Circular Economy and Circular Cities

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An alternative way to the current way cities develops and operate is provided by the circular economy (CE). The idea of circular economy finds its roots in environmental and ecological economics, industrial ecology and management and corporate sustainability. The circular city represents a relatively new concept, and as a result, assumptions about these types of cities are often incorrect and require further explanations to understand their way of functioning. A framework for a circular economy not only reduces the raw materials used within the system but also brings opportunities for sustainable consumption, waste management and innovation in all fields, as well as human development and increased well-being for everyone. However, the nature of circular systems mandates for the collective effort of governments, businesses and consumers likewise. Therefore, a circular economy should be an integrated part of the cities' and regions' development plans for achieving healthy circular ecosystems.

Keywords: circular economy ; circular cities ; sustainability ; urban circular economy

1. A Circular Economy Overview

A circular economy is viewed as a "new engine of green growth worldwide" [1]. The primary concept behind circular practices is the development of systems that go beyond linear "take-make-dispose" economic models and aim for closed-loop usage of materials and energy that sustain the value of resources in the economy [2]. In a circular economy, the economic growth is decoupled from resource use by lowering materials input, maximizing the usability and minimizing the waste generation [3][4][5][6][7]. With this design, closing the loops aims at solving the problems of resource scarcity, bio-chemical flows and climate change while having a regenerative and restorative benefit for communities [8][9]. Circularity compared to sustainability is a much newer approach, with a deeper interest in minimizing the system inputs, enhancing and preserving the natural sources, efficiency in the management of finite resources and reducing the overall risks. Circularity is also much radial in its design and can be easily associated with the concept of a "self-sustainable" regenerative city [10].

Nevertheless, the circular economy does not remain at the stage of efficiency (results of actions) but exceeds it, adding efficacy (as compared to the effects produced at a strategic, higher level). The efficacy of the economy naturally generates the balance of resources, the environment and the well-being of the inhabitants of the earth in a long term, representing the basis of sustainable development. The circular economy aims at the controlled integration of degenerative activities (active, extensive by definition) and regenerative activities (reactive, intensive by definition in order to preserve the natural balance and, within it, of society, aiming at sustainable development. In addition, these notions can be used in both a smart and resourceful manner for current and future urban planning. To sum up, the circular economy is an umbrella-type concept [11] that, when it is put into practice, has the effect of minimizing environmental impact and stimulating the economy, including slowing raw material inflows and minimizing waste generation, leading to decoupling economic growth of natural resource consumption.

A circular economy aims to create products based on consumers' demands in an eco-friendly and sustainable fashion. This can be difficult and creates the demand for sustainable innovation. Through this process of innovation, new high-tech jobs and technologies can be created to help a circular economy thrive. Furthermore, the shift toward a circular economy system can empower a community by gaining more independence with regards to raw materials and can reduce environmental stress [12]. A circular economy not only reduces the consumption of raw materials but also creates opportunities for sustainable consumption, waste management and innovation in many fields, as well as community development and increased well-being.

However, the circular economy is far from being a perfect concept, and there is still a need to refine circular principles and improve the way they are implemented through various projects and actions. First, public awareness of the benefits and gains of the circular economy is not high, especially in developing countries. This may also be a result of low ecological literacy, but younger generations are more open to reducing resource consumption, recycling and reuse [6]. Another major

challenge for the circular economy is its implementation in less economically rich areas, where investments in new high-tech infrastructure are not a possibility. It remains an open question, whether in the absence of investment in new infrastructure (e.g., renewable energy) to replace incumbent unsustainable systems, cities can become truly circular [13]. As far as resource flows are concerned, the Life Cycle Analysis is one of the current instruments used to measure the flows of resources and their impacts on the environment. Although relevant, Life Cycle Analysis is not complete if it solely looks at the material component; it should also embody parts as energy, water or air, for instance. Another tool currently used is the Eco Label, which emphasizes the compatibility of a product with the environment. This label can be used as an integrated aspect of circularity indicators. The current system of indicators is still underdeveloped and fails to capture the wholeness of a city—the definition of circularity and circular cities are still not complete; therefore, the monitoring system lacks comprehensibility [12].

2. Circular Consumption and Production

The first core step in a circular economy is the exploration of a region's natural resources and the extraction and utilization of those resources in a sustainable manner. After available natural resources have been analyzed, mining and processing of raw materials can take place. In the next phase, market research should be conducted in order to evaluate consumers' needs. After consumers' needs have been analyzed, the design process begins. In the design process, innovation occurs as engineers and developers create long-lasting, sustainable products that can meet the consumers' needs. This process can be very daunting as it requires manufacturers to shift their thinking from a linear process to a circular one. They have to identify what sustainable materials are needed to ensure the recyclability of the products and also to assess the eco-friendliest production process that generates the least amount of waste and pollution.

The production process involves using recycled and repurposed materials gathered primarily from local, sustainable natural resources and manufacturing that is done in factories that utilize clean renewable energy. In order to reduce pollution and waste, all stages of one production process must be thought of from a circular and sustainable perspective. Each step must be conducted in such a way that nothing is wasted from the materials used to the energy spent on producing the end product [14].

As these products have been developed from a recyclable and reusable perspective from the beginning, it makes the products easier to be used and repurposed. However, consumers must also change their behavior in how they use products. For example, instead of using a product once and simply throwing it away, they must consider alternative options. Some of these options include gifting their products to others who may need them, repurposing these items or recycling them if they no longer serve any purposes.

There are many different ways that consumers can repurpose their used products. Various ways that these products may be repurposed are as simple as taking an old container and turning it into a gardening pot or using pulverized used rubber tires as turf in a playground to prevent injuries from falling. There are also many organizations and initiatives around the world that collect used products in order to repurpose them as gifts or for profit, furthering the ability of a circular economy to function.

If a product is no longer able to be reused or repurposed, the last consumer option in a circular economy would be to recycle the product. This stage becomes easier again as the products were developed from the beginning to be recyclable. However, much depends on consumers to also act in an eco-friendly manner and for local governments to provide efficient recyclable collection containers and to have efficient recycling centers to properly repurpose the products there.

To sum up, a circular economy requires improved collection and processing of recycled products, investments in infrastructure, sustainable design trends and the optimization of a product's life cycle, among many other aspects. At the same time, it requires sustainable education, consumers encouragement and public participation, ecological market development and the promotion and encouragement of reuse and repurposing. Therefore, a circular economy cannot function on the reliance and choices of any one individual or organization but rather on the actions of the entire community. Otherwise, the circular economy lacks systemic validity and relevance and can be easily discredited as its goals are unachievable [8].

3. Circular Cities: Fundamental Aspects

As cities are expected to host 66% of the world's population by 2050 [15], decision-makers are taking action in the field of sustainability, and the circular economy is one of the models that is gaining momentum. To date, it is more complicated to understand a circular economy by looking at it in its entirety and more difficult to imagine how to create a circular economy

by observing it from this perspective. A circular economy requires many different stakeholders to work together in order to function efficiently. The circular economy practices can be implemented in every part of a functioning economy, at micro-, meso- and macro-levels (*micro* refers to processes in a factory, for instance, *meso*- refers to industrial park or city level and *macro*- refers to regional, national or continental level for instance). In this section, we will discuss the meso level, a level in which the circular economy is based on the city's intrinsic characteristics and sectors and not all of those parts can be created and implemented at the same time [12]. This is why it is critical to first understand how a circular economy functions in an urban context.

At the moment, the majority of cities around the world function in a traditional, linear economic model. They focus their economic activities on commercial products, which are developed as single-life, non-reusable with the aim of serving a singular purpose for immediate convenience [16]. Moreover, cities lack smart and efficient energy and water systems, sharing platforms and operate on inefficient data transmission networks [17] resulting in various pollution issues and resource depletion, as well as more financial capital [18]. Additionally, human effort and time are and will be consumed as the transition from traditional to smarter and circular cities requires more effort [19]. However, such a struggle creates opportunities to rethink the current system and make it less vulnerable, more sustainable and competitive in resource efficiency, waste management and production patterns at different levels.

In the context of urban development, the circular economy can ensure competitiveness, autonomy and multisectoral resilience in the face of upcoming economic and environmental challenges of cities and long-term sustainability. This is achieved by preserving, increasing and (re)using the intrinsic and extrinsic value of all resources. The circular economy involves a circular and rational management of all resources (land, water, energy, infrastructure, goods, etc.). Moreover, the implementation of a circular economy can enhance sustainable growth and economic recovery within the planetary boundaries by restoring natural systems, reducing the negative impacts of climate change and maintaining the minimum use of raw materials. Therefore, the circular economy could be an integrated part of cities' and regions' development plans for closing material loops and a hub for healthy circular ecosystems.

The transition towards a circular economy in cities entails large-scale collaboration between all stakeholders involved; this includes industrial parks as producers, consumers, policy makers and citizens. Moreover, circularity cannot be taken out of the modern digitalized environment as urban spaces are hubs not only for physical products and materials but also data coming from daily activities [20]. In order to fully consider these aspects, cities require an undergoing process of redesign and rearrangement in terms of infrastructure, layout and behavioral patterns, each fully designed to each individual needs. Cities can act as a collaborative platform, which, with an adequate design, can map out synergies to progress linearly to a circular economy.

China and Japan were the first to implement the concept of the circular economy, whereas the model has been applied ever since also in European cities. Examples of the Japanese model have been used in industrial ports such as Dunkerque (France) and Kalundborg (Denmark) [10]. Various circular city experimentations were also conducted in Almere, Amsterdam, Birmingham, Dusseldorf, Genoa, Ghent, Ljubljana, London, Utrecht, etc. through waste management systems, local food systems, industrial symbiosis experiments, material recycling or various strategic plans for circular economy businesses and institutions [10]. At the moment, many cities have already embraced the circular economy concepts and have developed their circular strategy. Through projects, such as EU Horizon 2020 R2pi projects (2016–2019), centred on circular business models and Horizon 2020 CLIC projects (2017–2020) focused on cultural heritage and landscape regeneration and adaptive reuse as drivers of circular economy, more cities are encouraged to become future-oriented, circular cities [10].

As far as production and consumption are concerned, different from a linear economy that focuses on taking precious natural resources to create non-renewable products, a circular economy at the city level functions on recycling and eliminating waste as much as possible. For example, both urban symbiosis and industrial symbiosis are key activities for CE success in cities as they are based on the synergistic opportunity arising from geographic proximity through the transfer of physical resources [21]. These tools are more important as the industry must rethink its profligate approach to resources [22]. The geographical proximity within the urban contexts can facilitate byproducts exchanges among different stakeholders so that the overall wastes can be minimized [21]. This would also facilitate sharing of labor, capital and infrastructure, as well as opportunities for efficient transportation systems and technological spill-overs. Additionally, the minimal and efficient use of raw materials, resource allocation, domestic competitiveness and equal distribution would improve the environmental quality and the overall well-being of the citizens [23][24].

Introducing waste as a resource in the system makes smart recycling both cost-effective and robust. One of the main advantages is that CO_2 emission is substantially reduced as a result of fossil fuel resource substitution. The reduced amount of organic solid waste used as fuel compared to the original fossil resources used makes the recycling system

more robust because it is not influenced by the changes both in the amount of waste generated and the demand for recycled wastes. Additionally, if a significant amount of waste has the potential to be recycled, the number of incinerators for conventional waste treatment can be reduced [25].

The terms circular and smart cities are often used interchangeably in practice, but this is not the case. Smart cities rely on technology and do not always utilize resources in a sustainable fashion as circular cities do. In a smart city, far more attention is normally placed on how to develop smart systems for a city to operate in a more efficient way. However, it is not necessary for smart cities to function in a sustainable way to still be considered 'smart.' The focus is placed rather on smart design of energy systems, water systems, public transport, waste management, health care, education and infrastructure via cutting edge-technologies and high-speed data transmission. In a smart city, IoT (the internet of things) is fully utilized in order to connect all of the working parts of a city. In general, smart cities can operate in an efficient manner via technological innovation but are not required to function in a sustainable way by definition. However, they can operate in both an efficient and renewable way by incorporating the core principles of a circular economy. By utilizing the core concepts of a circular economy, these cities can function in a way that operates efficiently

To sum up, the circular economy principles at the city level can create an important opportunity to reduce urban waste production and resource consumption towards closed-loop systems [26]. Urban areas represent a fertile environment for implementing, demonstrating and replicating innovative circular solutions as they present a high concentration of resources, capital, data and talent over a small geographic territory [27]. In many ways, a circular city is not a new idea and still requires much effort to exist, and it is not possible to create a circular city in one day. However, the scope of the circular economy has improved from the original concept, as it has assimilated a broader efficiency orientation aside from waste and resources; therefore, the circular economy now also embeds land management, soil protection and even public procurements [23]. The focus needs to be applied to each of the different aspects of a circular economy first in order to create a fully functioning circular city over time.

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