

The 9Rs Strategies for the Circular Economy 3.0

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ABSTRACT

Circular economy (CE) was first introduced in the 1970s as an alternative economic model for replacing the traditional linear industrial economy, the take-make-use-throw approach. However, transition to a more circular economy can be challenging due to the untenable assumptions. It is viewed as a strategy enabling the 'decoupling' of resource use from economic growth, but there are still questions whether the CE can decouple resource use from economic growth. The purpose of this article is to study the evolution of the circular economy and the synthesis of the 10Rs hierarchy, to examine the circular economy roadmap and to review the strategies of 9Rs and the benefits of circular economy. Documentary study and literature review were used for data collection. It is found that the history of circular economy started as early as before World War II, known as closed economy. Then, the concept of circular economy evolved to CE 1.0, CE 2.0, and CE 3.0 since 2010 onward. Although 10R hierarchy (from R0-R9) was proposed to solve confusion around new conceptions of circularity, the waste-to-energy (Recovery) does not promote resource efficiency when considering the loss of value of potentially recyclable materials through combustion. Circular Economy, when successfully implemented, can clearly bring environmental, social and economic benefits. However, a CE roadmap should integrate the key stakeholders' views on the essential developments and actions required for the transition as well as clarify their own role in the transition.

Keywords

The 9Rs strategies, Evolution of Circular Economy, the Circular Economy 3.0

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Introduction

It has been estimated that 20% of global material extraction ends up as waste [1]. To minimize waste at best, products must be designed and industrial processes must be done to keep resources in use in a perpetual flow, a full circular economy. The circular system aims to optimize the use of pure raw material by designing products to be easily maintained, reused, repaired or refurbished to extend their useful life, then, to be easily disassembled and recycled into new products, with waste reduction concept at all stages of the extraction-production-consumption cycle [2].

The development of the concept of circular economy for products and materials aims to increase circularity of the materials used in production and consumption. The concept of circularity has already been implemented in different parts of the globe with regards to longer loop value retention options, such as energy recovery and recycling. The EU and the UN basically suggest 3R's concept which has been used widely in many national waste regulations all over the world. To implement a circular economy, it is important to define what producers should actually do to achieve the greatest impact. These action imperatives have been expressed as the various R's based on preference and priority [3]. When using a 3R's to 10R's waste hierarchy, even the one's using 3R's or 4R's do not refer to the same R's [4]. R-imperatives are conceptualized differently among different scholars and disciplines. Different numbers of R-imperatives, such as 3Rs, 4Rs or 6Rs in different groups assign different attributes and meanings which implies divergent conceptualizations of the key circular economy

principle. From different academic backgrounds such as environmental sciences, engineering, logistics, policy studies and more, it is found that there is complexity around the 3 or more R's as value retention imperatives [5].

A circular economy offers a path to reduce future resource and material supply chain risks for industries and businesses as well as increase their resilience to the shortage of supplies and sudden changes in prices. It also helps reduce resource dependency, spur innovation and increase competitiveness. Besides, the circular economy is an opportunity for economic and industrial renewal with a related increase in investments. Transition to a circular economy can be challenging, especially for companies whose structures, strategies, operations and supply chains are deeply rooted in the linear approach. Although the transition to a circular economy often offers economic benefits, it is necessary to change production processes from linear to circular, which may require initial investments, modification of processes, feedstock, re-training of staff, and coordination within the wider value chain.

Evolution Of Circular Economy

Circular economy (CE) was first introduced in the 1970s as an alternative economic model for replacing the traditional linear industrial economy. The linear economy is based on a linear process of take-make-use-dispose emphasizing towards high throughput and low production costs relying on the abundant availability of raw materials at relatively low cost. The traditional process consists of a series of steps including resource extraction, manufacturing, consuming

and disposing of products at the end of their life cycle. On the contrary, the circular economy aims at lowering environmental impact by reducing the use of raw material, minimising waste at the end of their lifespan, as well as turning waste into resources for others through re-use, re-manufacture, re-cycle, waste reduction and other practices. In other words, CE focuses on material restoration through design and intention [6].

Since the early 2010s, there have been concerns about environmental issues including resource scarcity, especially strategic resources, such as rare earth elements; and negative environmental impacts of unsustainable production and consumption [7]. The main economic reasons are the suddenly rising commodity prices and the potential economic benefits of new markets for the circular economy business models [8]. In December 2015, the European Commission launched the Circular Economy Action Plan, particularly focusing on circular economy as its new mainstream sustainable development framework. The European Commission's plan suggests that the EU economy change the five stages of the lifecycle of products and services: 1) design, 2) production, 3) consumption, 4) waste management and 5) secondary materials treatment. The plan also defines five priority areas, which face specific challenges. According to the Action Plan, relevant legislation was amended between 2015 and 2019 for addressing these challenges by starting with proposed directives on waste, landfill and increased usage of organic and waste-based fertilizers [9].

According to EU policies, moving towards a circular economy can help Europe achieve its commitments under the UN Sustainable Development Goals (SDGs). In fact, circular economy contributes to many of the 17 goals either directly or indirectly. It has the most impact on Goal 12 which aims for sustainable consumption and production while it indirectly impacts on Goal 7, Goal 11, Goal 13, and Goals 14 and 15 focusing on clean energy, sustainable development, climate action, and ocean and terrestrial ecosystem protection respectively.

During the last decade, the concept of the 'circular economy' (CE) has gained increasing attention from different countries around the world as the global organizations like the OECD, the WEF, and UNEP have actively promoted the urgency of closing materials loops through various reports and events. Japan and China were the first Asian countries introducing the CE policies at the national level. Many countries in Europe, most notably Denmark, Germany, the Netherlands, and the UK are taking lead in implementing CE initiatives, policies and pilot programs. The European Union (EU) is also following suit with a CE action plan, including legislative proposals [10].

However, transition to a more circular economy can be challenging due to the untenable assumptions. Circular economy is widely viewed as an alternative model of production and consumption that enables economic growth without threatening the natural resource. It is viewed as a strategy enabling the 'decoupling' of resource use from economic growth, thus, contributing to sustainable development [11]. There are still questions whether the CE can decouple resource use from economic growth [12]. The 2011 UNEP [13] report on "Decoupling Natural Resource Use and Environmental Impacts from Economic Growth"

disclosed that related sustainability concepts and approaches such as eco-efficiency, Cleaner Production (CP), and Industrial Ecology (IE), have partly, not absolutely, contributed to achieving the decoupling. Therefore, there is still a concern that circular economy has been argued to lack conceptual clarity and an accepted definition [14]. However, there recently have been literature reviews on key conceptual elements of CE and its link to other sustainability related concepts [15].

Circular economy has a longer history than the current use of the notion. In many parts of the globe, most notably in Europe, the term 'circularity' has long been known in the businesses and industries. In the following paragraphs, the history of the circular economy can be artificially divided into three distinct phases leading to the current framing of the concept [16]. Blomsma and Brennan [17] has also provided a similar overview on circular economy which they characterize as an umbrella concept and as a 'new framing around expanding resource productivity'.

Evolution Of The Circular Economy In Three Phases

The history of circular economy started as early as before World War II. Some earliest directed examples of closing material loops could be dated back to the 19th century in the work by P.L. Simmonds (1814–1897). After World War II, "closed economy or spaceman economy" was introduced in the work by Kenneth E. Boulding, 1966 where he contrasted the 'closed economy' with the 'open economy' [18]. His essay is often cited as the first expression of the "circular economy" [19]. Besides, there has always been economic evolution of using waste and by-products such as dyes in petrochemicals (Ayres and Ayres, 1996). After then, the global economy has been growing and waste management becomes increasingly problematic and needs to be regulated. There are concerns in controlling and abating pollution but still lack of integrative waste management [20].

The first phase, during 1970 to 1990s, is the time of dealing with waste. During the 1970s, the 3R concept of 'reduce, reuse and recycling' increasingly gained attention alongside environmental movements in Europe and the US. Although there were no principles of waste prevention, most of businesses actively followed governments' regulation on pollution limitation through the policies such as "polluter pays". Due to the large amount of waste being treated outside 'one's borders' or even being dumped in less affluent countries, scholars and environmentalists became more concerned about waste problems and realized that local and global waste problems are connected and the problems will eventually affect the human, social, and economic wellbeing. In this phase, over 30 states of America considered or enacted restrictions on out-of-state waste and 140 recycling laws were enacted in 38 states [21]. Therefore, the roots of the circular economy can be said to lie in this phase.

The second phase, during 2000-2010s, circular economy has put in place specific and ambitious actions to reduce the use of raw material in Europe ensuring the circularity of materials, increasing the use of secondary raw materials and dealing with the waste at source. The action plan should include guidelines to promote the sustainable use of natural

resources as well as circular and sustainable products. According to the European Commission's report in 2019, EU was successfully implemented the CE action plan it adopted in 2015. One of the actions was the revision of waste legislative framework aiming to reduce the environmental impact of selected single-use products made of plastic (Single-Use Plastics Directive) [22]. In the CE 2.0, the concept of environmental prevention such as Design for the Environment is also established in businesses. In the early of years 2000, scientific data on global warming, water shortages, loss of biodiversity also increases awareness on environmental sustainability. Digitalization and the internet also make information sharing faster and connect the local to the global environmental issues.

The third phase of circular economy, CE 3.0, from 2010 onward, although economic gains have been focused, sustainability becomes more challenging due to the population growth and resource depletion. More attention, hence, is paid to retaining the value of resources. And with the fear of unsustainability, nations become more aware of the excessive resource extraction [23]. From this context, nations agree on the newly developed idea of CE, decoupling growth from resource use [24].

One of decisive elements of a more transformative view of CE, nuanced material hierarchies as operationalization principle of CE, R-hierarchies or imperatives. Although the 3R-imperatives of 'reduce, reuse recycle' form an accepted notion of CE in theory and practice, there has recently been emphasis on more nuanced hierarchies with longer loop options like 'redesign', 'refurbish', 'repurpose' to promote the highest possible value retention of resources over multiple product life cycles. Varying numbers of R-imperatives, such as 3Rs, 4Rs or 6Rs, different author (groups) assign different attributes and meanings which implies that divergent conceptualizations of this key CE principle dominate the literature [25]. To respond the recent calls for better conceptualization [26], the most common perspectives on R-imperatives are reviewed and synthesized into a single systemic typology of 10 resource value retention options (ROs) or as a number of Rs. The 3R's concept has been synthesized and reorganized into a 10R hierarchy (from R0-R9); refuse, reduce, resell/reuse, repair, refurbish, remanufacture, repurpose, recycle (material), recover (energy), re-mine in order to solve confusion around new conceptions of circularity [27].

The 10R hierarchy has been distinguished into three different loops; from short loops (R0-R3) existing close to consumer; middle long loops (R4-R6) relating more in business activities with indirect links to consumers; and long loops (R7-R9) existing traditional waste management activities which includes recycling, different forms of energy recovery and, more recently, re-mining. While government policies in CE 1.0 and 2.0 focus on these options, they are viewed as the least desirable among many scholars who apply clear hierarchies with their R's. Although materials or particles received from longer loop recycling can serve as input for shorter loop R's, it is still challenging how recycled materials can be produced in higher-value application, especially in the countries where mass recycling is already well organised (mostly in North-west and central Europe) [28].

CE Roadmap

Transition to a circular economy can promote well-being and competitiveness, as well as ensure a sustainable future. The circular economy not only provides solutions to critical challenges we are facing such as overconsumption of natural resources, climate change and biodiversity loss. A road map towards a circular economy is an essential tool for change as it helps define what steps we should take, incorporate key stakeholders' views for the essential changes and outline actions required for the circular transformation. It also includes a vision and goals as well as tangible actions that will move country forward towards a circular economy. Since the circular economy concept was introduced to address the environmental crisis, the potential research and innovation that can ensure its successful implementation need to be exploited before such crisis happens in order to facilitate the eco-friendly manufacturing systems that will increase the sustainability and resilience in ecosystems. The roadmap to circular economy should be designed to prepare the manufacturing and production system to face disruptive events such as COVID-19 pandemic, earthquakes, political and social conflicts. It should ensure raw materials and production supply, logistics and distribution, factories operation, international cooperation, as well as products and services needed to maintain citizens' health, welfare, and proper functioning of modern economies [29]. A circular economy road map should integrate the key stakeholders' views on the essential developments and actions required for the transition as well as clarifies their own role in the transition. It is a proven tool for engaging key stakeholders and creating shared understanding about the changes needed on the path towards a future that fits within the planetary boundaries and avoids shortfalls in well-being. (as figure 1) The participation of different groups is a matter of fairness too. In order to successfully start the implementation of the road map and achieve the road map goals, they need to be shared by all who are affected by the process. That is why co-operation based on trust is key throughout the process. At its best, a circular economy road map is a combination of strategy and action plan that will inspire others to become involved in the transition and generate new ideas, actions and initiatives among those who are participating.

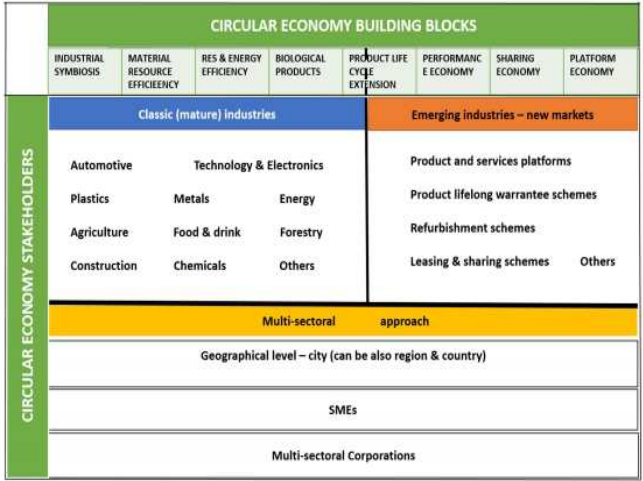


Figure 1. The Circular Economy Progress for Stakeholders (CEPS) framework [30]

While policy agenda has been set for the transition to a circular economy in Europe, the linear model of producing and consuming goods and services still exist. One reason is that circular economy concept is more complex, and eventually will affect all sectors of the economy. Policy-making is not effective enough for fostering this transition. Therefore, the CEPS Framework (Circular Economy Progress for Stakeholders Framework) which identifies relevance of circular economy to the different types of stakeholders in the circular economy – classic (mature) industries, emerging industries, SMEs, multi-sectoral corporations, cities and regions was introduced as a tool for policy-makers and business to identify sectors and stakeholders affected by the transition to a circular economy. Through the CEPS Framework, a standardised approach to policy-making can be established for the circular economy and for creating synergies between various building blocks and stakeholders. When incorporating the CEPS Framework into EU policy, Europe will be able to better exploit the opportunities offered by the circular economy. Besides, it will also strengthen the three ‘pillars’ of the circular economy: 1) environmental benefits, 2) cost savings from reduced natural resource needs and 3) additional economic benefits reaped from the creation of new markets [31].

Moving towards a circular economy can be challenging, but it’s worth for people, nature, and economies. We all need to come together to be better consumers. A circular economy is not only about consuming less, it is also about consuming better. As a consumer, it means we will make our choices on products and services in a more sustainable version or those can be recycled. It can also mean changing what we consume which offers emissions and other natural resource benefits. Consumer awareness of sustainability is on the rise globally, with the majority of consumers expect brands to do what is right.

Circular Economy Strategies: 9RS

To prevent excessive and rapid environmental degradation and social inequality on both a local and global level, circular economy can be viewed as a means to an end. It offers transformative measures to cut greenhouse gas emissions while promote circular and low-carbon agenda. Circular business models and improved resource efficiency are also a means to lower the emission, reduce extraction and could improve supply security when materials are kept in the region. Ultimately, it helps us achieve ecological safety and provide more space for humankind. The key concept of a circular economy is to recycle materials from waste in order 'to close the loop'. It is also a framework for recovering energy from waste and it aims to eliminate waste. In the case that waste is unavoidable, it must be adequately controlled to be safe for human health and the environment.

Table 1 propose the 9Rs hierarchy from Refuse (R1) to Recycle (R9). It does not include a further R strategy—the Recovery of (embodied) Energy from waste and residues, which is often mentioned in combination with the 9Rs. (as table 1) Upon the view of waste management, energy recovery is an environmentally friendly option comparing to landfill disposal according to the waste hierarchy principle.

However, the waste-to-energy does not promote resource efficiency comparing to other 9Rs, when considering the loss of value of potentially recyclable materials through combustion. Hence, the activities of energy recovery are not considered as substantially contributing to the circular economy in this 9Rs hierarchy [32].

Table 1. Circular economy strategies [33]

R	Strategy	Description
R1	Refuse	Make product redundant by abandoning its function or by offering the same function by a radically different (e.g. digital) product or service
R2	Rethink	Make product use more intensive (e.g. through product-as-a-service, reuse and sharing models or by putting multi-functional products on the market)
R3	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials. It includes the prevention of food waste along food value chains including in agricultural production, processing, manufacturing, distribution and consumption
R4	Reuse	Reuse of a product which is still in good condition and fulfils its original function (and is not waste) for the same purpose for which it was conceived
R5	Repair	Repair and maintenance of defective product so it can be used with its original function
R6	Refurbish	Restore an old product and bring it up to date (to specified quality level)
R7	Remanufacture	Use parts of a discarded product in a new product with the same function (and as-new-condition)
R8	Repurpose	Use a redundant product or its parts in a new product with different function
R9	Recycle	Recover materials from waste to be reprocessed into new products, material or substances whether for the original or other purposes. This includes the reprocessing of organic material but does not include energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations

Solutions to the resource, waste and environmental degradation challenges have been discussed and worked out for more than half a century. The circular economy is a tool for combating waste by continuously improving and redesigning economy to retain the quality of products and natural resources longer in the economy, before discards them as waste. The improvements need to be done in the way the extraction, use and depletion of renewable resources does not exceed the speed of the regenerative cycle for nature to replenish them [34]. The CE is defined as a set of common economic behaviours based on the 9-R concept or “R-behaviours” that promote the transition to a circular economy. These behaviours were originally called as the 3-R concept (reduce, reuse, recycle). Then, the concept is expanded to the 6-R (with the addition of recover, redesign and remanufacture) and later evolved into the 9-R concept (with the further addition of refurbish, repair and refuse). The circular economy based on these 9Rs is more than waste reduction [35].

The key reason for having ‘Refuse’ included in the 9Rs hierarchy is that it helps reduce the risk of hazardous chemicals running back into the circular economy. (as figure 2) The hazardous chemicals, for example, some flame retardants, used in electronics products, should be removed and replaced at the design stage. To encourage the CE efficiency, these substances can be removed at the recycling stage, but effective removal is often nor technically nor economically viable. The hazardous chemicals in products are viewed as an impediment to a circular economy [36].

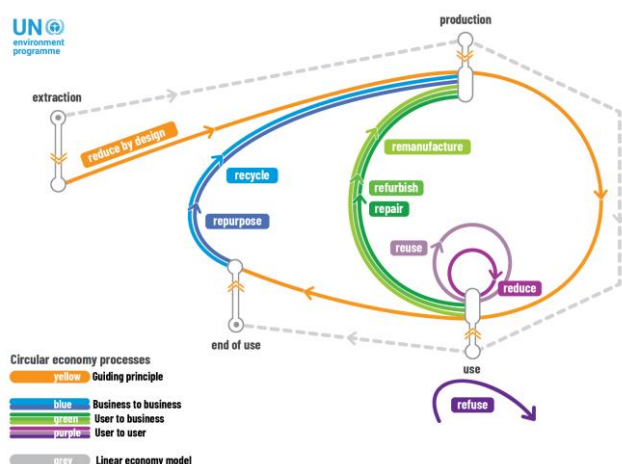


Figure 2. The UNEP Circularity approach using the 9-R concept [37]

CE promoting behaviours related to the Circularity and 9-R concept serve the double purpose of mitigating linear risks, as well as to identify business opportunities. Replacing the take-make-waste linear economy principle with circular economy will help nations tackle complex and systemic challenges by rethinking and reengineering. This is a gradual process that can be accomplished by supplementing our economies with these virtuous economical “R-behaviours”. However, the transition still lack of financial support despite the growing recognition of the effects of economic activity on climate, biodiversity, ecosystems, water, soil, air and society over the past two decades [38]. Circular Economy, when successfully implemented, can clearly bring environmental, social and economic benefits. Potential economic growth is expected to be worth 4.5 trillion dollars globally. Without transition to circular economy, we will find ourselves in a destructive environment, a surge in prices and inundated with waste [39]. In circular economic system, there are more collaboration among companies, public administration, and researchers, and even consumers to make waste of a process of production and consumption circulate in the system. Circular Economy also improves product quality and saves production cost as it focuses on products with longer life and being able to upgrade and repair. Implementing the circular economy approach in manufacture of more durable products can save be-tween €340 to €630 billion per year in the EU alone [40]. As consumers become more aware of how product is made and what impact it brings to the environment, the companies included in the circular economy context will find themselves more competitive. Besides, CE can reduce environmental impact as it can lead to reduction of resource extraction, lower greenhouse gas, and decrease of waste. (Figure 3)

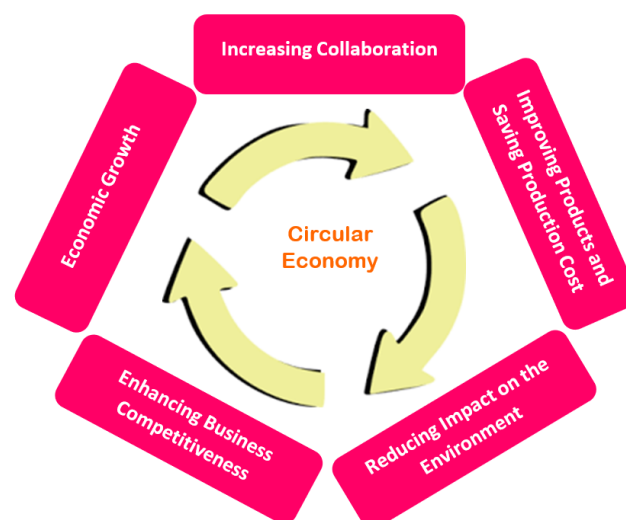


Figure 3. Environmental, Social and Economic Benefits of the Transition to Circular Economy

Conclusion

The circular economy is gaining more attention as it aims to reduce the pressure on the ecosphere through a number of strategies. A circular economy is an economic approach that involves separating economic activity from the consumption of finite resources, and designing waste out of the system. It helps minimize resource extraction, waste, emission, and energy leakage by slowing, narrowing, and closing energy and material loops. This can be achieved through refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, and recycle. With all the knowledge, power and collaboration we have, we can move towards circular economy. Replacing the take-make-waste linear economy principle with circular economy will help nations tackle complex and systemic challenges by rethinking and reengineering. Although it takes deep collaboration between business, government and civil society, the rewards will be well worth it as economy and environment will become more sustainable and resilient to disruptive events such as pandemic, natural disasters, political and social conflicts. People and nature will be able to live together in harmony. Realizing both the urgency and the opportunity, an increasing number of countries and national governments are now beginning to shape their strategies in order to support investment towards sustainable and specific circular economy agendas.

This new economic model represents sustainable green growth, moving from a consumption to a system that extends the life of products and materials and minimizes waste. The circular economy can bring many environmental, climate, social and economic benefits to nations. It provides a structural framework aiming at increasing the value, use and life of materials, products and assets and designing out waste from production and consumption. The CE 3.0 seeks to identify ways to improve waste management, as well as the possibilities of achieving savings on the state budget through waste generation prevention, eco-design and product reuse. Effective collaboration among the central authorities, the recycling, collection, and sanitation industries, and waste generators is also an important element

of CE 3.0 and will enable directives on packaging waste and the waste management system. Additionally, one of decisive elements of a more transformative view of circular economy is operationalization principle of R-hierarchies or imperatives. While the 3R-imperatives of 'reduce, reuse recycle' establish an acceptable notion of circular economy in theory and practice. There has recently been emphasis on more nuanced hierarchies with shorter loop options as enabling the highest possible value retention of resources over multiple product life cycles. The most common perspectives on R-imperatives were put into a single systemic typology of 9 resource value retention options as a number of Rs by designing life cycle in connection with the 9Rs concepts.

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