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Abstract

This paper is about the cradle to cradle (C2C) concept that is correlated with circular economy (CE). The C2C notion means; products should be without producing any waste. It is considered as a biometric procedure to design the products and materials in healthy ways. The C2C model is sustainable for present and future generations. In the past few years, C2C concept has grown wide interest among the nations of the world and the demand for environment friendly products has been increasing day by day globally. The C2C notion is based on the idea of non-waste production systems that do not harm the environment. Within the C2C framework, two distinct metabolisms: the biological metabolism and the technical metabolism are identified. In the study the development of C2C approach around the world is discussed. As the global natural resources are decreasing; C2C becomes new efficient strategy in production arena. Sustainable products, healthy materials, responsible consumption, and environmental responsibility are essential issues for the 21st century. The objective of C2C is the production without waste and elimination of the harmfulness from the products. C2C inspires that all products to be manufactured with alternative materials. This article tries for the successful implementation of C2C in the society.

Keywords: Cradle to Cradle, Biological Nutrient, Recycling, Clean Environment, Upcycling
JEL Codes: I31, O44, P35, P36, Q01, Q53, Q56, Q57

1. Introduction

The term cradle to cradle (C2C) was coined by Walter R. Stahel (1946-), a Swiss architect and industrial analyst, in 1976, in opposition to the current linear economic system. It is a registered trademark that is owned and licensed by McDonough Braungart Design Chemistry, LLC (MBDC). The concept of C2C was firstly developed during the 1990s by the American architect William Andrews McDonough and the German chemist Michael Braungart. In 2002, they have popularized it in their book "*Cradle to Cradle: Remaking the Way We Make Things*" [McDonough & Braungart, 2002]. The C2C pattern represents a new standpoint for the design and development of products and services as, "*Cradle-to-cradle design enables the creation of wholly beneficial industrial systems driven by the synergistic pursuit of positive economic, environmental and social goals*" [Braungart et al., 2007]. C2C is the production and building concept for the 21st century. It focuses on an ideological transition from 'less bad' to 'more good'. Sustainability rests on three main factors: humans, the economy, and the environment. To achieve a sustainable world based on the C2C atmosphere in the society, products should be beneficial in health, environmental, and economic terms [Toxopeus et al., 2015]. The C2C policy suggests that industry must protect and enrich ecosystems and biological metabolism of the nature should be safe [McDonough & Braungart, 2002]. The C2C strategy is considered as a universal, economic, industrial, and social framework which seeks to create systems that is not only efficient but also must be essentially waste free [Lovins, 2008]. The new C2C policy takes solid steps to create products with positive effects instead of reduced negative externalities. It leads to an unlimited use of resources, and finally consequences in a CE. The CE structure has been inspired from the fundaments of the C2C concept [Braungart et al., 2007]. The C2C design concept is one of the most promising approaches for CE in terms of consumer goods [Korhonen et al., 2018]. The C2C structure may be formed in such a way that nature of designing and producing of goods must neutralize the effects on global natural resources [McDonough & Braungart, 2002]. C2C indicates that sustainability is built on ecological benefit and eliminates negative effects on the natural world [Hou & Li, 2014].

C2C means benefit as much as possible of the product by recycling it and reintroducing it in new forms and uses to serve both the economy and the environment. It is a revolutionary change of the organizations in the products and services design, and production and distribution [Burchard-Dziubińska, 2017]. The C2C concept supports the principle of nature that, "*there is no waste on the earth*" and "*waste equals food*". The waste of one process becomes the food for another which is called as nutrients. There are two types of nutrients: biological nutrients and technical nutrients [Bhise & Kashikar, 2014]. Technical nutrients, inorganic materials, should be non-toxic, non-harmful synthetic materials and have no negative effects on the natural environment. Biological nutrients are organic materials that decompose into the soil without affecting the natural environment. Technical nutrients are considered for industrial recycling whereas biological nutrients return to the soil and feed environmental processes. If more waste creates in the environment, the more nutrients are available for producing new products [McDonough & Braungart, 2002; Bjørn & Strandesen, 2011].

The technological or biological nutrients are classified as: upcycling and downcycling [McDonough & Braungart, 2013]. Downcycling is the recycling process of waste where the recycled material is of lower quality than the original material. For example, steel scrap from end-of-life vehicles is often contaminated with copper from wires and tin from coating. This contaminated scrap yields secondary steel that does not meet the specifications for automotive steel and therefore, it is mostly applied in the construction sector [Pires et al., 2019]. On the other hand, upcycling is the process of transforming byproducts, waste materials, useless, or unnecessary products into new products or materials seeming to be of greater quality and useful or valuable. The C2C design aims to avoid downcycling materials and uphold upcycling ones. In C2C process materials can be used several times without downcycling and ultimately will be non-toxic waste [Zhuo et al., 2014].

The C2C model has been implemented by a number of companies, organizations and governments in the EU, China, and the USA. C2C is a biometric attempt for designing the products and systems that models materials as high-quality nutrients circulating in productive, healthy and safe metabolisms. By C2C strategy waste can be reduced or eliminated by the process of reused. It creates a cyclical process instead of a linear one like the cradle to grave approach. For example, when an animal dies, waste is created. That waste breaks down and becomes nutrients for another process [Lovins, 2008]. The focus on recovery of resources, recycling and reuse can be designated as C2C resource management [Kumar & Putnam, 2008]. The C2C concept is eco-effectiveness (effectiveness means "doing the right things") and eco-efficient approaches in a unique in manufacturing that indicates exact counterpart of eco-efficiency (efficiency means "doing the things right") [Cradle to Cradle Certified, 2020]. The cradle to grave (C2G) policy indicates that the raw materials are extracted from the finite resources of the earth to produce valuable and useful goods, after use disposed in the form of Landfill and where it is of no use to anyone [Allan & Phillips, 2021].

2. Literature Review

William McDonough and Michael Braungart show that biological and technical cycles are closed without damaging effects on the environment. To achieve the C2C procedure they have indicated that waste can be transformed into food, the sun can be used for renewable energy only, and diversity, species, cultural and innovation diversity must be enjoyed efficiently. They have used eco-effectiveness for the shortcomings of eco-efficiency that aims as far as possible to reduce and compensate the harmful effects on the environment. Eco-effectiveness aims for the development without harmful effects on the environment [McDonough & Braungart, 2002].

Anders Bjørn, and Maria Strandesen have identified three inherently critical points of the C2C concept as [Bjørn & Strandesen, 2011]: i) 100% closed loop recycling of technical nutrients, ii) environmental benefit of biological nutrient addition, and iii) compatibility with continued economic growth. Walter Stahel and Geneviève Reday-Mulvey have provided that C2C has influential impact on job creation, economic competitiveness, resource savings, and waste prevention [Stahel & Reday-Mulvey, 1981]. M. E. Toxopeus and his coauthors have tried to explain why the eco-effective C2C vision in practice provides only eco-efficient approach by analyzing several conflicts between theory and practice [Toxopeus et al., 2015]. Nikolay Minkov and his coauthors have analyzed C2C certified for external communication in the context of environmental labeling and declarations. In addition, they have compared with the established standardization labeling typologies, namely Type I and Type III [Minkov et al., 2018]. Viktoria Geng and Cornelius Herstatt have studied the potential intersections between C2C and the Fuzzy Front End (FFE) theory. They have applied FFE success factors to C2C and derive enablers for successful C2C implementation. They have examined almost 140 companies and 400 products in this respect [Geng & Herstatt, 2014].

Nii A. Ankrah and his coauthors have analyzed the cradle to cradle philosophy in business sector. Business sites are categorized as the core activity of organizations that are co-located on the site, with classifications, such as science or technology parks, research parks, office parks, retail parks, light and heavy industrial areas, and export processing zones [Ankrah et al., 2015]. Anders Bjørn and Michael Hauschild have shown controversies between LCA and C2C. They have revealed that C2C defines a desirable sustainable future but it has some inherent faults to perform well with environmental impacts, waste treatment and energy generation [Bjørn & Hauschild, 2012]. Helen Kopnina shows the ways how CE and C2C can be used in university teaching. She emphasizes on upcycling policy rather than downcycling. She stresses on both theory of sustainable production and sustainability and practical research on CE and C2C models [Kopnina, 2018].

3. Methodology of the Study

The C2C policy is a supporting tool that organizations can use at the product level. C2C is inspired by nature as well, also had an influence on the development of the CE concept [Sherwin, 2013]. Throughout the study we have used the secondary data sources. The reliable data are collected from: i) national and international journals, ii) various publications of foreign governments or of international bodies and their subsidiary organizations, iii) various research reports of research scholars, iv) books of well-known authors, research note books, hand books, theses, magazines, and newspapers, v) websites, and vi) public records and statistics, historical documents, and other sources of published information. Also we have taken help from the unpublished data that are collected from diaries, letters, unpublished biographies and autobiographies, and also from scholars and research workers, trade associations, and other public/private individuals and organizations [Mohajan, 2020a].

We have taken attempt to discuss C2C certification in the beginning that helps consumers to recognize C2C products. Then we have tried to highlight the fundamental principles of C2C: i) waste equals food, ii) use current solar income, and iii) celebrate diversity. Later, we have thought that five pillars of C2C, namely material health, material reutilization, renewable energy and carbon management, water stewardship and social fairness are vital at the present world. The reliability and validity are essential issues in any research. In this article we have tried our best to maintain the reliability and validity throughout of the research [Mohajan, 2017, 2018, 2020b].

4. Objective of the Study

The general objective of this article is to analyze the successful implementation of C2C policy in the global society. It is considered as a vision for a sustainable world inspired by nature. Some other special objectives are as follows:

- to highlight three qualitative principles and five pillars of C2C,
- to show the arrangement of C2C, and
- to explore the benefits and barriers of C2C policy.

5. C2C Certification

C2C certified is the global standard for the products that are safe, circular, and responsibly made. It is an effective vision for the world. It is a scheme for the certification of products that meets the criteria and principles of the design approach. Its positive results show that it does do more good instead of doing less bad [CCPII, 2011]. The C2C philosophy with positive growth drive force to innovate and expand is well-received in many manufacturing companies. The attempts of Michael Braungart and William McDonough have played a leading role in the consultancy firms Environmental Protection Encouragement Agency (EPEA) and McDonough Braungart Design Chemistry (MBDC) to support companies in their effort to develop C2C products [Toxopeus et al., 2015]. The "*Cradle to Cradle Products Innovation Institute*" (C2CPII) was founded by Braungart and McDonough [McDonough & Braungart, 2002]. In 2010, a license to manage the program was granted to the C2CPII, a not-for-profit organization. It helps consumers to recognize C2C products, and is regarded as the best way of labeling a product's sustainability [Cradle to Cradle Certified, 2020]. In 2012, MBDC was transferred to the Cradle-to-Cradle Product Innovation Institute to ensure the independence and openness of the certification process [MDBC, 2016].

Product certification is awarded at five different achievement levels as; Basic, Bronze, Silver, Gold, and Platinum, with specified criteria for each level. It is the process of certifying that a certain product has passed performance tests and quality assurance tests. The establishment of 100% C2C policy in the society at platinum level possible if all the limited natural and man-made resources must be used efficiently [CCPII, 2012].

6. Fundamental Principles of C2C

The C2C concept supports "zero emissions, zero resource use and zero toxicity" that is, a product should not create any waste or emit any pollutants into the environment [Baumgartner & Zielowski, 2007; McDonough et al., 2003]. The C2C design aims not to reduce the linear material flows and production but make nutrients to live in circular cycles, where value once created, remains the same. C2C is a development paradigm that focuses on eco-effectiveness [Toxopeus et al., 2015]. In nature, waste creates by one creature must become a nutrient for another. Also in the earth all energies come from the sun and use of renewable energies must be increased. All the materials of nature must be non-toxic and safe for humans and the environment [McDonough et al., 2003; Toxopeus et al., 2015]. The C2C concept is based on three fundamental and qualitative principles [McDonough & Braungart, 2002; Kumar & Putnam, 2008]: i) waste equals food, ii) use current solar income, and iii) celebrate diversity.

6.1 Waste Equals Food

The elimination of the very concept of waste to be inspired by endless nutrient cycles of nature. Hence, all products and industrial processes should be designed in such a way to enable the perpetual flow of the nutrients within one of the two distinct biological and technical metabolisms [Llorach-Massana et al., 2015]. Technical nutrients are inorganic or synthetic materials manufactured by humans, such as plastics and metals. These can be used in continuous cycles as the same product without losing their quality. Biological nutrients are organic materials which are used once decompose into the soil. These nutrients provide food for bacteria and microbiological life forms without affecting the natural environment. Technical nutrients should be designed for industrial recycling whereas biological nutrients should be designed for returning to the soil and feed environmental processes [Braungart et al., 2007]. C2C indicates that a product can reenter in a biological cycle or a technical cycle at the end of its life. For example, organic waste materials will become food for bugs, insects and other small forms of life will take as food; decompose it and return it to the natural environment which we then indirectly use for food of human beings [McDonough & Braungart, 2002]. All materials and emissions are seen as beneficial for the environment. Products shall be deliberated in a way that they pose no danger to human health and can be recycled continuously [CCPII, 2016].

6.2 Use Current Solar Income

It indicates that the energy of fuelling a closed loop C2C must all come from the sun or other forms of energy, such as renewable energy from photovoltaic, geothermal, wind, hydro, and biomass [McDonough & Braungart, 2002]. It enhances the elimination of the use of fossil fuels in production. The renewable energy sources are widely and abundantly available without practical restrictions [Toxopeus et al., 2015]. The C2C renewable energy resources can highly reduce the environmental problem, energy problem and satisfy the human requirements as well and use of renewable energy must be increased as much as possible. The use of renewable energy makes energy consumption no longer relevant as an environmental impact for the C2C [CCPII, 2016]. Implementation of 100% renewable energy (platinum level) for products manufacturing and materials recycling has not been obtained by any product yet. Present world is still far to achieve an energy system based 100% on renewable energies. In 2008, only the 12.9% of the world energy demand was supplied by renewable energies [IPCC, 2011b]. It is expected that by 2050, only 15% of consumed energy will come from renewable sources [IPCC, 2011a; Resch et al., 2008].

6.3 Celebrate Diversity

It avoids one-size-fits-all solutions, i.e., design products that are technically diverse [Llorach-Massana et al., 2015]. To improve a system's resilience, diversity is necessary. It tries to design products and systems with local environments, economies and cultures in mind. It does not try to reduce negative impacts on the environment [McDonough & Braungart, 2002]. It eliminates the instability and imbalance, provided by a narrow view of production [Kumar & Putnam, 2008]. Biodiversity, cultural and conceptual diversity improve relationships, creativity and innovation. The ultimate goal of the C2C theory is to connect the natural resources and the artificial ingredient harmoniously [Toxopeus et al., 2015].

7. Five Pillars of C2C

Five pillars of C2C are as: material health, material reutilization, renewable energy and carbon management, water stewardship and social fairness [CCPII, 2018]. Material health indicates that the knowledge of the chemical ingredients of every product classify as biological or technological nutrient. It ensures that materials should be safe for humans and the environment. Material reutilization describes the process of returning components of a product into the different cycles. It is required prior to design concept to assure that material loops can be carried out. Water stewardship is also vital in the C2C project; as clean water is essential to life as a precious resource. The production of goods should neither harmful nor reduce water quality. Therefore, the used water with the chemical ingredients in the production process must be clean and pure as of drinking quality. Renewable energy and carbon management represents that the whole project should be run solely on by renewable energy sources. Social fairness represents the objective of making a positive impact on the life of local communities in the form of creating employment with fair wages and elevating their quality of life. It respects human rights and contributes to a fair and equitable society. Clean air and climate protection protect environment, promote renewable energy, and reduce harmful emissions [Toxopeus et al., 2015; Cradle to Cradle Certified, 2020]. Above five pillars of C2C reflect several components of CE. So that C2C can be considered as a part of CE [Lieder & Rashid 2015; Korhonen et al., 2018].

8. Application and Arrangement of C2C Policy

There are lots of uses of C2C globally. Some renowned uses of C2C are in research institutes, factories, all kinds of architectures, office spaces, private residences, etc. The arrangement of C2C needs to augment the clean environment policy.

8.1 Low Carbon Policy

Control of carbon emissions from fossil fuel is low carbon policy, which is still in its infancy in the world. The C2C strategy indicates low carbon community, such as low carbon in building, energy efficient utilization, green transportation hierarchy, resources recycling, and low carbon life initiate [Hou & Li, 2014].

8.2 C2C Policy in Business Sites

The C2C is a sustainable business strategy that mimics the natural recycling cycle and waste is reused. But when and how to apply the C2C concept successfully in business is still controversial [Zhang & Huang, 2019]. The C2C ideology affects consumers' values and ultimately changes consumer spending habits. By the proper use of raw materials producers can accelerate the repeated purchase frequency of consumers [O'Lear, 2010].

Business sites have been associated with poor environmental management, pollution, traffic congestion, and reduced quality of life. The development of business site is laid by the clustered development in regional planning where different organizations are gathered for the mutual benefits, such as modern services, physical infrastructure and services of other local companies [Bergman & Feser, 1999]. C2C policy contributes to the success of a positive relationship between business sites and the social, cultural, and natural environment. Business organizations educate and encourage manufacturers to design their products in such a way that these can be reused and remanufactured. These strategies will supply nontoxic materials to the consumers around the world according to their demand [Tudor et al., 2007].

8.3 C2C in the Industrial Sector

The industrial sectors take necessary steps of low carbon policies in production and distributions. The materials and manufacturing processes of the industries must be material health, material reutilization, renewable energy & carbon management, water stewardship, and social fairness. Products meet the standard of C2C certified. For example, industries applied C2C principles in the design of PVC-free commercial carpet tiles that are separable into component materials for carpet-to-carpet recycling [McDonough & Braungart, 2002]. Factories must try to:

- use 100% renewable energy for production,
- successful elimination of hazardous ingredients from textile manufacturing,
- disclose all product ingredients into the public reach, and
- maximize area of human and environmental health.

9. Benefits of C2C Policy

C2C is essential and beneficial for companies when a product is performed in a sustainable way. The C2C concept incites businesses to be aware and to do better. It minimizes damage to the environment. C2C will create better conditions for work and living in the society. It replaces waste as a new nutrition for a new product. Some scholars have claimed that C2C propel the "*third green wave*" and the "*next industrial revolution*" [Bakker et al., 2010; Reay et al., 2010]. It lies on eco-effectiveness that is an "*an alternative design and production concept to the strategies of zero emission and eco-efficiency.*" C2C removes harmful substances, such as carcinogens and toxic materials from the industrial cycle and to find safe alternatives to them that creates healthier and more cost-effective workforce [Braungart et al., 2007].

10. Barriers in Implementation of C2C

C2C plan is a useful tool for the present and future. The C2C strategy has many successes for steps of the improvement of environment in future. The C2C certification cannot guarantee environmental protection for all types of products. Yet it has some drawbacks [Llorach-Massana et al., 2015]. As the technological and biological nutrients are limited in the world, unlimited growth is not possible by using C2C approaches. Due to resource scarcity, technological limitations and political incoordination, apply of renewable energy in every stage of the society is not possible that hinders the implementation of C2C atmosphere. Absorption of all the biological nutrients is not possible that creates a negative effect on nature and biodiversity. Consequently, biological nutrient cycles are not feasible at large scale and C2C policy is not possible in all stages at all times. In fact, waste management is not possible in all over the world and C2C approach is not full effective.

The main criticism of the C2C concept is that some aspects of a product's lifecycle, such as transportation or use, are not considered [McDonough & Braungart, 2002; Llorach-Massana et al., 2015].

11. Conclusion and Recommendation

The C2C policy provides safety to humans and environment that develops optimization strategies for social improvement. It deals with environmental features of production and company activity that provides an innovative and interesting perspective. It supports continuous improvement of the products that are beneficial for all global people and the planet. It can be applied to any system in modern society. In the study we observe that C2C policy encourages the products that are manufactured with alternative materials which are both nonhazardous and biodegradable. The C2C attitude helps the society to think about the harmful significances of environmental unfriendly products before producing. The C2C policy helps to think both producers and consumers at least to about harmful effects of toxins in various products and try to produce clean and sustainable products. The C2C process has gained popularity amongst companies as a way to distinguish more environment friendly products.

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