Circular Economy and Value Chains (Life Cycle Analysis)

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Adopting the circular economy concept is of paramount significance for sustainable development, societal metamorphosis, and alleviating pressures on natural systems. This paradigm shift transcends linear consumption models, championing a resource-efficient system where conservation, renewal, and judicious resource use prevail. Integral to this transformation are value chains, pivotal in reshaping production methods, prolonging product longevity, and advocating reuse and recycling. A cornerstone tool in translating circular economy principles into action is Life Cycle Analysis (LCA). LCA meticulously evaluates products' holistic environmental, social, and economic ramifications, pinpointing areas for enhancement and empowering informed decisions towards sustainability. A profound grasp of the circular economy coupled with instrumental tools such as LCA facilitates the sustainable stewardship of resources, an imperative for harmonizing human advancement with environmental preservation in times ahead.

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1 Circular economy

The idea of a circular economy was shaped by two key factors. The first relates to the flow of materials through the economy, while the second concerns the consideration of economic conditions that could lead to such a flow. Both aspects of this thinking originated in the 1960s and 1970s, when various environmental movements began to emerge with the goal of preserving the environment (Ekind et al., 2020). The current concept of the circular economy is not new, as its early foundations began to take shape in the early 1980s. One of the key milestones in the development of the circular economy was a report prepared by the Club of Rome in 1973. It is an international organization of experts, policymakers, and scientists focused on analysing global challenges such as economic growth, environmental impacts, and sustainable development. In the mentioned report, titled The Limits to Growth, members of the Club presented the results of simulations that warned of both the unsustainability of existing economic systems and the limitations of natural resources (Meadows et al., 1973). Their findings sparked further discussions on the necessity of transitioning to more sustainable economic models.

1.1 Beginnings of the Circular Economy

The first serious approach to the conceptualization of the circular economy was undertaken by Walter Stahel and Genevieve Reday-Mulvey (1981), who aimed to address the then-ongoing crisis of high oil prices and unemployment in Europe. Their approach was based on job creation through extending the lifespan and refurbishment of products, as well as replacing the use of primary resources with recycled materials. The result of their vision of such a "looped" economy was the first visual representation of the circular economy, in which they summarized its impact on job creation, economic competitiveness, resource savings, and the prevention of additional waste generation.

The concept of a circular economy was first put forward by the environmental economists Pearce and Turner in 1989. In their book *The Economics of Natural Resources and the Environment*, they emphasized that the traditional open economy developed without an inherent tendency toward recycling, which was reflected in the treatment of the environment as a dumping ground for waste. Pearce and Turner (1989) made a distinction between the (circular) natural system and the (linear)

economic system, drawing on the contribution of Kenneth E. Boulding in his work *The Economics of the Coming Spaceship Earth* (1966).

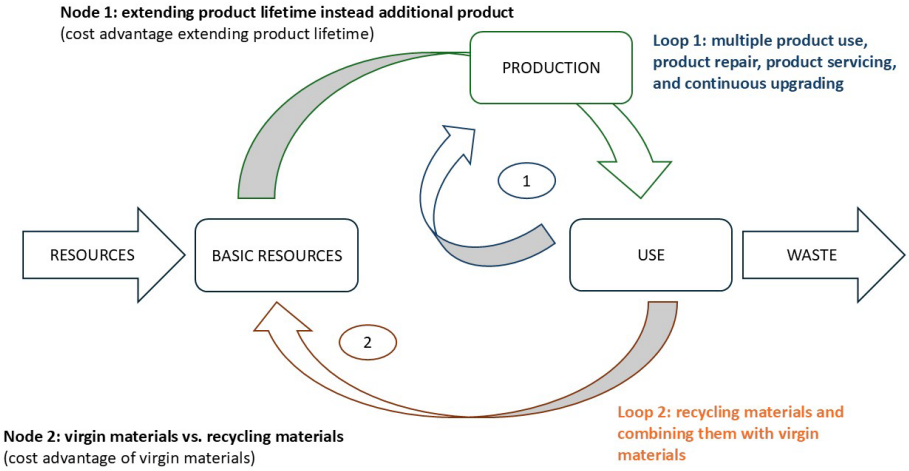

Figure 1: Conceptualization of the circular economy
Source: Stahel & Reday-Mulvey (1981)

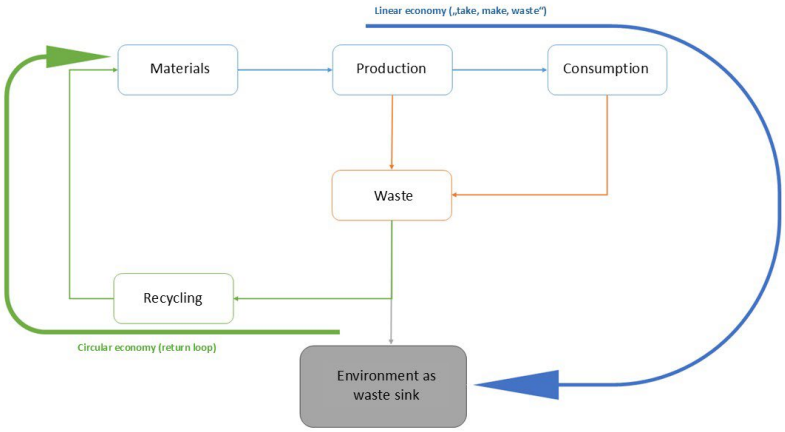

Figure 2: Conceptualization of the circular economy
Source: Pearce & Turner (1989)

In this essay, Boulding highlighted the importance of the laws of thermodynamics, particularly the concept of limited resources and energy. He emphasized the need to shift from the linear "cowboy economy", characterized mainly by unlimited resource consumption, to a "spaceship economy" in which the Earth functions as a closed system with finite amounts of resources. Boulding emphasized, as Pearce and Turner further developed in their model, that the economy and the environment are not linear and mutually separate entities, but are interconnected in a circular loop, where all resources must enter flows that can be reused. In such a system, which forms the basis of today's concept of the circular economy, each resource becomes an input for another.

After the sudden emergence of the circular economy, the idea somewhat faded for twenty years, as in the 1990s there was little research or publications on the topic (Ekins et al., 2020). The moment that sparked further research and work was the publication by McDonough and Braungart in the book *Cradle to Cradle: Remaking the Way We Make Things*. The concept of cradle-to-cradle design views the production processes of natural "biological metabolism" as models for developing a 'technical metabolism' for industrial materials. All products can be designed for continuous reprocessing and reuse as biological or technical nutrients in processes (McDonough and Braungart, 2002).

Then, in 2010, Ellen MacArthur and her organization, the Ellen MacArthur Foundation, emerged. This is the most authoritative global network on the topic of the circular economy, which has brought awareness of the circular economy to a broader public level. While the circular economy had been mostly a topic of scientific discussions for decades, Ellen MacArthur succeeded in bringing it closer to policymakers and businesses. As a result, the circular economy became an important topic on a global level. The accelerated development of the circular economy was also supported by the changing attitude of companies, where corporate social responsibility now goes beyond ecological practices and has become more of a rule than an exception. The result of their efforts was also the conceptualization of the so-called "butterfly diagram" of the circular economy, where both sides of the diagram are important for the environment.

The right side of the diagram represents the technical cycle, closing the resource loops enabled by circular strategies such as reuse, refurbishment, and recycling, while the left side of the diagram illustrates the biological cycle, with loops and cascades

that ensure the sustainable management of biological resources, creating renewable flows and stocks. The ultimate goal of the circular economy economic model is to minimize the extraction of raw materials and the generation of waste as much as possible. In December 2015, the European Commission adopted and presented an ambitious new package for the circular economy, aimed at promoting Europe's transition to a circular economy that would strengthen global competitiveness, encourage sustainable economic growth, and create new jobs. This new package will help European businesses and consumers transition to a circular economy, where resources are used in a more sustainable way.

The proposed measures will contribute to "closing the loop" of product life cycles through higher rates of recycling and reuse, bringing benefits for both the environment and the economy. The plan was to promote the maximum value and use of raw materials, products, and waste, while generating energy savings and reducing greenhouse gas emissions. The proposals put forward by the European Commission cover the entire life cycle, from production and consumption to waste management and the market for secondary raw materials. The European Commission has financially supported this transition with funds from the ESIF, 650 million EUR from the Horizon 2020 program (the EU program for research and innovation), 5.5 billion EUR from structural funds for waste management, and investments in the circular economy at the national level.

This circular economy package sent a clear signal to economic actors that the EU is using all available tools to transform its economy, opening the way for new business opportunities and enhancing competitiveness. The broad measures highlighted by the European Commission go beyond a narrow focus on the product utilization rate and encompass the entire life cycle, emphasizing the European Commission's clear ambition to transform the EU economy and achieve results. Due to the incentives introduced by the European Commission, it is expected that increasingly innovative and efficient methods of production and consumption will emerge. The circular economy has the potential to create numerous jobs in Europe, while preserving valuable and increasingly scarce resources, reducing environmental impacts, and adding new value to products (European Commission, 2015). Furthermore, the European Commission prepared an updated Action Plan for the Circular Economy and presented it in early 2020, along with the European Green Deal in 2019.

2.1 Definitions of the circular economy

The circular economy is a rapidly developing field. In line with its development, various definitions of the circular economy are emerging, among which it is important to mention the definition provided by the Ellen MacArthur Foundation: "The circular economy is an industrial system that is designed to be restorative or regenerative by intention and design." The concept of "end-of-life" is replaced with restoration, shifting towards the use of renewable energy sources, eliminating the use of toxic chemicals that hinder reuse, and striving to eliminate waste through the superior design of materials, products, and systems, within which new circular business models are also developed (EMF, 2013: 7).

Table 1: Overview of the development of circular economy definitions

Št.	Authors	Content	Main findings
1	Ghisellini et al. (2016)	Summary of 155 articles on the circular economy	The circular economy requires a systemic approach, where all stakeholders (policy, public, and industry) must be involved. Policy should promote sustainable production and consumption.
2	Lieder and Rashid (2016)	Comparing the concept of circular economy and sustainability	The development of a circular economy and sustainability requires systems that include both the environment, material resources and economic contribution for all stakeholders.
3	Blomsma and Brennan (2017)	Summary of literature on the circular economy in the manufacturing industry	The circular economy serves as a catalyst for the formulation of policies and strategies for waste management and resource management, with the development of technologies in the field of industrial ecology being crucial.
4	Sauvé et al. (2016)	Explanation of the origin of the circular economy concept	The need for an interdisciplinary approach in the conceptualization of the circular economy. The issue of establishing a unified concept that would be practically feasible in the real world.
5	Murray et al. (2017)	Comparing the concept of the circular economy with environmental sciences and sustainable development	Circular economy as a tool for implementing sustainable development, developing strategies (9R), and managing resources. The main issue related to the current limitations of the concept and its contribution to the public, not just industry.
6	Geissdoerfer et al. (2017)	Comparing the concept of circular economy and sustainable business enterprise	Although sustainability and circular economy are gaining traction in academia, industry, and politics, there is no clear connection between the two

Št.	Authors	Content	Main findings
			concepts that would enable integration in the real world.
7	Lewandowski (2016)	Conceptualization of a circular business model	The circular economy is implemented by companies for financial, social, and environmental benefits. A comprehensive approach needs to be established to enable effective implementation at all levels (businesses, cities).
8	Kirchher et al. (2017)	Overview of 114 definitions of the circular economy	The need for a systemic approach is crucial for the effective implementation of the circular economy. There is often an excessive focus on economic prosperity and environmental quality, while social justice (the social aspect of sustainability) is largely neglected.
9	Kovačič Lukman et al. (2016)	The positioning of the circular economy in sustainable development	The circular economy is a tool that enables the introduction of sustainability into existing production and service processes in businesses and societal environments, primarily through comprehensive systemic approaches and global policies.

Source: Kovačič-Lukman et al. (2016)

From the images in section 1.1, it is evident that recycling (circulation) was a key element in the conceptualization of the circular economy from its very inception. Over time, however, the number of "R's" has increased. For example, the Japanese government's "3R" initiative (reduce, reuse, recycle) was launched in 2004. Furthermore, the European Commission introduced the "4R" concept (reduce, reuse, recycle, recover) in the Waste Framework Directive of 2008 – reduce, reuse, recycle, and recovery.

After reviewing 114 existing definitions at the time of their publication, Kirchherr et al. (2017) proposed an updated definition, stating: "A circular economy describes an economic system that is based on business models which replace the concept of the end-of-life with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. These processes operate at the micro level (products, companies, consumers), meso level (eco-industrial parks), and macro level (city, region, nation, and beyond), with the aim of achieving sustainable development, which implies creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations" (Kirchherr et al., 2017, 224–225).

If we once again focus on both definitions–those by the Ellen MacArthur Foundation (EMF) and Kirchherr et al.–we can observe that the EMF definition is broadly formulated and uses terminology aligned with ecological and symbiotic ideas, which formed the foundation of the circular economy concept in its early development (Ekins et al., 2020). It is important to note that it does not mention recycling.

The definition by Kirchherr et al. (2017), on the other hand, defines the circular economy as an **economic system** (rather than merely an industrial system, as in the EMF definition) and mentions four out of the nine R-strategies. The definition includes two key components: – 1) the idea of levels, and 2) the connection to sustainable development, both of which are discussed further below. The latter is presented as the ultimate goal of the circular economy (Kirchherr et al., 2017). The latter is presented as the goal of the circular economy (Kirchherr et al., 2017). Ekins et al. (2020) argue that the definition by Kirchherr et al. (2017) is utopian, as no known economy has yet succeeded in "simultaneously creating environmental quality, economic prosperity, and social equity for the benefit of current and future generations," although they believe this should indeed be a goal for global society. Ekins et al. (2020) also identify a common shortcoming in both definitions: the absence of policy. Finally, the definition by Kirchherr et al. (2017) also identifies two factors: business models (which also appear in the EMF definition) and "responsible consumers". Furthermore, Ekins et al. (2020), in connection with this definition, refer to these as enabling factors–business models and responsible consumers–while pointing out that the main point of contention among enabling factors is policy.

The OECD adopted a definition that focuses on the characteristics of the circular economy (McCarthy et al., 2018), identifying its key features as: increased repair and refurbishment of products, enhanced material recycling, more robust and durable products, greater remanufacturing, reuse and repair, improved material productivity, better resource utilization, and changed consumer behavior. The anticipated effects of these features are listed as: reduced demand for new goods (and virgin materials), substitution of secondary raw materials in production, an expanded secondary sector, more durable and repairable products, and a growing sharing and service economy (McCarthy et al., 2018).

2 Circular economy policies, strategies and directives

As explained by Ekins et al. (2020), public policy intervention in environmental policy, sustainable development, and the circular economy can be defined and categorized in various ways, depending on the purpose and interests of the classifier. One approach is to group interventions according to how they operate, particularly by using three broad categories that are well established in environmental policy literature and regulation:

- setting requirements or prohibitions;
- changing economic incentives and
- providing information to actors in the economy or society, on the basis of which they can make informed decisions.

These categories align and aim to address classic market failures, and they represent an important, though insufficient, set of tools for promoting radical innovations and transformations. Another approach is categorizing by sectors or stages of the value chain (or circularity strategies) that the political initiative seeks to address (or encourage), as shown in figure (4). However, such an approach can be cumbersome, as many interventions affect various sectors or elements of the value chain (Ekins et al., 2020). In 2015, the EMF published a document titled "Circular Economy Policy Makers' Guide," aimed at supporting "policy makers who have committed to transitioning to a circular economy in designing strategies to accelerate this process" (EMF, 2015: 39). Although the document is primarily intended for national policy makers, the authors emphasize that this tool is useful for policy makers at all levels, from municipal to supranational. The guide includes six categories of policy interventions (as shown in Figure 5). This categorization reflects the three categories aimed at addressing classic market failures, but it is complemented by categories of interventions that seek to further encourage and support innovations and bring them to the market.

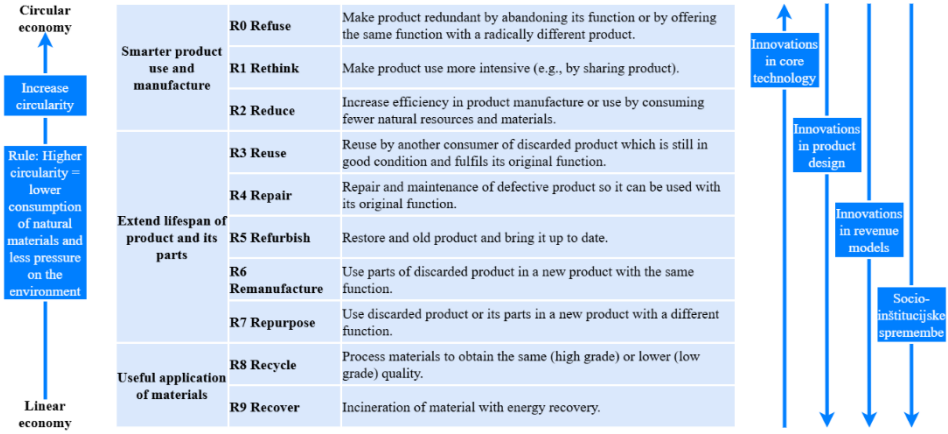

Figure 3: Circular economy strategies

Source: Potting et al. (2017)

POLICY INTERVENTION TYPES	EXAMPLES
EDUCATION, INFORMATION & AWARENESS	Integration of circular economy/systems thinking into school and university curricula.
	Public communication and information campaigns.
COLLABORATION PLATFORMS	Public-private partnership with businesses at national, regional and city level.
	Encouragement of voluntary industry collaboration platforms, encouraging value-chain and cross-sectoral initiatives and information sharing.
	R&D programmes in the fields of, for example, material sciences and biosystems.
BUSINESS SUPPORT SCHEMES	Financial support to business, for example direct subsidies, provisions of capital, financial guarantees.
	Technical support, advisory, training and demonstration of best practices to business.
PUBLIC PROCUREMENT & INFRASTRUCTURE	Public procurement.
	Public investment in infrastructure.
REGULATORY FRAMEWORKS	Government (sector) strategy and associated targets on resource productivity and circular economy.
	Product regulations, including design, extended warranties and product passports.
	Waste regulations, including collection and treatment standards and targets, the definition of waste, extended producer responsibility and take-back systems.
	Industry, consumer, competition and trade regulations, for example on food safety.
	Accounting, reporting and financial regulations including accounting for natural capital and resources, and the fiduciary duty of investors.
FISCAL FRAMEWORKS	VAT or excise duty reductions for circular products and services.
	Tax shift from labour to resources.

Figure 4: European Commission policy guidelines on the circular economy

Source: Evropska komisija (2015)

The establishment of a circular economy is a complex, multifaceted challenge that must be addressed with appropriate mixes of policies. There is no one-size-fits-all political direction, but basic policy interventions, in order to be effective, must be consistent in their implementation (both within and across governance levels), aligned with their objectives, and sufficiently credible to build trust among stakeholders in the economy (Wilts & O'Brien, 2019). Key to this is learning and disseminating lessons from past experiences, such as the OECD guidelines on resource efficiency policy (OECD, 2016a). However, in an increasingly interconnected global economy, establishing circularity at the required scale and level will involve substantial international cooperation in data and knowledge sharing, investments, and political alignment. Specifically, Geng et al. (2019) propose five priority measures to facilitate the "globalization" of the circular economy: (1) establish a global database to capture links between resource use; 2) create a global platform for knowledge exchange on the circular economy; (3) establish international alliances to promote large-scale experiments; (4) develop international standards for measuring performance, reporting, and accounting for key products; and (5) develop approaches for enforcing regulations, resolving disputes, and implementing sanctions. They suggest that these efforts should be coordinated to form an international agreement on sustainable resource management.

In line with the development of the circular economy, in 2015 the European Commission adopted its first Circular Economy Action Plan. It included measures to promote Europe's transition to a circular economy, enhance global competitiveness, foster sustainable economic growth, and create new jobs. The Action Plan outlined specific and ambitious measures covering the entire lifecycle: from production and consumption to waste management and the secondary raw materials market, as well as the revised waste legislative proposal (European Commission, 2015). It included 5 key action areas for the circular economy that needed to be restructured: production (product design, manufacturing processes), consumption, waste management, secondary resources, and supporting systems (innovation, investments, and monitoring). In line with these areas, priority sectors were established, which the European Commission specifically targeted, primarily to ensure the consideration of interactions across the entire value chain (European Commission, 2015). These were: plastic materials, food waste, critical raw materials, the construction sector, and biomaterials.

The original Action Plan was followed by the second Circular Economy Action Plan (2020), which is a key element of the European Green Deal. The European Commission anticipates that the EU's transition to a circular economy will reduce pressure on natural resources and create sustainable growth and jobs. It also sees the circular economy as a prerequisite for achieving the EU's climate neutrality goal by 2050 and halting biodiversity loss. The new action plan announces initiatives across the entire product life cycle (European Commission, 2021a). In line with the action plan, a framework policy for sustainable products was established, aimed at increasing incentives for manufacturers to transform the current linear system into a circular one, thereby reducing the environmental impact throughout the entire product life cycle (European Commission, 2020). In accordance with the provisions, the European Commission focused primarily on three specific goals: The goals included: designing sustainable products, empowering consumers and public buyers, and promoting circularity in manufacturing processes. Since the greatest impact of a product occurs during the manufacturing process, a significant portion of these provisions is directed at manufacturers within the value chains of key products, such as: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, as well as food, water, and nutrients (European Commission, 2020).

Recently, there has been a strong emphasis on integrating logistics and value chains into the circular economy itself. This primarily refers to reverse and green logistics. The goal of green logistics is to ensure that logistics processes are carried out correctly, while minimizing their negative impact on the natural environment as much as possible. Green logistics is a multi-level concept that includes both "green" logistics activities and social activities that support green logistics management, standardization, and reverse logistics as its subsystem (Zheng & Zhang, 2010). From the definitions of green logistics, it is clear that this concept not only serves to conserve natural resources but also ensures a connection between natural resources and products, as well as between products and consumers. It represents a tool for closing the loop in the circular economy system. Key activities of green logistics in implementing the circular economy concept include: green packaging, green transportation, storage, and material flows (Seroka-Stolka & Ociepa-Kubicka, 2019). Understanding the principles of circular economy is the first step toward understanding why it is necessary and how it is implemented in practice.

3 Life cycle analysis and LCT

To understand life cycle analysis, one must first comprehend what the life cycle actually represents and how it is considered within this context. LCT, or "Life Cycle Thinking" is an approach that seeks to define possible improvements for products and services in terms of reduced environmental impacts and lower resource use throughout all stages of the life cycle. LCT begins with raw material extraction, is maintained during production and distribution, use and/or consumption, and ends with the reuse and recycling of materials, energy recovery, and final disposal (Mazzi, 2020).

In this context, LCT aims to prevent burden shifting. In a generalized sense, this refers to reducing impacts at one stage of the life cycle in a geographical region or a specific impact category without increasing the burden elsewhere. If we return to the chapter on circular economy, a simplified example could be the production of a product where we replace energy from a thermal power plant with solar energy. Although we have reduced the burden of energy, we have increased the burden of waste solar panels, as well as the burden of their production, theoretically resulting in a reduction or increase within the product's production line. In this sense, LCT has a much broader perspective, as it needs to consider not only environmental impacts but also raw materials, materials, value chains, product use, and ultimately the effects of disposal, reuse, or recycling (Mazzi, 2020).

LCT largely relies on the theory of systems thinking, which is a methodology where the main lever is primarily a holistic approach. Value chains should not be viewed as isolated systems but rather as a collection of individual systems, with the main focus being on the interconnections and interdependencies between them. In the context of systems thinking and, consequently, LCT, the key points are the connections and interactions within the system and the external environment surrounding the system, and we consider it as a whole rather than as individual units or subsystems (Kim, 1999). In practical terms, this primarily means focusing on:

- interrelations, meaning the search for context and connections within the system or between individual components and the external environment;

- perspectives, where we recognize that each actor within and outside the system has their own unique view and opinion about the current state of the system or the situation;
- boundary setting, where we must be aware of the optimal boundaries of a system, its limitations and weights, by which we will evaluate and adjust the boundaries, and ultimately, what improvements or corrections within the system are advisable and will further enhance it.

The introduction of LCT into the circular economy offers a great opportunity for the transition from a linear to a circular system. Although there is much discussion about the implementation of circularity, it should be noted that the theoretical perspective alone does not provide sufficient evidence of the practicality of the circular economy. Authors thus support the introduction of the circular economy, while also emphasizing the need to measure and monitor its practical implementation in the economy, to ensure statistical evidence of improvements. In this regard, there is a strong emphasis on incorporating LCT into the circular economy itself, as it would provide a platform or tools to conduct both preliminary and subsequent analyses of circular activities and also gain insights into potential improvements as well as possible deterioration of the current state. This systematic approach is key to enabling further improvements (Gheewala & Silalertruksa, 2020). For this purpose, tools have been conceptually designed, among which the most well-known is "Life Cycle Analysis" (LCA).

3.1 Life Cycle Assessment (LCA)

LCA (Life Cycle Assessment) is the original and fundamental model upon which other similar models and concepts, including comprehensive LCM, have been developed and implemented. Iyyanki & Manickam (2017) define LCA as a technique for assessing the environmental aspects of a product throughout its entire life cycle, while Cowie et al. (2019) define LCA as a framework for assessing the environmental impacts of product systems and making decisions. Algren et al. (2021) understand LCA as a systematic, standardized approach to quantifying the potential environmental impacts of products or processes, from the extraction of primary raw materials to the end of the life cycle. By using LCA, organizations can gain insights into the entire life cycle of their products or processes and make more informed decisions to achieve sustainability goals. In doing so, they can contribute to reducing

negative impacts on the environment and society and improve their sustainability practices.

In general, LCA includes four key stages based on the ISO standard 14040, which are as follows (Iyyanki & Manickam, 2017):

- defining boundaries, where we need to be aware of what the optimal boundaries of a system are, what the limitations and weights are, by which we will assess and adjust the boundaries, and ultimately, what improvements or adjustments within the system are meaningful and will further enhance the system;
- the first step is defining the goals and scope of the study, where we specify which stages of the product's life cycle we will include in the assessment and what the final results will be used for. This step also includes defining the criteria for system comparison and specific timeframes.
- the second step is the inventory analysis, which allows us to understand the mass and energy flows of the product system and its interactions with the environment, such as the consumption of primary raw materials and emissions. Key processes, secondary energy sources, and material flows are described in detail at this stage, which serves as the basis for further analysis;
- the third step summarizes the details from the inventory analysis and uses them to assess the environmental impacts. The results of indicators from all impact categories are described in detail at this stage, where the significance of each impact category is assessed through normalization and the assignment of weights;
- the fourth step demands the synthesis of all the aforementioned steps and includes the explanation of the life cycle, along with a critical review of the data and preparation of the presentation of results;
- by using LCA, organizations can gain insights into the entire life cycle of their products or processes and make more informed decisions to achieve sustainability goals. This helps reduce negative impacts on the environment and society, and improve their sustainable practices.

3.2 Implementing LCT/LCA in practice

By considering life cycle perspectives, organizations, governments, and society can develop products, offer services, and implement strategies, policies, and initiatives to promote the "green economy." Understanding the life cycle and expanding horizons based on the principles of this approach opens up extensive opportunities to reduce impacts on the economy, environment, and society, allowing decision-makers to make more informed choices. The use of the life cycle approach enables the selection of strategies that proactively foresee and prevent the transfer of environmental issues from one stage or phase of the life cycle to another stage or phase, to other impact categories, society, and the global level, including other countries and regions worldwide. Similar to the sustainability approach, this method also contributes to the protection and preservation of the environment for future generations (LCI, 2012).

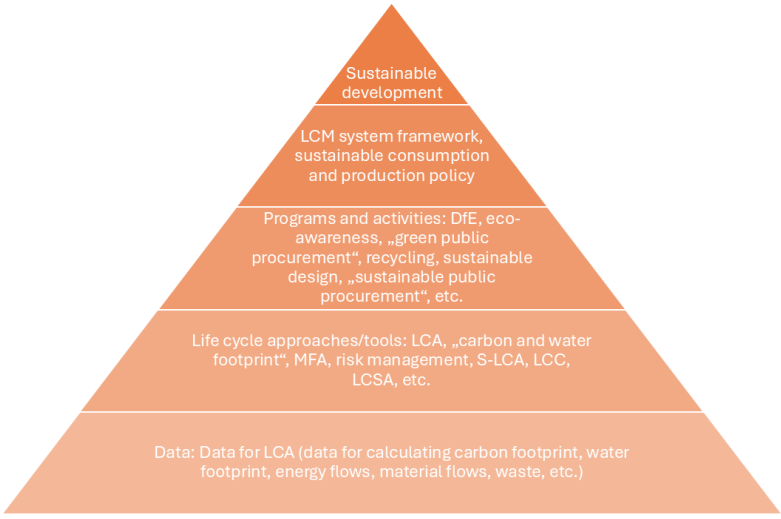

Figure 5: Schematic representation of LCT implementation in practice
Source: LCI (2022)

As mentioned, LCT represents the theoretical aspect of systems thinking or the approach to sustainable circular economy, while LCM provides practical tools, methodologies, and systems that enable the execution of measurements, analyses, and the feasibility of implementing sustainable and consequently circular activities within a selected system or product. In line with this, the LCI organization has

developed a schematic approach for implementing LCT in practice, along with extensive documentation that describes all the steps, procedures, and methodologies for successful execution.

LCT largely follows the methodology provided for the implementation of other LCA analyses. The presented scheme shows only the key reference points for execution, while the actual methodology for conducting LCA analyses is much more extensive, and it is recommended that it is read thoroughly before beginning the analysis. As mentioned numerous times in the previous subsections, LCA analyses are only meaningful if they are correctly conducted, with data collected systematically and comprehensively reviewed and verified, and the analysis conducted according to pre-qualified methods and methodologies provided by organizations in the field of LCA techniques (LCI, 2012).

The integration of LCT and the circular economy enables a holistic approach to achieving sustainable development. The circular economy represents a new type of economic concept, which is gradually being introduced in certain sectors of the economy and is already being implemented in practice. On the other hand, LCT is an approach that guides us toward sustainable thinking in the current economy and is more theoretical in nature, as it is not yet as widely implemented in practice. The key connection between both concepts is that the circular economy introduces concrete and practical changes, while LCT allows us to verify and assess the effectiveness of the implementation of circular practices. By using LCT, we can evaluate how successfully we have implemented circular practices and assess their impact on the product or service lifecycle. LCT enables us to examine the current state and identify areas where it would be most meaningful to introduce circular approaches to achieve more sustainable outcomes (LCANZ, 2020).

By combining the circular economy and LCT, we can make progress toward a sustainable society. The circular economy introduces practical changes based on sustainability principles, while LCT enables a comprehensive analysis and assessment of the effectiveness of these changes. By combining knowledge of the lifecycle and sustainable development, we can achieve a holistic approach to creating a more sustainable future. This enables better planning, more thoughtful decisions, and more efficient use of resources, which is crucial for creating a more sustainable and responsible society. This ensures that products, services, and strategies are

directed toward sustainable development and contribute to the protection of our planet and the well-being of all.

References

Algren, M., Fisher, W., & Landis, A. E. (2021). Machine learning in life cycle assessment. V J. Dunn, & P. Balaprakash, Data Science Applied to Sustainability Analysis (str. 167-190). Amsterdam: Elsevier. doi:10.1016/B978-0-12-817976-5.00009-7

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. Journal of Industrial Ecology, Vol. 21, 603-614.

Boulding, E. K. (1956). General Systems Theory--The Skeleton of Science. Management Science, 2(3), 197-208. doi:http://dx.doi.org/10.1287/mnsc.2.3.197

Boulding, E. K. (1966). The Economics of the Coming Spaceship Earth. In *H. Jarrett (Ed.), Environmental Quality in a Growing Economy* (pp. 3-14). Baltimore: Johns Hopkins University Press.

Cowie, A. L., Brandao, M., & Soimakallio, S. (2019). Quantifying the climate effects of forest-based bioenergy. V T. M. Letcher, Managing Global Warming An Interface of Technology and Human Issues (str. 399-418). Cambridge: Academic Press. doi:https://doi.org/10.1016/B978-0-12-814104-5.00013-2

EC. (2016). Buying green! A handbook on green public procurement. Bruselj: Evropska Unija. doi: 10.2779/246106

Ekins, P., Domenech, T., Drummond, P., Bleischwitz, R., Hughes, N., & Lotti, L. (2019). "The Circular Economy: What, Why, How and Where?". Paris: OECD. Pridobljeno iz https://www.oecd.org/cfe/regionaldevelopment/Ekins-2019-Circular-Economy-What-Why-How-Where.pdf

Ellen MacArthur. (2017). A new Textiles Economy: Redesigning fashion's future. Cowes: Ellen MacArthur.

EMF. (2013). Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition. Cowes: Ellen MacArthuer Foundation.

EMF. (2015). Delivering the Circular Economy: A Toolkit for Policymakers. Cowes: Ellen MacArthur Foundation.

European Commission. (15.. Januar 2015). Closing the loop: Commission adopts ambitious new Circular Economy Package to boost competitiveness, create jobs and generate sustainable growth [Press Release]. Pridobljeno iz EC: https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6203

Evropska komisija. (11.3.2020). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A new Circular Economy Action Plan For a cleaner and more competitive Europe (COM(2020) 98 final izd.). Bruselj: European Commission.

Evropska komisija. (2.12.2015). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Closing the loop - An EU action plan for the Circular Economy (COM(2015) 614 final izd.). Bruselj: European Commission.

Evropska komisija. (2021). Critical raw materials. Pridobljeno 18. januar 2022 iz European Commission: https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

Evropska komisija. (2021a). Circular economy action plan. Pridobljeno 18. januar 2022 iz European Commission: https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geng, Y., Sarkis, J., & Bleischwitz, R. (2019). How to globalize the circular economy. Nature, 565, str. 153-155. doi:https://doi.org/10.1038/d41586-019-00017-z

Gheewala, S. H., & Silalertruksa, T. (2020). Life Cycle Thinking in a Circular Economy. V An Introduction to Circular Economy, str. 35-53. Singapur: Springer. https://doi.org/10.1007/978-981-15-8510-4_3

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production, Vol. 114, 11-32.

ISO 14040 International Standard. (2006). Environmental management-Life cycle assessment - Principles and framework;. Ženeva: International Organization for Standardization.

ISO 14044 International Standard. (2006). Environmentalmanagement- Life cycle assessment - Requirements and guidelines. Ženeva: International Organization for Standardization.

Iyyanki, M., & Manickam, V. (2017). Life Cycle Assessment. V M. Iyyanki, & V. Manickam, Environmental Management: Science and Engineering for Industry (str. 57-75). Oxford: Butterworth-Heinemann. doi:https://doi.org/10.1016/B978-0-12-811989-1.00005-1

Kim, D. H. (1999). Introduction to Systems Thinking. Waltham: Pegasus Communications .

Kirchher, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221-232. doi:https://doi.org/10.1016/j.resconrec.2017.09.005

Kovačič Lukman, R., Glavič, P., Carpenter, A., & Virtič, P. (2016). Sustainable consumption and production – Research, experience, and development – The Europe we want. Journal of Cleaner Production, 138(2), str. 139-147. https://doi.org/10.1016/j.jclepro.2016.08.049

LCANZ. (2020). LCA, LCT and transitioning to a Circular Economy. Wellington: LCANZ.

LCI. (2012). Greening the Economy Through Life Cycle Thinking - Ten Years of the UNEP/SETAC Life Cycle Initiative. Nairobi: UNEP.

LCI. (2022). Life Cycle Management. Pridobljeno 8. januar 2022 iz Life Cycle Initiative: https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/life-cycle-management/

Lewandowski, M. (2016). Designing the Business Models for Circular Economy–Towards the Conceptual Framework. Sustainability, 8(1), 43. https://doi.org/10.3390/su8010043

Mazzi, A. (2020). Chapter 1 - Introduction. Life cycle thinking. V Life Cycle Sustainability Assessment for Decision-Making, str. 1-19. https://doi.org/10.1016/B978-0-12-818355-7.00001-4

McDonough, W., & Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press.

Meadows, D. H., Meadows, D. L., Randers, J., Behrens, W., & Club of Rome. (1972). The limits to growth: A report for the Club of Rome`s project on the predicament of mankind. New York: Universe Books.

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, 140(3), 369-380. https://doi.org/10.1007/s10551-016-3174-3

OECD. (2016a). Policy Guidance on Resource Efficiency. Pariz: OECD Publishing. doi:https://dx.doi.org/10.1787/9789264257344-en

Pearce, D. W., & Turner, R. K. (1990). Economics of Natural Resources and the Environment. Baltimore: John Hopkins University Press.

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: Measuring innovation in the product chain. The Hague: PBL Netherlands Environmental Assessment Agency. Pridobljeno iz https://www.pbl.nl/sites/default/files/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf

Reday-Mulvey, G., & Stahel, W. R. (1977). The potential for substituting manpower for energy : final report 30 July 1977 for the Commission of the European Communities. Geneva: Bastelle, Geneva Reseach Centre.

Seroka-Stolka, O., & Ociepa-Kubicka, A. (2019). Green logistics and circular economy. Transportation Research Procedia, 39, 471-479. doi:https://doi.org/10.1016/j.trpro.2019.06.049

Stahel, W. R., & Reday-Mulvey, G. (1981). Jobs for tomorrow : the potential for substituting manpower for energy. New York: Vantage Press.

Wilts, H., & O'Brien, M. (2019). A Policy Mix for Resource Efficiency in the EU: Key Instruments, Challenges and Research Needs. Ecological Economics, 155, 59-69. doi:https://doi.org/10.1016/j.ecolecon.2018.05.004

Zheng, L., & Zhang, J. (2010). Research on green logistics system based on circular economy. Asian Social Science, 6(11). doi:10.5539/ass.v6n11p116