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Closing the loop for packaging: finding a framework to operationalize Circular Economy strategies

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Abstract

This paper examines some of the most common frameworks available to companies in implementing circular economy strategies, i.e. the Cradle-to-Cradle design protocol, the Material Circularity Indicator and the Life Cycle Sustainability Assessment framework intended as a combination of Life Cycle Assessment, Environmental Life Cycle Costing and Social Life Cycle Assessment. We focus on the packaging sector and use the case of closed-loop aluminium can supply to illustrate the benefits and limitations of combining some of these frameworks. Our recommendation is to use the Life Cycle Sustainability Assessment framework to evaluate circularity strategies, since it is the most comprehensive and still operational framework and best at preventing burden shifting between stakeholders in the value chain.

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Keywords: Life Cycle Sustainability Assessment; life cycle thinking; Life Cycle Assessment; environmental Life Cycle Costing, Social LCA; cradle to cradle; material circularity indicator, aluminum; circularity

1. Introduction

The vision of a circular economy (CE) has recently gained a key role in the political and business agenda on how to decouple economic growth from resource constraints. The European Commission's action plan for the circular economy aims at the development of a sustainable, low carbon, resource efficient and competitive European economy [1]. In a CE, the objective is to maximize value at each point in a product's life, since the aim is to keep products, components and materials at their highest utility at all times [2]. Companies look at the challenges of maintaining the value of products, materials and resources and minimizing waste generation as competitive advantages. The conceptual basis of a circular economy is simple: "closing the loop". But it is not straightforward to identify at which level (e.g. product? material?), to which degree and from which perspective (e.g. user? producer?) such loops should be closed.

Nomenclature

CE	Circular Economy
CM	Carbon Management
C2C	Cradle-to-cradle
FU	Functional Unit
LCA	Life Cycle Assessment
ELCC	Environmental Life Cycle Costing
SLCA	Social Life Cycle Assessment
LCSA	Life Cycle Sustainability Assessment
MCDA	Multi Criteria Decision Analysis
MCI	Material Circularity Indicator
MH	Material Health
MR	Material Reutilization
PB	Planetary Boundaries
RE	Renewable Energy
SD	System Dynamics
SF	Social Fairness
WS	Water Stewardship

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The CE is about resource scarcity, environmental impact, and economic benefit [3], even though the environmental and also social dimensions of sustainability have so far attracted less interest compared to the economic dimension and hence need a stronger attendance to ensure the sustainability of CE strategies [4].

This paper contributes to the discussion on more comprehensive, yet still operational approaches to assess circularity strategies at the company level to ensure better decision support. Previous research has mainly addressed the development of the circular economy framework at the conceptual level [3, 4]. We focus on the industrial practices in implementing circular economy strategies in the packaging sector, which is one of the priority sectors in the European circular economy agenda [1,5]. The paper examines some of the most common frameworks available to (packaging) companies in implementing circular economy strategies, i.e. the Cradle-to-Cradle (C2C) design protocol [6], the Material Circularity Indicator (MCI) [7] and the Life Cycle Sustainability Assessment (LCSA) framework [8]. We argue that we need to consider the economic, environmental and social aspects to implement effective and efficient circularity strategies, to avoid burden shifting between different stakeholders and life cycle stages and to target an overall sustainability of the analyzed strategies and actions. The case of aluminium cans is used to illustrate the benefits and limitations of combining some of these frameworks in the assessment of the sustainability performance of a specific circularity strategy, i.e. closed-loop aluminium can supply.

2. The relevance of the beverage packaging sector

The frequency of purchases and high volumes associated with consumer products mean that consumers buy large amounts of packaging— an estimated 207 million tonnes globally with a value of USD 384 billion each year [5]. Packaging represents a large share of the material flows for many materials, e.g. plastics and aluminum. In 2014, 39.5% of the European plastics demand was used for packaging [9]. In 2012 aluminium cans represented the second major packaging format (30%) at European level for beer, and nearly half of all cans produced in the EU were destined for the brewing sector [10]. At the global level, packaging represents the second largest source of aluminium scrap [11].

In the context of the EU Action plan for the CE [1], clear targets for waste reduction have been presented in the revised legislative proposals on waste, including a common EU target for recycling 75% of packaging waste by 2030. Particularly in the beverage sector, packaging is necessary to deliver the product to consumers. However, most one-way packaging is discarded after use, entering the waste stream after a use period of typically less than a year. Therefore, there is a great potential for “closing the loop” in such sector. However, there could be many options to close the loop for beverage packaging and the selection of the best solution is material- and context- dependent. The role of industry, local authorities and consumers is key to define the financial performances of one-way and refillable packaging systems [12, 13]. Seyring et al. [14] in their assessment of collection schemes for packaging and other recyclable waste in the EU-28 concluded that local circumstances, such as the organisation of the waste management system or how long the solutions for waste management have been in place, influence the definition of ‘the optimal collection system’ for waste stream such as glass, plastic and metal [14].

3. The C2C design framework

The Cradle to Cradle® (C2C) design framework is oriented towards product quality and innovation and aims at increasing the positive footprint of products by designing “eco-effective” solutions, i.e. maximizing the benefit to ecological and economic systems [6]. The C2C vision is identified as one of the main conceptual pillars of the CE concept [4]. It is based on three principles: 1) “Waste equals food”, i.e. everything is a resource for something else; 2) “Using current solar income”, i.e. energy should be renewable; 3) “Celebrate diversity”, i.e. there is no “one-size-fits-all” solution [6].

Two material cycles can be distinguished in the C2C design framework: the technical cycle and the biological cycle. The focus here is on the technical cycle, which is fed with technical nutrients, i.e. materials that have the potential to remain safely in a closed-loop system of manufacture, recovery, and reuse, maintaining their highest value through many product life cycles [15].

One operational tool available to companies to apply the C2C vision is the C2C certified™ product standard, hereafter “C2C certification program” [16]. The C2C certification program includes five criteria: material health (MH), material reutilization (MR), renewable energy and carbon management (RE&CM), water stewardship (WS), and social fairness (SF). It operates with five levels of accomplishment (basic, bronze, silver, gold, platinum), where the lowest achievement across the five criteria determines the overall certification result.

The first two criteria (MH and MR) assess the composition of the product. MH provides material assessment ratings (the so-called “ABC-X assessment”) based on the hazards of chemicals in products and their relative routes of exposure during the intended (and highly likely unintended) use and end-of-use product stages. MR provides a quantitative measure of the product´s design for recyclability (technical cycle) and/or compostability (biological cycle).

The last three criteria refer to the production process and organization. RE&CM provides a quantitative measure of the share of renewable energy utilized in the manufacture of the product. WS gives a quantitative and qualitative measure of water usage and water effluent related directly to manufacture of the certified product, meanwhile SF refers to a qualitative measure of the impact of product manufacture on people and communities.

The focus of the C2C philosophy is concentrated on the main material, through the MH and MR criteria, while the remaining aspects (RE&CM, WS, SF) are implemented and assessed far less extensively [17]. This leads to a discrepancy between C2C theory and practice, which has been pointed out in the case of packaging [17].

4. The Material Circularity Indicator Project

The Material Circularity Indicator (MCI) Project by the Ellen Mac Arthur Foundation and Granta [7] developed indicators that measure how well a product performs in the context of a circular economy, thereby allowing companies to estimate how advanced they are on their journey from linear to circular. The indices developed in the project consist of a main indicator, the MCI, measuring how restorative the material flows of a product or company are, and complementary indicators, addressing risks and impacts, that allow additional impacts and risks to be taken into account. The set of indicators can be used in the design of new products (to support the use of circularity as a design criterion), for internal reporting purposes or for procurement decisions, for example, by defining a minimum requirement for the purchase of products [7].

The inputs used to calculate the *MCI* basically refer to the following four aspects: i) material input in the production process, i.e. the recycled content; ii) utility during use stage, i.e. how long and intensely is the product used; iii) destination after use, i.e. the recycling rate and iv) efficiency of recycling, i.e. the yield of the recycling process. A detailed bill of materials for the product is needed to compute the MCI, listing the above data for all its components and materials.

The complementary *risk* indicators may provide further insights into potential risks in relation to business priorities, e.g. material price variation, material supply chain risks, material scarcity and toxicity. The complementary *impact* indicators may provide additional information to evaluate how changing the level of material circularity affects other impacts of interest to businesses and their stakeholders, e.g. energy usage, CO_2 emissions, water.

5. Life Cycle Sustainability Assessment framework

The basis of the Life Cycle Sustainability Assessment (LCSA) framework lies in the 'three pillars' interpretation of sustainability, entailing that for assessing sustainability, the environmental, economic and social aspects have to be tuned and checked against each another [8]. At the same time, the system has to be analyzed in its full life cycle and therefore LCSA is based on a combination of the three methodological elements: Life Cycle Assessment (LCA), environmental Life Cycle Costing (ELCC) and social Life Cycle Assessment (SLCA).

5.1. LCA

Companies in the beverage packaging sector were among the pioneers in the implementation of environmental sustainability strategies in their business: the first studies of life cycle energy analysis were indeed performed for beverage containers [18]. LCA is a quantitative evaluation of the environmental performance of a product system across its life cycle [19]. The use of LCA in the beverage packaging sector is highly consolidated both for comparing different packaging alternatives [20,21] and for identifying the hotspots in the life cycle and develop optimization strategies to reduce the environmental impacts of products [22, 23].

LCA applied to beverage packaging can definitely outline the potential environmental impacts of circularity strategies aiming at maximizing the value of materials in each step of their life cycle, such as increased collection rates [23] or light weighting as a form of waste prevention [24].

5.2. ELCC

A Life Cycle Costing analysis summarizes all those costs associated with the life cycle of a product that are directly covered by one or more of the actors in the product life cycle (e.g. supplier, producer, user or consumer, end-of-life manager) [25]. Differently from the Conventional LCC, which represents traditional financial assessments carried out typically by individual companies focusing on their ‘‘own’’ costs, the Environmental LCC (ELCC) includes the costs incurred by all the affected stakeholders on top of the financial assessment from the company perspective [26].

ELCC is typically conducted in combination with LCA to identify both the environmental and economic implications of the analyzed strategy. In the beverage packaging sector, most of the cases of combined LCA-ELCC analyses focus either at the product level, e.g. beer [27], or at the packaging waste systems, e.g. from the local authorities perspective [28]. However, in the circular economy framework, where circularity strategies need to be assessed considering each step of the value chain, there is a need to perform full chain analysis, including the perspectives of producers, users and waste management operators. It is important to avoid double counting, since what is an economic gain for one actor is an economic loss for another.

5.3. SLCA

Social LCA is a social impact assessment technique that aims to assess the (potential) social and socio-economic impacts of products along their life cycle [29]. Social impacts are seen as *consequences of positive or negative pressures on social endpoints (i.e. well-being of stakeholders)* [29].

The main goal of SLCA is to promote improvement of social conditions and of the overall socio-economic performance of a product throughout its life cycle for all of its stakeholders. Five stakeholder categories can be identified: workers, consumers, local community, society, and value chain actors [29]. According to a recent systematic literature review in social LCA [30], the two most explored sectors have so far been manufacturing and agriculture. As far as packaging is concerned, SLCA has been used in combination with LCA to assess different end-of-life options for one packaging [31] or to assess alternative integrated packaging waste options [32].

6. Comparison among frameworks

Table 1 summarizes how the three different frameworks address the three pillars of sustainability, i.e. environmental, economic and social aspects.

Table 1. List of environmental, economic and social aspects in the Cradle-to-cradle (C2C) certification program [16], Material Circularity Indicator (MCI) [7] and Life Cycle Sustainability Assessment (LCSA) [8].

	Aspect		
Framework	Environmental	Economic	Social
C2C	MH, MR, RE&CM, WS criteria	-	SF criterion
MCI	MCI Impact indicators (energy use, CO2 emission, water) Risk indicators (material scarcity, toxicity)	Risk indicators (material price variation, material supply)	-
LCSA	LCA	ELCC	SLCA

As it can be seen from Table 1, the LCSA framework is the only one (by definition) addressing all the three sustainability pillars. Meanwhile, the MCI focuses on the environmental and economic aspects and the C2C design framework addresses the environmental and social aspects, even though the business aspect is somehow included in the overall philosophy.

The concept of a circular economy, as included in the EU action plan [1], refers to an economy where the value of products, materials and resources is maintained for as long as possible, and the generation of waste is minimized. The focus is explicitly on the economic aspects and resource use (i.e. environmental) aspects. Therefore, it might seem sufficient for companies to target the environmental and economic aspects, e.g. through the MCI and complementary risk indicators. However, the socio-economic benefits of the CE are equally emphasized in the EU action plan for CE. The CE is indeed intended not only to "*boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to create new business opportunities*" [1] but also "*to create local jobs at all skills levels and opportunities for social integration and cohesion and innovative, more efficient ways of producing and consuming*" [1]. Therefore, also implications on the societal level should be assessed and measured. The SLCA methodology, despite being the least mature among the life cycle based methodologies, can provide indications on both job creation and social integration such as equal opportunities and discrimination, fair salaries, working hours. Figure 1 represents the correlation between CE, LCSA and the three pillars of sustainability (environmental, economic and social).

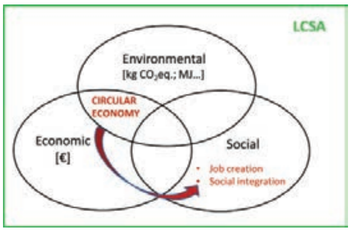

Fig. 1. Direct and indirect connection of the circular economy concept to the three sustainability pillars.

7. Case study: closing the loop for aluminum cans

The combination of different approaches can provide benefits to companies in the beverage packaging sector towards the implementation of circularity strategies. We consider here the learnings from the case study of aluminum cans and the assessment of a specific circularity strategy: "closed loop aluminum can supply".

LCA is typically used to assess the potential environmental impacts of one aluminum can, i.e. one loop including production and recycling [33]. Moreover, LCA can be used to assess the environmental performances of multiple loops of production and recycling, only if the actual aluminum alloy is taken into account [34].

LCA turned out to be suited to assess the environmental impacts associated with different levels of some C2C certification requirements, i.e. MR and RE. Even though receiving a higher certification level does not necessarily mean environmental burden reduction in the LCA sense, the use of LCA for C2C purposes helped to identify which actions should be prioritized for reaching higher C2C certification levels in the case of aluminum cans [35].

A combined use of LCA and C2C design framework provides not only benefits but also drawbacks, as outlined in the Strengths Weaknesses Opportunities and Threats (SWOT) Analysis [36]. Strengths and Weaknesses mainly refer to internal factors, i.e. the inherent limitations and opportunities in the LCA and C2C certification program respectively, such as the knowledge of material composition at the ppm level (for MH) or the quantification of recyclability potential (for MR). Opportunities and Threats mainly refer to the external factors, i.e. the actions needed to facilitate a combined use in product development and optimization, such as the access to confidential information from suppliers or the possibility to consider the unintended use of the product during use and disposal stage.

Both LCA and the C2C design framework supported the creation of a closed loop system for aluminum cans, but from the perspectives of environmental impacts (climate change) and innovation potentials respectively (provided that the composition of the can is optimized) [37].

When the economic aspect was considered in the comparative LCA-ELCC analysis of aluminum cans production, use, collection and recycling in two different cities (Bologna and Copenhagen), a trade-off emerged since the best option from an environmental point of view (closed loop recycling) is also leading to higher costs [38]. Figure 2 summarizes the results of both the LCA and ELCC identifying the contribution from the main actors of the value chain, i.e. consumers, producers and waste management operators. The functional unit (FU) considered is the delivery of 1 hl of beer and recovery of 303 units of 33cl aluminum cans in Bologna/Copenhagen in 2013 [38]. Such analysis showed the importance of including the different perspectives and trade-offs between economic and environmental criteria while analysing circularity strategies. Therefore, in order to provide decision makers with a true decision support tool, there is a need to provide a weight for the different criteria.

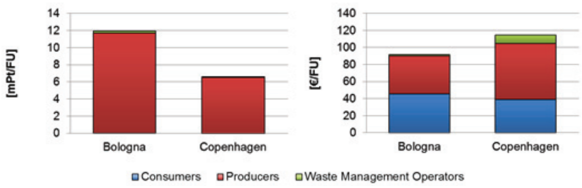

Fig. 2. LCA (left) and ELCC (right) results split according to the contribution from the different value chain actors, adapted from [38].

8. Discussion

The selection of the best framework to operationalize the circular economy in an industrial context is not straightforward. With our analysis of different frameworks for circular economy implementation we aim to stimulate the discussion on the role of decision support tools when translating a vision (circular economy) into practice, building on a practical experience in the beverage packaging sector. Combining different frameworks is useful to help companies overcome the challenges posed by the circular economy. However, in the decision making process it is important not only to balance the environmental, economic and social impacts of circularity strategies, but also to include a value chain perspective. Therefore future research should focus on combining the environmental (i.e. life cycle indicator scores), economic (i.e. environmental life cycle costs) and social (i.e. different stakeholder categories) criteria with multi-criteria decision analysis (MCDA) methodology, which allows the weighting of the different scores. MCDA is an operational decision support system that is suitable for addressing complex problems featuring high uncertainty, conflicting objectives, multiple interests and perspectives [39].

Moreover, to identify the links and dynamic relationships between stakeholders in the value chain, the system dynamics (SD) methodology through causal loop diagrams could be used. A causal loop diagram is a visual representation of the feedback loops in a system whereby the stocks and flows (i.e., involving different variables, parameters, indicators and metrics) are connected by either positive or negative loops [39]. SD has been applied in different corporate and industrial decisions worldwide, which have the intention of understanding and modelling the interrelationships (i.e., feedbacks) between controlled variables, indicators and metrics over time [39], e.g. the modelling of multiple product lifecycles [40].

Finally, in order to ensure that the circular economy and the companies' circularity strategies lead to a true progress towards sustainable production and consumption, companies need to be able to position the improvements on a scale of absolute (environmental) sustainability, e.g. building on science-based targets like the Planetary boundaries [41]. However, to ensure that industries deliver their essential contribution to society within the absolute boundaries of sustainability while adopting strategies for circular economy, it is necessary to translate global or regional boundaries for environmental impact to a set of absolute requirements to the individual industry. This will allow industries to document that they are not just getting greener but that they are sustainable, i.e. not impacting more than they can be entitled to in a sustainable society.

9. Conclusions

A major issue in assessing the effectiveness of circular economy strategies is to avoid to optimize one part of the value chain (e.g. production) at the expense of other parts (e.g. end-of-life) or to unintentionally favor one category of stakeholders (e.g. consumers) at the expense of other stakeholders (e.g. waste management operators and regulators). Another challenge is to identify the positive aspects of circularity strategies, e.g. in terms of job creation. This calls for the use of a comprehensive framework, able to capture not only some of the sustainability dimensions, as done by the C2C design framework or the MCI and risk indicators. Based on the findings for the case of aluminium cans, our recommendation is to use the LCSA framework to evaluate circularity strategies, since it is the most comprehensive and still operational framework with a very broad coverage of impacts, and with its life cycle perspective it is best at preventing burden shifting between stakeholders in the value chain.

Given the breadth of the circular economy concept and its implications for production and consumption systems, it is essential to go beyond the borders of different scientific disciplines to make sure that the theory is put into practice without unwanted consequences for economy, society or environment.

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