntegrating sustainability into the core business and governance, and embedding sustainable development targets across all functions within the company, is key to achieving set goals’ [21, p.5]. As companies have their own economic goals and targets, it would be necessary to effectively position SDGs-related issues in their economic goals. However, it is difficult to incorporate the SDGs into a company without considering its economic effects. The consideration of this point is missing from the SDG Compass.

Accounting can thus support managers in such a situation by providing cost–benefit information. MFCA could provide such information on the SDGs to managers. In the previous section, we indicated that when a company intends to incorporate SDG 12 and 13, it can use MFCA information for more efficient and effective decision-making. If the effects for society and the environment are identical, managers could choose more cost-effective options amongst their alternatives based on available accounting information. Without such an analysis of the economic impact of SDG initiatives, it is impossible to anchor the sustainability goals within a business, as required by the SDG Compass. Even if they could be superficially incorporated, it would be difficult to develop their sustainability goals in the context of business as usual, as each business operates around profit targets.

However, when using MFCA, managers must be cautious not to hinder the SDG-related initiatives by pursuing only positive economic effects. If managers choose an option with a higher economic but a lower social benefit, it would be contrary to the spirit of the SDGs. In other words, managers should not ignore the SDGs just because the economic effect revealed by the MFCA analysis is greater. In Fig. 3, for example, it is undesirable to stop efforts to reduce CO<sub>2</sub> in the product disposal stage for economic reasons. If MFCA might lead a company to decide not to reduce CO<sub>2</sub> in the product disposal stage, it would be far from supporting the SDGs, with such a decision only justified when the effects on the SDGs remain constant. On the contrary, evaluating activities based only on economic benefits might not achieve a sustainable society. To avoid such a situation, it is important to prioritise and target activities in Steps 2 and 3 with an emphasis on sustainability aspects; assessing the economic aspects of each activity through accounting methods, including MFCA, should be performed at a later step (Step 4). Without this step, however, companies will not be able to integrate the SDGs into their business.

## Conclusion

The purpose of this study was to clarify how MFCA can contribute to the SDGs by improving management decision-making; accordingly, we conducted three analyses. First, we reviewed the literature on MFCA and examined

to which SDGs MFCA could potentially contribute to. Second, we explained the interplay between MFCA and management decision-making on the SDGs adapting the framework of the MFCA-LCA integrated model developed by Kokubu et al. [39]. Third, to introduce MFCA into a company for supporting the SDGs, we evaluated where to introduce MFCA in the five implementation steps illustrated in the SDG Compass. The results revealed that as a method of evaluating economic effects, MFCA could help integrate the SDGs into business, and improve management decision-making.

The first literature review suggested the possibility of MFCA contributing to multiple SDGs, and indicated significant potential. In the second analysis, the model analysis confirmed that MFCA could improve management decision-making. In the third analysis, we discussed how to introduce MFCA in the management process to integrate the SDGs into management decision-making. The practical implication from these analyses is that managers should introduce MFCA, taking caution not to over-emphasise economic objectives over the environment.

The SDG Compass—that is, guidelines for companies to incorporate the SDGs into their business—is insufficient for incorporating the SDGs into business as usual because it does not consider the economic effects arising from SDGs-related initiatives. To apply the SDGs to businesses, an analysis of economic aspects of the project is indispensable. This study indicates that properly positioning MFCA in the steps that the SDG Compass proposed could overcome the above weakness and strengthen its contribution. Additionally, the tension between economics and sustainability suggested by previous studies [16] can be resolved through the use of an MFCA–LCA integrated model.

Although this study selected MFCA as an accounting method that contributes to the SDGs, the arguments developed here can be applied to other environmental management accounting tools, including environmental budget, environmental investment appraisal, full cost accounting, etc. Hopefully, this discussion will facilitate the introduction of other accounting tools into corporate sustainability initiatives in companies to promote pursuance of the SDGs.

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