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Review Article

An Evaluation on the Circular Economy Model and the Loops Design in the Context of Waste Management*

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Abstract

The linear economy, which has grown further with the technological, social and economic developments after the first two industrial revolutions, had irreversible negative consequences on the environment. While the global resource use has increased rapidly, our disposable lifestyles have transformed the planet into a 'take-make- use and throw' world and waste generation has become one of the prominent problems of this economy. It is now much clearer that the business as usual linear economy model is not sustainable; besides, increasing population along with the demand on resources makes this model even more unsustainable. Current estimates show that total global consumption has already exceeded 50% of the planet's self-renewal capacity. If nothing is done to rationalize the use of natural resources and to change those unsustainable production and consumption patterns, the situation that is already critical will continue to deteriorate further. To turn the society into a one that can create more value with less natural resource input, a new economic system based on the sustainable use of raw materials, resources and renewable energy is almost a necessity. In this respect, a recent paradigm, 'Circular Economy', is viewed as a promising approach to help to reduce our global sustainability pressures. Based on a narrative literature review, this study focuses on the circular economy, examines the model and the loops underlying the system, then analyses the respective product design strategies under the model within the scope of waste management. In its attempt to provide an analysis of the design strategies for slowing and closing the loops, the models and strategies proposed by some key earlier studies are utilized. Based on the studies, it is evident that the circular economy model would be an effective tool for waste and resource management. However, in general, it is seen that closing loops through recycling is more prominent compared to slowing loops. In the waste management hierarchy, preventing waste before it is generated has the highest priority, accordingly it is concluded that slowing loops is even more important than closing loops. Furthermore, changing only the production patterns would not be enough, it is imperative to change the consumption patterns as well.

Keywords: Circular Economy, Closed Loops, Circular Product Design Strategies, Waste Management.

Döngüsel Ekonomi Modeli ve Atık Yönetiminde Döngülerin Tasarımına İlişkin Bir Değerlendirme

Öz

İlk iki sanayi devriminden sonra teknolojik, sosyal ve ekonomik gelişmelerle hızla ilerleyen lineer ekonominin çevre üzerinde geri dönüşü olmayan olumsuz sonuçları olmuştur. Küresel kaynak kullanım hızlı bir oranda artarken, tek kullanımlık yaşam tarzlarımız gezegeni al, yap, kullan, at dünyası haline getirmiş ve atık oluşumu lineer ekonominin en belirgin sorunlarından olmuştur. Mevcut lineer ekonomi modelinin sürdürülebilir olmadığı daha da açık hale gelmektedir, bunun yanında artan nüfus ve kaynaklar üzerindeki

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talep bu modeli daha da sürdürülemez kılmaktadır. Mevcut tahminler, toplam küresel tüketimin gezegenin kendini yenileme kapasitesini şimdiden %50 oranında aştığını göstermektedir. Doğal kaynakların kullanımının rasyonelleşmesi ve sürdürülebilir olmayan üretim ve tüketim kalıplarının değiştirilmesi için bir şey yapılmadığı takdirde, zaten kritik olan bu durum giderek daha da kötüleşmeye devam edecektir. Toplumu, daha az doğal kaynak girdisiyle daha fazla değer yarabilen bir topluma geçirmek amacıyla, hammadde, kaynak ve yenilenebilir enerji kullanımlarını esas alan yeni bir ekonomik sistemin ortaya çıkması neredeyse bir zorunluluk haline gelmiştir. Bu bağlamda, güncel bir paradigma olan 'Döngüsel Ekonomi', küresel sürdürülebilirlik baskılarını azaltmaya yardımcı olacak umut verici bir yaklaşım olarak görülmektedir. Literatür araştırmasına dayalı bu çalışma, döngüsel ekonomi modeline odaklanmakta, modeli ve sistemin temelini oluşturan döngüleri incelemekte, model altında önerilen ilgili ürün tasarım stratejilerini atık yönetimi kapsamında değerlendirmektedir. Döngülerin kapatılması ve yavaşlatılması için tasarım stratejilerinin incelenmesi girişimi temelinde, öncü temel çalışmalar kapsamında önerilen modeller ve stratejiler kullanılmıştır. Çalışmalara dayanarak, döngüsel ekonominin atık ve kaynak yönetimi için etkili bir araç olacağı açıktır. Ancak, genel olarak geri dönüşümün, yani döngülerin kapatılmasının döngülerin yavaşlatılmasıyla karşılaştırıldığında daha fazla öne çıktığı görülmektedir. Atık yönetimi hiyerarşisinde, atıkların oluşumundan önce oluşmadan önlenebilmesi önceliklidir; bu doğrultuda döngülerin yavaşlatılmasının döngülerin kapatılmasından daha önemli olduğu değerlendirilmektedir. Diğer taraftan, yalnızca üretim kalıplarının değiştirilmesi yeterli olmayacaktır, tüketim kalıplarının da mutlaka değiştirilmesi gerekmektedir.

Anahtar Kelimeler: Döngüsel Ekonomi, Kapalı Döngü, Döngüsel Ürün Tasarım Stratejileri, Atık Yönetimi.

1. Introduction

The most problematic environmental problems such as climate change, chemical emissions, and hazardous wastes have transboundary effects. Another common point of these problems is that they are closely linked to the production and consumption of products and services. As a result of our disposable lifestyles, it is much more evident that the level of human resource metabolism is not sustainable and needs to be reduced (Schaffartzik et al., 2014). A recent UN forecast suggests that the global population, currently at 7.3 billion, will grow in the coming decades to 9 billion is likely to exceed 11 billion by the end of 21st century (UN DESA, 2015), further draining the planet's already strained natural resources. Such a dramatic growth in population, purchasing power and consumption are already having and unprecedented impact on demand for many resources, moreover demand is expected to increase. (Andrews, 2015: 308). Over the last four decades, the global use of materials almost tripled, from 26.7 billion tonnes in 1970, to 84.4 billion tons in 2015. Not only has material use been increasing but it has been accelerating; resource extraction increased 12-fold between 1900 and 2015, with further doubling forecast for the next 30 years to 2050 (Circularity Gap Report, 2018: 4).

On the global scale, more pollution and waste are generated each day and the pressure on the ecosystem is increasing. It is envisaged that this amount will increase in line with the population growth, increasing income and urbanization simultaneously. Annual waste generation is estimated at 3.4-4 billion m^3, and according to a OECD (2011) study, these figures indicate that about a fifth of raw materials extracted worldwide ends up as waste. In addition, a World Bank study points out that the current amount of domestic waste of 1.3 billion tons would reach 2.2 billion tons by 2025 (Wilson et al., 2012). Similarly, hazardous waste is rapidly increasing in the domestic waste composition, while new types of waste such as e-wastes are also of concern.

Waste management is an issue that concerns many aspects of society and the economy, with close relationships with health, climate change, poverty prevention, food and resource security, sustainable production and consumption. On 25 September 2015, the UN General Assembly adopted the 2030 Development Agenda titled "Transforming our world: the 2030 Agenda for Sustainable Development", including 17 Sustainable Development Goals (SDGs) to end poverty, combat inequality and injustice and overcome climate change by 2030. Under the SDGs, it is seen that waste management is referred both directly and directly. The objectives of the Goal 11 "Making cities inclusive, safe, resilient and sustainable", Goal 3 "Ensuring healthy lives and promote well-being for all at all ages" and Goal 12 "Ensuring sustainable consumption and production patterns" are directly linked to waste management.

With its rise to political prominence, 'Circular Economy' is viewed as a promising approach to help to reduce our global sustainability pressures, and it is an alternative to current and predominant linear model (Andrews, 2015: 305). Through the circular economy, focusing on waste and resource management while setting and monitoring global targets for waste management will contribute significantly to attain SDGs. The model is promoted by many governments, business advocacy bodies and international organisations. China enacted a law for the promotion of the circular economy in 2008, while in the European Union (EU), the Circular Economy Package including a comprehensive action plan and legislative proposals for waste was adopted by the European Commission on December 2, 2015 line with the objective of transition towards a resource-efficient, green and competitive low-carbon economy (Sapmaz Veral, 2018: 463). This study focuses on the circular economy model, examines the model and the loops underlying the system, then discusses the product design strategies for closing and slowing the loops within the context of waste management.

2. Material and Method

Based on narrative review, this paper reviews the literature on circular economy with the aim of improving our understanding of the loops underlying the system as well as the importance of loops design in the context of waste management. Literature and the relevant documents were searched by using "circular economy", and the search resulted in collection of both academic and non-academic literature, then through snowball sampling the reference lists of key documentation were examined. The selected studies were summarized respectively.

This paper has the following structure: After a brief introduction with the waste concept and waste management approaches, the circular economy model and the loops underlying the model were described. For the description of the model, the reports of Ellen Mac Arthur Foundation (EMF) and European Environment Agency (EEA) were taken as a starting point, since these reports have been responsible for the increased attention of business, government and other actors for the circular economy concept across Europe and worldwide. Notwithstanding, other studies which have defined the circular economy concept were regarded as well. Then, in its attempt to provide an analysis of the relevant design strategies for slowing and closing the loops in the context of waste management, the product design strategies proposed by Bocken et al., which builds on the works by Stahel and Braungart et al., were utilized. Finally, the effects of slowing and closing loops were discussed and evaluated in the context of waste management.

3. Literature Review

3.1. 'Waste' Concept and Waste Management Approaches

Although "waste" is a very broad concept, it can be defined as unwanted or discarded materials, rejected as useless, unnecessary or excess (GWMO, 2015: 23). Barles (2014: 199-226) point out that wastes that we define today emerge from three different terms in the past; in the first category there are terms related to themes of loss and uselessness (dechet in French, garbage in English, residency in Spanish and abfall in German). The second category consists of terms that emphasize pollution (immondice in French, horridus in Latin). The last category describes the materials that make up the waste (boues in French, rubbish in English, spazzatura in Italian). Waste could also be defined as a combination of the four wrongs: a wrong substance, in a wrong quality, in a wrong place at a wrong time (Huda cited in GWMO, 2015). Although this use of the term waste is very wide, it includes undesirable outputs of human activities such as gases, liquids and solids, as well as discharges to air, water and soil (GWMO, 2015).

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal includes an internationally accepted, narrower definition of waste: 'substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law' (Basel Convention). In the EU Waste Framework Directive 2008/98/EC, waste is defined as 'any substance or object which the holder discards or intends or is required to discard'(EC,2008).

When the waste management approaches of the different countries are examined, it is seen that the approaches and the capacities differ according to the development levels. When its historical development is examined, it is seen that periodic conditions have shaped waste management approaches. Public health, environmental concerns and resource value of waste have been the main factors shaping waste management.

Wilson et al. (2012) identifies 6 main factors driving the development of waste management. Public health problems as cholera epidemics in the 19th century have led to the development of waste collection systems, in the 1970s, the prominent environmental protection movement tackled the uncontrolled disposal issue and led to tighter technical standards. The resource value of the waste, which has been a historically important factor supporting especially the poor's livelihood in the past, still remains as an important factor. Currently, in developed countries, owning to its resource value, transition from waste management to a more integrated waste and resource management is becoming more common. Other important factors include social awareness along with corporate responsibility issues. It is also underlined that one single factor does not determine the development of waste management; it will vary among the countries in line with their conditions and perspectives. Increased disposal costs from the 1980s and increased public opposition to new sites have led developed countries to rediscover recycling for their wastes. Furthermore, with the increasing concerns related to the depletion of natural raw materials and resource scarcity, a focus on waste prevention and resource efficiency has begun.

A more recent factor shaping waste management policies is the significant negative impacts on the global environment, that is, human-induced climate change. IPCC (2013) predicts that methane emissions from solid waste management, particularly from landfill facilities, account for about 3% of global greenhouse gas emissions in 2010. Better waste and resource management will contribute much to combat climate change. Similarly, recycling replaces raw materials with a much lower cost of carbon and reduces emissions. It is stated that focusing on waste and resource management for many sectors has the potential to reduce greenhouse gases by 15-20% in the short term in combating climate change. In Germany, for example, 24% of the reduction in greenhouse gas emissions from 1990-2006 stems from solid waste management (GWMO, 2015: 8).

Consequently, while the initial focus was on waste after it had been discarded, at present, attention has moved upstream, addressing the problem at its source through, such as, designing out waste, preventing its generation, reducing both the quantities and the uses of hazardous substances, minimizing and reusing, and, where residuals do occur, keeping them concentrated and separate to preserve their intrinsic value for recycling and recovery and prevent them from contaminating other waste that still has economic value for recovery (GWMO, 2015).

Today, in developed countries, a transition from waste management to resource management is realized with complementary policy initiatives such as sustainable consumption and production, circular economy and green economy that are embodied by the UN summits.

3.2. The Circular Economy Model

The circular economy model is defined as a model of clean production enabling reuse of products and raw materials with almost zero waste generation, in which energy and all resources are used efficiently and waste is recycled through a holistic process. Haas et al. (2015: 765) describes the circular economy, as a simple, but convincing strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows. UNEP (2006) defines the circular economy as a model that balances economic development with the protection of the environment and resources. Circular economy means reuse, repair, refurbishing, and recycling of the existing materials and products; what was earlier considered to be waste becomes a resource (Jurgilevich et al., 2016), while the central point of circular economy is to create value through material retention (Buruzs and Torma, 2016).

Circular economy focuses on natural systems; where, nature becomes the source of inspiration for resource efficiency, and the model mirrors natural life cycles (Andrews, 2015: 305). Circular economy is also related to the concept of cycles, including biological-chemical cycles and the recycling of products (Bocken et al., 2016). The system is not only about recycling; it focuses on the use of sustainable energy sources such as solar, wind, biomass and waste from energy; along with increase in the reuse, repair, recycling and recovery of existing materials and products (Korhonen et al., 2018: 545). Preston (2012: 3) emphasizes that in a Circular Economy, large volumes of finite resources (metals and minerals, for example) are captured and reused by closing the resource loop; other products can be made from plant-based materials, which will eventually biodegrade into fertilizers at the end of their product life. The redesign of the industry at the system level will also enable energy efficiency, while the remaining energy will be provided by renewable energy sources. At this point, as Preston (2012) underlines, spreading the logic to the whole economy requires profound changes in the basic structures of industrial systems.

The circular economy model seeks to maximize the value of natural resources. It is regenerative and restorative in terms of design; aims to eliminate waste generation through the design of materials, products, systems and business models (EASAC, 2015). The redesign of manufacturing and service supply systems in circular economy focuses on value creation (Murray, 2017: 373). In the circular economy, focusing on the lifecycle approach from the cradle to the cradle in the whole product chain, the resources are kept in use for the longest possible time, and their maximum values are attained, unlike the traditional take-make-use- throw model of the linear economy. Murray et al. (2017: 1) also states that the Circular Economy places emphasis on the redesign of materials and the cycling of materials, hence may contribute to a sustainable business model, but they criticize the lack of social dimension in most of the definitions. Korhonen et al. (2018) points out that circular economy aims not only to promote sustainable production, but it also aims to promote sustainable consumption.

A study by the EEA shows a simplified model of circular economy (Figure 1). The basic idea is to minimize waste generation and material inputs through eco-design, recycling and reuse of products. Thus, while the dependence on extraction and imports will be reduced, both economic and environmental benefits will be attained.

The outer circle represents the overall energy flows. Relevant parameters are the share of renewables and total energy efficiency, which are expected to be much higher compared to the linear model. Although the energy recovered from incineration can compensate for fuel use, the incineration should also be minimized, because the energy obtained from the incineration can only be used once and removes materials from the loop.

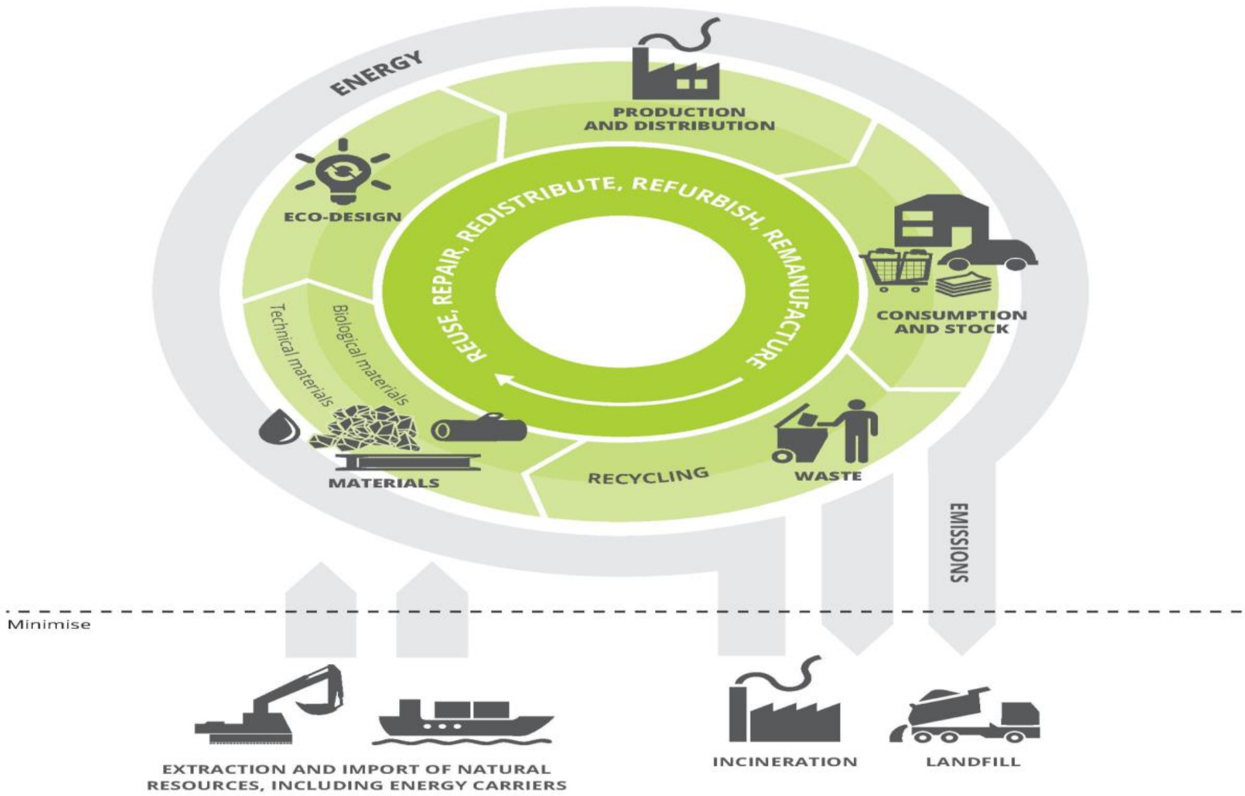

Figure 1. EEA's Circular Economy Model Outline (EEA, 2016: 10)

The middle circle represents the material flows in the recycling loop and distinguishes between abiotic technical materials such as metals and minerals and biological materials. Since they are completely renewable, it would be beneficial to increase the share of biological materials. In practice, technical and biological materials are often mixed, which has consequences for biodegradability and reversibility. On the other hand, with the use of more biological materials, there is a risk of exerting additional pressure on natural capital, with impacts on ecosystem resilience.

The inner circle represents reuse, redistribution, repair, remanufacture and refurbishment, bypassing waste generation and recycling, so that the minimum amount of resource input is possible. With these approaches, it is possible to retain the value of products, components and materials at the highest possible level (EEA, 2016: 9).

Ellen MacArthur Foundation (EMF), which advocates and supports the move to a circular economy model with business world in Europe in particular, defines the circular economy as an industrial system that is restorative or regenerative by design replacing the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse. At its core, a circular economy aims to design-out waste (EMF, 2015b:3). Thus, in this economy, resource extraction, emission and environmental pressures associated with waste are reduced, while the need for virgin materials and energy input is minimized. This system requires more efficient and sustainable management of natural resources throughout life cycles. As a result, it provides opportunities to create welfare, growth and new jobs while reducing environmental pressures. Eco-design, repair, reuse, renewal, remanufacturing, product sharing, waste prevention and waste recycling are all important in the circular economy. At the same time, if inevitable, the energy recovery from non-recyclable waste; landfills and incineration will be deployed, but their share will be minimized, and material losses will be reduced.

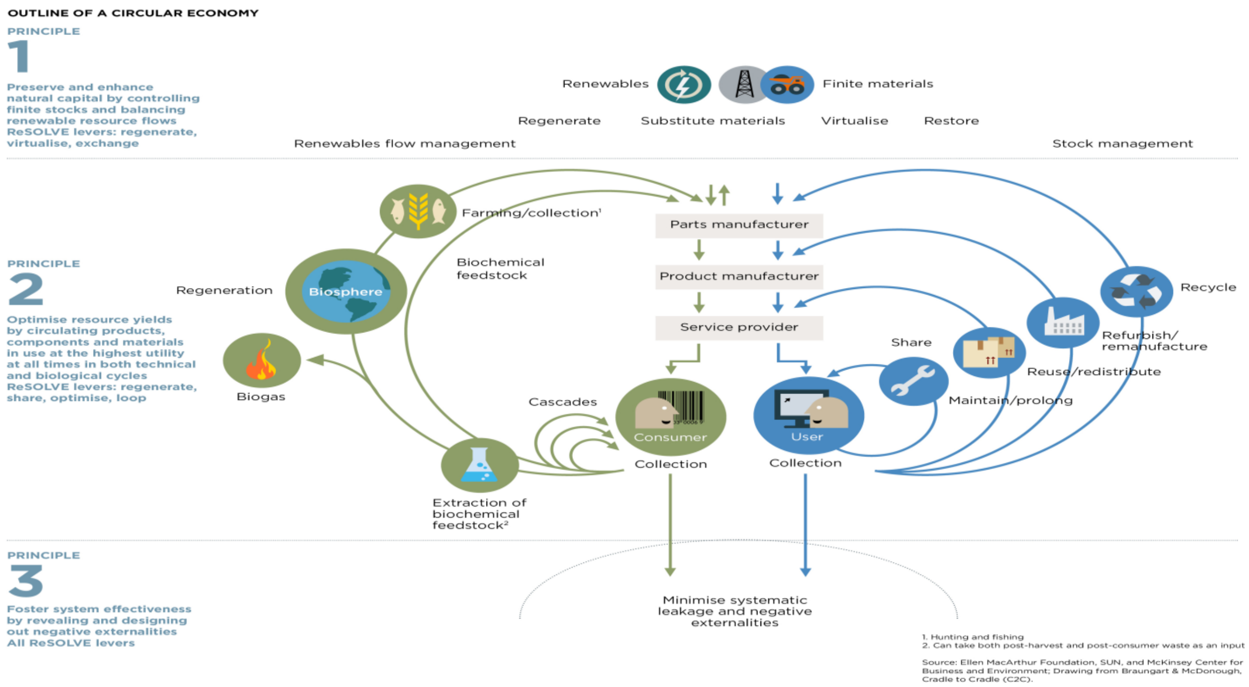

Figure 2. EMF's Circular Economy Model Outline (EMF, 2015a: 24)

3.3. The Loops under the Circular Economy Model

Although there are different definitions regarding the circular economy, it is seen that cyclical, closed-loops are widely in common (Murray et al., 2017), and there is a distinction between technical and biological cycles of resources. In the circular economy, material flows are made up either of biological materials, which after discard are available for ecological cycles; or of materials designed to circulate within the socioeconomic system with reuse and technical recycling (Haas et al, 2015: 765). As for waste materials, there are only two possible long-run fates: either recycling and reuse, or dissipative loss (Bocken et al., 2016: 308).

EMF (2015a) identifies four key elements as the sources of value creation in the circular economy with the loops (Figure 3).

- The power of the inner circle (lower cost in production): A tighter circle allows the product to return to use faster and has higher potential savings on the shares of material, labor, energy and capital embedded in the product.
- The power of circling longer (extending the life of the products): Keeping the circling longer means maximizing the number of consecutive cycles (repair, reuse, remanufacturing or recycling) and / or maximizing the time in each cycle. As a result, more material, energy and labor use necessary to create a new product or component would be avoided.
- The power of cascaded use (waste is food): This refers to diversifying reuse across the value chain, for instance, the use of cotton clothing as second-hand apparel first, then re-use of it as fiber-fill in upholstery in the furniture industry, later for reuse in stone wool insulation for construction and so on…This substitute for an inflow of virgin materials, providing important advantages.
- The power of pure circles: Uncontaminated material streams increase collection and redistribution efficiency while maintaining quality, which, in turn extends product longevity and material productivity (EMF, 2015a)

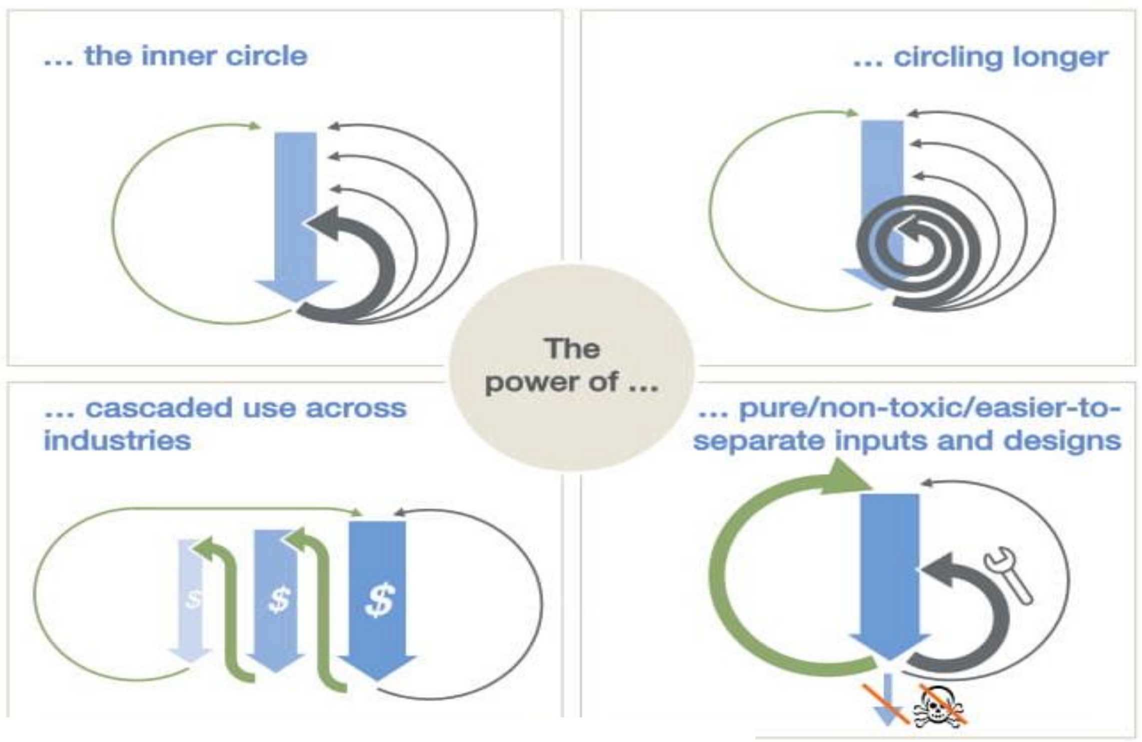

Figure 3. Sources of Value Creation for the Circular Economy (EMF, 2015a: 13)

In the closed-loop system, Stahel distinguishes between the reuse of goods and the recycling of materials in the technical loops. Recycling closes the cycle between post-waste utilization and production but does not affect the flow rate of materials or goods in the economy. Building on Stahel's work, McDonough and Braungart propose two fundamental strategies: (i) slowing resource loops and (ii) closing resource loops. In the former strategy, the utilization period of products is extended or intensified, resulting in a slowdown of the flow of resources. Rather, in the latter strategy of closing resource loops, through recycling, the loop between post-use and production is closed, resulting in a circular flow of resources (Bocken et al., 2016).

As a third approach, in the efficient use of resources or resource efficiency, it is aimed to use less primary/virgin resources; where efficiency is associated with the concept of cleaner production (Rizos, 2017: 10). At this point, Bocken et al. (2016: 310) notes that resource efficiency implies a constant flow of materials independent of time, and hence may result in further accelerating the linear flow of resources.

3.4. Product Design Strategies

It is agreed that circular economy offers significant advantages including economic, environmental and social benefits. However, the transition to a circular economy requires an entirely new way of thinking, as well as a new approach to process and product design. Whilst major strides have been made in improving resource efficiency and exploring new forms of energy, it is stressed that less thought has been given to systematically designing out material leakage and disposal (EMF, 2015a). In the concept of the circular economy, preserving the value of products for as long as possible plays a central role, and products centre-stage in the transition process (EEA, 2017: 6). Andrews (2015) argues that just as designers facilitated the development of the linear economy, they have the potential to facilitate and even lead the development of a circular economy. McDonough (1993), defines *good design* as the one in which the things we made must not only rise from the ground but return to it, so everything that is received from the earth can be freely given back without causing harm to any living system.

Circular economy necessitates eco-friendly design of products providing the same service with less material input that increases life-times, facilitating repair and resale, product upgrades, modularity and remanufacturing, component reuse and finally facilitating recycling at the end of product life (Haas et al., 2015: 774). Bocken et al. (2016: 310) stress that it is important to make process design at the early stages of the product design process, as it is difficult to make changes after resources, processes, infrastructures and activities are associated with a specific product design. In this design for future, a systematic perspective during the design process should be adopted and the right materials should be employed for appropriate lifetime and extended future use (Circularity Gap Report, 2018).

Table 1 presents the design strategies for closing and slowing loops as proposed in the study of Bocken et al. (2016), their proposed strategies are then summarized afterwards.

Table 1. Design Strategies to Slow and Close Loops

Design Strategies to slow loops	**Design strategies to close loops**
Designing long-life products	Design for a technological cycle
Design for attachment and trust	Design for a biological cycle
Design for reliability and durability	Design for dis- and reassembly
Design for product-life extension	
Design for ease of maintenance and repair	
Design for upgradability and adaptability	
Design for standardization and compability	
Design for dis- and reassembly	

Reference: Bocken et al., 2016: 310

Under slowing resource loops, the first major design strategy is to design long-life products. This is to ensure longer use of products. Design for attachment and trust is concerned with the creation of products that will be loved, liked and trusted for longer periods of time. This is also referred to as the design for emotional durability. Design for durability is related to the development of products with physical durability, which take wear and tear without breaking down and in which material selection for durability is the most important part of the design process. In the design for reliability, a product will operate throughout a specified period without experiencing a chargeable failure, in which product testing to mimic normal use can help test the reliability of the product (Bocken et al., 2016: 311).

The second design strategy for slowing resource loops is designing for product-life extension. This strategy is related with the extension of the use period of goods through the introduction of service loops, including reuse of the product itself, maintenance, repair and technical upgrading, and combination of these. Users can easily repair and replace the broken parts. Another strategy for slowing the loops is design for maintenance and repair. In the design for upgradability and adaptability, products are designed in an upgradeable way allowing future expansion and modification. The third strategy, design for standardization and compliance, is about creating products that can be compatible with other products. Fourth, design for dis and reassembly is about ensuring that products and parts can be separated and reassembled easily. This strategy is essential to separate materials that will enter different biological or technological cycles (Bocken et al., 2016: 311).

Bocken et al. (2016) also emphasize that the Cradle-to-Cradle design philosophy, created by McDonough and Braungart to close loops, has inspired many companies and designers to apply an ambitious strong circular approach to product design. McDonough and Braungart developed two strategies for product design, similar to the work of Ayres. According to Ayres, there are only two possible long-run fates for waste materials: either recycling and reuse, or dissipative loss. Hence, dissipative losses are to be made compatible with biological systems, fit for the biological cycle; whereas other materials are to be completely recycled, fitting a technological cycle. Design strategy for a technological cycle is suitable for service products rather than products for consumption. When designing a technological cycle, designers aim to develop products that can be recycled into new materials or products continuously and safely.

Design for a biological cycle is suitable for products of consumption that are consumed or wear during use and results in a dissipative loss of resources. With this strategy, products for consumption are designed with so-called “biological nutrients”, safe and healthy materials, which create food for natural systems across their life cycle and biodegrade to start a new cycle. Design for dis and re-assembly, which also exists under the strategy for slowing loops, is a strategy that contributes to design for a technological and biological cycle. This strategy is fundamental to separate materials that are biologically and technologically diverse (Bocken et al., 2016).

4. Results and Discussion

In this study, it is intended to contribute to the debate for the impacts foreseen for a circular economy in the context of waste management. The literature on circular economy model is reviewed with a focus on the loops underlying the system, and the relevant design strategies for slowing and closing the loops are examined. As emphasized by Rizos et al. (2017), circular economy is a complex concept and it is unlikely that in the short term there can be an international consensus on its meaning. While there are many different definitions regarding the circular economy model, cyclical, closed-loops are widely in common.

In contrast with the dominant paradigm of traditional 'take-make-use and throw' linear flow of resources, in this closed-loop system, resources are kept in use for as long as possible while preserving the value of products plays a central role. For this reason, a new approach to process and product design is essential. This eco-friendly design would systematically design out material leakage and disposal, while providing the same service with less material input. The system works to reduce waste before it is produced and treats waste as a resource after it is produced. As for the proposed product design strategies, in the strategy of slowing loops, the utilization period of products is extended or intensified, resulting in a slowdown of the flow of resources; while in closing resource loops, through recycling, the loop between post-use and production is closed.

All these design strategies support a circular approach and minimize waste generation while minimizing the need for the extraction of the virgin raw-materials. As far as the waste management hierarchy is concerned, preventing waste before its generation has the highest priority. Likewise, the design strategies should follow the hierarchy as well, with the highest priority to be given to waste prevention and designing-out waste. Consequently, while closing resource loops through recycling is of vital importance, slowing loops through designing for long-life products and designing for product-life extension, facilitating repair and reuse, thus, preventing new waste generation is as important as, even more important than closing resource loops. As noted by Haas et al. (2015), circularity cannot be achieved on the basis of recycling alone, and achieving a reversal of the trend of global growth in resource consumption into a dynamic of reduction, or at least a steady-state physical economy, remains the greatest challenge of all. This would require fundamental changes not only in the production patterns but also in the consumption patterns respectively.

5. Conclusions and Recommendations

It is clear that the circular economy is promising in terms of waste and resource management. Nevertheless, as stated in an EEA report (2016), current work on indicators that track progress towards a circular economy has been driven, to a large extent, by developments in material resource efficiency and waste management but these statistics fall short of providing a basis for material losses and the qualitative aspects of recycling, while more robust data are needed on new business trends and sustainable consumption.

Regarding sustainable consumption, generally, as it is the "wants" rather than the "needs" which underlines the overconsumption in most of the developed countries, in the past, it has been assumed that it would be sustainable enough if their waste is recycled. However, circularity cannot be achieved based on recycling alone and in order to be an important tool in terms of sustainability, the system should be effective in changing the consumption patterns as well as the production patterns. In a world of increasing population and per capita consumption where planetary boundaries are at risk, rather than discarding products before their value are fully utilized, consumers should use and re-use them. In this sense, in this study, it is argued that in the product design strategies, while closing resource loops through recycling is of vital importance, slowing loops through designing for long-life products and designing for product-life extension, facilitating repair and reuse, thus, preventing new waste generation is as important as, even more important than closing resource loops. Future work and adequate number case studies will be necessary to assess the environmental, social and economic impacts of each separate product design strategies and to explore the most efficient regulatory frameworks and incentives to alter the consumers' preferences in that sense.

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