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Editorial

It Is Time to Synergize the Circularity of Circular Bioeconomy with Sustainability and Resiliency Principles

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1. Bioeconomy and Its Circularity

Bioeconomy mainly refers to an economic system based on the sustainable production, conversion, and utilization of biological resources, such as crops, forests, fish, and microorganisms, to produce food, feed, energy, and other products. Following this production, conversion, and utilization principle, the bioeconomy can start replacing most finite and non-renewable resources with renewable and biologically derived resources [1]. Biofuels, bioplastics, bio-based chemicals, bio-based textiles, bio-based fertilizers, organic waste bioremediation, and others are some notable examples of bioeconomy. With recent developments and significant advancements in technologies and processes that aid bioeconomy, bioeconomy is expected to be increasingly important, especially in addressing global challenges such as waste management, climate change, food security, and sustainable development [2]. Additionally, the recent progress in bioeconomy concepts, especially from a sustainable development standpoint of view and the application of a lifecycle perspective, suggest that bioeconomy could promote the transition of the current linear economy model to a more sustainable one called circular economy, leading to the emergence of *circular bioeconomy*, under which circularity is more focused [3].

Bioeconomy's circularity refers to keeping resources in use for as long as possible, extracting their maximum value, and then recovering and regenerating them at the end of their useful life [3]. This includes practices such as recycling, reusing, and remanufacturing products and materials, as well as the restoration of degraded ecosystems following the principles of various *circular economy business models* [4]. One such example of a circular bioeconomy considering the flow of biomass is shown in Figure 1 [5]. Overall, *circular bioeconomy* aims to create a more circular and equitable society combining economic, social, and environmental goals by recognizing the interconnectedness of human well-being, the natural environment, and the economy and seeking solutions that benefit all three.

Now to understand how research solutions are being proposed to benefit human well-being, the natural environment, and the economy, we opened a Special Issue titled "*Sustainable Circular Bioeconomy*" calling for contributions (https://www.mdpi.com/journal/sustainability/special_issues/circular_bioeconomy_sust, accessed on 3 August 2023). The response was positive with a wide range of contributions, based on which we (the editors) carried out a discussion (Section 2.1), paving the way for a fresh research agenda in the field of circular bioeconomy, i.e., "*synergizing the bioeconomy's circularity with sustainability and resiliency*" (Section 2.2). Recommendations on how to synergize and ways to perform this are provided in Section 3.

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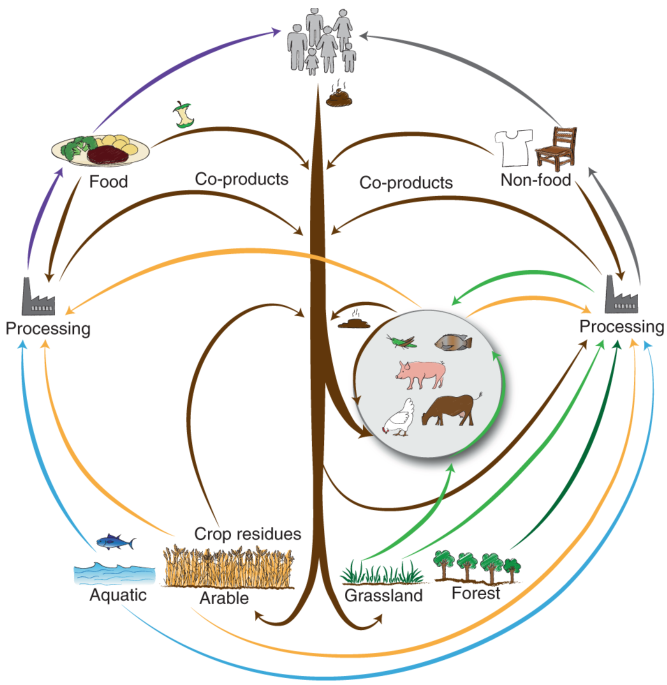

Figure 1. Circular bioeconomy illustration with biomass flows. Adopted from [5] and reprinted with permission from Springer Nature.

2. "Sustainable Circular Bioeconomy" Special Issue in MDPI Sustainability

2.1. Discussion on the Special Issue Contributions

The contributions published in the "*Sustainable Circular Bioeconomy*" Special Issue are varied in their subject fields but broadly fall under the bigger umbrella of circular bioeconomy [6]. The first published article (https://www.mdpi.com/2071-1050/14/1/466, accessed on 26 July 2023) highlights the use of technology to integrate the planning and stakeholder phases with the social, economic, technological, and environmental phases. The focus of key technologies are the Internet of Things (IoT), smart energy grids, GPS tracking systems, and blockchain. The authors have shown how these technologies promote a transition to sustainable progress in the bioeconomy field. The second published article (https://www.mdpi.com/2071-1050/14/2/994, accessed on 26 July 2023) showed the application of agro-lignocellulosic waste as a substrate for producing oyster mushrooms, where the authors just focused on the production process and testing of the mushrooms for their quality. The third published article (https://www.mdpi.com/2071-1050/14/3/1161, accessed on 26 July 2023) is about distiller-dried grains with a soluble diet as a substitute for standard corn-soybean for swine production in the United States of America, where the authors formulated the diet and modeled the life cycle assessment to assess the sustainability of the diet. In the fourth published article (https://www.mdpi.com/2071-1050/14/3/1897, accessed on 26 July 2023), the authors study biomass self-sufficiency status for European member states to meet the European Green Deals by 2050. It is mentioned that most European member states are biomass self-sufficient, but the resilience of such sufficiency relies on the ecological boundary. In the fifth published article (https://www.mdpi.com/2071-1050/14/4/2044, accessed on 26 July 2023), the authors focused on the use of technology to identify situations like aqua farmers involved in constructing illegal fishponds by taking Kolleru Lake in Andhra Pradesh, India as a case study. In the sixth published article (https://www.mdpi.com/2071-1050/14/4/2281, accessed on 26 July 2023), the authors depict the NTFP-based bioeconomic prospect in Kashmir, India. The authors identified that a lack of proper information on the extraction, consumption, and traded quantities of NTFPs in Kashmir, India were significant drawbacks in quantifying the NTFP's contribution to the bioeconomy, suggesting the need for a better decision support system, infrastructure, and regulation to aid bioeconomic prospects. In the seventh published article (https://www.mdpi.com/2071-1050/14/5/3126, accessed on 26 July 2023), the authors detail the environmentally friendly extraction and precipitation process of phenolics and a waste valorization technique of Cocoa Bean Shells to promote bioeconomy. However, the authors did not mention much about the scalability, further process optimization approach, and the process's lifecycle and techno-economic feasibility assessment. In the eighth published article (https://www.mdpi.com/2071-1050/14/6/3369, accessed on 26 July 2023), the authors present the impact of biofuel crop expansion on other crops in the GDP of Thailand. The authors used a computable general equilibrium (CGE) model combined with a life cycle impact assessment. As per the authors, although biofuel promotion could promote Green GDP, policymakers should emphasize the prevention of and the transformation of forests to agricultural land. Without technological advancements, expanding biofuel crops for alternative energy would not ensure efficient resource utilization and prevent environmental degradation. The ninth published article (https://www.mdpi.com/2071-1050/14/15/9678, accessed on 26 July 2023) focused on the accountability of sustainability, where the authors have suggested a model for achieving sustainability in agro-industrial companies. Their model combines the principles and goals of the water-energy-food nexus with existing business excellence models. This model can assist companies in making decisions and managing tradeoffs and synergies as they strive to become more sustainable. In the tenth published article (https://www.mdpi.com/2071-1050/14/16/10299, accessed on 26 July 2023), authors pursued sustainability initiatives after realizing how sustainable progress could emerge in the Brazilian Amazon. This study found a range of new seeds of change; however, more needs to be conducted to support transformation toward sustainable and equitable development in the region. In the eleventh published article (https://www.mdpi.com/2071-1050/14/20/13686, accessed on 26 July 2023), authors from CAZRI in Jodhpur, India, HICCER in Palakkad, India, propose a solar photovoltaic winnower cum-dryer for drying Phoenix dactylifera L. fruits by keeping the socio-economic status of farmers. They performed a techno-economic assessment, showing a high internal rate of return and a shorter payback period. They also showed that their design could serve multiple functions apart from drying, for instance, the effective winnower operation even without natural wind. In the twelfth published article (https://www.mdpi.com/2071-1050/15/1/656, accessed on 26 July 2023), the authors believe that having a scientific understanding of the apparel life cycle among apparel consumers is very important. So with that hypothesis, they investigated three research questions: what is the current norm of clothing acquisition, maintenance, and disposal behavior? What is apparel consumer clothing acquisition, maintenance, and disposal behavior circular-driven? What is a sustainable way of clothing acquisition, maintenance, and disposal? They provided a circular economy lens framework that could serve as new guidelines for consumers to exercise mindful clothing consumption. In the thirteenth published article (https://www.mdpi.com/2071-1050/15/2/1634, accessed on 26 July 2023), the authors suggest using a mixed method approach to assess the implementation and priority level of internationally defined bioeconomy objectives in Latvian policy planning documents. This study found that these objectives were highly prioritized, especially in higher-level policy planning records.

2.2. Need for Synergizing Circularity of Bioeconomy with Sustainability and Resiliency

Considering the case of biomass flows in a circular bioeconomy, as shown in Figure 1 [5], the effectiveness of a circular bioeconomy can only be defined when such flows are aligned with sustainability and resiliency principles. Only then can our societies and ecosystems thrive over the long term in a sustainable development path. Now the question is, what are sustainability and resiliency? How do they matter in this context?

Sustainability refers to the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. This requires the responsible use and management of natural resources, the efficient use of technology and processes that reduce or limit environmental impacts, and the promotion of social and economic equity. Based on Figure 1 [5], the circular bioeconomy of biomass flows might be sustainable only when the most energy-efficient and less material-intensive processes are used (materials that have lower environmental impacts); at the same time, all waste coming from bioproducts or co-products are managed effectively through appropriate waste management technology.

Resiliency, on the other hand, refers to the ability of systems to bounce back from disturbances and adapt to changing conditions. In the face of ongoing environmental and social challenges such as climate change, resource depletion, and social inequality, it is critical to prioritize sustainability and resiliency in order to build a more equitable and sustainable future for all; however, building a circular bioeconomy aligned with sustainability and resiliency principles might be the best option. Based on Figure 1 [5], the circular bioeconomy of biomass flows may be resilient only when all stakeholders are prepared for disturbances and take appropriate actions to recover from them and ensure the learning of adaptation mechanisms.

Overall, to ensure that circular bioeconomy initiatives are truly sustainable and resilient, they need to be integrated with a wide range of principles from a systems innovation approach [6]. This requires a holistic approach that takes into account the interrelated nature of these factors and involves collaboration and coordination across sectors and stakeholders. However, whether these are actually happening is the question. Suppose we see the discussed circular bioeconomy concepts from the Special Issue in Section 2.1 and other articles published elsewhere; we can observe that almost all the studies lack this systems approach. More or less, most studies are limited to one set of analyses, which may or may not provide sufficient insights into whether the circular bioeconomy initiative is sustainable and has the potential to become a resilient solution. Therefore, it is a needed approach that we look into all three aspects (circularity, sustainability, and resiliency) when we propose a circular bioeconomy initiative. By synergizing circularity with sustainability and resiliency, the bioeconomy can become a powerful tool for achieving long-term, equitable, and environmentally sound development.

3. How to Realize the Circularity of Circular Bioeconomy with Sustainability and Resiliency

Realizing the circularity of circular bioeconomy with sustainability and resiliency requires a comprehensive, integrated approach that considers the interrelated nature of performance (that is otherwise called technical considering resilience and reliability), social, economic, and environmental factors, for instance, the *RePLiCATE (Resilience Performance, Life Cycle Analysis and Techno-Economics) approach* as proposed in Ref. [7], see Figure 2. While pursuing the above said *RePLiCATE* for designing circular bioeconomy concepts, a few other aspects can also be followed which may further provide deeper insights on circular bioeconomy implementation; see Box 1.

By adopting these points, we can realize a circularity of circular bioeconomy with sustainability and resiliency and build a more equitable and sustainable future for all. By embracing circularity, we can minimize waste and pollution and promote the more sustainable use of resources. By promoting sustainability and resiliency, we can create a system that is not only environmentally sustainable but also resilient to external shocks, ensuring that we can meet our needs both now and in the future, which is in line with the developmental goals of sustainability [11]. Thus, synergizing sustainability and resiliency with circularity is a critical need of the hour that needs to be given the utmost importance while developing circular bioeconomy concepts and business initiatives.

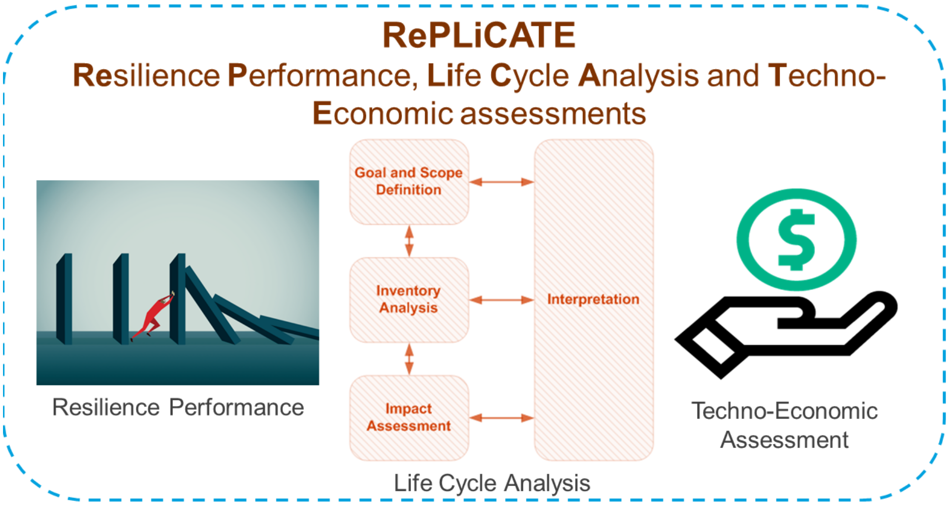

Figure 2. RePLiCATE approach to realize the circularity of circular bioeconomy in line with sustainability and resiliency principles. Adopted from authors own sources [4,7].

Box 1. Points that can help to achieve circular bioeconomy's circularity aligned with sustainability and resiliency principles.

Adopt a Circular Design in a Circular Bioeconomy: This involves designing products and processes to maximize the use of resources and minimize waste. This is only possible if circular design concepts are followed while designing [8].
Design that follows the pre-conditions of RePLiCATE framework: This involves analyzing the products and processes following the *RePLiCATE* framework (Figure 2) pre-conditions such as what should be considered to make a process safe to fail, product a tamper proof, sustainability data quality, recycling technologies and others that are applicable as per circular economy principles and energy efficiency standards, detailed economic parameters considering both the present and future markets and so on to assess circularity, sustainability, resilience, and economic viability [7].
Promote resource efficiency: This involves reducing the use of non-renewable resources and minimizing waste generation by adopting sustainable production and consumption practices [4,9].
Digitalization: This involves the digitalization of circular bioeconomy value chain stakeholders; upon doing so, there is a high possibility for tracing material flows and their characteristics, allowing us to evaluate sustainability and resiliency issues with near accuracy [8–10].
Foster social equity: This involves ensuring that circular bioeconomy initiatives are inclusive and benefit all members of society. This can be achieved through stakeholder engagement, participatory decision-making, and the promotion of fair labor practices [4,9].
Protect biodiversity: This involves minimizing the impact of circular bioeconomy initiatives on ecosystems and promoting the conservation of biodiversity [1,2,8].
Build resilience: This involves designing circular bioeconomy initiatives that are adaptable to changing environmental and social conditions and can withstand disturbances, such as natural disasters and economic shocks [4,7,9].
Foster collaboration: This involves working with multiple stakeholders across sectors and disciplines to ensure that circular bioeconomy initiatives are designed and implemented in a way that maximizes benefits across social, economic, and environmental dimensions [4,9].

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