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M3. Environmental Management, Impact and Risk Assessment

3.2. Circular economy

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Content

Circular Economy. General Aspects

Linear Economy. Definition and Disadvantages

The global population is continuously growing. Currently, there are approximately 8 billion people worldwide, and it is estimated to reach 8.5 billion by 2030 and 9.7 billion people by 2050 (UN, 2022). Over time, with this growth, a significant improvement in the standard of living has been observed, leading to the development of a consumption-based society. The consequences of a consumption-based society involve the depletion of natural resources and the generation of larger and more diverse quantities of waste. Resources used in the economy play a crucial role in the sustainable development of a society, considering the entire life cycle of a product, from the extraction of the natural resources needed for the production and consumption stages to the materials released into the environment, namely waste disposal and emissions into water and air.

The economy based on the model of extraction, production, consumption, and waste disposal is known as a linear economy. This model can be described as follows (Figure 1): raw materials are extracted from the environment, processed to obtain products, transported to consumers for use, and eventually, at the end of their life cycle, they become waste.

Figura 1. Modelul economiei circulare

The linear economy has several disadvantages, such as:

a) Environmental Disadvantage - Environmental degradation. The ecological disadvantage of the linear economy is that it is driven by the production of goods and services at the expense of our ecosystems' productivity. The excessive pressure it exerts on ecosystems jeopardizes the provision of essential services such as water, air, and soil treatment (Michelini et al., 2017). The extraction of raw materials leads to high energy and water consumption, the generation of emissions of toxic substances, and the disruption of natural capital. The manufacturing of products is accompanied by high energy and water consumption, as well as the emission of hazardous substances. At the end of their life cycle, when products are discarded, certain natural areas are occupied by this waste, and toxic substances are often released into the environment (PLB, 2018).

b) Economic Disadvantages. The linear economy model jeopardizes the supply of raw materials. This uncertainty is caused by fluctuations in raw material prices, the scarcity of rare materials, geopolitical dependence on various materials, and increasing demand.

Loss of embedded value in materials and products. The amount of raw material used in the economic system in 2011 was 79 billion tons, of which approximately 10% did not end up in the final product and was lost in the production process as waste. It is estimated that by 2060, the quantity of raw materials required to be introduced into the economic cycle could reach approximately 167 billion tons (OECD, 2018).

The growing demand for materials leads to the depletion of limited resources. With the increase in the global population, there has been a corresponding increase in people's well-being, and it is estimated that the number of middle-class consumers (with higher material consumption demands) will increase by 3 billion by 2030. The lifespan of products is continually decreasing, and consumers are acquiring new products at a faster rate (Circle Economy, 2018). Natural resources have become increasingly scarce, their value gradually rising, prompting producers to rethink their strategies for using raw materials and energy (Geissdoerfer et al., 2017). Industries such as metals, electronics, electrical products, and the automotive industry heavily rely on critical materials (e.g., indium, chromium) in their production processes.

Fluctuating prices. Since 2006, the level and fluctuation of mineral prices have significantly increased. This growth creates problems for both raw material extractors and buyers, discouraging investments in material extraction and processing, leading to price increases. Price fluctuations prevent companies from making price predictions, putting them in a weaker competitive position than companies that are less dependent on specific materials (Circle Economy, 2018).

Interdependence. Due to increased trade, the political interconnectedness of products has become stronger. For example, countries with a water deficit but a surplus of oil may sell oil to purchase grains. The deficit of a raw material will have a widespread impact on the prices and availability of multiple goods (European Commission, 2020).

The main issues the population faces, closely related to the circular economy model, include climate change, biodiversity reduction, risks to human health, and risks to wildlife and flora.

To address all these disadvantages, a transition to a circular economy model is necessary. The circular economy is an economic model that aims to minimize waste as much as possible, essentially moving towards zero waste. It is a new paradigm, an economic cycle in which, from the design phase, the conception of products or processes falls into two categories: either they use a biodegradable component or a component with 100% recycling potential. When a product reaches the end of its life cycle, the materials in it are kept in the economy as much as possible. These materials can be reused in production, creating added value. The circular economy is a model of production and consumption (Figure 2) that involves the reuse, recycling, and repair of products, sharing and renting to extend the lifecycle of products (European Parliament, 2018).

Circular Economy. Definition and General Aspects

The most widely used definition for the circular economy model is provided by the Ellen MacArthur Foundation, which describes the circular economy as an industrial system based on valorization and/or regeneration. This concept replaces the end-of-life concept with valorization, shifts toward the use of renewable energy, eliminates the use of toxic substances that hinder reuse, and aims to eliminate waste through superior design of materials, products, systems, and business models (Ellen MacArthur Foundation, 2013a).

In the circular economy, there are two categories of materials: (1) biological materials that can return to the biosphere as raw materials and (2) technical materials that are not biodegradable. This economic model must allow for efficient flows of materials, energy, information, and labor so that natural and social capital can be rebuilt (Ellen MacArthur Foundation, 2013b).

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Figure 2. The Circular Economy Model (European Parliament, 2018)

At the European Union (EU) level, the European Commission has included a description of this concept in the study "Closing the Loop - An EU Action Plan for the Circular Economy," which is part of the circular economy package. Within this package, the following aspect is specified: "In a circular economy, the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and when a product reaches the end of its life, it is used again to create added value; this can bring significant economic benefits, contributing to innovation, economic growth, and job creation" (European Commission, 2015). Transitioning to a circular economy would make a significant contribution to the EU's efforts to develop a sustainable, low-carbon, and resource-efficient economy.

The circular economy is based on three principles:

a) Elimination of waste and pollution. The circular economy highlights the negative effects generated by economic activities that have a detrimental impact on human health and natural systems. These effects include greenhouse gas emissions and hazardous substances, air, water, and soil pollution.

b) Keeping products and materials in use for as long as possible. The circular economy promotes activities that preserve the value of a product in the form of energy, labor, and materials. Products are designed to be durable, reusable, repairable, and recyclable to keep products, components, and materials in circulation. Circular systems efficiently use biological materials, encouraging multiple different uses for them as they circulate between the economy and natural systems.

c) Regeneration of natural systems. The circular economy avoids the use of non-renewable resources and conserves them, for example, by returning valuable nutrients to the soil to support regeneration or by using renewable energy, as opposed to energy obtained from fossil fuels (Ellen MacArthur Foundation, https://archive.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail).

The principles of the circular economy

The mission of the circular economy is to recover and regenerate value, whether it's financial, human, manufactured, natural, or social (Ellen MacArthur Foundation, 2015). This economic model

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aims to ensure an increased flow of goods and services provided by businesses. The Ellen MacArthur Foundation was established in 2010 as a charity organization with the goal of accelerating the transition to the circular economy. Since its inception, this foundation has become a global leader in global sustainability, driving circular economy thinking.

In Figure 3, an overview of the circular economy is presented as developed by the Ellen MacArthur Foundation.

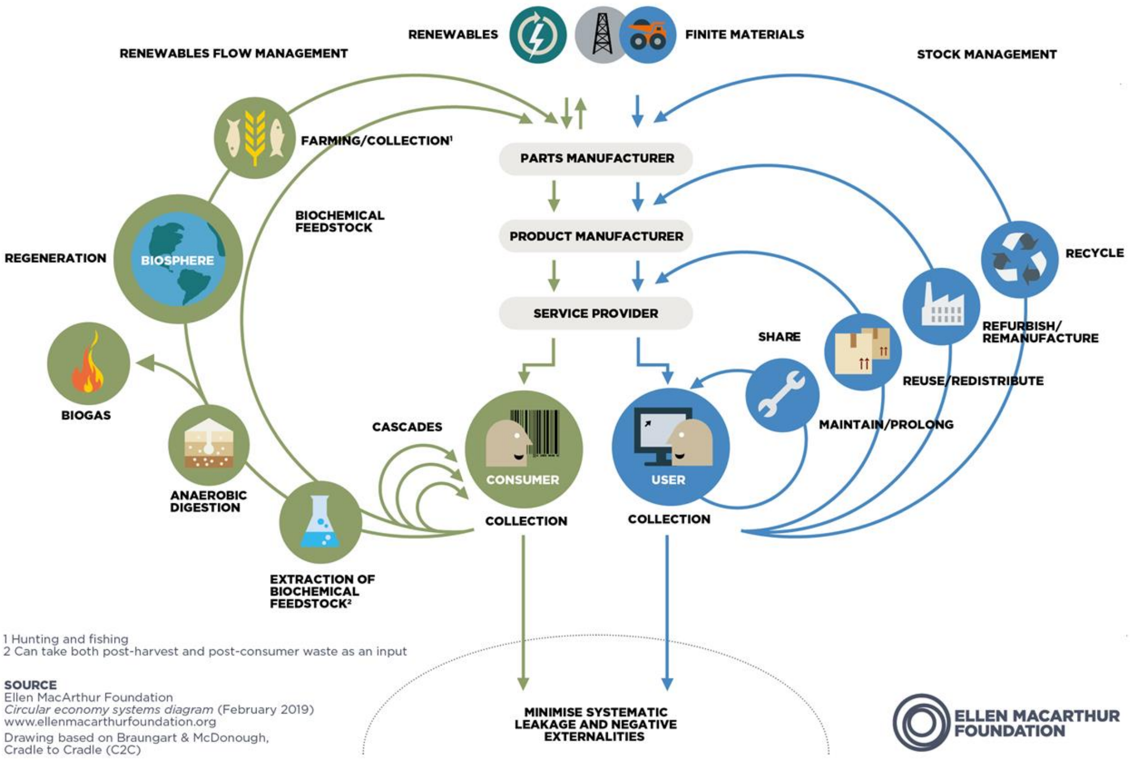

Figure 3. Principles of the Circular Economy (based on Ellen MacArthur Foundation, Circular economy systems diagram, 2019)

Principle 1 - Conservation and enhancement of natural capital through finite stock control and balancing the flows of renewable resources. When resources are needed, the circular system selects technologies and processes with good performance and uses renewable resources. This principle focuses on the selection of durable materials a company will use to manufacture its products. It's common to consider the cheapest finite material to maximize profit margins, but the circular economy encourages the use of durable and easily recoverable materials. This ensures that a product can be collected and transformed into added value through various loops of reuse, reconditioning, and recycling.

Principle 2 - Resource loops. Optimizing resource efficiency by recirculating products, components, and materials for the highest utility, both in technical and biological cycles.

This means designing products so that they can be rebuilt, recycled to keep technical materials and components in circulation, thereby contributing to economic growth. Circular systems use narrower and inner loops (e.g., maintenance instead of recycling) whenever possible, retaining more embodied energy and other value. These systems maximize the number of consecutive cycles

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and/or the time spent for each cycle by extending product lifespans and optimizing reuse. Circular systems encourage biological nutrients to return to the biosphere safely for decomposition, becoming valuable raw material for a new cycle. In the biological cycle, products are designed to be consumed or metabolized by the economy to regenerate new resource value.

The diagram (Figure 3) presents four loops that can be used to achieve a circular economy, each loop enters a new supply chain at different levels, meaning an organization that produces a product or service can choose one of these four loops.

Collection represents a general constraint through which organizations can regain their value and can be called a reverse supply chain that involves retrieving products back from customers. This route is often incentivized through product buyback or deposit refund schemes.

Product maintenance/repair is the shortest resource loop, where products are collected from consumers and repaired to be functional again for consumers. This resource loop is done to extend a product's life cycle, reducing the need to introduce new products to the market and reducing material and energy consumption. By extending the product's life cycle, organizations can contribute to a circular economy, keeping their products or services in the market's circulation for a longer period.

Reuse cycles are used to exploit the residual value of a product that the consumer no longer wants. An example of reuse is the second-hand product market. When a product is no longer desired by the initial customer, there are platforms through which the customer can sell the product at a certain value. This creates a market for consumers to generate value from purchases considered unnecessary or unused. This loop delivers the product to a service provider or distributor.

Reconditioning is an act of renewal, re-fabrication, and restoration of a product to a new state and/or appearance. When a product has a high level of wear or consists of multiple components, the component parts of one product are used to repair another product. An example of this could be considered reconditioning a heavily worn chair that requires fabric replacement. After the product has been reconditioned, it can be redistributed to consumers at a lower price, making it more accessible to a new segment of customers. Reconditioning extends the life cycle, requires minimal material and energy requirements for repair. The reconditioning loop delivers the product back to product manufacturers for reintegration into their supply chain.

Recycling is the most commonly used resource loop that encourages consumers to consider the material values of products they possess. Recycling transforms waste into reusable materials, focusing on the intrinsic value of materials used in product manufacturing.

Raw material consumption is a key aspect of the waste model associated with the linear economy. Recycling is a method used to reduce the impact on raw material consumption and involves dismantling and processing products to be used in a new manufacturing stage. This loop returns materials to product manufacturers and part suppliers or to other industries that require processed materials.

Principle 3 - Design for system efficiency. This principle refines the circular economy process through design and presentation of how to reduce negative effects. Efficiency and effectiveness are key factors for the success of the circular economy. Negative externalities are known as costs borne by a third party (recovering wasted resources). This principle includes reducing damage to systems and fields such as: food, mobility, shelter, education, health, and the management of externalities such as land use, air pollution, water pollution, noise pollution, and the release of toxic substances into the environment.

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Benefits of the Circular Economy

Since the Industrial Revolution, humanity has followed a linear model of production and consumption. Raw materials were transformed into goods and services, which were later sold, used, and then turned into waste, often discarded or improperly managed. The circular economy is a regenerative industrial model by intention and design, aiming to improve resource performance and address the volatility that climate change could bring to businesses. The benefits of transitioning to the circular economy model can be economic, environmental, and beneficial for companies and the population.

Economic Benefits refer to economic growth, substantial cost savings, job creation, and the promotion of innovation.

Economic growth, as defined by Gross Domestic Product (GDP), could be achieved through a combination of increased revenues from emerging circular activities and lower production costs through more efficient use of raw materials. These changes in economic production activities affect supply, demand, and prices across the entire economy. European GDP is estimated to increase by about 11% by 2030 and 27% by 2050. It would be ideal if economic growth were decoupled from resource consumption. Higher revenue from new circular activities, together with more cost-effective production through the acquisition of functional, easily disassembled, and reusable products and materials, can lead to an increase in GDP.

According to the European Commission, more efficient use of raw materials and resources throughout the supply chain can reduce demand for new raw materials by 17-24% by 2030, with estimated savings of about €630 billion per year. Substantial savings in raw material costs could lead to a 3.9% increase in European GDP and create millions of new jobs. The circular economy could save 8% of the annual turnover of industries while reducing total greenhouse gas emissions by 2.4%. Substantial reductions in material and energy consumption can lead to up to a 79% reduction in raw material use compared to the linear economy model. Environmentally, it helps avoid pollution during the extraction of new materials.

New profit opportunities and improved competitiveness arise from lower raw material costs, which generate higher profits for businesses employing the circular economy model. Profits can come from reducing waste costs, energy, and ensuring supply chain continuity. Extending the productive use of materials, reusing, and increasing their efficiency enhances the competitiveness of companies adopting the circular economy model. Consumers are increasingly concerned about how a product is made and its environmental impact.

Reducing Volatility and Protected Supply: The transition to a circular economy model significantly reduces the number of materials used, utilizing recycled (reusable or easily transformed) materials with a higher proportion of labor costs, making companies less dependent on price fluctuations in raw materials. This could protect companies from geopolitical crises, safeguarding supply chains that could be affected by climate change and making companies more resilient to unexpected changes.

New Service Demand: The circular economy model has the potential to create new service demands and job opportunities, such as collection and reverse logistics companies supporting products that can be reintroduced into the system, sales platforms that facilitate longer product use, and component rebuilding and refurbishing services.

Product Improvement and Reduced Production Costs: Implementing the circular economy model in the production of durable, long-lasting products could lead to savings of between €340

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billion and €630 billion per year in the European Union alone, representing approximately 12% to 23% of the costs required for material production. For some consumer goods, such as food, beverages, textiles, and packaging, the potential for resource savings is estimated at nearly €700 billion per year.

Better Customer Understanding: The circular economy model encourages business models where products are leased by customers for different periods. This allows businesses the opportunity to learn about customer usage patterns and behaviors, interacting more frequently with them. This closer relationship between producer and customer could improve customer satisfaction and loyalty, contributing to the development of products and services that better meet market requirements.

High Job Creation Potential: The Ellen MacArthur Foundation and McKinsey conducted the largest comparative study of the impact of transitioning to a circular economy on employment, analyzing 65 scientific papers. New jobs can be created through increased recycling and repair practices, new business opportunities through innovation processes, and increased consumption and lower prices. According to estimates by the European Commission, approximately 700,000 new jobs can be created in the European Union by 2030.

Environmental Benefits refer to reduced greenhouse gas emissions and protecting ecosystems.

One of the objectives of the circular economy is to have a positive impact on ecosystems and prevent the overexploitation of natural resources. This economic model has the potential to reduce greenhouse gas emissions and raw material use, optimize agricultural productivity, and reduce negative externalities brought by the linear economy model.

The circular economy contributes to reducing greenhouse gas emissions by:

- Using energy from renewable sources in the long term, which are less polluting than fossil fuels.
- Promoting reuse and dematerialization, requiring fewer materials and production processes to deliver quality products.
- Valuing waste as much as possible, making them useful in the manufacturing process.
- Preferring energy-efficient and non-toxic materials.
- Healthy and Resilient Soils: Circular economy principles for the agricultural system ensure the return of nutrients to the soil through anaerobic processes or composting, helping to improve land and natural ecosystem health. Waste that reaches the soil contributes to its health and resilience, allowing a greater balance in the surrounding ecosystems. The circular economy is considered truly useful for soils and the economy since soil degradation costs approximately $40 billion annually worldwide, with hidden costs such as increased fertilizer consumption, biodiversity loss (World Economic Forum, 2014).
- Reduced Negative Effects: The transition to the circular economy model allows the reduction of waste and greenhouse gas emissions and manages those externalities that are not sustainable, such as land use, air, water, and soil pollution, toxic substance release, and climate change.

Case Studies with Relevance in Rural Areas

Bioenergy Villages

This case study focuses on rural communities that produce and use most of their energy demand from local biomass sources, such as agricultural and forestry waste, as well as other renewable energy sources. Biomass from agriculture or forestry is a significant source of renewable energy that can be used to provide electricity and heat for public buildings, homes, and industry. This circular economy model stimulates economic development in rural communities and contributes to slowing down climate change.

In Europe, there are numerous bioenergy-based villages that contribute to reducing costs and ensuring the energy security of rural communities. A bioenergy-based village primarily relies on biomass or other renewable energy sources. Various technical solutions are used, such as wood chip boilers, pellet stoves, log-fired boilers, biogas installations, and wood chip-based cogeneration systems. Such villages can be found in Germany (Juhnde), Austria (Gussing), and Denmark (Samso), setting an example of best practices that could be adopted by other countries.

Electricity is delivered to consumers through the local power grid, and heat is distributed through a central heating network. Adopting this circular economy model reduces dependence on fossil fuels and supports global economic development. Shifting from fossil fuels to green energy can redirect funds towards wood processing, local farmers, and artisans.

In Romania, two localities with high biomass potential have been proposed: Estelnic and Ghelinţa. Estelnic already has biomass installations, and Ghelinţa has a wood processing industry but does not utilize the by-products from this sector.

Upcycle House

The Upcycle House is a residence constructed entirely from recycled materials, covering approximately 120 square meters. It was built in 2013 in Nyborg, Denmark. The project aimed to reduce the carbon footprint of the newly constructed building compared to conventional construction materials.

For the house's structure, two shipping containers were used, insulated externally. The roof consisted of corrugated metal panels sourced from recycled aluminum cans used in various soft drinks. Recycled pressed paper was used for the building's facade, previously treated to enhance durability. The kitchen floor was made from corks from wine and champagne bottles, and recycled glass panels were used for bathroom cladding. The walls were covered with oriented strand board (OSB) panels, and the wood chips for the OSB came from local timber mills.

Energy efficiency was a core consideration in this building's design, with principles of sustainable development, including orientation towards cardinal points, local temperature patterns, optimizing natural light, sun protection, and natural ventilation. Ultimately, it was found that the carbon footprint of this house was 86% smaller than that of a conventionally constructed home.

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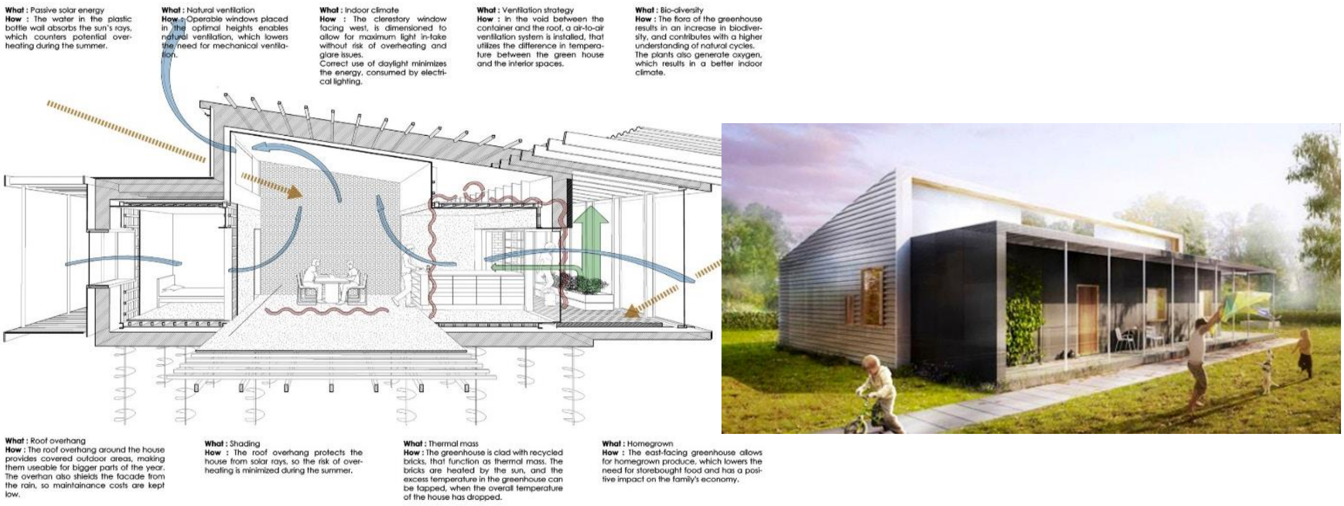

Figure 4: Upcycle House.

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