Measuring Product Sustainability: A Literature Review

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Abstract

Since the turn of the new millennium, public awareness of sustainability has dramatically increased. Terms like “climate change” and “renewable energy” have become common household phrases. Sustainability is a holistic term referring to three main systems: humans, the economy, and the environment. Yet measuring the sustainability of a product remains difficult. The leading method for measuring the “eco-effectiveness” of a product is the Cradle-to-Cradle (C2C) concept. C2C encourages products to be manufactured with alternative materials that are both non-hazardous and biodegradable, thus improving the output from industry into the environment. A main criticism of the C2C concept is that some aspects of a product’s lifecycle, such as transportation or use, are not considered. For that reason, the existing literature suggests combining C2C with an Environmental Life Cycle Assessment (ELCA), which incorporates more environmental aspects into a product. The combination of C2C and ELCA does not, however, take into account human behavior. This paper suggests that product design should also include a Social Life Cycle Assessment (SLCA), which is a relatively new method of rating human factors into a product. This literature review therefore calls for a more inclusive method of measuring the three conventional levels of sustainability.

Keywords
Product Design for the Environment, Sustainability, Cradle-to-Cradle, Environmental LCA, Social LCA

1. Introduction

Although the term sustainability was coined by environmentalists in the 1980s, today there is consensus that sustainability is not only about environmental issues [1,2]. What must be kept in mind today is that sustainability is not only about environmental issues. Sustainability’s so-called “triple bottom line” rests on three factors (humans, economy, and the environment) shown in Figure 1 and must be assessed in those terms [1]. This paper examines the literature on how to measure and assess the sustainability of a product using existing methods.

The paper’s literature review is organized into four main parts: introduction to Cradle-to-Cradle (C2C), C2C critiques, the intersection of Environmental Life Cycle Assessment (ELCA) with C2C, and the intersection of Social Life Cycle Assessment (SLCA) with both ELCA and C2C. The desirable C2C product certification provides a baseline measurement of the sustainability of products, but its comprehensive nature is critiqued. The establishment of ELCA addresses the environmental impact of a product’s life stages. Its methods are compared to the C2C certification. Lastly, the human element of SLCA is discussed and reviewed with respect to both C2C and ELCA. Figure 1 overlays these various approaches with the sustainability triple bottom line. Our conclusion discusses opportunities in this area with respect to a comprehensive approach to establishing a product’s sustainability.

Figure 1: Systems Influencing Measuring Product Sustainability
2. What is Cradle-to-Cradle?
The concept of zero emissions, or “eco-efficiency,” is the premise that a product should not create any waste or emit any pollutants into the environment [3, 4]. [4] argue that “eco-efficiency” only slows down the process of depleting natural resources, resulting in a hard-to-detect “efficient destruction” of our environment. Instead of the traditional “cradle-to-grave” philosophy of making a product that is lost forever after use, or using various harmful recycling techniques under the label of “eco-efficiency,” they argue that we should aim for “eco-effectiveness” [4]. Aiming for eco-effectiveness, Cradle-to-Cradle is a philosophy, developed by [4], of designing products using industrial processes that turn materials into nutrients for either biological (i.e., biodegradable and non-hazardous) metabolisms or technical (i.e., synthetic and not biodegradable) metabolisms [5]. In essence, they argue that biological nutrients should be released into the environment safely for both humans and the natural ecosystem, whereas technical nutrients should either be reused without losing quality or down-cycled [5].

The C2C concept focuses on three qualitative principles: (1) waste equals food; (2) solar energy should be used for production; and (3) diversity should be celebrated [6]. The first principle claims that all waste produced can be utilized as an input in either a biological or technical metabolic cycle. [5] discard the term “waste” because it implies an end to use, which is not the case when the output of a process or product becomes the input of another. Therefore, if every output is considered useful, the quantity of output does not matter, which makes minimizing emissions (i.e., eco-efficiency) irrelevant [4, 6]. The second principle directly supports production via solar energy. By doing so, energy consumption becomes irrelevant as an environmental impact [6]. The third C2C principle states that products’ design should respect cultural, economic, and environmental issues; differing views in a global economy can make this quite a challenge [6]. [5] argue that eco-effectiveness goes hand-in-hand with economic growth, as long as the product incorporates appropriate use of the two metabolisms [5].

If manufacturers want to produce C2C goods they have to shift from being eco-efficient to being eco-effective. [5] have generated a stepwise approach to do so: (1) “free of...”; (2) personal preferences; (3) the “passive positive list”; (4) the “active positive list”; and (5) reinvention. The first step, “free of...” requires the removal and replacement of all dangerous materials in a product that can indeed be replaced [5]. “Personal preferences,” the second step, suggests that a designer’s or manufacturer’s own preference can decide the replacements for those substances removed in the first step. This allows companies to subjectively decide which substances they must or must not have without regard for how good or bad the influences are on nature; potentially counterproductively. Third, the “passive positive list” classifies each substance according to its eco-toxicological characteristics and its capacity to be reused in biological or technical metabolisms. Products considered environmentally dangerous can still be utilized if no alternative is found, but the list generated should help find necessary places for future improvement [5]. Fourth, the “passive positive list” is optimized into an “active positive list.” Where each material in a particular product must be either a biological or a technical nutrient [5]. The last step includes the reinvention of the relationship between the product and the consumer. [5] want consumers to think of a product as something they use rather than something they own. Products should be leased, and then be given back to the manufacturer so that they can let those materials flow again into either of the two metabolisms [5].

Following the introduction and success of the C2C concept, a C2C certification was established in 2010 [7]. The C2C certification helps consumers recognize C2C products, and is regarded as the best way of labelling a product’s sustainability. The C2C certification measures products in five categories: (1) material health, (2) material reutilization, (3) renewable energy and carbon management, (4) water stewardship, and (5) social fairness [8]. A qualified, independent third party assesses each product in each of these categories and submits the report to The Cradle-to-Cradle Products Innovation Institute institute for review [8]. The certification promotes continuous improvement by making C2C labels expire after two years, after which manufacturers must prove good faith efforts to improve their products.

3. Cradle-to-Cradle Critiques
There has been a great deal of enthusiasm for the C2C concept, with some scholars claiming it propelled the “third green wave” [9] and the “next industrial revolution” [10]. [9] state that although McDonough and Braungart are optimistic, they are nevertheless inspirational visionaries. The creators of the C2C concept have been complimented for their efforts to reduce toxic substances in consumer goods [9]. Yet the C2C concept has received substantial criticism as well.
3.1 General Critiques

One common critique of C2C is that it underestimates the complexity of both nature and the use of nature in real, industry settings. [10] who interviewed eight experts about their opinion on the C2C concept, argue that nature is intrinsically a very complex system. Science cannot predict in advance how nature will, making it difficult to label an impact as either “positive” or “negative.” Yet the C2C concept requires companies to establish direction of impact lists for the materials in their products. Most companies do not know the exact toxicological properties of every material that is used for a product; determining these exact compositions is a challenge with little to no incentive beyond the certification itself [9]. Thus, there is often doubt as to whether a C2C-certified product is really produced to C2C standards. Recognizing this problem, [11] tried to solve it with two strategies: (1) creating a banned list of chemicals; and (2) attempting to establish a database of every substance’s properties, as well as potential alternatives, even if they are not currently available.

A second point of contention is the feasibility of the concept itself. There are two schools of thought on the possibility of a completely closed loop recycling system. One states that a completely closed loop of recycling as proposed by the C2C concept is not completely possible, because there will always be inefficiencies and leaks in the system [10, 12]. A second school of thought is that the technical cycle is just a slow downward spiral and not a true loop, which would imply inherent down-cycling [10]. [4], by contrast, were trying to avoid down-cycling altogether.

Third, the C2C concept does not consider the whole lifecycle of a product, as [6] show in their comparison between the C2C concept and environmental Life Cycle Assessment (ELCA). There are five stages to the life cycle of a product: raw material, transportation, production, use, and end of life [6]. ELCA analyzes each of these stages holistically in terms of energy consumption, whereas C2C only considers the raw material stage and the end of life [6]. The other three stages are omitted in the current C2C definition and certification process. Yet for many products these stages are the most environmentally unfriendly, especially the use stage [6]. The energy consumption of a product in use is not observed in the C2C concept; thus C2C only attacks part of the problem.

A final critique of C2C is that the performance of synthetic alternatives, not necessarily C2C approved materials, is generally more attractive than organic-based materials, making organic acceptance into the market difficult [10]. A few modern examples for “attractive” biological nutrients are corn or soybeans, which perform better than their synthetic alternatives but are more expensive [13]. In addition, [14] recently discovered a strain of bacteria living in mealworms that could eat and decompose plastics. This offers the potential opportunity to consider synthesizing certain synthetic products as biodegradable products. Ultimately, these newer materials and processes create more expensive and in turn more expensive products [13]. These products have a potential to have a fixed place in the market once they garner more attention [13]. Currently, however, there is not enough demand for these products to make this endeavor economically sustainable for companies at the onset. Therefore, there is even more reason to establish an easily implemented rating for a product’s sustainability that assesses all aspects of a product’s life to ensure increase use and saturate the market, while being economically viable for companies.

3.2 Critiques of Cradle-to-Cradle Principles

The first principle of the C2C concept, “Waste equals food,” is often criticized. [15] gives a few examples from the past of how biological nutrients have negatively affected the environment. Most hazardous materials can be classified as biological nutrients as well, since many of them are naturally occurring [10, 15]. In addition, [15] argues that changes in the concentration of a biological nutrient do have an ecological effect and that high concentrations of any one particular substance may have a negative impact on the environment or human health. Therefore, biological waste may have a diminishing rate of returns beyond a particular threshold, and may not always be as good or healthy as [4] claim.

The second C2C principle can also be critiqued. By only using renewable energy, the creators of the C2C concept assume that there will be no negative impacts for the environment regardless of the amount of energy used. There is however no proof yet that renewable energy solutions, including solar power, have absolutely no negative impact on the environment. Moreover, with the current state of systems and technology, it is not possible to only use solar energy because it is not available to everyone everywhere [6]. Although the future of renewable energy is always evolving, predictions of majority or full market saturation are reliant upon government influences and incentives to switch, many of which vary regionally.
Lastly, [6] argue that the third principle, “celebrate diversity,” directly conflicts with the biological nutrient metabolism. This is because, as [15] argues, too much of any nutrient in nature can harm species who have adverse effects to these nutrients [16].

3.3 Critiques of C2C Certification
The C2C certificate has not gained much attention in the literature yet; most articles focus on the C2C concept itself. [12] compare a C2C certified paper stock with conventional paper and come to the conclusion that the certified paper actually has a higher negative impact on the environment than conventional paper does. This example is not representative, however, and is highly dependent on the definition of a “negative” impact. No general conclusions can be made.

4. Environmental Life Cycle Assessment (ELCA)
ELCA is a commonly practiced method for assessing the environmental aspects of products [16]. ELCA can assess multiple environmental impacts (e.g., air or water pollution, eutrophication, etc.) in multiple stages of a product’s life cycle [16]. Traditionally, ELCA has four or five stages: raw materials, manufacturing/production, transportation, use, and end-of-life. Within each stage of ELCA there are boundaries that simply focus on that stage, with inputs from another stage or outputs that turn into inputs on the following stage. The first stage, raw materials, is unique in where it can have inputs from both new and recycled materials. An open-loop system is where the system does not completely connect itself; this normally occurs during the disposal stage (i.e., end-of-life). A closed-loop system is when the system does connect to itself, where instead of disposal at the end-of-life that product gets recycled. Further details of how to appropriately execute an ELCA, however, is out of the scope of this paper.

4.1 Prior Research: ELCA and C2C
[6] compare ELCA and C2C as measures of environmental sustainability and conclude that each methodology includes factors that the other does not. C2C considers toxicity, whereas ELCA does not. However, the C2C concept does not observe energy consumption, whereas ELCA does, because C2C assumes the use of renewable energy and that there is no negative impact on the environment. [6] therefore suggest combining both methods.

We look for a measure of sustainability that includes all factors of the triple bottom line (planet, people, and profit). Both C2C and ELCA consider aspects such as emissions and energy consumption, so that the environmental factor is fully covered. According to C2C, economic growth follows automatically when designing a product according to the C2C concept. Economics with regard to ELCA only occurs if a particular system is designed to incorporate that level of information. Both C2C and ELCA can incorporate economics, yet there is only one factor of sustainability missing: people. Therefore, in order to be a good measure of sustainability, the combination of C2C and ELCA needs to include an assessment of the extent to which a product is social. One method that fits well with C2C and ELCA is Social Life Cycle Assessment (SLCA).

5. Social Life Cycle Assessment (SLCA)
A tool that also adapts to the human life cycle of a product led to the creation of SLCA [17]. The SLCA method consists of four phases: goal definition, scope definition, inventory analysis, and impact assessment. The goal of SLCA is to assess social, not environmental, effects of a product [20]. The most common critique about SLCA is that there is actually no standardized method, because SLCA is still under development. The development of SLCA started in 2004, and it was said at the time that it would take five to ten years for SLCA to become a validated measure of social aspects [17]. [21] conducted interviews on the implementation of SLCA factors and come to the conclusion that SLCA demands expertise and is very time consuming. Additionally, most of the surveyed companies are already satisfied with existing social assessment methods even if they do not cover as broad a range as SLCA [21]. Another point of criticism is that SLCA sees social impact as a characteristic of a company rather than of a certain process, which makes it more difficult to analyze and trust a company’s answers [20]. Also, what happens if an environmentally good product (i.e., approved by ELCA) is made by a socially “bad” company (i.e., not approved by SLCA) – is it okay to make or even purchase that product?

5.1 Prior Research: SLCA and C2C
So far there has been no combination of SLCA and C2C in the literature. This may imply that the combination of different measures of sustainability is simply uncommon, or too new to have appeared yet. Probably the combination of C2C with an assessment method for social factors has not been considered yet because the C2C
certification process is supposed to rate social fairness (i.e., one of the five categories) as well; how it does this is currently unknown. However, the philosophy of the original C2C concept which is the underlying premise of the C2C certification does not do that. It only rates the environmental sustainability of a product and lacks analysis of social sustainability. This means that the C2C concept should be combined with some kind of a social assessment.

5.2 Prior Research: SLCA and ELCA
Since SLCA was initially designed to combine with ELCA, there have been attempts to combine these two methods. For example, [18] incorporates social aspects into ELCA, and [19] developed Social and Environmental Life Cycle Assessment (SELCA). However, none of the suggested combinations are deemed fully satisfactory, even by their creators [18, 19].

6. Conclusions
The C2C approach helped people to start thinking about the consequences of environmentally unfriendly products before even producing them. It made both producers and consumers start thinking about toxins in various products. Yet there are still points that the C2C concept does not consider: energy consumption, nature’s complexity, and the feasibility of the concept itself. However, the C2C concept sets the tone for how society should start thinking about the possibilities of sustainable products. It shows that the solution is not necessarily to change what we have but to rethink the things we have for the better. Despite the critiques concerning the C2C biological cycle, the examples brought up by [13] and [14] show that it is possible to implement the biological aspect of the C2C concept. The possibility of biodegrading products that are currently considered non-biodegradable suggests that it may be possible to find a method to assist the technical cycle. The C2C concept should be combined with other methods such as ELCA [6]. By doing so both the energy consumption and the toxicity of a product can be reviewed and all lifecycle stages can be considered.

Even though the C2C certification includes social fairness, the C2C concept itself does not specify that point. This is why we cannot be sure whether C2C considers the human element which is a part of the triple bottom line. For that reason, it is advisable to include an additional method that measures this factor. One method for assessing the human factor would be Social Life Cycle Assessment (SLCA). This method seems to be appropriate since it was created to be combined with ELCA. However, since there is still no consensus on how actually to conduct SLCA, it is difficult to measure the social impacts of a product being assessed by this method.

Additionally, there is an unwillingness to implement these concepts [10, 22]. Is this because these methods are not feasible or because they are too high in cost? The latter is not unlikely when companies need to maximize profit margins. Even though profit is a part of sustainability, sustainability is supposed to cover the entire triple bottom line. In order to make companies really use these methods, therefore, they need incentives. These incentives must go beyond altruism or the desire to create a better image for the consumer, because then a company’s main goal might only be to do just enough so that the consumer thinks that a company or product is sustainable even though it may not actually be. Potential incentives could come from companies, similar to how Wal-Mart pressured manufacturers of various products to change or it will not be sold in their stores, or from the government that could require more post-consumer content or a various kind of rating on the label. Future work should examine the meteoric rise of the U.S. LEED system on how their incentives to implement their labelling design system occurred and see if the same model could be used in products.

There is no general measure for sustainability yet; there are only measures for the individual factors of the triple bottom line: human, economics, and the environment. Therefore, there is no way for the consumer to tell whether a product is truly sustainable or not. The importance of developing such a measure cannot be stressed enough. Acting sustainably is the future, and the importance of sustainability keeps on growing. Being sustainable includes the purchase or leasing of products that are sustainable in every aspect and in every life stage. But this kind of purchase is difficult as long as there is no way to fully measure sustainability.

There are two ways to approach this problem. One way is to measure each of the factors of sustainability and then conclude the degree of sustainability afterwards. However, as shown in the critiques, all three measures (i.e., C2C, ELCA, and SLCA) have downsides and are individually complex. Combining them, although comprehensive in theory, would not decrease this complexity. This makes the production of fully sustainable products less attractive for companies, since higher complexity implies higher costs. A potential solution might be continuous improvement of these measurement tools in order to systematically eliminate these downsides without causing new ones. The
second way to handle the need for measures of sustainability is the creation of a whole new measure that assesses all factors of sustainability. No matter which course of action occurs in the future, something has to be done to make it possible for consumers to distinguish between those products that are sustainable from those that are not.

References