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Editorial

Afterword for the Special Issue "Circular Economy Strategies for Sustainable Development: Applications and Impacts"

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1. Background

Circular economy (CE) is a holistic approach to sustainable development that aims to minimize waste and make the most of resources. It involves designing products, processes, and systems with an emphasis on all strategies leading to a recirculation of materials into new production cycles or flows so that it is possible to take advantage of their highest value and the maximum number of cycles [1,2]. Potting et al. [3] suggest the 9R methodology, which, within this SI, perfectly serves as a compilation of strategies to pursue the proposed thematic of circularity through innovative applications and impact measurement. This is an environmentally preferred hierarchical approach for closing material loops. The tighter the loop (lower R), the lesser external inputs are needed to close it, and the more circular the strategy. The longer the loop (higher R), the less circular it is, and the less we it should be prefered. Indeed, the approach is based on a hierarchical framework from the most circular to the most linear systems, under three greater groups of strategies: smarter product use and manufacture, extend the lifespan of products and its parts, and useful application of materials. The first set comprises strategies such as refusing, rethinking and reducing, while the second group spans from reusing, repairing, refurbishing, remanufacturing and repurposing; and the third one deals with recycling and recovering options.

Measuring the impacts of the newly proposed solutions is obviously crucial, as this enables an effective assessment of the benefits achieved, also accounting for resource efficiency, waste reduction and the regeneration of natural systems. Environmental indicators together with economic and social benefits associated with these circular strategies can be evaluated in a holistic manner, promoting more informed decisions and policy-making under a life cycle thinking perspective [4]. Long-term planning as well as benchmarking and comparisons are also anchored in impact measurement, which is a key aspect of sustainability. In summary, measuring the impacts of circular economy strategies is integral to accountability, improvement, and the overall success of sustainable practices, supporting transparency, and contributing to the ongoing evolution of circular economy principles.

These topics collectively highlight the multidimensional nature of CE strategies, incorporating environmental, social, and economic considerations. Research in these areas contributes to the ongoing efforts to create a more sustainable and circular approach to resource use and economic development.

2. Overview of the Special Issue

This Special Issue belongs to the Section "Sustainable Management" of the journal *Sustainability* and was open between January 2021 and January 2023. Its Guest Editor is Ana Ramos (Institute of Science and Innovation in Mechanical and Industrial Engineering), senior researcher in the area of environmental engineering who specialized in waste-to-energy techniques, sustainability, life cycle thinking and circular economy. The keywords for this Special Issue include circular economy, sustainability, environmental assessment, climate change, sustainable development goals, socio-economic impacts, sustainability indicators, energetic efficiency, industrial engineering, and innovation. This Special Issue

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focuses on the development and impact measurement of circular strategies to foster sustainable development and to promote the regeneration of resources, while enabling pollution decrease and restoring biodiversity.

After the call to contribute a paper to this Special Issue (Contribution 1), several authors have accepted the invitation, and a compilation of eleven works was achieved, representing a wide set of geographies (Poland, Ukraine, Germany, Mexico, Belgium, Chile, China, Portugal, The Netherlands, Italy, and Switzerland).

From these, a review on seaweed functionality as a sustainable bio-based material was proposed by Pranav Nakhate and Yvonne van der Meer (Contribution 2), highlighting a new feedstock possibility to maximize value creation in bio-based materials. Indeed, developmental process, by-product promotion, financial assistance, and social acceptance approaches were also put forward in order to promote seaweed as a circular material accounting for several sustainability dimensions. Matheus Oliveira, Ana Ramos, Eliseu Monteiro and Abel Rouboa (Contribution 3) reported an improved purification process for crude glycerol, as a by-product in the production of biodiesel, towards higher circularity in biofuel production. A 99.77% purification degree enabled the final product to meet the specifications for pharmaceutical uses, simultaneously allowing the development of new products with greater added-value and contributing to the zero-waste principles.

Under the technical point of view, Baharam Roy, Peter Kleine-Möllhoff and Antoine Dalibard (Contribution 4) developed an innovative biorefinery concept that includes superheated steam drying and the torrefaction of biomass residues, recovering the volatile fraction as well as several valuable platform chemicals (e.g., 5-(hydroxymethyl)furfural and acetic acid). The authors also conducted the economic evaluation of the proposed solution (Contribution 5), comparing two systems: one that supplies various platform chemicals and torrefied biomass and the other providing thermal energy for external consumers in addition to platform chemicals. Both options have shown to be profitable if the focus of the platform chemicals produced is on high quality and higher-priced segments. With this, a viable business model could be developed.

Product-wise, Virginia Lama, Serena Righi, Brit Maike Quandt, Roland Hischier and Harald Desing (Contribution 6) suggested the recently developed resource pressure method to assess the environmental sustainability of various carpet design alternatives. The product system was evaluated in relation to its consumption of primary resources and the final generation of waste, with a good correlation for most of the considered impact categories being observed. Thus, the method has proved to be simple and effective in predicting environmental impacts, accounting for the environmental pillar of sustainability.

From a more tactical-related perspective, Aleksandra Kuzior, Olena Arefieva, Zarina Poberezhna and Oleksiy Ihumentsev (Contribution 7) described the mechanism of formation of the strategic potential of an enterprise in circular economy, providing the potential for compliance with the strategic goals of the company, and allowing decisions to be made on the implementation of measures to better meet these goals. The conditions for the transition to a circular economy at the macro level were stated after a review of the circular economy concept and its impact on business and resource conservation, as well as in environmental protection. Furthermore, Carlos Scheel and Bernardo Bello (Contribution 8) developed a roadmap to transform linear value chains into an industrial ecology cluster of zero-waste chains, enabling institutions to exploit a circular value extended system. Their systemic approach enables the possibility to create a socially inclusive, environmentally resilient, and economically viable system of capital, with guidelines to transform linear value chains into a cluster of circular economy systems being provided for a dedicated case study in the mining industry in British Guyana.

Enduring the social sphere of sustainability, Katherine Mansilla-Obando, Fabiola Jeldes-Delgado and Nataly Guiñez-Cabrera (Contribution 9) analyzed stakeholders' perception of circular economy strategies using the 3Rs framework and stakeholder theory, conducting a case study for a glass company through a qualitative methodology. The main takeaway was that stakeholders perceive the contribution of the 3Rs approach to have

social implications, such as supplier evaluation with social impact, responsibility for the product, and decent work conditions. In a different area, Nuri Cihan Kayaçetin, Chiara Piccardo and Alexis Versele (Contribution 10) proposed a social impact assessment framework tested on a living lab for the construction sector. A multitude of impact categories relevant to different stakeholder groups were qualitatively and quantitatively assessed for production and construction phases. New indicators for circular construction methods were identified, with the social impacts being discussed for each stakeholder category. Also, recommendations were provided from a construction-based view, with the capability to be integrated into existing social impact assessment guidelines. Also, in the field of construction, Houchao Sun, Yuwei Fang, Minggan Yin and Feiting Shi (Contribution 11) assessed the promotion of prefabricated buildings from a low-carbon, environmental protection and high-efficiency perspective under the "Double Carbon" framework. A decision-making laboratory method together with an interpretation structure method were used to build a multi-level hierarchical structure model of constraints, the logical relationship, hierarchical relationship and relative importance of each constraint being clarified.

Finally, Haisheng Chen and Manhong Shen (Contribution 12) analyzed the effect of the central inspections of environmental protection on the development of a green economy, verifying that it varies from time to time and place to place. The authors state that it is important to regulate the use of administrative resources and strengthen inter-provincial coordination to promote synergy and cooperation across environmental inspection systems. This provided insights for understanding the logics behind the implementation of such environmental inspection mechanisms, and for promoting the green transformation of regional and national economy in China.

3. Concluding Remarks

Indeed, this series of works confirmed that circular economy is a topic to be embraced at different levels, by distinct stakeholders and within diverse applications. Correspondingly, the impact assessment of the circular strategies was evaluated, a multitude of examples spanning from the environmental concerns to the economic viability, the technical feasibility, and the social impacts being described.

The primary overarching message conveyed in this work is that linear economy should be replaced by circular systems, and waste cannot simply be discarded because it persists on our planet, impacting our lives in various ways. It is unavoidable to recognize the existing situation as an opportunity for evolution towards a more environmentally friendly direction. Therefore, individual behavioral changes can play a pivotal role in reducing both the volume of generated waste and the energy demands linked to a comfortable and affluent lifestyle, as well as the replacement of fossil-based products by more sustainable alternatives. Plus, from an industrial perspective, all sectors and interested parties should make the transition, taking advantage of the momentum created. On a macroeconomic scale, a comprehensive reevaluation of the current production and supply chains would also promote a more sustainable existence on Earth.

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