Chapter 101

Circular Bioeconomy: An analysis of operational principles and limits

**Abstract.** The necessary transition from an economy based on fossil fuels to one based on renewable energy sources has paved the way for new, more stable, resilient, and sustainable production models. The strategies of the Circular Economy (CE) have defined closed economic cycles, where the use of biomass for the production of materials is preferred, promoting ad hoc Bioeconomy strategies. In these economic cycles waste ceases to be called such, to acquire added value for reuse in the same or new productions, becoming a secondary raw material. Over time, the synergies between the two concepts led to concept of Circular Bioeconomy (CBE). In this context, although there is particular interest in the scientific field, still today there is no clear definition of the concept, much less how to apply it. Therefore, the purpose of the paper is to provide a first analysis of the Circular Bioeconomy (CBE) concept, outlining its basic characteristics and defining the operational principles through which it operates and its limits.

**Keywords.**  Circular Bioeconomy, Biomass, Cascading, Biorefinery, Waste management.

# Introduction

The global challenges deriving from climate change, biodiversity loss, and soil degradation, together with demographic increase and the careless management of natural resources have, for some time now, highlighted the need to rethink the production and consumption model from linear to circular.

The circularity of the economy is now understood as an irreversible transition of modern economies. For this reason, many countries in the world, including the European Union, have initiated this change through common policies, strategies, and overall visions (Marcinek & Smol, 2020).

The circular economy (CE) is defined as a restorative and regenerative economy (Ellen MacArthur Foundation, 2013). This type of production model is designed to eliminate waste, promoting the circularity of products and materials at their highest value, and ensuring the sustainability of the process. In the circular economy field of research often a distinction between different type of materials to be reinserted into the economy is necessary. It is, therefore, possible to define two types of materials: those of a technical nature and materials of biological origin. The bioeconomy deals with the latter.

This concept refers to the production, use, and conservation of biological resources (Summit on the bioeconomy, 2018). The bioeconomy is often seen as the renewable component of the circular economy and as part of the solution for starting a more sustainable economy and society (Carrez & van LeeuWeen, 2015).

The interconnection between the concepts of CE and bioeconomy has given rise to the concept of “circular bioeconomy” (CBE) (Stegmann et al., 2020).

The CBE concept is frequently used when it comes to biologically derived productions, such as agriculture (Kircher, 2022).

However, in literature, there is still a gap related to its definition and the definition of its operational principles. This paper aims to define the characteristic of the concept of circular bioeconomy through the analysis of its main operational principles. Furthermore, the paper explores the principal limits of its application.

# Methods

The paper explores the operational principles behind the circular bioeconomy, trying to define the dimensions and limits of this concept.

Firstly, the characteristics and dimensions of the circular bioeconomy have been highlighted. Then, the cascading concept has been analysed in the light of the circular bioeconomy concept, underling the main differences and similarities between the two. Finally, the main limitation of circular bioeconomy concept are highlighted. To conduct the analysis, a literature review (scientific and grey) was performed.

# Results and discussions

The concept of circular bioeconomy is still vague today in the scientific literature. At the moment there is no single definition, nor are the operational principles through which it operates clear (Tan & Lamers, 2021).

In particular, CBE is a concept that derives from the intersection of circular economy and the bioeconomy, whereby the use of bio-based materials can be reintroduced into the economy in multiple ways and cycles.

The two components not only coincide in some aspects but play an enabling role for each other (Tan & Lamers, 2021).

Considering the literature regarding the operational principles of CBE, a common practice appears to be the concept of biomass “cascading” (Stegmann et al., 2020). A concise definition of the term regards the transformation of biomass into a bio-based final product that is used at least once for different uses and ultimately for energy purposes (Fehrenbach et al., 2017).

However, Bezama A. (2016) suggests considering some dimensions within the concept: including the quality of material flows and the often-neglected spatial dimension.

In particular, concerning the “quality of material flows” dimension, other authors have also stressed that cascading can be interpreted as an order of priority of different biomass transformation (Olsson et.al, 2018), which goes from the highest added value to the lowest (Stegmann et al., 2020; Zabaniotou, 2018).

In this sense, biomass is initially exploited for the production of high-added-value products for different industries, before the final use of the remaining material as an energy source. The added value can be considered either financial, environmental, or social depending on the possible uses of the waste material (OECD, 2018).

The "spatial" dimension, on the other hand, appears to be one of the characteristics of the bioeconomy. The cascading use of biomass is capable of interconnecting different value chains (OECD, 2018).

This produces a ripple effect resulting from the fact that countries adopting circular practices must be able to make the most of the networks of companies present in their regional industrial landscapes.

Different regions may have different biological resources or be strong in different sectors of technology or research, depending on local conditions (Global Bioeconomy Council, 2018).

In every industrial landscape (geographically limited) the production plants interact with each other in synergy (Bezama A., 2016), creating important opportunities to produce networks where waste materials are used circularly. These local networks, or clusters, make it possible to initiate important industrial symbiosis processes, with positive repercussions in environmental and economic terms.

A more complete view of the operational principles of the CBE can be outlined considering that the cascading use of biomass goes hand in hand with the application of the waste hierarchy (European Commission, 2015). Directive n. 98 European Commission of 2008 provides for waste management practices in order of priority consisting of waste prevention, reuse, recycling, recovery for energy purposes, and controlled landfilling.

The main technology of this cascading process is the biorefinery. This technology, typical of bioeconomy processes, is understood as the sustainable transformation of biomass into a spectrum of marketable products and energy (International Energy Agency Bioenergy Task 42 Biorefinery, 2012). At the same time, OECD (2018) points out, that this technology adapts to the concept of circular economy, complementing it. The biorefinery makes it possible to reuse organic waste materials in ways that go beyond the classic circular economy practices, such as reuse and recycling or regeneration. The biorefining process produces completely new materials using waste materials and waste as secondary raw material.

In this sense, to close the biological cycle by eliminating waste, in terms of a circular bioeconomy it is therefore necessary to consider all the principles, dynamics, dimensions, and technologies previously highlighted.

An important question remains for the future which is essentially identified by a gap in the scientific literature in the univocal definition of the concept of cascading, aligning, and adapting the terminology of the topic. In this context, it is necessary to set up a monitoring system with indicators that effectively indicate the circularity of the bioeconomy.

This need is complemented by the research that according to Stegmann et al., (2020) must concretely analyse how these cascading chains can be applied in practice and institute efforts to identify under which circumstances multiple cascading of biomass can prove to be more sustainable (environmentally, socially and economically).

These considerations then must necessarily clash with the reality of the places where the CBE must be applied. Its efficient and optimal application, being closely related to the network of companies able to collaborate to achieve common objectives, must involve as many players as possible. In particular, it is necessary to start a serious debate between the various local actors and stakeholders (companies, consumers, engineers, etc.) to design optimized and efficient synergies (Bezama, 2016; Stegmann et al., 2020).

Finally, it is necessary on the part of politics to overcome the current contradictions. In particular, the creation of "virgin" products from secondary raw materials makes it difficult to classify biorefining within the classic waste hierarchy (OECD, 2018). In this sense, it becomes necessary to update the policies by overcoming this contrast. In fact, despite all the actions implemented and the investments in new plants, the lack of a clear regulatory framework capable of leveraging the strengths, high-quality standards remain one of the main obstacles to the development of the EC (CNBBSV, 2018), thus losing the ability to exploit the mitigation potential of the total environmental impacts deriving from the circular bioeconomy.

# Conclusions

The synergies between the concepts of Circular Economy and Bioeconomy have led over time to the concept of Circular Bioeconomy (CBE). In this context, even if there is particular interest in the scientific field, still today there is no clear definition of the concept, much less an agreement on how to apply it.

From a first analysis of the scientific literature, it seems evident that the concept of CBE draws key characteristics from both the concepts of CE and bioeconomy and that the two components not only partially coincide but play an enabling role for each other. The cascading use of biomass seems to be in the literature the key principle of application of CBE, with the use of biomass for different productions and finally for energy purposes.

Although the literature can find agreement in some technical characteristics of this concept, there is still little practical development and effective application of the CBE, which often depends on the clear, economic technical characteristics of the regional industrial landscape in which it is to be applied. Finally, the most important limitation remains the political one, as a clear regulatory framework is still lacking today that is an essential element for encouraging investments.

# References

Bezama, A. (2016). Let us discuss how cascading can help implement the circular economy and the bio-economy strategies. In *Waste Management and Research* (Vol. 34, Issue 7, pp. 593–594). SAGE Publications Ltd. https://doi.org/10.1177/0734242X16657973

Carrez, D., & van LeeuWeen, P. (2015). Bioeconomy: circular by nature. *The European Files*. https://biconsortium.eu/sites/biconsortium.eu/files/publications/EuropeanFiles\_Bioeconomy-circular-by-nature.pdf

CNBBSV. (2018). *La Bioeconomia CIrcolare: suo ruolo per la ripresa economiaca, sociale, sanitaia, ed ambientale del Paese* (pp. 1–10). http://cnbbsv.palazzochigi.it/it/materie-di-competenza/bioeconomia/

Fehrenbach, H., Köppen, S., Kauertz, B., Detzel, A., Wellenreuther, F., Breitmayer, E., Essel, R., Carus, M., Bienge, K., & von Geibler, J. (2017). *BIOMASSEKASKADEN Mehr Ressourceneffizienz durch stoffliche Kaskadennutzung von Biomasse – von der Theorie zur Praxis*.

Global Bioeconomy Summit. (2018). *Innovation in the Global Bioeconomy for Sustainable and Inclusive Transformation and Wellbeing*. 1–108. https://gbs2020.net/wp-content/uploads/2021/10/GBS\_2018\_Report\_web.pdf

International Energy Agency Bioenergy Task 42 Biorefinery. (2012). *Bio-based Chemicals. Value Added Products from Biorefineries*. www.iea-bioenergy.task42-biorefineries.comwww.ieabioenergy.com

Kircher, M. (2022). Economic Trends in the Transition into a Circular Bioeconomy. *Journal of Risk and Financial Management*, *15*(2), 44. https://doi.org/10.3390/jrfm15020044

Marcinek, P., & Smol, M. (2020). Bioeconomy as one of the key areas of implementing a circular economy (CE) in Poland. *Environmental Research, Engineering and Management*, *76*(4), 20–31. https://doi.org/10.5755/j01.erem.76.4.27536

OECD. (2018). *Realising the Circular Bioeconomy*. <https://www.oecd-ilibrary.org/docserver/31bb2345-en.pdf?expires=1655722038&id=id&accname=guest&checksum=BB95C1F504267ACCE8A288F0D2206FD7>

Olsson, Olle, et al., 2018. Time to Tear down the Pyramids? A Critique of CascadingHierarchies as a Policy Tool. Wiley Interdiscip. Rev. Energy Environ. 7 (2), e279.https://doi.org/10.1002/wene.279

Stegmann, P., Londo, M., & Junginger, M. (2020). The circular bioeconomy: Its elements and role in European bioeconomy clusters. In *Resources, Conservation and Recycling: X* (Vol. 6). Elsevier B.V. https://doi.org/10.1016/j.rcrx.2019.100029

Tan, E. C. D., & Lamers, P. (2021). Circular Bioeconomy Concepts—A Perspective. *Frontiers in Sustainability*, *2*. https://doi.org/10.3389/frsus.2021.701509

Zabaniotou, A. (2018). Redesigning a bioenergy sector in EU in the transition to circular waste-based Bioeconomy-A multidisciplinary review. *Journal of Cleaner Production*, *177*, 197–206. https://doi.org/10.1016/j.jclepro.2017.12.172