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Are Cradle to Cradle certified products environmentally preferable? Analysis from an LCA approach

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Abstract

The Cradle to Cradle (C2C) certification has gained popularity amongst companies as a way to distinguish more environmentally friendly products. This article analyzes the C2C certification from a scientific point of view by determining how successful this eco-labeling scheme is in distinguishing environmentally preferable products. Furthermore, we identify for which product types the C2C certification results in environmental impact reduction. The implementation of C2C at a large scale could potentially have energy and infrastructure limitations. In addition, it could lead to negative consequences on natural ecosystems by changing soil and water characteristics affecting negatively to biodiversity conservation. Moreover, the C2C certification cannot guarantee environmental protection for all types of products as it has a partial view of the full life-cycle. C2C is focused on raw materials and end of life stages, however some product concentrate most of their environmental impacts in other stages (e.g use stage). As a consequence, the promoted strategies by C2C do not always guarantee a relevant environmental improvement for products.

Life cycle assessment (LCA) is an internationally accepted methodology for quantifying environmental impacts. In this paper, LCA results for different product categories are used to determine if the life-cycle stages considered under the C2C approach coincide with the most relevant stages in terms of life-cycle environmental impacts. This helps ascertain if and when C2C can be considered an appropriate ecolabel. The results show that for products with high energy consumption during use, C2C does not guarantee relevant environmental improvements. Furthermore, in the best of the analyzed case studies, C2C only considered 70% of the product's environmental impact, consequently avoiding 30%. For these reasons, we argue that C2C is not an appropriate scheme to distinguish environmentally preferable products.

Keywords

cradle to cradle (C2C)
life cycle assessment (LCA)
ecolabelling
product sustainability
recycling

Highlights

A scientific review focused on Cradle to Cradle concepts was realized. ► Cradle to Cradle is not eventually feasible at large scale. ► Life cycle assessment results from European Ecolabel background reports were analyzed. ► Cradle to Cradle do not always distinguish environmentally preferable products.

1. Introduction

Nowadays society is more conscious than in the last decades about the Earth's environmental and climate change problems (for example: deforestation, species extinction or increasing CO_2 concentrations). The evidence of the need for a change has influenced our societies' mentality. As a consequence, the demand for environmentally friendly products has been increasing (Imkamp, 2000). Accordingly, consumers need to be able to identify and distinguish those products more respectful with the environment from those which are not, and producers are motivated to differentiate those environmentally preferable products.

In order to be more eco-efficient, the European Commission promotes a Sustainable Consumption and Production (SCP) action plan (European Commission, 2008a). SCP fosters a more sustainable lifestyle, buying behavior and a better product and services use and dispose from consumers. It also concerns companies, whose sustainability challenges should be seen as economic opportunities providing environmental preferable products and services for consumers.

Under the SCP action plan, integrated product policies (IPP) have been promoted to standardize voluntary and mandatory tools to reduce environmental degradation produced by products and services throughout their entire life-cycle. The main objectives are to promote ecological product design, increase ecologic products demand by ensuring fair prices, and transmit environmental information from companies to consumers. Two of the IPP strategies (European Commission, 2012a), to achieve these objectives, are to promote (1) ecolabelling systems and (2) the use of Life Cycle Assessments (LCA), which is a recognized and standardized tool for quantifying environmental impacts supported by the United Nations Environment Program (UNEP, 2010) and the European Commission (European Commission, 2001; 2012b).

As shown, some of the SCP and IPP objectives and strategies are intended to satisfy the previously mentioned needs of society and companies alike. Presently there is an important necessity to inform consumers about environmental aspects and one of the possible ways is by using trusted, objective and credible ecolabels certificates.

1.1 Ecolabels

Ecolabels are voluntary tools used to communicate environmental information from business to consumers (B2C) or business to business (B2B) perspectives. These tools inform purchasers in an easy and effective way, helping them to select more environmentally friendly products. According to ISO 14020 (ISO 1998) there are three standard types of environmental labels: Type I (ISO 14024 - B2C); Type II (ISO 14021 - B2C); and Type III (ISO 14025- B2B).

Type I ecolabels consist of a "voluntary, multiple-criteria based, third party program that awards a license which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a product category based on life cycle considerations" (ISO, 1998). They are based on LCA results for defining the criteria, but do not require it for obtaining the ecolabel. A Type I label implementation example, under the IPP scheme, is the European Ecolabel.

Type II ecolabels are "informative self declaration claims" (ISO, 1998), developed by the producer and not involving an independent audit. Type II labels give information such as recycled content; energy consumption; non-use of certain hazardous chemicals or indoor air quality. These labels might not be used to contrast products from different companies, they are just informative.

Type III certifications are environmental product declarations. They are defined as "voluntary programs that provide quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party, based on LCA and verified by that or another qualified third party" (ISO, 1998). Environmental product declarations do not involve any improvement associated with the product, simply inform about their environmental impact. Nevertheless, they can be used to establish a benchmark for a company's environmental improvement plan (EPDsystem, 2011; GEDnet, 2013). The main objective of Type III ecolabels is to give results, under a standard procedure, for obtaining quantitative environmental data with the same bases.

In addition to the three standardized label types, there are other ecolabelling schemes that do not fit the previous requirements or characteristics. One example is the Forest Stewardship Council (FSC 2010), which is a nongovernmental organization which certifies that the wood used to produce a product, comes from a forest with an environmentally appropriate management ensuring: productivity, biodiversity and ecological processes. Other certifications examples are: "Made in green", "Rainforest Alliance"; "TCO certification"; "Marine Stewardship Council"; "OEKO-TEXT" or the "Energy Star". This article focuses on one of such alternative ecolabelling schemes: the Cradle to Cradle (C2C) Certification due to its presence in the market looks set to increase in the coming years (C2C Institute, 2011).

1.2. Cradle to Cradle

1.2.1. C2C Concept

The C2C concept was conceived by architect William McDonough and chemist Michael Braungart. C2C proposes to replace eco-efficiency by eco-effectiveness (creating solutions that maximize economic value with no adverse ecological effects (Braungart et al., 2007)) to achieve the "state of zero: zero waste emissions, zero resource use and zero toxicity" (Braungart et al., 2007; McDonough et al., 2005).

C2C is focused on three qualitative principles. To achieve zero resource use, the first principle, is based on the idea that “waste equals food”. This concept consists of a system design where waste is considered a nutrient for nature (biological nutrient metabolism) or for other industrial processes (technical nutrient metabolism). The premise is that this closed cycle system does not need to be eco-efficient (reduce resources use and wastes) because the more waste it creates, the more nutrients are available for producing new products (McDonough, 2005).The materials which are classified as technological or biological nutrients are defined as upcycling materials. They are designed to close cycles and maintain their status as a source. On the other hand, the waste that is not reused either biologically or industrially is defined as downcycling material. Downcycling "reveals poor design of a life-cycle and the related materials flows" (MBDC, 2012; McDonough, 2013). C2C aims to avoid downcycling materials and promote upcycling ones to achieve closed cycles.

The second principle is the use of energy from "current solar income"(McDonough, 2005). As a consequence, the use of renewable energy makes energy consumption no longer relevant as an environmental impact for the C2C.

Finally, the third principle is to "celebrate diversity" (McDonough, 2005). C2C understands diversity as a cultural, economic and environmental issue, existing a strong relation between them. Consequently, designed systems should be respectful with all these aspects. Then, if there is no economic growth and industry is eco-efficient instead of eco-effective nature, societies and cultures stability and survival could be affected negatively (McDonough, 2005).

1.2.2. C2C Certification

Based on the C2C concepts, the C2C product certification scheme was launched in 2005 as a private system registered as a trademark by McDonough Braungart Design Chemistry (MBDC). Later, in August 2010, Braungart & McDonough created the Cradle to Cradle Products Innovation Institute, an independent non-profit organization, based in North America (MBDC, 2012). In Europe it is represented by the company Environmental Protection Encouragement Agency (EPEA) established by the authors of the concept.

The C2C certification is a nongovernmental ecolabel that the MBDC defines as "a multi-attribute, continuous improvement methodology that evaluates products across five categories of human and environmental health (Material health; Material reutilization; Renewable energy and carbon management; water stewardship; Social fairness). Product certification is awarded at five levels (Basic, Bronze, Silver, Gold, Platinum), with the expectation that an applicant will optimize each aspect of their product over time. The ultimate goal of its implementation is to encourage innovation and the design of products that effectively and positively impact people and the environment" (C2C Institute, 2012a).

1.2.3. Previous reviews

At first glance C2C concepts and principles seem to be a solution which may contribute to solve some of the current sustainability problems; however, some reviews questioned the feasibility of the ecolabel comparing C2C and LCA approaches (NL Agency, 2011; Bjørn and Hauschild, 2012).

On the one hand, the NL Agency concluded that C2C is an innovation driver that brings qualitative solutions, which may not, however, be relevant under a life cycle approach (NL Agency, 2011; Bakker et al., 2009). Their conclusions lead to think that not all C2C strategies ensure a direct environmental improvement on products.

On the other hand Bjørn & Hauschild (2012) also reflected controversies between LCA and C2C. They concluded that C2C defines a desirable sustainable future; however, it has some inherent shortcomings: C2C does not seem (1) to perform well with environmental impacts measured by LCA and (2) to be feasible with current waste treatment and energy generation infrastructures; additionally (3) biological nutrients could have adverse effects on other organisms.

Moreover, another review from Stephen D. Reay, Judith P. McCool and Andrew Witheel (Reay et al., 2011) questioned the suitability of "closed loop" for technical nutrients and the concept of biological nutrients. The theory considerations laying behind the technical nutrients approach do not seem to have in consideration physics laws whereas biological nutrients could generate ecological modifications when they were introduced in a natural system in large concentrations producing negative ecological consequences.

2. Objectives

The general objective of this article is to determine whether C2C certified products can be trusted by consumers to be environmentally friendly. To achieve the general objective two specific objectives are proposed. The first objective is to evaluate the C2C concept and certification from a technical and scientific point of view. Secondly, we aim to determine for which product types the C2C certification results in environmental impact reduction, using LCA as a reference for the estimation of environmental impacts.

3. Material and methods

The article is divided in two parts, one for each specific objective. The first part consists of a literature review to analyze C2C principles and certification. This review takes into account scientific and grey literature, as well as technical publications and other articles related with C2C concepts. The outcomes are structured according to the three C2C basic principles: "waste equal food"; "celebrate diversity" and "current solar income". The principles are analyzed and questioned in relation to other principles or theories.

The methodology (figure 1) to achieve the second specific objective is divided into three steps:

3.1. Step 1. Product selection

We chose different typologies of products representative of the EU Ecolabel (as is based on LCAs and considered one of the reference ecolabels in Europe), and the C2C certification. From this group of product types, we selected products with varying energy intensity during the use phase, which is defined as the ratio between the product's energy consumption during use (KJ) and the product's mass (kg), in a given period of time. Data used for this classification is based on technical specifications of products (e.g. TVs and light bulbs technical sheets) or on existing wide-sectorial reports as it is the case of EU Ecolabel product categories' bases and preliminary reports (European Commission, 2013).

3.2. Step 2. Analyzing LCAs for the defined product categories

The purpose of this step is to identify which life-cycle stages concentrate the most relevant environmental impacts for each of the established product categories by using LCA studies as reference. Different LCA studies available for each product category are analyzed to determine how their environmental impact is distributed throughout their entire life-cycle, which is divided into 5 stages: material resources, transportation, production, use and end of life. For the present case study, those stages with less than a 25% of the environmental impact are considered irrelevant.

To calculate the percentage of environmental impact for each phase, the relative contribution of six impact categories was added and later divided by the number of impact categories. This process was repeated for all products from each product category and their 5 life-cycle stages

The selected impact categories for the study are: abiotic depletion potential (ADP, kg Sb eq.), acidification potential (AP, kg SO2 eq.), eutrophication potential (EP, kg PO3−4 eq.), global warming potential (GWP, kg CO2 eq.), ozone layer depletion potential (ODP, kg CFC-11 eq.) and human toxicity potential (HTP, kg 1.4-DB eq.).

The LCA studies were available from the European Ecolabel product categories' bases (European Commission, 2013) that include wide-sectorial LCA data. This database is considered trustful and reliable as it comes from public sources and it is supported by the European Commission (European Commission, 2012c). The available sectorial LCA studies analyze different subgroups of products for each EU Ecolabel product category. Therefore, for each product category there is some variability in the distribution of impacts among life cycle stages. For this reason, a range of approximate values will be defined according to the higher and lower values that can be found in the LCA studies for each of the categories defined in step 1.

For defining the distribution of environmental impacts for furniture, information coming from the EU Ecolabel background report (European Commission, 2008b) do not facilitate LCA results; therefore, other case studies were used to support results, which assessed the global warming potential of wooden furniture products (González-García et al., 2011) and analyzed a specific case study based on wooden childhood furniture (González-García et al., 2012).

3.3. Step 3. Defining for which product categories, if any, C2C certification distinguishes environmentally friendly products

Given that environmentally relevant life-cycle stages sometimes may not be included in the C2C scope, this step aims to analyze for which product categories C2C strategies promote real environmental improvements under a life-cycle approach. Those products with relevant environmental impacts associated to life-cycle stages affected by C2C strategies, will be considered significantly more environmentally friendly when applying C2C.

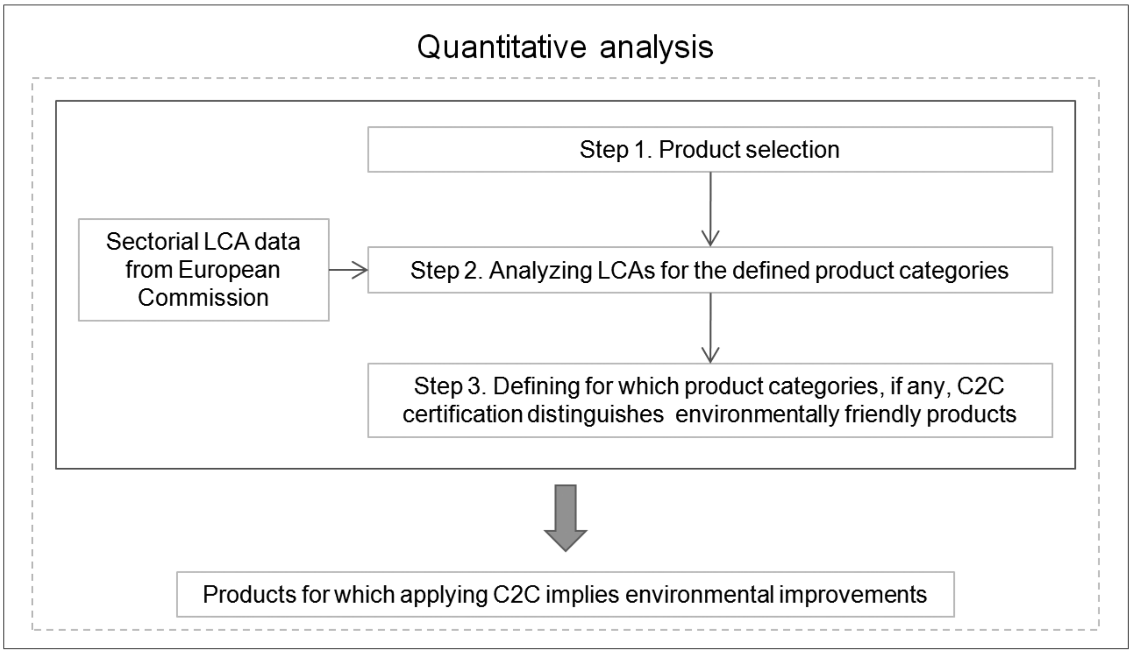

Figure 1: Methodology of the quantitative assessment

4. Results & Discussion

Results and discussion are divided in three sections. Sections 4.1 and 4.2 derive from the bibliography review. Section 4.3 carries out the study to determine for what type of products applying C2C can be considered an appropriate environmental certificate.

4.1. Waste equals food & Celebrate diversity principles

4.1.1. Nutrients metabolism and the limits to growth

According to the MBDC, C2C principles understand diversity also as an economic approach that defends unlimited growth (MBDC, 2012; McDonough, 2005). However continuous growth, even in the case that infinite technical nutrient cycles were viable (entropy law demonstrated they are not under a holistic approach), are not feasible at long term (Bjørn and Hauschild, 2012).

Historical development shows a relation between direct material consumption per inhabitant and economic growth (EEA, 2010); then provably, even when applying 100% closed cycles, virgin resources would be required to feed growth (Bjørn and Hauschild, 2012).

These virgin resources demand could be compensated by being more efficient and reducing material masses needed for production (as dematerialization concept proposes); nevertheless, being more efficient is not one of the proposed strategies on C2C agenda. Consequently, closed technological nutrients metabolism is called in question because of the need of introducing virgin materials into the cycle in a context of limited planetary resources (Meadows et al., 1972).

As Nicolas Georgescu-Roegen (1971) said, "The entropy law is the taproot of economic scarcity". Nowadays economy is a system which extracts low-entropy resources from nature and throw high-entropy wastes into the environment. These low-entropy resources are the result of high quantity of solar energy absorbed during years (wood) or hundred million years (fossil fuels). Today entropy levels are increasing at a faster level than the natural capacity of ecosystems to absorb wastes and renew stocks of raw materials, which leads to resource scarcity (Ayres, 1998; 2004; Kallis, 2011; Kerschner, 2010). Therefore, biological nutrient cycles may not be compatible with infinite growth because natural regeneration processes are slower than the velocity of resources are consumed.

4.1.2. Biological nutrients metabolism and ecological consequences

As was mentioned in "1.2.3. Previous Reviews" section, introducing large quantities of biological nutrients in an ecosystem, could cause negative ecological effects (Stephen D. Reay, 2011 ; Reijnders, 2008). Reijnders (2008) defends that a high concentration of biological nutrients will require a massive local consumption of oxygen, which could affect surrounding organisms. Furthermore, higher concentrations of fixed nitrogen and phosphates could change soil characteristics and cause water eutrophication. These changes cloud be associated with the disappearance of native species (Lal, 2004).

Another potential problem that can result from increased biological nutrients are allelopathic substances, substances secreted by organisms that have an inhibiting growing effect on others. These species-specific substances may be detrimental for other organisms (Reijnders, 2008). For example, organic residues coming from the processing of guayule for producing paper pulp, linoleum filler, wallboard or pressed fuel logs, reduce the percentage of germination of crops because of allelopathic substances (Schloman Jr et al., 1991).

Biological nutrients cycles could be a good solution at a small scale with limited flows of biological nutrients introduced in nature; nevertheless, numerous flows and concentrations of biological nutrients may collapse the capacity of ecological systems to assimilate them.

In summary, C2C biological nutrient metabolism does not seem to be a simple solution as C2C principles suggest. Exposed controversies give the impression that biological nutrient metabolism is not being in line with the "Celebrating Biodiversity Principle".

4.1.3. Closing cycles and current paradigms

Implementing C2C approaches in an economy requires important logistic changes. For closing cycles, all products' materials must be recovered at the end of their life; nevertheless, under the current paradigm it may be easier for consumers to throw away their wastes. For many reasons, it cannot be expected from all users to give back to the manufacturer all products after their use. Hence, the 100% closed cycle is difficult to implement. Furthermore, a new waste management directive could be required to ensure that manufacturers recycle their products at end-of-life.

To ensure closure of the cycle new consumers and waste management paradigms may be required. These new paradigms would involve an increase of transport and management of goods that are associated with higher energy consumption. The energy requirements may result in a scenario where materials' management for closing nutrient cycles could represent a higher environmental impact than other waste management solutions.

Therefore, implementing the C2C concept in a whole society requires important social and infrastructure modifications. Furthermore, these changes do not automatically ensure an environmental improvement because of transport and management requirements. Thus, the effectiveness of this concept seems not to be guaranteed.

4.1.4. Product stages that C2C & LCA take into account

Another controversy (Bjørn and Hauschild, 2012; NL Agency, 2011) is that C2C does not seem to promote environmental improvements in all life-cycle stages. As the C2C concept defines, one of its principles is mainly focused on materials, namely their extraction and recycling as technical and biological nutrients, and ignores the use stage of the product as shown by figure 2.

For production and transportation, C2C promotes the use of renewables to solve environmental aspects but this strategy has some limitations as is mentioned in the next section ("Current Solar Income Principle"). Because of these limitations C2C results in the omission of production, transportation and use stages; therefore, the potential environmental impacts related to these stages are not taken into account under the C2C approach and certification scheme (Figure 2). In consequence, C2C focuses exclusively on specific and fixed strategies instead of adapting solutions to each case study.

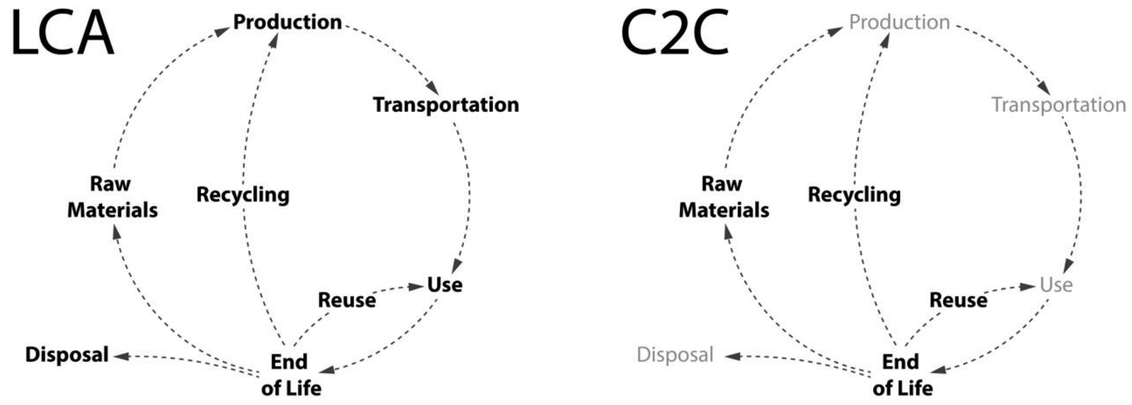

Figure 2: Comparison between stages that LCA and C2C take into account accordingly to a life-cycle approach. Stages taken into account are in bold

4.2. Current solar income principle

The C2C certification demands the use of 100% renewable energy for products manufacturing and materials recycling in the case of the highest standard of certification: Platinum level (C2C Institute, 2012a), which has not been obtained by any product yet. However, C2C certification does not really consider energy not associated with manufacturing (e.g. energy consumed in use).

Under nowadays paradigms one product is able to be produced with the use of 100% renewable energy; nevertheless, it cannot be expected to produce all our society’s products with renewable as C2C authors purpose. Our society is still far to achieve an energy system based 100% on renewable energies (C2C considers renewable energy next sources: solar, wind, hydropower, biomass, geothermal and hydrogen fuel cells), which limits the feasibility of the ‘Solar income principle’ at a broad scale. In 2008, only the 12.9% of the world's energy demand was supplied by renewable energies (IPCC, 2011a). Some optimistic previsions foresee that in 2050 80% of the global energy supply could be based on renewables (IPCC, 2011b). However, more pessimistic projections , which assume world's population increase and energy demand per capita, suggest that only 15% of consumed energy will come from renewable sources in 2050 (IPCC, 2011b). Furthermore, the possibility of achieving an energetic paradigm fully based on renewable energies is limited to resource scarcity as well as technological, political and efficiency limitations (Resch et al., 2008).

Also, it cannot be considered that renewable energies have zero environmental impact, as the C2C eco-effectiveness concept promotes (maximize economic value with no adverse ecological effects). This fact is related to raw materials' and production's environmental impacts associated to the required infrastructures for producing clean energy and its maintenance (IPCC, 2011b). For example, the IPCC (2011b) recognizes that wind energy have some potential ecological and environmental impacts: (1)

when generating electricity between 20 and 80 g CO_2eq/kWh are produced (depending if wind energy is onshore or offshore); furthermore (2) wind energy's onshore infrastructure affects the level of birds' population and generates ecosystem modifications; while (3) offshore harms marine life.

In conclusion, a widespread application of the C2C concept in the current economic system would encounter with mentioned limitations to achieve an energetic system fully based on renewable energies and would effect on ecosystems.

4.3. For which products applying C2C concepts will represent an environmental improvement under a life cycle approach?

This section is divided into three steps according to the methodology in order to carry out the second specific objective:

4.3.1. Step 1. Product selection

As figure 3 shows, five different groups, with differences in material use and energy consumption are considered for this study: furniture; office buildings; cleaning products; textiles; and electronic devices. The selected product groups try to cover most of material intensity ranges. Furniture was selected as a representative group of products with zero energy intensity because it is the one with the highest number of C2C certifications (C2C Institute, 2012b). Buildings, with high energy consumption but low energy intensity (due to high mass), are represented by office buildings because LCA results from the EU Ecolabel are focused on these typology of buildings. Similarly, cleaning products consider handwashing soap and detergents for dishwasher and laundry, according to the product typologies included in the EU ecolabel reports. Electronic devices category groups those products with high energy consumption and high energy intensity.

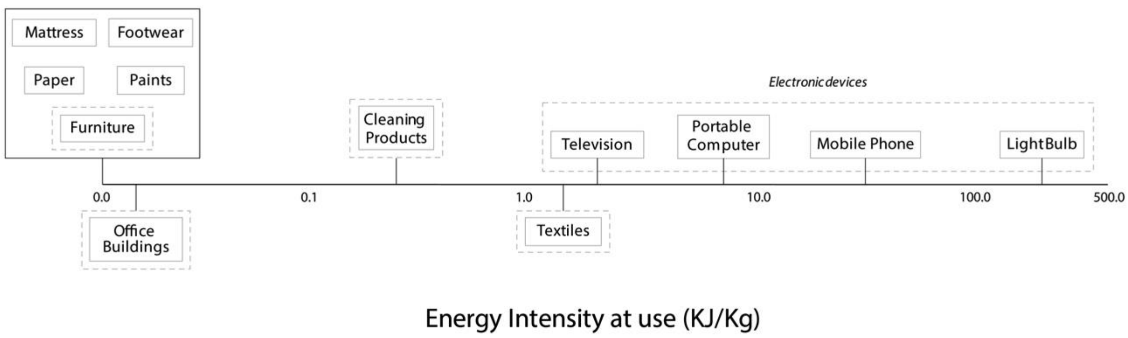

Figure 3: Product classification taking into account energy intensity during use. A logarithmic scale (x10) is used to represent results. [*Furniture, Mattress, Footwear, Paper and Paints have an energy intensity equal to 0. For the rest of groups specific references were used: office buildings (European Commission, 2011a); cleaning products (European Commission, 2011b; Gamble et al,. 2006; Dewaele et l., 2004); textiles (Beton et al., 2010); televisions (Sony, 2013; Samsung, 2013a; Philips, 2013a); portable computers (ASUS, 2013; Apple, 2013a; Hp, 2013); mobiles (Samsung, 2013b; Apple, 2013b; htc, 2013); and light bulbs (LightingEurope, 2013; Philips, 2013b)*]

4.3.2. Step 2. Analyzing LCAs for defined product categories

Taking into account the defined product categories, table 1 shows how each group's environmental impact is distributed in their different life-cycle phases.

		Raw Materials	Transportation	Production	Use	End of life
1	**Furniture**	**55-70%**	15-25%	15-25%	<5%	<5%
2	**Office buildings**	10-20%	<5%	<5%	**75-90%**	<5%
3	**Cleaning products**	**40-50%**	<5%	<10%	**25-35%**	10-20%
4	**Textiles**	**45-55%**	<5%	10-20%	**35-45%**	<5%
5	**Electronic devices**	<5%	<5%	<10%	**80-90%**	<5%

Environmental impact < 25%

Environmental impact > 25%

Highest environmental impact

Table 1: Environmental impact approximate distribution for each defined product category

Furniture. The most environmentally relevant impact of this group is associated to a phase that C2C strategies take into account: materials. Values for this stage depend on materials used: wood, stainless steel, aluminum, leathers, glass, plastics among others *(*González-García et al., 2011; González-García et al., 2012; European Commission, 2008b). Selected materials also determine the environmental impact associated to production. However, despite being a favorable category, the C2C only pays attention to life-cycle stages that account for 70% of the impact as the certification is exclusively focused on raw materials and end of life stages.

Office buildings. The most relevant environmental impact is at use stage (associated with energy consumption mainly for lighting, heating or cooling (European Commission, 2011a)) which C2C strategies omit. For this group C2C tackles less than the 25% of the environmental impact.

Cleaning products. Because of certain chemical substances that cleaning products contain, the highest environmental impact is at raw materials (European Commission, 2011b; Gamble et al., 2006; Dewaele et al., 2004). Between the 50 and 70% of the environmental impact is taken into account under C2C approaches.

Textiles. For this group raw materials are the source of the highest environmental impact; values for the stage varies according to the selected natural or synthetic fibers and coloring agents (Beton et al., 2010). Use has also a relevant environmental impact due to the cleaning of fabrics (Beton et al., 2010). In the best case, for textiles, C2C cares about the 60% of the environmental impact.

Electronic devices. The highest environmental impact is at use stage (LightingEurope, 2013; European Commission, 2008c). For the rest of the stages values are lower than 10%. For this group less than the 10% of the environmental impact is associated to stages where C2C strategies promote environmental improvements.

4.3.3. Step 3. Defining for which product categories, if any, C2C certification distinguishes environmentally friendly products

C2C sets environmental criteria only on the material and end of life stages (see "Product stages that C2C & LCA take into account" section); consequently, C2C certification will communicate that a product is more environmentally friendly if product's environmental impacts are associated to these stages.

For furniture, cleaning products and textile categories, raw materials are responsible for the 40-70% of the environmental impact. Therefore, when C2C is used for certifying one product within these categories, it may be certifying and communicating environmental improvements on relevant life-cycle stages.

However, C2C applied to buildings or electronic devices may be misleading consumers, as it certifies good environmental performance on non-relevant life-cycle stages. For these categories use stage concentrates between the 70-90% of the environmental impact because of energy consumption.

As a consequence of avoiding the use phase of products, the C2C strategies are not always useful in promoting significant environmental improvements in products nor are they helpful in identifying more environmentally friendly products.

5. Conclusions

The C2C is based on strategies that other fields, like industrial ecology, apply to reduce products' environmental impacts. Nevertheless C2C focuses exclusively on specific and fixed strategies instead of adapting solutions to each case study. The review and analysis done showed that:

- Unlimited growth is not feasible under a C2C approaches because of technological and biological nutrients limitations.
- Biological nutrient recycling could potentially intensify flows and concentrations of biological nutrients, collapsing the capacity of ecosystems to absorb them, having a negative effect on nature and biodiversity. Consequently, biological nutrient cycles are not feasible at large scale.
- A waste management infrastructure able to close high levels of the whole economy technological cycles does not seem possible under current paradigms.
- The solar income principle, which promotes a system fully based on renewables, cannot be implemented at short or midterm because of resource scarcity; as well as, technological and political limitations.
- C2C does not tackle environmental issues from a life-cycle approach. The main problem is that it focuses on raw material and end of life stages; therefore, it gives partial environmental solutions which do not adapt correctly to the life-cycle distribution of environmental impacts for each type of product. Hence, C2C strategies cannot be trusted to guarantee relevant environmental improvements for all products.
- LCA results showed that products with high energy consumption during use cannot be always trusted as environmentally friendly if are only labeled with C2C.
- For other products, environmental improvements are obtained; however, as C2C do not tackle the whole product's environmental impact, improvements are limited.
- In the best of the studied cases (furniture) it only takes into account the 70% of the impact and avoids the 30%.

Consequently, the C2C certification cannot be considered always an ecollabelling scheme able to distinguish environmentally preferable products as do not ensure always environmental improvements for all types of products.

To improve the implementation of the C2C the MBDC should give a life-cycle approach to the certification. Requirements for each type of product should be adapted according to those specific issues that produce most of its environmental impact. Furthermore as can be considered that any human activity has an impact on nature, including renewables, the C2C should also include eco-efficiency strategies to reduce environmental impacts.

Concluding, C2C may be a useful tool to promote life-cycle thinking and more environmentally friendly products; however, it has some shortcomings that condition the credibility of the concept, and weaknesses affecting the certification, that should be solved and clarified when certifying products to avoid confusions and protect consumers.

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