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Assessing handprint potentials for business's eco-innovation☆

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ABSTRACT

Exploring how businesses can adopt eco-innovations, which may involve their market expansion, and meet their climate change targets, was the objective of this research. We investigated to what extent an organization with a milk packaging eco-innovation could create a positive impact on climate and calculated their potential carbon handprint using the Sustainability and Health Initiative for NetPositive Enterprise (SHINE) Handprint assessment method. Changes and potential handprint pathways were defined from the perspective of two actors who can bring about the change: organization and consumers. The potential carbon handprints were calculated for changes resulting from switching from current milk packaging to eco-innovation at the global milk market. The assessment explored options for organization to realize handprints within their own markets and via market expansion in their competitors' markets. Results showed that SHINE Handprint assessment provides a systemic approach for organizations to adopt eco-innovations, pursue market expansion, and reduce overall sector's climate change impacts.

1. Introduction

Actions by businesses are essential to lowering anthropogenic greenhouse gas (GHG) emissions (Pineda et al., 2020), and to reaching other sustainability targets such as net-zero carbon emission target (Science Based Targets Initiative, 2021) that can bring human activity to within the carrying capacity of the biosphere (Rockström et al., 2009). Standardized methods of life cycle assessment (LCA) defined by ISO 14040 (2006a) and ISO 14044 (2006b), standardized carbon footprint method (ISO, 2013), and the conceptualization of Corporate Value Change (Scope 3) Standard for GHG emissions (World Resource Institute, 2015) have helped broaden businesses' and stakeholders' perspectives on the broad set of activities over which they have actual or potential influence, whether directly or at least indirectly. These perspectives look at the full supply chain of a company and the products that it produces; and where feasible they also include downstream activities across the value chain and life cycles of sold products (Hellweg and Milà i Canals, 2014). In this manuscript, we refer to the perspective taken by the methods in this group as Shrink-Own-Footprint (SOF) perspective whether it refers to shrinking direct GHG emissions or to one of shrinking the full "cradle-to-grave footprints" of the organization and its sold products. In the past 15 years, authors published many LCA studies that evaluated the environmental footprints of products, for example dairy products (Daneshi et al., 2014; González-García et al., 2013). In their book, Acharya et al. (2017) discussed smart innovation that could help design environmentally benign products. Several authors focused on how can businesses SOF. For example, Almeida et al. (2019) discussed ways to mitigate environmental impacts in Brazilian companies by including greater government support and dissemination of LCA. Elias Mota et al. (2020) researched how to bridge the gap between LCA and supply chain management. Kaenzig et al. (2011) discussed limitations of existing environmental disclosures by businesses and sought to improve transparency throughout the entire value chain. Finally, Stewart et al. (2018) pointed that LCA remains weakly present in corporate sustainability report-

Abbreviations: SOF, Shrink Own Footprint; SHINE, The Sustainability and Health Initiative for NetPositive Enterprise; LCA, Life cycle assessment; O-LCA, Organizational LCA; P-LCA, Product LCA; C-LCA, Consumer LCA; DfE, Design for Environment; MfE, Market for Environment.

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ing. Rockström et al. (2009) concluded that the current footprint reductions were falling drastically short of the net magnitude needed to prevent catastrophic climate change, loss of biodiversity, and other environmental changes within the planetary boundaries.

The SOF perspective, while helpful, is still incomplete, meaning that it fails to capture the full scope of actual and potential influence (positive impact) of companies on anthropogenic emissions and environmental impacts. And this incompleteness can cause it to be misleading. For example, if a business has developed a product whose life cycle impacts are lower than those of other products sold on the market, should the company be encouraged to sell more of the new product? The current SOF perspective would say no: it would assign a higher footprint to the organization if it sold more of a product, even if doing so would reduce the total human footprint. In our literature review, we present most recent research that advocates inclusion of positive impacts in environmental and social LCA and most recent approaches that provide framework how to calculate positive impacts and thus bridge the gap in the SOF perspective.

2. Literature review

Inclusion of positive impacts of products into environmental and social LCA has been discussed in the latest publication by Croes and Vermeulen (2021). The authors proposed criteria for inclusion of positive impacts in LCA. According to Croes and Vermeulen (2021), positives must be externalities outside the seller-buyer transaction, or type 2 positive internalities, for example, a technology designed for the environmental impact mitigating purpose (such as innovation), which could show best 20% mitigating performance on the market. The authors discussed the existing methods used to quantify the positive impacts (Croes and Vermeulen, 2021). One option discussed by Croes and Vermeulen (2021) was handprinting, as proposed by Norris (2015). However, authors argued handprinting should be separate from LCA footprinting, i.e., direct comparison handprint and footprint used in net positive assessment should be omitted (Croes and Vermeulen, 2021). According to Sustainability and Health Initiative for NetPositive Enterprise (SHINE) Handprint method used in this study (Norris et al., 2021), handprint is not a property of the product, but the ownership is of an actor (organization, individual, etc.), which includes all positives and negatives. By omitting the negatives, we may get a false idea about how relevant the handprint is and did the organization or consumer make a significant change or drop in the ocean. Thus, in this paper we go a step further in interpretation and include net-positive assessment for both actors: organization and consumers. The existing standardized frameworks about business's impacts included accounting frameworks such as Greenhouse Gas Protocol and LCA, which depending on the goal and scope of the study may be business's organizational LCA or may focus only on their product/service LCA. We choose organizational LCA (O-LCA) as a framework to calculate company's business as usual footprints. In this framework, business can reduce their own footprint, and only positive impacts (reductions in footprint) within the O-LCA boundary are counted. In fact, in the case of innovation product growing at the market it would increase the footprint of the business's organizational footprints. Thus, besides footprint-reduction framework which we called in the manuscript SOF framework we include broader impact of innovation on business and consumers. This broader scope helps to resolve the conflict between current O-LCA methods (Blanco et al., 2015) and one common core strategic mandate of businesses—to increase sales. Allowing these strategies to align, when environmentally appropriate, can harness market forces for good. To be consistent in the scopes, we propose to use the consumer LCA (C-LCA) for individuals/consumers, which at the moment is considered an emerging approach (Hellweg and Milà i Canals, 2014).

Several authors provided frameworks for accounting positive impacts. Russell (2019) summarized existing approaches and provided guidelines for the Avoided Emissions perspective. Grönman et al. (2019) provided framework called the VTT-LUT Carbon Handprint approach. Avoided Emissions are calculated as a positive difference (footprint reduction) in total life cycle emissions between two products from different actors with the equivalent function, for example, a plastic milk jugs vs. paperboard cartons (Russell, 2019). In recent years, Avoided Emissions claims were made by researchers (Zhai et al., 2012), by countries (Köhler and Michaelowa, 2014), and by companies (Russell, 2019). Russell (2019) identified several major existing guidelines applicable to Avoided Emissions, which were built on LCA standards ISO 14040 (2006a) and ISO 14044 (2006b). The main conclusions were that there was a considerable uncertainty and variation in practice across a wide range of accounting methods. Also, authors found there was a low level of consensus for selecting the baseline option, attributing positive impacts to value-chain partners, scaling results to product's market size, and aggregating results to the level of an entire company or product portfolio (Russell, 2019). We believe that with wide adoption of the SHINE Handprint method (Norris et al., 2021), the problems encountered by Russell (2019) would be avoided.

Authors of the VTT-LUT Carbon Handprint approach defined handprint as positive impact announced to the product of the organization that shrinks footprint of their consumers (Grönman et al., 2019). In this, the SHINE Handprint method differs because handprint can only be owned by an actor and not by the product itself (Norris et al., 2021). Thus, in this research we included two perspectives of actors who can make a change and create handprints: the organization's perspective and consumers' perspective. Also, Grönman et al. (2019) demonstrated their case using renewable diesel and their approach focused on carbon handprint. While our case study focused only on carbon handprint, the SHINE Handprint method presented in this paper can be used for other impact categories.

The SHINE handprinting framework presented in Norris et al. (2021) and showed in the current paper provides a systematic way to account for broader impacts of the business. It does so by following, to its logical conclusion, the expansion of responsibility that was started by LCA and the SOF perspective. Although a business can reduce their footprint, they are not able to eliminate it entirely. Making changes in business footprints is limited to their scope and thus the SOF framework limits the scope of action. The SHINE Handprint method provides a consistent framework for selecting the baseline option, attributing positive impacts to value-chain partners, scaling results to product's market size, and aggregating results to the level of an entire company or product portfolio.

Previous work characterized the implication of the SHINE handprint method for cases involving product innovation and cases involving the co-causing of innovation in a company's supply chain (Norris et al., 2021). This paper explores a unique application of handprinting to a case involving market share growth (combined with product innovation, although this is not essential to the case study). The specific case involves an innovation in beverage packaging and marketing globally. Results showed that if properly framed, it is possible to give quantitative guidance to businesses to both adopt environmentally preferred innovations and to pursue market expansion, and to do so in a manner that reduces overall impacts of human activity on the natural environment.

3. Methods

Norris et al. (2021) defined that organizations and individuals can create handprints through voluntary actions (e.g., process innovation, investments, initiatives, common goods, information, and behavioral changes) resulting in positive impacts such as footprint reductions. In this study, we focused on a specific case of product innovation, called eco-innovation. Eco-innovation is a new product or process which provides customer and business value and decreases environmental impacts (Díaz-García et al., 2015). We used a case study of an aseptic carton manufacturer introducing a packaging eco-innovation to global milk market with environmental benefits achieved via paperboard, which is produced from 82% eco-certified wood, barrier layer containing 100% bio-based plastic, and substitution of aluminum foil layer with a plant-based barrier. The SHINE handprint assessment method includes defining goal and scope, inventory analysis, environmental impact assessment, and interpretation (Norris et al., 2021).

3.1. Goal and scope

The goal of the study was to provide a general method for calculating handprints which are caused by business's eco-innovation and/or consumer's behavioral change to eco-innovation. First, we presented a methodological framework and then we used a case study to calculate potential ex-ante handprints for Organization A which is providing an eco-innovation (Scenario 1) and Consumers who are adopting behavioral change to eco-innovation (Scenario 2). Also, we used net-positive assessment to provide interpretation of the handprint results from perspectives of both actors Organization A and Consumers. Handprints were assessed across global market shift pathways including Scenario 1a) substituting Organization A's existing aseptic milk carton with eco-innovation in their markets; Scenario 1b) substituting a competitor's (Rest-of-Market) milk containers with eco-innovation, which increases Organization A's market share and thus, its footprint; Scenario 2a) Organization A consumers switching to eco-innovation; and Scenario 2b) Rest-of-Market consumers switching to eco-innovation.

Because the SHINE handprint framework quantifies positive actions, changes, and impacts, a product cannot be the agent of change; only actors can, for example, an organization or an individual (Norris et al., 2021). In the life cycle of the milk consumption, different actors could be an agent of change, including packaging manufacturer, rest of the milk packaging manufacturers, milk processors, and milk consumers. A manufacturer will often create change by modifying products and services, but it is how a product is used (by customers and consumers) that determines whether that product's use creates changes relative to business-as-usual. We focused on evaluating potential handprints for packaging manufacturer (Organization A) and milk consumers (Consumers). Organization A can either use eco-innovation to SOF (internal handprint) in their own market, or to reduce the footprint of others (external handprint), for example, of consumers in ambient and/or chilled milk markets. Also, consumers could change their behavior because of eco-innovation resulting in their SOF (internal handprint).

The SHINE handprint assessment does not require the definition of a functional unit because it amounts to a comparison of two scenarios, which may or may not be functionally balanced: one without and another with a specified action to bring about change (Norris et al., 2021). There might be differences in functionality and convenience when eco-innovation is replacing alternatives such as plastic milk containers. The assumption was that systems behave equally except the moment the consumer chooses a different option. Also, we assumed equal relevance of choice, as consumer footprint was implicitly static. Impact assessment results were presented for climate change, i.e., carbon footprint/handprint only (Intergovernmental Panel on Climate Change, 2014).

3.1.1. System boundary

Fig. 1 shows system boundary of the baseline state in Time 1, including a relative share of the chilled and aseptic milk markets, and relative share of plastic and carton milk packaging. In 2018, the global milk market was ~90 million tons (Mordor Intelligence, 2018). Consumers represent milk markets including Americas, Asia, Europe, and Africa. Organization A, which produces aseptic milk cartons, covers a share in the ambient milk packaging market. Also, we have the Rest-of-Market, which is not agent of change, however, the SHINE scope goes beyond the comparison of an existing product and eco-innovation because Organization A and Consumer's actions can include positive and negative changes within the expanded system boundary. Rest-of-Market represents the rest of the milk packaging market (ambient and chilled). More than half of the total milk belongs to cold supply chain. The dominant packaging options are plastic containers for chilled milk and carton for ambient as shown in Fig. 1. The modeled size of packaging was assumed to be one-liter pack size.

3.2. Data inventory analysis for handprint calculation

The inventory analysis included data collection of product LCAs (P-LCA) carbon footprints for aseptic milk cartons, other milk packaging, and eco-innovation. The data were collected from literature and from the company, as shown in Tables 1–3. Two types of P-LCAs were considered: cradle-to-gate and cradle-to-grave, as shown in Fig. 2. Data for cradle-to-gate P-LCAs were obtained from Organization A (Wellenreuther et al., 2018), and data for cradle-to-grave P-LCAs were collected from the literature (Burek et al., 2018). Both studies followed the LCA method standards and included comprehensive list of environmental impacts (ISO, 2018, 2006a, 2006b). Only climate change impacts i.e., carbon footprints were extracted from both studies. For cradle-to-gate P-LCAs, the authors used a functional unit of delivering 1,000 liters of milk to a customer and included container material production and container manufacturing life cycle (LC) stages, as shown in Fig. 2a. Milk farm production, the end-of-life (disposal) of carton, and plastic packaging were excluded from the assessment. Table 1 shows the cradle-to-gate carbon footprints. For a cradle-to-grave P-LCA, the authors used a functional unit of delivering 1,000 liters of milk to a consumer and included milk production on farm, container material production, container manufacturing, milk processing, supermarket, consumer, and end-of-life LC stages, as shown in Fig. 2b. Table 2 shows the cradle-to-grave carbon footprints of average milk consumption. To be consistent with the chilled packaging, the ambient carton was used to represent cradle-to-grave carbon footprint of eco-innovation.

3.2.1. Scenario 1a—Organization A is an agent of change in the market they own

In this scenario, Organization A produces one-liter aseptic milk cartons and Rest-of-Market produce chilled and aseptic one-liter milk containers. In Time 1, Organization A has a percent of the total milk packaging market, as shown in Fig. 1. Let's assume that in Time 2 Organization A produces an eco-innovation, which has a lower carbon footprint. Organization A introduces an eco-innovation in the market they own, which is called innovation change. For example, Organization A starts replacing 25% of their existing market with eco-innovation, as shown in Table 3. Because the change occurred within their own market, there would not be any changes in post-processing milk distribution and consumption.

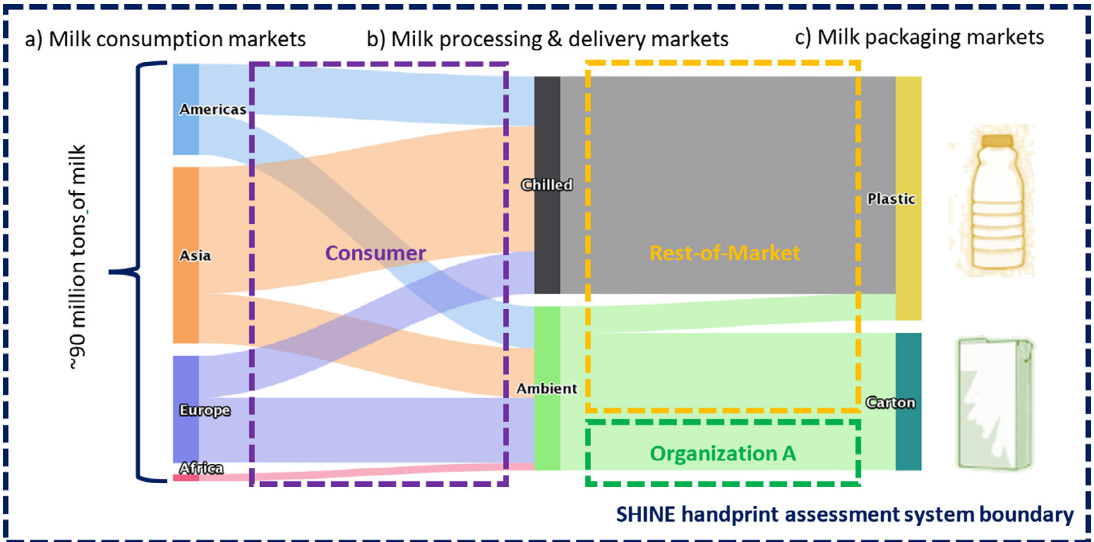

Fig. 1. Sankey diagram shows milk consumption, milk processing & delivery, and milk packaging markets: a) left nodes show relative size of milk markets including Americas, Asia, and Europe, b) middle nodes show relative size of the ambient and chilled markets, and c) right-side nodes show relative shares of carton and plastic milk packaging. Blue dash line shows the system boundary for the whole milk market, purple dash line shows consumers (Consumer), orange dash line shows the market share of the rest of the milk packaging market (Rest-of-Market), and the green dash line shows the market share of the aseptic carton packaging manufacturer (Organization A). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Cradle-to-gate carbon footprints of milk packaging (kg CO_2-eq/1,000 kg milk).

Milk	Market	Material	Carbon footprint (kg CO_2-eq/1,000 kg milk)	Data source
Aseptic	Carton	Paperboard	74	(Wellenreuther et al., 2018)
Aseptic	Plastic	Average PET*/HDPE**	120	(Wellenreuther et al., 2018)
Aseptic	Carton	Eco-Innovation	36	(Wellenreuther et al., 2018)

* PET—Polyethylene terephthalate.
** HDPE—High-density polyethylene.

Table 2
Cradle-to-grave carbon footprints of milk consumption (kg CO_2-eq/1000 kg milk).

Milk	Market	Material	Carbon footprint (kg CO_2-eq/1,000 kg milk)	Data source
Chilled	Plastic	Average PET/HDPE	2,000	(Burek et al., 2018)
Ambient	Carton	Paperboard/Eco-Innovation	1,850	(Burek et al., 2018)

Table 3
Input data for handprint calculation.

Actors	Market	Action		Market
		Scenario 1a & 2a	Scenario 1b & 2b	
	Time 1	Time 2		
	Milk market (1,000,000 L)	Innovation/behavioral change (1,000,000 L)	Market/behavioral change (1,000,000 L)	Milk market (1,000,000 L)
Organization A	134,918	33,729 (25% Organization A)	+19,102 (10% of Rest-of-Market)	154,019
Rest-of-Market	191,015	–	−19,102 (10% of Rest-of-Market)	171,914

3.2.2. Scenario 1b—Organization A is an agent of change in the Rest-of-Market

This scenario allows for an exploration of the role of eco-innovation and a switch to optimized packaging materials might play in the wider system. Time 1 is same as in Scenario 1a. At Time 2, Organization A introduces an eco-innovation outside their own market, which is called market change. Organization A expands market by replacing 10% of Rest-of-Market products, as shown in Table 3. Scenario 1b included evaluating changes caused by market expansion and changes caused by shrinking of Rest-of-Market. Because there would be changes in post-processing milk distribution and consumption, we presented results using both cradle-to-gate and cradle-to-grave P-LCAs for Scenario 1a and 1b.

3.2.3. Scenario 2a—Consumers are agents of change in the Organization A market

In this scenario, at Time 1, Consumers are purchasing aseptic milk cartons from Organization A. In Time 2, Organization A introduces product eco-innovation to their milk processors (Customers) who decide to pack the milk. However, it is the Consumers who decide to change their behavior and switch from one type of packaging to eco-innovation and thus agents of change. We assumed

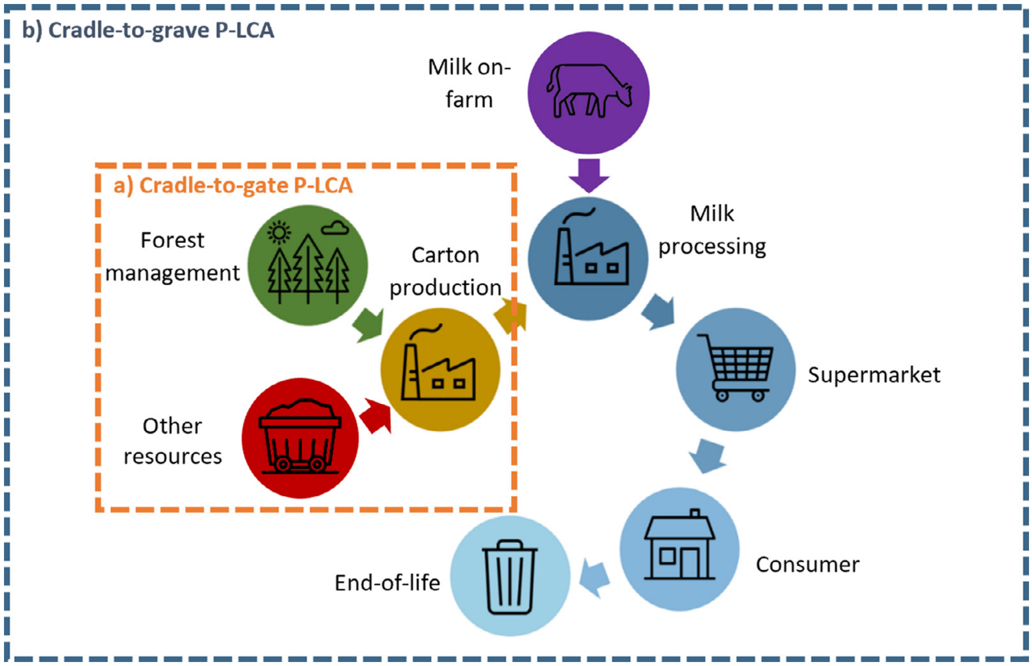

Fig. 2. Orange dash line delineates system boundary for a) cradle-to-gate P-LCA of milk carton, which includes forest management and other resources. Blue dash line delineates system boundary for b) cradle-to-grave P-LCA of milk consumption, which includes all inputs for carton production, milk production on farm, milk processing, supermarket, consumer, and end-of-life. Arrows between life cycle stages describe transportation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

25% of Consumers purchase eco-innovation, which is called behavioral change, as shown in Table 3.

3.2.4. Scenario 2b—Consumers are agents of change in the Rest-of-Market

The Organization's A eco-innovation may have additional post-processing footprint-reducing benefits for consumers who are currently consuming chilled milk. Because the aseptic cartons are shelf-stable, they reduce refrigeration and milk loss (Burek et al., 2018). In Time 1, Consumers are purchasing chilled milk from the Rest-of-Market. At Time 2, 10% of Consumers shift their consumption from Rest-of-Market to eco-innovation, as shown in Table 3.

3.3. The SHINE handprint method

The SHINE handprint calculation included above-described scenarios. For Scenario 1a and 1b, we calculated Organization A internal and external handprints. For Scenario 2a and 2b, we calculated Consumers internal handprints.

A broad definition is that internal handprints are changes made by an organization or consumer within the scope of their footprint (Norris et al., 2021). For example, in the Scenario 1a, Organization A may replace their existing carton with eco-innovation across their value chain eventually over the years, which is often called Design for Environment (DfE) (Fiksel, 2009), but in this scenario, we are interested in what if this positive change can be achieved faster. Thus, we assessed the internal handprint of eco-innovation, which could happen if consumer demand triggers the rapid substitution of standard packaging with the eco-innovation. The switch from an existing aseptic milk carton to an eco-innovation occurs within the organization's market in one year.

A broad definition is that external handprints are changes made by an organization or consumer outside the scope of their footprint (Norris et al., 2021). In this study, the mechanism of handprint creation was external, by market expansion. For example, in Scenario 1b, we are interested in finding out what is a potential handprint of delivering eco-innovation across the global milk value chain. This case is called Market for Environment (MfE) (Woodward, 2005).

3.4. Handprint calculation for Scenario 1

Fig. 3 shows primary steps for calculating handprints for Scenario 1. Potential handprints measure footprint reductions of DfE (Scenario 1a) and MfE (Scenario 1b). Organization A is the actor, and the action is switching milk packaging from existing packaging options to eco-innovation. The change for Scenario 1a occurs within the Organization A market and for Scenario 1b in the Rest-of-Market. When DfE occurs, Organization A creates internal handprint (SOF). In case of MfE, Organization A creates internal handprint (increasing the footprint due to market expansion) and external handprint (due to Rest-of-Market reduction).

3.4.1. Scenario 1a & 1b — Organization A internal handprint calculation

The P-LCAs from Tables 1 and 2 were used to calculate cradle-to-gate and cradle-to-grave market carbon footprints. The market carbon footprint of current product(s) for Organization A in Time 1 was calculated using Eq. (1):

$$FP_i^A(t_1) = (M_o \times L_o)_i \quad (1)$$

where $FP_i^A(t_1)$ is the market footprint of milk packaging of Organization A in Time 1 (t_1), i is an impact category, M_o are the milk consumption markets of Organization A measured in functional units, L_o is the footprint of a current product per functional unit, and i is impact category.

Next, we calculated the market footprint of the milk packaging of Organization A after an innovation change in Time 2 (t_2) for Scenario 1a. First, we defined the footprint of eco-innovation per functional unit, or "unit footprint" L_{new}, which is equal to the old plus the change, as shown in Eq. (2):

$$L_{new} = L_o + \Delta L \quad (2)$$

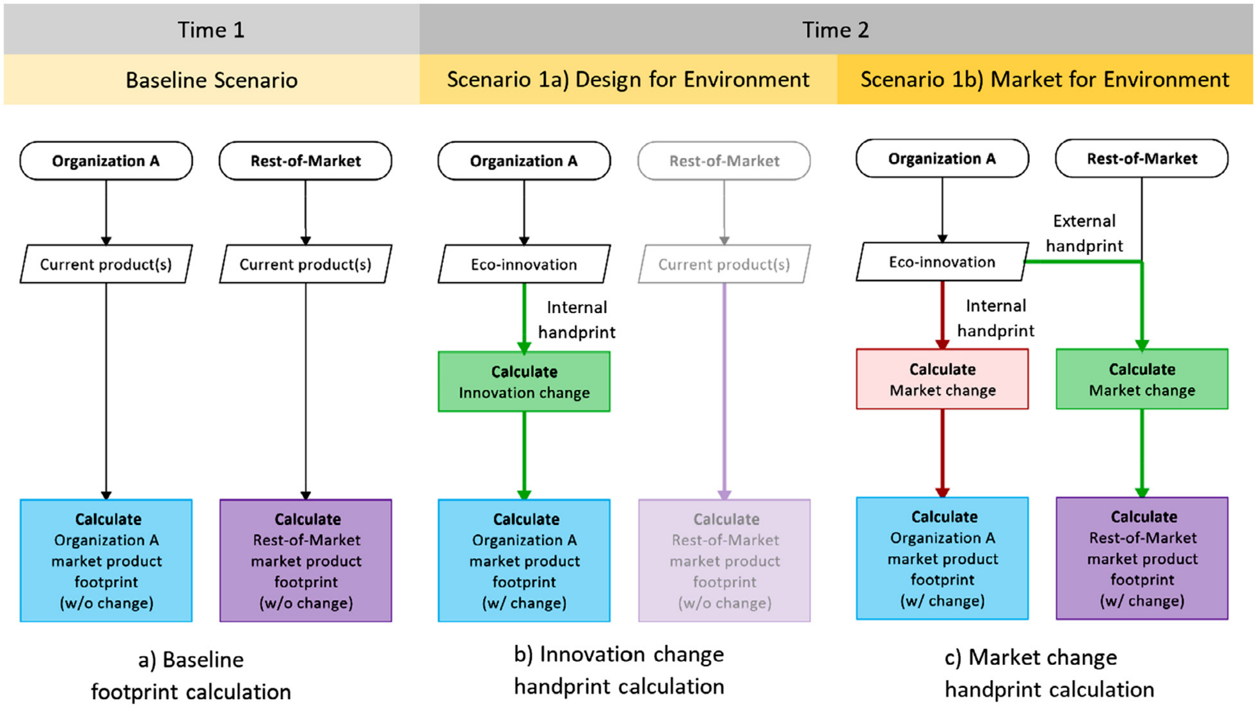

Fig. 3. Flow charts of the main steps used to calculate a) baseline market footprint calculation of Organization A (w/o change) and Rest-of-Market (w/o change) in Time 1; b) internal handprint due to innovation change (Scenario 1a) and resulting market product footprint of Organization A (w/ change) in Time 2; and c) internal and external handprint due to market change (Scenario 1b) of Organization A and resulting market product footprint of Organization A (w/ change) and Rest-of-Market (w/ change) in Time 2.

where ΔL is the change in L, and it is negative for a reduction and positive for an increase in footprint. Because in Scenario 1a only fraction of the market X belonging to Organization A is affected by changes, the market footprint $FP_i^A(t_2)$ is equal to the sum of an unaffected portion of the market multiplied by L_o and the affected portion of the market multiplied by eco-innovation footprint. The condensed formula is as shown in Eq. (3):

$$FP_i^A(t_2) = (M_o \times (L_o + X \times \Delta L))_i \tag{3}$$

where $FP_i^A(t_2)$ is a market footprint of Organization A in Time 2 (t_2), i is an impact category, M_o is milk consumption market of Organization A, X is a percent (%) of milk market replaced by the eco-innovation, and ΔL is calculated using Eq. (2).

In Scenario 1b, Organization A captures some Rest-of-Market using eco-innovation with unit footprint L_{new}. The new market is defined in Eq. (4).

$$M_{new} = M_o + \Delta M \tag{4}$$

where M_{new} is total new market, M_o is initial market, and ΔM is change in M, which can be negative for market loss and positive for market gain. The footprint of Organization A increases by an amount $\Delta M \times L_{\text{new}}$. Also, there is a reduction in the footprint of the other suppliers in the Rest-of-Market, whose old unit footprint was L_R by an amount $\Delta M \times L_R$. The new market footprint for Organization A is equal to the sum of the unaffected portion of the market multiplied by the original unit footprint L_o and the affected portion of the market multiplied by the new unit footprint L_{new}. The market footprint for Organization A due to market change in Time 2 for Scenario 1b is shown in Eq. (5):

$$FP_i^A(t_2) = (M_o \times L_o + \Delta M \times L_{\text{new}})_i \tag{5}$$

where $FP_i^A(t_2)$ is a Scenario 1b footprint of the Organization A in Time 2, i is an impact category, M_o is milk consumption market, L_o is current milk packaging footprint of Organization A, ΔM is change in M, and L_{new} is a footprint of an eco-innovation per functional unit. The calculation of an internal handprint due to innovation change was done by comparing the current market product footprints against eco-innovation and calculating their difference. Eq. (6) was used to calculate potential internal handprints iHP_i^A for Scenario 1a and 1b.

$$iHP_i^A = \sum \left(FP^A(t_1) + FP_D^A - FP^A(t_2)\right)_i \tag{6}$$

where iHP_i^A is internal handprint of Organization A, i is an impact category, $FP_i^A(t_1)$ is a market footprint of Organization A with current milk packaging in the market, FP_D^A is a footprint occurring due to growing demand. In all scenarios, $FP_D^A = 0$ meaning we assumed no natural growth of the market. $FP_i^A(t_2)$ is a market footprint of the Organization A for Scenario 1a and 1b. In Scenario 1a $FP_i^A(t_2) < FP_i^A(t_1)$ and thus, iHP_i^A is positive, which results in footprint reduction for Organization A. When a business is pursuing DfE, footprints measure a static difference in environmental impacts per functional unit between products, but handprints measure dynamic differences of product impacts multiplied by market. In Scenario 1b $FP_i^A(t_2) > FP_i^A(t_1)$, and thus, iHP_i^A is negative, which results in footprint increase for Organization A.

3.4.2. Scenario 1b– Organization A external handprint calculation

For Scenario 1b, the external handprint of Organization A was calculated based on Fig. 3. First, we calculated footprint of current products for Rest-of-Market, as shown in Fig. 3. The calculation of an external handprint due to market change was done by comparing the current market product footprints and remaining market product footprint after eco-innovation and calculating their difference.

We calculated market footprint of current product(s) for Rest-of-Market in Time 1 using Eq. (7):

$$FP_i^R(t_1) = (M_R \times L_R)_i \tag{7}$$

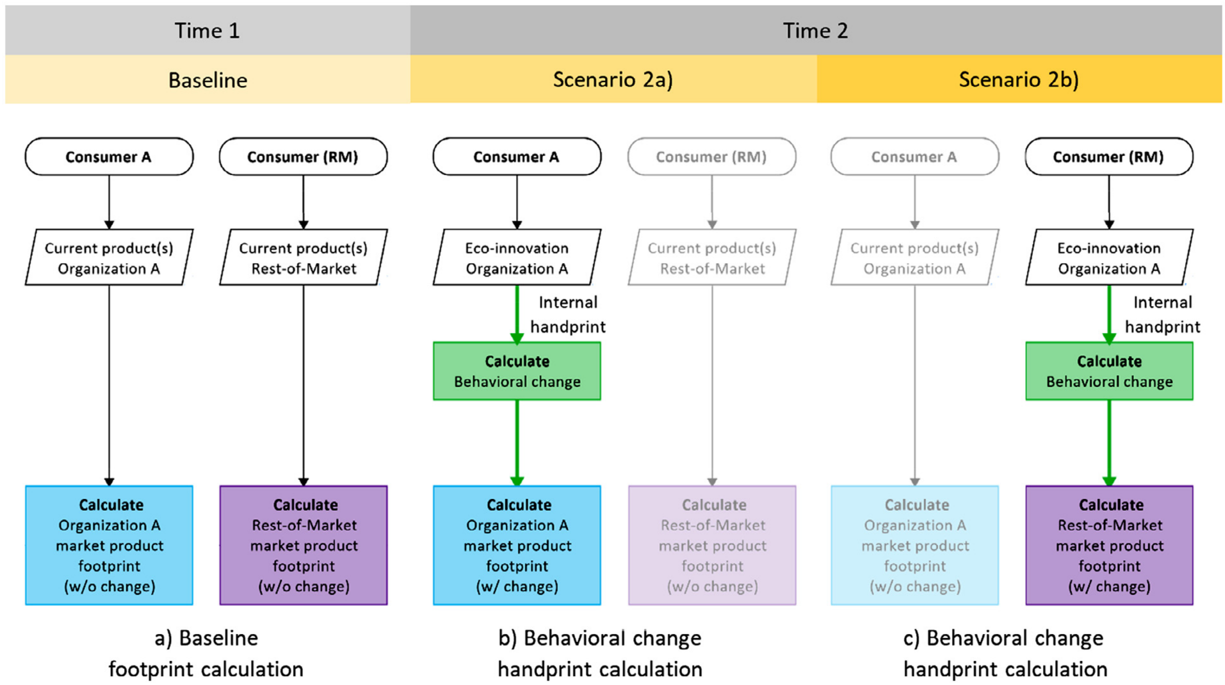

Fig. 4. Flow charts of the main steps used to calculate a) baseline market footprint calculation of Consumer A (w/o change), which purchase milk from the Customer supplied by Organization A and Consumer RM, which purchase milk from the Customer supplied by the Rest-of-Market (w/o change) in Time 1; b) Consumer A internal handprint due to behavioral change to Eco-innovation (Scenario 2a) and resulting market product footprint of Organization A (w/ change) in Time 2; and c) Consumer RM internal handprint due to behavioral change to Eco-innovation (Scenario 2b) and resulting market product footprint of Rest-of-Market (w/ change) in Time 2.

where $FP_i^R(t_1)$ is a market footprint of one type of milk packaging in Rest-of-Market, i is an impact category, M_R is milk consumption market of Rest-of-Market, and L_R is a footprint of a current product in Rest-of-Market per functional unit.

Next, we calculated market footprint of the Rest-of-Market for Scenario after the eco-innovation has taken over a portion of market belonging to Rest-of-Market in Time 2, as shown in Eq. (8).

$$FP_i^R(t_2) = ((M_R - \Delta M) \times L_R)_i \tag{8}$$

where $FP_i^R(t_2)$ is a market footprint of the milk carton in Time 2 for Rest-of-Market, i is an impact category, M_R is milk consumption market of Rest-of-Market, ΔM is change in M, and L_R is a footprint of the milk carton in Rest-of-Market per functional unit.

Eq. (9) was used to calculate external handprint eHP_i^A of Organization A in different markets for Scenario 1b. The calculation of an internal handprint because of innovation change was done by comparing the current market product footprints against eco-innovation and calculating their difference.

$$eHP_i^A = \sum \left(FP^R(t_1) + FP_D^R - FP^R(t_2)\right)_i \tag{9}$$

Because in Scenario 1b $FP_i^R(t_2) < FP_i^R(t_1)$, eHP_i^A is positive, which results in footprint reduction of Rest-of-Market.

3.5. Handprint calculation of Scenario 2

Fig. 4 shows primary steps for calculating handprints based on the SHINE method for the case study of Scenario 2 in which the main actors are Consumers and action/change is consumers' behavior from existing packaging provided by Organization A (Scenario 2a) or Rest-of-Market (Scenario 2b) to eco-innovation. Cradle-to-gate and cradle-to-grave P-LCAs were used to calculate internal handprint for the Consumers in Scenario 2a and 2b, as shown in Tables 1 and 2.

3.5.1. Scenario 2a—Organization A consumers internal handprint calculation

In scenario 2a, consumers are buying product from customers who purchased packaging from Organization A at Time 1. When Organization A launches eco-innovation at Time 2, consumers change behavior to buying their eco-innovation at Time 2, as shown in Fig. 4b. Substitution of the packaging material for the same product does not involve the change of consumption habits as we can assume full functional equivalence. Because the change is self-motivated or motivated by other consumers, we calculated internal handprint of Consumers.

The potential internal handprint of consumers is calculated using Eq. (10). The calculation of a handprint was done by comparing the current purchasing behavior against beneficial actions of purchasing eco-innovation and calculating their difference.

$$iHP_i^C = iHP_i^A = \sum (FP^A(t_1) + FP_D^A - FP^A(t_2))_i \tag{10}$$

where iHP_i^C is internal handprint of Consumers. iHP_i^C for Scenario 2a is equal to iHP_i^A for Scenario 1a because in the ambient milk market the post-processing distribution, consumption, and end-of-life is assumed to be equal for all ambient milk packaging. Thus, the internal handprint of Consumers in Scenario 2a is identical to footprint reduction of Organization A resulting from innovation change.

3.5.2. Scenario 2b— Rest-of-market consumers internal handprint calculation

Scenario 2b shows the potential reduction of Consumers that can be achieved if the consumers shift their consumption habits from chilled milk to ambient. In Scenario 2b, Consumers are buying chilled milk from Rest-of-Market at Time 1. When Organization A launches eco-innovation at Time 2, Consumers change behavior and buy aseptic milk packed in product eco-innovation from Organization A. Because the change is self-motivated or motivated by other consumers, we calculated a potential internal handprint of

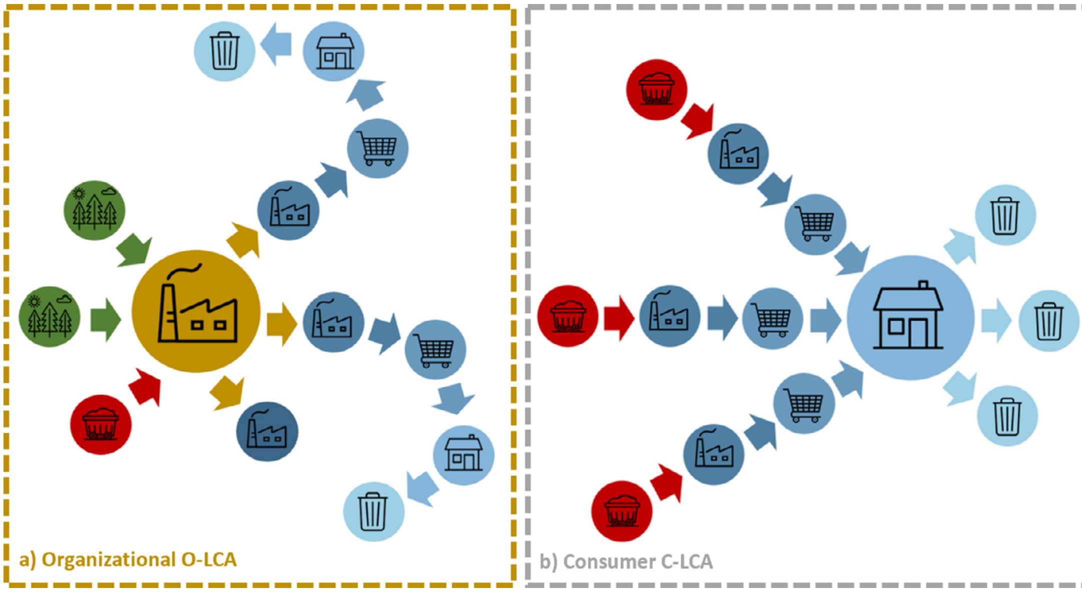

Fig. 5. Left flow diagram (brown dash line) shows the organization's LCA (O-LCA) system boundary. Right flow diagram (gray dash line) shows the consumers LCA (C-LCA) system boundary. The name of each life cycle stage is provided in Fig. 2 using same color and icon.

Consumers, as shown in Fig. 4c. The calculation of a handprint was done by comparing the current purchasing behavior against beneficial actions of purchasing eco-innovation and calculating their difference, as shown in Eq. (11):

$$iHP_i^C = iHP_i^A + eHP_i^A = \sum (FP^A(t_1) + FP_D^A - FP^A(t_2))_i + \sum (FP^R(t_1) + FP_D^R - FP^R(t_2))_i \quad (11)$$

where iHP_i^C is internal handprint of Consumer. If iHP_i^C is positive, it results in footprint reduction of Consumers. Thus, consumers internal handprint is equal to Organization A market expansion in Scenario 1b.

3.6. Interpretation

The net-positive assessment can be used for interpreting the results. It includes combined analysis of actor's footprint and handprint (Norris et al., 2021). For example, the net-positive assessment could play a role to interpret the footprint of an organization and/or consumers to handprints that could be achieved incrementally or as total. It is important that footprints and handprints are measured in the same physical units. The net-positive assessment includes calculating organization and consumers business-as-usual footprints, as shown in Fig. 5.

3.6.1. Organization A footprint calculation

It has become common for organizations and individuals to measure their footprints using organization LCA (Hellweg and Milà i Canals, 2014). The system boundary for O-LCA is shown in Fig. 5a. As shown in Fig. 5a, the use phase and end-of-life are included in describing O-LCA footprint. If they are not relevant to the case, and data are not available, then the study must include these caveats. Organization A followed the ISO/TS 14072 standard (ISO, 2014) to calculate their business-as-usual footprint, which in 2018 amounted to 1.5 million tons CO_2-eq per year (personal communication). For the consumers footprint, the average yearly GHG emissions per person varies regionally from 1.9 tons CO_2-eq in India, 5.6 tons CO_2-eq in United Kingdom to 16 tons CO_2-eq in the United States (Joint Research Centre, 2018). Globally, the average annual global citizen emissions is 5 tons CO_2-eq (Joint Research Centre, 2018).

Eq. (12) shows how to calculate Organization A footprint:

$$oFP_i^A = \left(O^A + FP_G^A\right)_i \quad (12)$$

where oFP_i^A is Organization A footprint, O^A is Organization A calculated using organizational LCA, FP_G^A is Organization A business-as-usual growth, and i is impact category. Organization A business-as-usual growth FP_G^A was assumed to be zero.

3.6.2. Organization A net-positive assessment calculation

The net-positive assessment calculation for Organization A includes organization footprint, footprint reductions that are not considered handprints, such as business-as-usual SOF actions, and internal and external handprints. The total handprint of Organization A was calculated using Eq. (13):

$$HP_i^A = \sum iHP_i^A + eHP_i^A \quad (13)$$

Fig. 6b illustrates the net-positive assessment calculation steps for Organization A. The net-positive assessment calculation for Organization A is shown in Eq. (14):

$$NP_i^A = oFP_i^A - \sum_1^f \left(FP_i^A\right)_f - \sum_1^h \left(HP_i^A\right)_h \quad (14)$$

where NP_i^A is net-positive assessment result for Organization A, i is impact category, oFP_i^A is Organization A footprint, $(FP_i^A)_f$ are other footprint reductions that are not handprints, f is the number of footprint reduction actions, $(HP_i^A)_h$ is handprint, and h is number of handprint causing actions. Note that oFP_i^A is different than $(FP_i^A)_f$ because oFP_i^A is a business-as-usual footprint of the whole organization (for example company) and $(FP_i^A)_f$ describes footprint reductions that would occur anyways (business-as-usual).

3.6.3. Consumer footprint calculation

The system boundary for consumer LCA (C-LCA) is shown in Fig. 5b (Hellweg and Milà i Canals, 2014). We used 2018 average annual global citizen emissions of 5 tons CO_2-eq and multiplied with a population of 4,960 million (~40 markets) to calculate consumer footprint. Based on these assumptions, the total C-LCA footprint of Organization A ~40 markets equaled 24,799 million tons CO_2-eq. Consumer's average footprint cFP_i is calculated using C-LCA, and i is impact category.

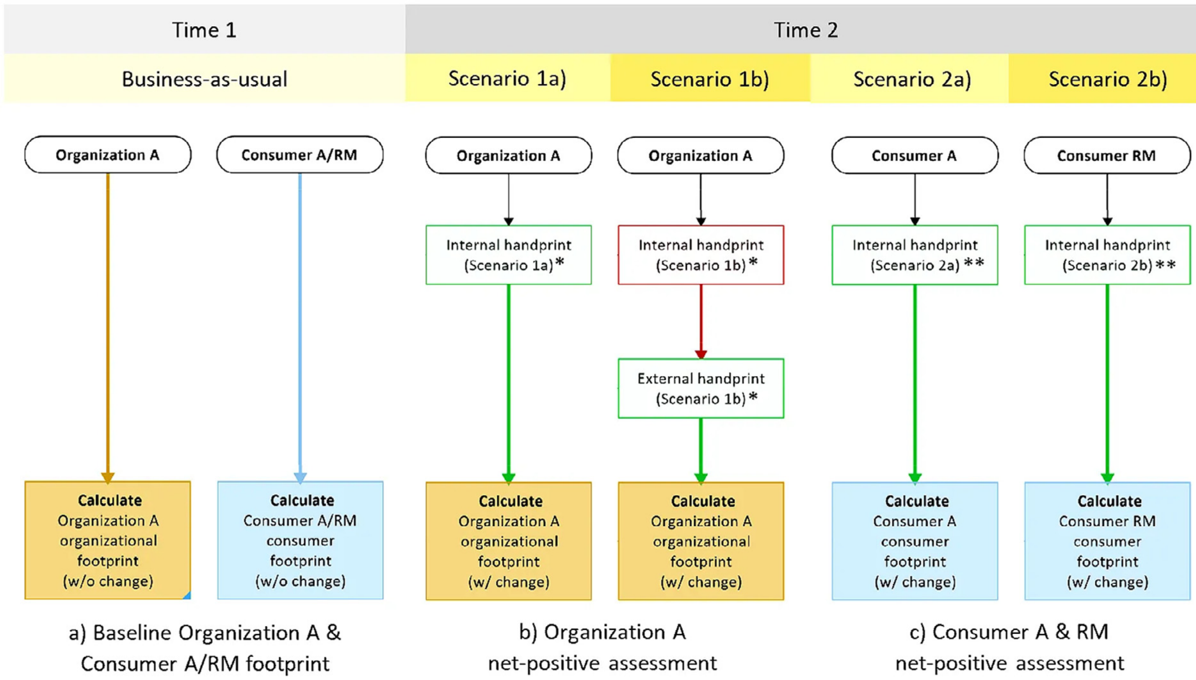

Fig. 6. Net positive assessment based on actors bringing about a change. Flow charts of the main steps for a) calculating baseline Organization A organizational footprint (w/o change) and Consumer A or Consumer RM consumer footprint (w/o change) in Time 1; b) Organization A net-positive assessment for Scenario 1a and Scenario 1b in Time 2; and c) Consumer A and Consumer RM net-positive assessment for Scenario 2a and 2b, respectively in Time 2. In b) handprint is dependent on the changes created by Organization A. Thus, in the illustration b) Organization A footprint (w/change) includes internal handprints (Scenario 1a) and internal and external handprints (Scenario 1b). In c) handprint is dependent on behavioral change of Consumer A and Consumer RM. Thus, in the illustration c) Consumer A and Consumer RM footprints include internal handprints (Scenario 2a and 2b).

3.6.4. Consumers net-positive assessment calculation

The net-positive assessment calculation for Consumers includes their footprint, footprint reductions that are not considered handprints, such as business-as-usual SOF actions, and internal and external handprints. The total internal handprint of Consumers was calculated using Eq. (15):

$$HP_i^C = iHP_i^C(2a) + iHP_i^C(2b) \tag{15}$$

Fig. 6c illustrates the net-positive assessment for Consumer A and Consumer RM. The net-positive assessment calculation for Consumers is shown in Eq. (16):

$$NP_i^C = cFP_i^C - \sum_1^f \left(FP_i^C\right)_f - \sum_1^h \left(HP_i^C\right)_h \tag{16}$$

where NP_i^C is net-positive assessment for Consumers, i is impact category, cFP_i^C is Consumers footprint, $(FP_i^C)_f$ is consumers footprint reduction (other than handprint), f is number of footprint reduction actions, $(HP_i^C)_h$ is handprint, and, h is number of handprint causing actions.

3.7. Limitations of the results

Footprints and handprints were calculated for one impact category, i.e., climate change. Including other impact categories may bring some trade-offs in the results, as shown in Burek et al. (2018). Because of that, there is a need to run inclusive LCA studies to measure trade-offs where substitution of alternatives plays a role.

For P-LCAs, the values reported in Tables 1 and 2 were used for exploration, not for comparison. Although these results are limited in geographical scope, they are sufficient for the goal and scope of this study. The cradle-to-grave P-LCAs did not include actual eco-innovation, instead a common aseptic milk carton was used because the impacts of change from chilled to ambient are higher from 12% distribution chilled milk losses to 0% ambient milk losses (Burek et al., 2018). The cold supply chain could be responsible for losses in the system, which differ widely between geographies. A global average of 12% distribution loss was assumed based on the U.S. case study (Burek et al., 2018). Thus, it is necessary to better understand the potentials of aseptic packaging to avoid losses in the cold supply chain.

Moving chilled milk into aseptic touches not only the functional equivalence of packaging system but also of a product, in this case, milk. Consumer might prefer fresh/chilled High-Temperature-Short-Time pasteurized milk believing in a higher nutritional value or taste even though aseptic/ambient Ultra-High Temperature pasteurized milk retains the nutritional value almost completely.

While the end-of-life of cartons may be similar, for plastic containers the end-of-life may become more relevant, especially because of concerns about plastic marine pollution. The substitution of systems with a completely different end-of-life may deliver less significant results as end-of-life might differ considerably between packaging alternatives in the different markets.

This analysis encompasses the global market, but potential handprints may differ by volume in different individual markets (i.e., country or region), and thus different markets could show different potentials. Including individual market analysis may offer valuable insights in identifying where driving change could be the most impactful for reducing consumer footprints by an organization bringing about a change using eco-innovation.

Finally, the modeled size of packaging was one-liter size, which is not the predominant size in all markets. For example, in the United States it is one gallon (Burek et al., 2018).

4. Results

In this study, we showed the application of SHINE handprint method on an organization manufacturing eco-innovation. The SHINE handprint assessment demonstrated positive changes that

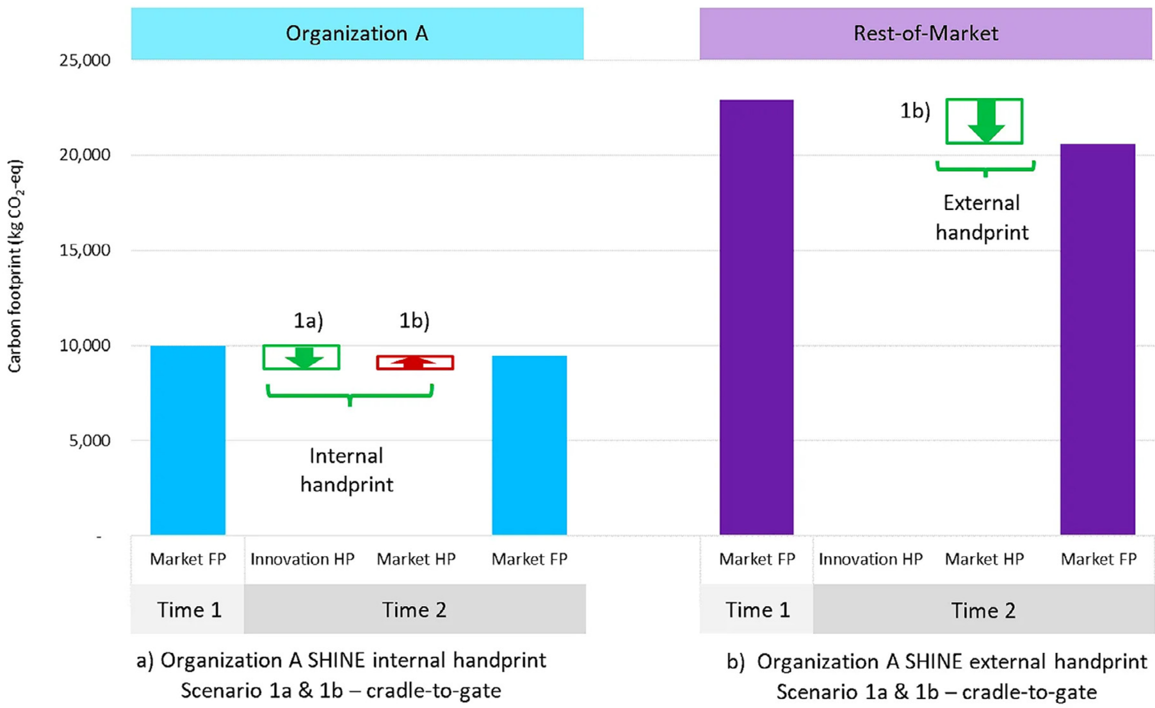

Fig. 7. SHINE handprint assessment for Organization A of Scenario 1a and 1b for carbon footprint. Blue columns show market product footprints (FP) or Organization A at Time 1 and 2. Purple columns show market product FP of Rest-of-Market at Time 1 and 2. Green squares show positive internal and external handprints (HP) and red square shows negative internal HP of Organization A. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

could be achieved by one's company product eco-innovation for two actors: Organization A and Consumers. For Scenario 1, the results showed that by expanding the scope there is a potential environmental benefit between Organization A and Rest-of-Market, i.e., handprint. For Scenario 2, the results showed there is a potential environmental benefit caused by a behavioral change of consumers. Also, the results showed that including all actors (in this case Organization A, Rest-of-Market, and Consumers) provided evidence that actions resulting in substitution of Rest-of-Market products of higher environmental impacts yield higher overall positive impact (external handprints) of the Organization A despite the increase in Organization A footprint. We included data, calculation, and figures presented in the following sections in Supplementary File 1.xlsx.

4.1. Scenario 1—Organization A handprint assessment

This scenario shows the environmental benefits of the Organization A investment in product eco-innovation. The SHINE handprint assessment included positive changes when Organization A introduces milk packaging eco-innovation within their own markets (Scenario 1a) and outside their markets (Scenario 1b). We calculated results using both cradle-to-gate and cradle-to-grave P-LCAs, as shown in Figs. 7 and 8, respectively. The y-axis shows carbon footprints in kg CO_2-eq. The x-axis shows market product footprints of Organization A and Rest-of-Market in Time 1 and Time 2 and internal and external handprints in Time 2. The environmental implication of DfE in Organization A's market was a decrease in market production carbon footprint and thus, the potential internal handprint of the Organization A, as shown in Figs. 7a and 8a. For Scenario 1b, handprint potential is measuring impact of the footprint reduction due to market shift from Rest-of-Market products to eco-innovation of Organization A (MfE). In Scenario 1b, the potential internal handprint is increasing the carbon footprint of Organization A, as shown in Figs. 7a and 8a, but the external handprint is decreasing the carbon footprint of Rest-of-Market due to shrinking of their market, as shown in Figs. 7b and 8b. The sum of the market product internal and external handprints resulted in positive handprint and thus, in environmental benefit.

4.2. Scenario 2 — Consumers handprint assessment

Scenario 2 included positive changes when Consumers change their behavior to buy eco-innovation from Organization A depending on whether they were initially buying ambient milk (Organization A) or chilled milk from Rest-of-Market. Fig. 9 shows the results of SHINE handprint assessment for Scenario 2a and 2b. The y-axis shows carbon footprints in kg CO_2-eq. The x-axis shows market product footprints of Organization A and B in Time 1 and Time 2 and internal handprints in Time 2. In both the overall market product footprints are decreasing because of behavior change of the Consumers to buy eco-innovation. The sum of the market internal handprints resulted in positive handprint and thus, in environmental benefit.

The internal handprint shown in Fig. 9b captured decreasing milk loss by switching from chilled to aseptic milk. Other potential benefits of this change may include reducing plastic pollution problem. However, changing fresh milk production to aseptic market is the most challenging scenario. First, because consumers are basing their choices mainly on the product they are buying, consumer willingness to change from purchasing fresh milk to shelf-stable milk may be difficult to achieve. Also, trade-offs associated with the increase in organizations footprint due to filling machines market expansion and due to increase in milk processing footprint may be some of the barriers to adopting and pursuing that action. Finally, once a specific packaging form or materials was selected, it would be very costly for liquid food manufacturers to switch to other packaging forms or materials, and demand-side substitutability is weak for paper-based aseptic packaging in the relevant markets (Fu and Tan, 2019). Due to high barriers in the areas of technology and capital requirements, manufacturers of other packaging equipment could not easily turn to producing paper-

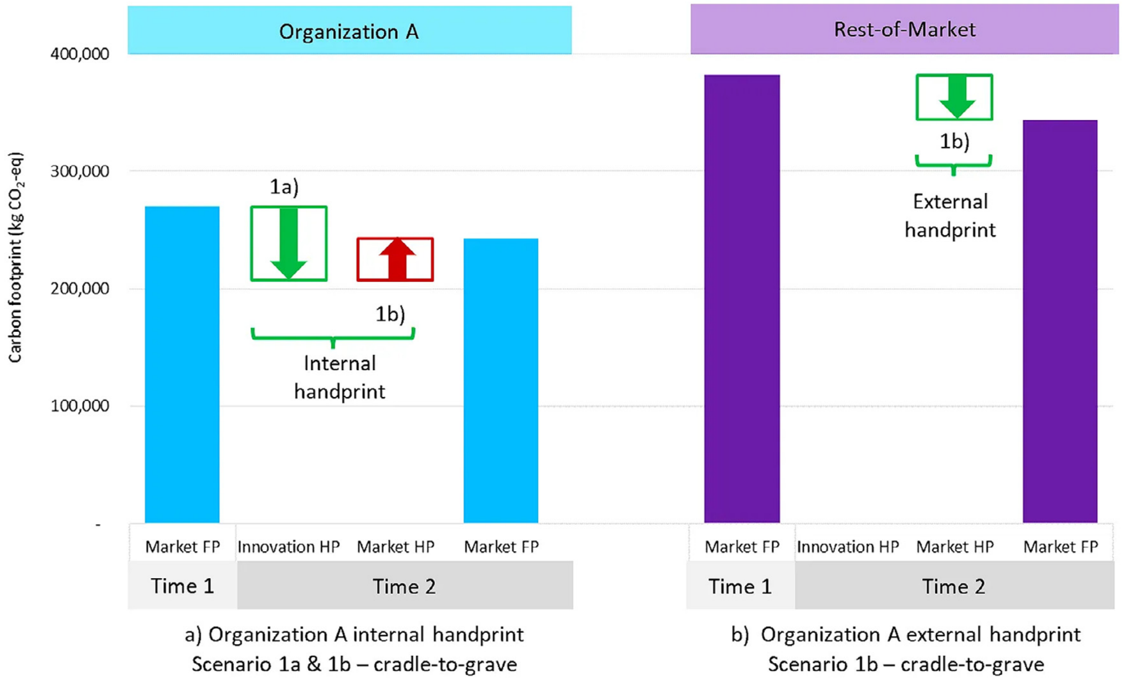

Fig. 8. SHINE handprint assessment for Organization A of Scenario 1a and 1b for carbon footprint. Blue columns show market product footprints (FP) or Organization A at Time 1 and 2. Purple columns show market product FP of Rest-of-Market at Time 1 and 2. Green squares show positive internal and external handprints (HP) and red square shows negative internal HP of Organization A. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

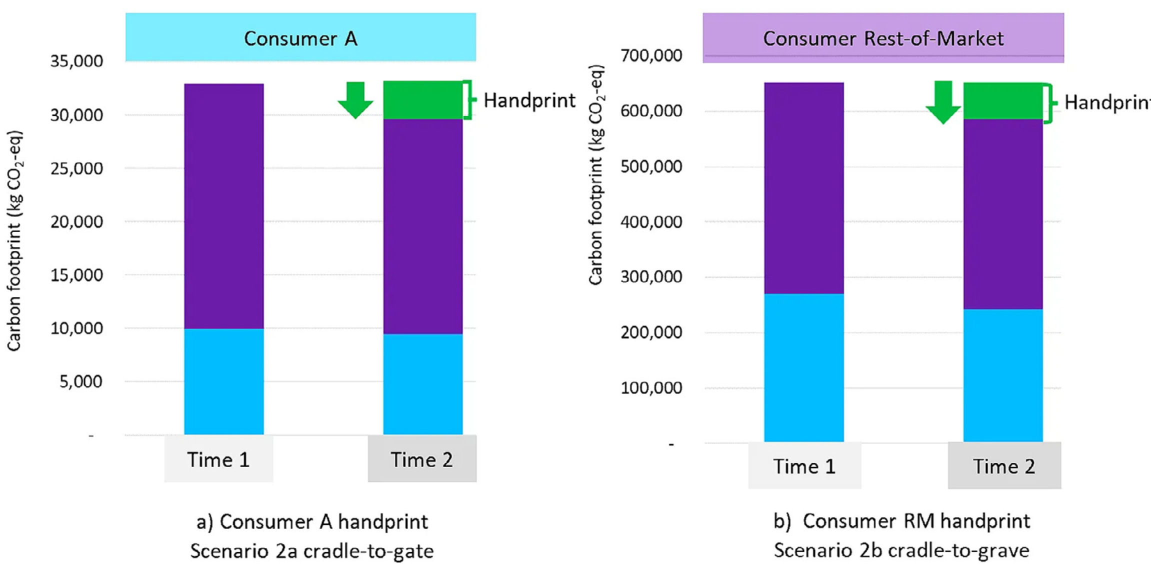

Fig. 9. SHINE handprint assessment for Consumer A (Scenario 2a) and Consumer Rest-of-Market (Scenario 2b) for carbon footprint. Blue columns show market product footprints (FP) or Organization A at Time 1 and 2. Purple columns show market product FP of Rest-of-Market (RM) at Time 1 and 2. Green squares show positive internal and external handprints (HP) of Organization A. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

based aseptic packaging equipment, especially high-speed filling machines (Fu and Tan, 2019). Thus, aseptic carton may not have high supply substitutability in some individual markets. Finally, changing fresh milk production to aseptic market is dependent on consumer choice. The choice could be triggered differently in different markets. If we assume that the consumer footprint is equal to the number of consumers choices, then, based on the market, our scenarios are approximations of how the consumer choices could be. Consumers could be screened in terms of their willingness to choose a different packaging. The screening could help understand consumers relevance for the organization in pursuing this action and challenges and barriers of making that change.

4.3. Net-positive assessment

Net-positive assessment showed potential impact on Organization A carbon footprint if they would increase carton eco-innovation in their market and replace alternatives such as plastics outside their market. When handprints exceed organizational and/or consumer footprint than an organization is net positive, as shown in Fig. 10.

The total Consumers handprint of Scenario 2a and 2b was 65,777 million kg CO_2-eq, which corresponds to the total annual footprint of 1.3 million people if using an average Global citizen footprint of 5,000 kg CO_2-eq/year. Changing chilled market into

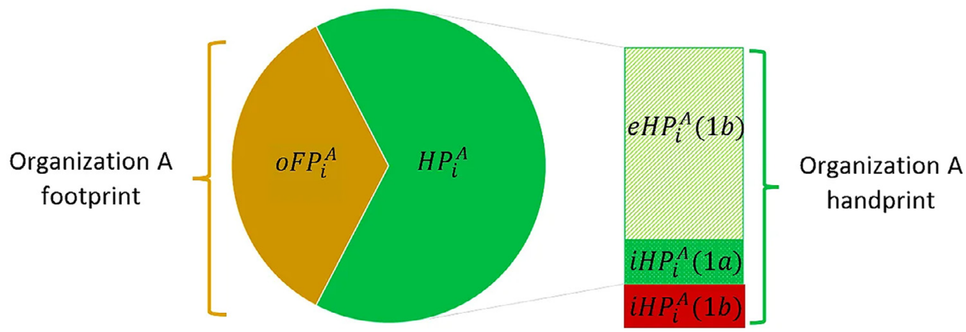

Fig. 10. Illustration of the net-positive assessment for Organization A including Organization A business-as-usual footprint and potential handprints calculated in Scenario 1a and 1b. oFP_i^A is organizational footprint of Organization A, HP_i^A is total potential handprint of Organization A, $iHP_i^A(1a)$ is a potential internal handprint and $iHP_i^A(1b$is a negative internal handprint of Organization A. Finally, $eHP_i^A(1b)$ is a potential external handprint of Organization A. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

aseptic is the most challenging one but it could potentially yield the largest handprints.

5. Discussion

5.1. What can handprinting mean for product eco-innovation?

The SHINE handprint assessment showed a deep understanding of all the changes a product eco-innovation could bring about. Thus, handprints can support the product or process design/redesign. By showing the leadership what the eco-innovation could be, it may remove some of the roadblocks to adopting the change. The action from Organization A could include providing better information to customers and consumers to understand the relevance of informed choices. Also, actions could include to further improving performance to increase the gradient between average solutions and eco-innovations. The SHINE handprint assessment could be used to show for which actions, and in which markets an organization can do better. Accomplishing this can be facilitated by addressing Avoided Emissions in the specific product's markets. Initial assessment may not require detailed information about local conditions. However, once several potential markets have been identified, in this kind of situations detailed information about local conditions of markets is needed. This means that at present if market of an organization's eco-innovation is growing, so does its organizational carbon footprint, and thus the SOF perspective does not capture positive impacts of the innovation. We also include different perspectives – organization and consumer to make sure all positive and negative impacts are included. Also, the organizations could invest more in finding what customers need in the market of greater handprint and then developing the best solution for it. By including handprints into their processes and methodologies, companies could make a difference not only in accelerating time to profitability of their eco-innovation, but in the long-term adoption of it in the market. Even without the complete substitution in all markets, the unique solutions could help differentiate company's business among the competition and give a boost to their own revenue while nudging the entire industry in a positive direction. Organization's handprints could also force others to innovate faster than business as usual, thus resulting in ripple handprints that would include also other milk and other beverage packaging industries.

5.2. What can net-positive assessment mean for product eco-innovation?

Because eco-innovation adoption depends on the consumers, the handprint assessment too should maintain a consumer-centric approach. The positive action also includes improving the environmental sustainability performance in a market, e.g., by collection and recycling improvements to add not only product purchase choices but also product disposal choices for consumers to reduce their footprint. The SHINE handprint approach allows organizations to take a more holistic view regarding the business model by including all actors (Customers, Rest-of-Market, and Consumers), which allows business to be ahead of the curve to seize opportunities to market their innovative product and achieve marketing excellence. After the market segmentation process through handprint assessment, the net-positive assessment can help form the most complete and detailed picture of the target audience(s) and to determine where the eco-innovation could have the most potential for making positive changes for both consumers and organizations. In the Scenario 1, in which the organization replaced their current aseptic carton with its innovative aseptic carton, the market share did not increase, and the business-as-usual Organization A footprint remained the same. However, shifting the packaging sector to an innovative sustainable carton will cause the organization to increase its organizational footprints. At the same time, this change may result in a reduction of the competitors' organizational footprint due to market loss.

5.3. Implications for theory and practice

Implications of this research for theory is that in many cases, companies have opportunities to be causes of massive reductions in the human footprint but are not adequately or properly reflected in accounting that focuses only on the company's footprint. By standardizing the method for calculating the positive impact, this research could have potential implications on how companies can aim for higher science based targets and achieve them more rapidly.

Implications of this research for practice is that there is a compelling scientific and moral obligation for business (producers) and individuals (consumers) to go above and beyond footprint abatement and take actions that cause credibly reportable footprint reductions beyond value chain impacts.

5.4. Novelty and significance of this work

This research demonstrated measurement of business's and consumers positive impacts by making change to eco-innovation and simple communication of this information using handprints and net-positive assessment.

6. Conclusion

In this manuscript, we provided a detailed methodological step for calculating handprints which are caused by business through eco-innovation and/or consumers behavioral change to eco-innovation. Then, we demonstrated the method on a case study of a business that is launching an aseptic milk carton eco-innovation. Also, we used net-positive assessment to provide interpretation of the handprint results from perspectives of both actors: Organization A and Consumers. The method was based on the general SHINE Handprint method framework and applied to unique positive impact that businesses and consumers can co-create due to producing an eco-innovation and behavioral change shift to eco-innovation, respectively.

This study has showed the role of handprints as a decision support tool for product eco-innovation. The most important contributions of this researchare in extending the scope of the assessment, scaling up to global markets, and examining handprint relevance for an organization and consumers. The case study examined how and where a global aseptic carton milk packaging producer might affect positive changes. The results presented here focused on the organization's internal and external handprints, consumers internal handprints, and net-positive assessment. To our knowledge, this was the first examination of potential external handprints created by a business producing an eco-innovation. Results showed what positive changes of product eco-innovation could be, where they could matter the most, and how to get them right. First, the results showed how organizations can use handprints to report about reductions in footprint (SOF) that they could create by product eco-innovation in their value-chain. Second, the results showed reductions in footprint that they could create with their product eco-innovation they bring about to out of the organization's footprint. This can support a company's decision-making, i.e., enabling organizations to choose between alternatives through both their value chain accounting and external markets. The results may inspire others to shift their businesses from focusing only on the environmental management to become drivers of sustainable development.

This research expands the way of thinking about climate change as a mitigation problem only and seeking solutions either in businesses or consumers behavioral change. It requires seeking solutions both in businesses and consumers.

The limitation of the case study is that these results are ex-ante assessments and thus are not intended to be used to assess the overall environmental performance of the products discussed and modeled. Instead, these findings serve as a decision-making tool, which can help organizations select the most impactful actions and markets where the change matters the most for both the organization and the consumer.

For businesses and consumers, future work should focus on implementation research including identifying approaches (potential factors) that could motivate behavioral change in identified markets for significant handprint. As far as the method advancements, future work will evaluate (i.e., measure actors' handprints relative to business as usual) other groups of actions (besides eco-innovation) for which businesses can provide reportable cause of positive impacts on climate and/or other impact categories that would not have happened were it not for the actions of the company.

Declaration of Competing Interest

There are no interests to declare. This work is original and has not been published elsewhere nor is currently under consideration for publication elsewhere. There are no conflicts of interest that would affect the decision to publish manuscript data, which have been either publicly available or modeled using well- established models. The manuscript contains enough detail and references to permit others to replicate the work. The named authors have no conflict of interest, financial or otherwise.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2021.10.006.

References

Acharya, S., Chakrabarti, A., 2017. Supporting Environmentally-Benign Design: Environmental Impact Estimation and Uncertainty Categories with Respect to Life Cycle Assessment in Conceptual Design. In: Smart Innov. Syst. Technol. 66, 3–18 https://doi.org/10.1007/978-981-10-3521-0_1.

Almeida, A.R., Alvarenga, R.A.F., Sartor, L.B., Simioni, F.J. https://doi.org/10.1016/j.jenvman.2019.01.094.

Blanco, J.M., Finkbeiner, M., Inaba, A., 2015. Guidance on Organizational Life Cycle Assessment.

Burek, J., Kim, D., Nutter, D., Selke, S., Auras, R., Cashman, S., Sauer, B., Thoma, G., 2018. environmental sustainability of fluid milk delivery systems in the united states. J. Ind. Ecol. 22, 180–195. doi:10.1111/jiec.12531.

Croes, P.R., Vermeulen, W.J.V., 2021. The assessment of positive impacts in LCA of products. Int. J. Life Cycle Assess. 26, 143–156. doi:10.1007/s11367-020-01820-x.

Daneshi, A., Esmaili-Sari, A., Daneshi, M., Baumann, H., 2014. Greenhouse gas emissions of packaged fluid milk production in Tehran. J. Clean. Prod. 80, 150–158. doi:10.1016/j.jclepro.2014.05.057.

Díaz-García, C., González-Moreno, Á., Sáez-Martínez, F.J., 2015. Eco-innovation: insights from a literature review. Innov. Manag. Policy Pract. 17, 6–23. doi:10.1080/14479338.2015.1011060.

Elias Mota, B.A., Cerqueira de Sousa Gouveia Carvalho, A.I., Azevedo Rodrigues Gomes, M.I., Ferreira Dias Barbosa-Povoa, A.P., 2020. Business strategy for sustainable development: impact of life cycle inventory and life cycle impact assessment steps in supply chain design and planning. Bus. Strateg. Environ. 29, 87–117. doi:10.1002/bse.2352.

Fiksel, J., 2009. Design for Environment: A Guide to Sustainable Product Development, Second Edition McGraw Hill Professional.

Fu, X., Tan, G., 2019. Abuse of market dominance under China's anti-monopoly law: the case of tetra pak. Rev. Ind. Organ. 54, 409–434. doi:10.1007/s11151-018-9638-8.

González-García, S., Castanheira, É.G., Dias, A.C., Arroja, L., 2013. Environmental life cycle assessment of a dairy product: the yoghurt. Int. J. Life Cycle Assess. doi:10.1007/s11367-012-0522-8.

Grönman, K., Pajula, T., Sillman, J., Leino, M., Vatanen, S., Kasurinen, H., Soininen, A., Soukka, R., 2019. Carbon handprint – an approach to assess the positive climate impacts of products demonstrated via renewable diesel case. J. Clean. Prod. 206, 1059–1072. doi:10.1016/j.jclepro.2018.09.233.

Hellweg, S., Milà i Canals, L., 2014. Emerging approaches, challenges and opportunities in life cycle assessment. Science 344, 1109–1113. doi:10.1126/science.1248361.

Intergovernmental Panel on Climate Change, 2014. Climate Change 2014: Synthesis report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel On Climate Change. IPCC, Geneva, Switzerland https://www.ipcc.ch/report/ar5/syr/.

ISO, 2006a. ISO 14040:2006 - Environmental management - life cycle Assessment - principles and Framework ISO https://www.iso.org/standard/37456.html (accessed 2.22.17).

ISO, 2006b. ISO 14044:2006 - Environmental management - life cycle Assessment - requirements and Guidelines. ISO https://www.iso.org/standard/38498.html (accessed 2.22.17).

ISO, 2014. ISO/TS 14072:2014 - Environmental management - life cycle Assessment - requirements and Guidelines for Organizational Life Cycle Assessment. ISO URL https://www.iso.org/standard/61104.html.

ISO, 2018. ISO 14067:2018 - Greenhouse Gases - Carbon Footprint of Products - Requirements and Guidelines for Quantification (revised). ISO URL https://www.iso.org/standard/71206.html.

Joint Research Centre, 2018. EDGAR - Fossil CO2 and GHG Emissions of All World Countries. European Commission https://edgar.jrc.ec.europa.eu/overview.php?v=booklet2019&dst=CO2pc.

Kaenzig, J., Friot, D., Saadé, M., Margni, M., Jolliet, O., 2011. Using life cycle approaches to enhance the value of corporate environmental disclosures. Bus. Strateg. Environ. 20, 38–54. doi:10.1002/bse.667.

Köhler, M., Michaelowa, A., 2014. Limiting climate change by fostering net avoided emissions: reducing fossil fuel supply and emissions from fuel exploitation. Law Rev. 8, 55–64.

ISO, 2013. ISO/TS 14067:2013 - Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication URL https://www.iso.org/standard/59521.html (accessed 1.24.19).

Mordor Intelligence, 2018. Global Dairy Market. https://www.mordorintelligence.com/industry-reports/dairy-products-market (accessed 11.10.20).

Norris, G., 2015. Handprint-based NetPositive assessment. https://hwpi.harvard.edu/files/chge/files/handprint-based_netpositive_assessment.pdf.

Norris, G.A., Burek, J., Moore, E.A., Kirchain, R.E., Gregory, J., 2021. Sustainability health initiative for NetPositive Enterprise handprint methodological framework. Int. J. Life Cycle Assess. 1, 3. doi:10.1007/s11367-021-01874-5.

Pineda, A.C., Chang, A., Faria, P., Farsan, A., 2020. Foundations for Science-based Net-Zero Target Setting in the Corporate Sector. CDP https://sciencebasedtargets.org/resources/files/foundations-for-net-zero-full-paper.pdf.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecol. Soc. 14. doi:10.5751/ES-03180-140232.

Russell, S., 2019. Estimating and reporting the comparative emissions impacts of products. https://www.wri.org/research/estimating-and-reporting-comparative-emissions-impacts-products

Stewart, R., Fantke, P., Bjørn, A., Owsianiak, M., Molin, C., Hauschild, M.Z., Laurent, A., 2018. Life cycle assessment in corporate sustainability reporting: global, regional, sectoral, and company-level trends. Bus. Strateg. Environ. 27, 1751–1764. doi:10.1002/bse.2241.

Science Based Targets Initiative, 2021. Business Ambition for 1.5°C - Science Based Targets. https://sciencebasedtargets.org/business-ambition-for-1-5c (accessed 6.8.21).

Wellenreuther, F., Markwardt, S., Schlecht, S., Busch, M., Drescher, A., 2018. Life Cycle Assessment of SIGNATURE PACK: a bev-erage carton containing polymers based on the mass balanced renewable material approach Final report. https://cms.sig.biz/media/3667/ifeu_sig_lca_signature-pack.pdf.

Woodward, R.T., 2005. Markets for the Environment.

World Resource Institute, 2015. Calculating and reporting the potential greenhouse gas emissions from fossil fuel reserves - a draft framework methodology.

Zhai, P., Larsen, P., Millstein, D., Menon, S., Masanet, E., 2012. The potential for avoided emissions from photovoltaic electricity in the United States. Energy 47, 443–450. doi:10.1016/J.ENERGY.2012.08.025.