Industrial Symbiosis in the Circular Economy: A Review

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Abstract

Purpose*- This article provides an overview of industrial symbiosis in the context of a regenerative economy. As industrial symbiosis represents a novelty in sustainable development, this area has yet to be explored in depth. Despite the research interest in the circular economy, only some studies have considered the philosophy of industrial symbiosis. The primary purpose of this study is to analyse the current body of research to establish a framework that clarifies the connection between the ecological economy and industrial symbiosis and the variables that enable it.*

Design/methodology/approach*- A literature review examines and evaluates the knowledge background. A semi-systematic analysis was issued by employing an assessment synthesis approach. A thorough investigation and analysis of related and current published works was conducted by carefully choosing articles from diverse scholarly databases.*

Findings*- The interaction between the environment and industry is crucial for industrial enterprises' functioning, as the climate's consequences exert a constant and growing struggle against them. Implementing industrial symbiosis would encourage the cooperation and integration of socioeconomic and ecological systems in our society by developing a circular economy, which would also be a significant and forward-thinking step towards achieving eco-industrial development.*

Originality/value- *This investigation contributes to understanding how business organisations can support sustainable development and deal with environmental issues by implementing the industrial symbiosis agenda. Substantial contribution is offered to the subject of sustainable development by providing strategic insights into the future agenda for business organisations.*

Keywords: *Industrial symbiosis, circular economy, industrial ecology, sustainability*

Introduction

Background and objectives

The circular economy represents a visionary idea for a future significantly distinct from the current socio-technological landscape. Our societies have already faced the difficulty of reevaluating the conventional model in which resources are used to create added-value products and services. This difficulty is mainly rooted in the updated resource and waste management criteria. The environmental issues and the sustainability agenda define the new criteria. Linear models distribute resources unidirectionally, leading to the depletion of ecological assets and the buildup of waste items. Conversely, the circular economy is driven by the primary objective of minimising waste and prolonging the lifespans of products and materials (Leppänen et al. 2020).

Geissdoerfer et al. (2017) have observed a notable surge in scholarly attention towards the regenerative economy, with a specific emphasis on its theoretical framework and practical strategies for implementation. Scholars widely regard the shift to the circular economy as offering numerous benefits, including the mitigation of environmental harm, the reduction of resource depletion, the decrease in demand for new resources, and the smaller ecological imprint associated with economic activity (Leppänen et al. 2020).

Other academics underscore the advantages of advancing innovative sectors and employment opportunities, as using innovative strategies in business, infrastructure, and technologies is crucial for the journey towards a circular economy (Yadav et al. 2020). Gregson et al. (2015) explain that the philosophy of a circular economy aims to separate economic growth from the ongoing requirement for additional resources while simultaneously promoting the reduction or elimination of waste. Álvarez and Ruiz-Puente (2017) assert that adopting a circular economic model necessitates implementing strategies that foster the development of eco-efficiency and industrial symbiosis principles.

The foremost goal of this article is to provide a conceptual framework that enhances understanding of the concepts of the regenerative economy and industrial symbiosis. This will be achieved by delineating their distinctions, highlighting their shared objectives and obstacles, exploring their intersection, and proposing areas requiring attention and further investigation to promote sustainable development. The primary objectives of this paper encompass scrutinising the explanatory framework for the regenerative economy and industrial symbiosis derived from the extant literature, identifying a possible gap in addressing a holistic conceptualisation of both concepts, identifying the differences between them and the intersection between both approaches; distinguishing the contribution of both strategies in terms of their contribution toward sustainability and sustainable development; and finally, identifying promising future research agenda. The concerns included within the scope of this study are structured as follows: a description of the employed methodology, the conceptual foundations of the circular economy approach, the theoretical fundamentals associated with the conceptualization of circular symbiosis, and conclusions and recommendations for a prospective research agenda.

Method approach

A literature review was issued in this research, and a semi-systematic analysis of the literature was employed by employing an assessment synthesis approach. A thorough investigation and analysis of related and current published works by carefully choosing articles from diverse scholarly databases such as ScienceDirect, Emerald Insight, Taylor & Francis Group, Springer, Elsevier, ResearchGate, SAGE Publications, MDPI, etc. Keywords used are "circular economy", "sustainability", "industrial symbiosis", "industrial ecology", and "symbiosis network". The chosen publications were subjected to a thorough examination of their abstracts and core topics, with a particular focus on evaluating their relevance to this study. Most of the articles incorporated in this analysis were released during the last ten years. The journals cited in this study encompass Ecological Economics, Procedia Environmental Sciences, Journal of Industrial Ecology Special Feature on Industrial Symbiosis, Resources, Conservation and Recycling, Journal of Cleaner Production, Waste and Biomass Valorisation, Environmental Science and Technology, Journal of Industrial Ecology, Procedia Environmental Sciences, Metallurgical Research and Technology, Waste Management, Economy and Society, Sustainability, Sustainable Production and Consumption, Renewable and Sustainable Energy Reviews etc.

Review of the literature

Circular Economy as a Novel Approach to Achieving Sustainability

The notion of a circular economy prioritising, reducing, reusing, and recycling products and resources has recently garnered considerable interest (Geissdoerfer et al. 2017). The fundamental principle underlying the circular economy is to establish closed material looping, minimise input, and promote the reuse or recycling of products and trash to enhance resource efficiency and ultimately improve quality of life (Peters et al. 2007). Tukker (2015)Product Service Systems (PSS explains that one of the fundamental core concepts in which circular economy is instituted is a mutually beneficial relationship between a flourishing economy and a sustainable environment.

The historical origins of the regenerative economy, according to Winans et al. (2017), may be traced back to the 1970s, and its increasing significance within the realms of environmental preservation and sustainable development is underscored. Lieder and Rashid (2016) present a compelling perspective on the circular economy as a viable way to address issues such as limited resources and the generation of waste, and the need to sustain economic benefits, emphasising that the concept does not characterise a novelty relying on the argument that activities such as recycling, remanufacturing, and reuse have historically contributed to the knowledge of circular economy.

According to Birat (2015), the notion of an ecological economy represents a contemporary and extensively adopted concept that relates to the management of materials and resources in a sustainable way. As Yuan, Jun, and Moriguichi (2006) stated, a circular economy is intentionally designed to restore and regenerate goods, constituents, and materials to consistently maintain their utmost utility and value. It differentiates between technological cycles, which involve reusing and recycling materials, and biological cycles, which involve returning materials to the natural environment (Yuan, Jun, and Moriguichi, 2006).

Korhonen et al. (2018) explain the circular economy as an elaborate economic system that optimises the utilisation of materials and energy in a continuous loop, maximising the value generated from the production-consumption process. The authors elaborate that the objective is accomplished using cycled assets, renewable energy sources, and cascading energy flows. Furthermore, Korhonen et al. (2018) argue that achieving a thriving circular economy positively impacts all three pillars of sustainable development. The circular economy aims to limit the rate at which materials are transported to an environmentally sustainable level. This is achieved

by integrating ecological cycles into economic cycles while respecting the natural reproduction rates of these cycles.

Several scholars have described the philosophy of a circular economy by comparing and contrasting it with the traditional linear model "take-make-dispose" (Geissdoerfer et al. 2017; Geng et al. 2009; Pavel 2018). According to Pavel (2018), a circular economy focuses on the principles of circularity and integration across the value chain as a proponent of a generative system that operates on the principles of a take-make-dispose model. Furthermore, the author explains that the analysis of the circular value chain helps organisations achieve competitive advantages in an environmentally friendly way, and the circular value chain framework supports enterprises in understanding the circular business model and implementing advanced decision-making techniques (Pavel 2018). The circular economy notion underscores the necessity of reevaluating the traditional linear paradigm of manufacturing and consuming, commonly referred to as «take-make-dispose» (Geng et al. 2009). According to Kirchherr et al. (2017) the significance of comprehending the circular economy as a systemic and regenerative methodology is underscored, with the objective of redefining the conventional linear economic paradigm of «take, make, dispose» into one that is intentionally restorative and regenerative.

There are convergences between researchers regarding core values and guideline principles that lead to a circular economy. Kirchherr et al. (2017) have identified the terms reduce, reuse, recycle, systems perspective, economic prosperity, and environmental quality as the core concepts theorising circular economy. Pavel (2018) states that the primary objective of a circular economy is to decrease waste and optimise resource utilisation through the processes of restoring, recycling, reusing, distributing, and upgrading materials and goods. Morseletto (2020) comprehensively explains and analyses the concept of the circular economy by identifying and examining the specific objectives of the circular economy, which include rejecting, reevaluating, reducing, reusing, restoring, repairing, remaking, reusing, recycling, and recuperating. Also, Jiao and Boons (2014) assert that the circular economy is an all-encompassing concept that involves the decrease, reuse, and recycling of materials and resources throughout the many stages of production, transportation, and consumption.

As a research discipline, circular economy, according to scholars, encompasses three levels of analysis (Kirchherr et al. 2017; Nikolaou and Tsagarakis 2021). Nikolaou and Tsagarakis (2021), by scrutinizing the existing repository of knowledge, explain the circular economy concept under the framework of a triple level of analysis, specifically in a micro context, which includes the specific practices implemented within individual organisations, in a meso context, which includes the collaborative efforts between different firms to achieve circular

economy principles, and a macro context which deals with circular economy on a larger scale, when contemplating its execution at the regional, municipal, and national scales (Nikolaou and Tsagarakis 2021). The same analysis context is also delineated by Kirchherr et al. (2017) and Merli et al. (2018), who describe that the circular economy operations related to manufacturing, delivery and consumption encompass various levels, beginning from the micro view, including companies, products and consumers; the meso view including the eco-industrial parks; and the macro view that involve cities, regions, nations and beyond. Elia et al. (2017) endeavoured to assess the criteria pertaining to the contribution of the circular economy at the micro-level. They put forth an integrative methodology that encompasses the attainment of various criteria, including an augmented proportion of renewable and recyclable resources, diminished losses of valuable materials, decreased emissions, reduced extraction and utilisation of natural resources, and enhanced durability of products.

Researchers emphasize the concept of eco-industrial parks in terms of sustainability. Zhang et al. (2009)the Chinese government proposed the circular economy (CE assert that industrial symbiosis in eco-industrial parks (EIPs) is a vital component of the circular economy idea, which serves as a strategic framework for achieving sustainable development. The sustainable urban development was emphasized also by Winans et al. (2017) who explain that circular economy could be successfully applicable across different sectors such as agriculture, manufacturing, and urban development by being supported through innovative business models, innovative technologies, policies and regulatory issues, infrastructure investments, and consumer behaviour.

Also, Gregson et al. (2015) that industrial symbiosis in eco-industrial parks (EIPs) is a vital component of the circular economy idea, which serves as a strategic framework for achieving sustainable development. According to Ghisellini, Cialani, and Ulgiati (2016) a circular economy›s ultimate goal is to improve resource efficiency and establish a more optimal balance, synergy and collaboration between the environment, the economy, and society. Kirchherr et al. (2017) describes circular economy as an initiative that fosters sustainable development by advancing environmental preservation, economic advancement, and social fairness. Also, as an initiative undertaken to yield advantages for both the current and forthcoming generations and is facilitated by innovative firm concepts and conscientious consumers. Pavel (2018) emphasises the significance of circular economy in advancing sustainable consumption and manufacturing, minimising ecological footprint and generating novel commercial prospects.

Other research asserts that there is not a complete convergence between circular economy and its contribution with all the components of sustainability (Geissdoerfer et al. 2017; Merli, Preziosi, and Acampora 2018). Concretely,

Geissdoerfer et al. (2017) have analysed the convergence between sustainability and regenerative economy and identified as commonalities the fact that both concepts underline the obligations made within and between generations, driven by environmental risks. Both concepts commonly utilise multidisciplinary techniques to incorporate noneconomic factors into development effectively, and both notions consider collaboration among stakeholders not just as desirable but as essential to meet their expectations. However, Geissdoerfer et al. (2017) also delineate that the concepts differ in origin, objectives, motives, prioritisations, institutionalisations, beneficiaries, timescale, and perception of duty.

After thoroughly examining the existing literature, Merli et al. (2018) emphasise that CE is frequently discussed within the broader sustainability framework. Moreover, they argue that although the triple-bottom-line approach to sustainability provides a clear strategy for addressing environmental problems, it fails to adequately address social consequences and attain an optimal equilibrium among the three fundamental pillars of sustainability. Salvador et al. (2020) have analysed circular business models (CBMs) to identify their contribution to CE development. The authors distinguish in this frame several involvements, including reducing the rate at which resources are being used or consumed, terminating the movement of resources by extending the resource value and implementing industrial symbiosis, restricting the movement of resources, realising this way optimisation of resource use and system orientation issues (Salvador at al., 2020).

Researchers have also delineated the interdisciplinary nature of circular economy (Lieder and Rashid 2016). Lieder and Rashid (2016) suggest a conceptual framework and a pragmatic approach for the implementation of a regenerative economy and the preservation of the natural environment that integrates a broad range of research fields, including chemical engineering, ecology, industrial design, material science, waste management, education, mathematics, architecture, technology, information and communication, and applied physics, while also requires as a must the joint support and collaboration of all stakeholders. The authors have also delineated the multidisciplinary nature of CE so that to be applicable as a philosophy, it requires the interaction between areas such as business rationale and economic structures, remanufacturing and closed-loop supply chains, industrial ecology, and government initiatives (Lieder and Rashid 2016).

Kirchherr et al. (2017) discuss the role of various stakeholders, such as businesses, governments, and consumers, in driving the changeover toward a regenerative economy. Also, Winans et al. (2017) asserts that collaborative efforts between all stakeholders are crucial to realise the full potential of the circular economy. Lieder and Rashid (2016) have also emphasized that the joint support and collaboration of all the stakeholders is a must to enable the full synergy of circular economy.

Industrial Symbiosis

Gibbs (2008) highlighted the significance of industrial ecology in promoting sustainable development, the integration of environmental enhancement and economic progress through industrial symbiosis, and its contribution in restructuring the industrial production into an "industrial ecosystem". According to Nikolaou and Tsagarakis (2021), the meso-level of circular economy examines the collaborative efforts of enterprises in which one firm receives waste resources from another firm to use as raw materials. This level of analysis identifies the roots of industrial symbiosis in a circular economy, since the way how industrial firms interact with each other to use resources in a more appropriate way aiming to reduce waste corresponds to the conceptualisation of industrial symbiosis.

The predominant countries in industrial symbiosis, as shown by research, are China and the United States (Neves et al. 2020). In particular, the manufacturing sector exhibits the most significant potential to foster symbiotic partnerships. Quantitative assessment has been conducted to evaluate the economic and environmental advantages of industrial symbiosis in the context of Kalundborg, Denmark (Jacobsen 2006). The significance of industrial symbiosis is considerable, mainly influenced by factors such as diverse industries, close geographical proximity, and supportive laws (Neves et al. 2019).

According to Bichraoui et al. (2013),low carbon emissions, production efficiency, economic viability, and corporate social responsibility. Our existing socio-technical systems should transition or evolve towards achieving systems sustainability. This study aims to operationalize the notion of systems sustainability by developing an Agent-based Model (ABM industrial sustainability is achieved by effectively using resources, reducing carbon emissions, improving production efficiency, attaining economically sustainable development, and committing to corporate social responsibility. Chertow (2007) asserts that identifying preexisting symbiotic relationships has resulted in a more sustainable trajectory of industrial development than planning and constructing eco-industrial parks. Furthermore, according to Chertow (2007), there has been a notable focus on industrial symbiosis since 1989. This concept involves the exchange of resources, energy, water, and waste products across various clusters of firms.

Chertow and Ehrenfeld (2012) define industrial symbiosis as a collaborative approach where independent industrial facilities work together to create synergistic exchanges to achieve a collective competitive advantage by facilitating mutually beneficial interactions between industries. Schlüter et al. (2020) describe industrial symbiosis as a mechanism to effectively manage the closure of resources and

energy cycles among enterprises operating in historically fragmented industries. Furthermore, Schlüter et al. (2020) point out that the philosophy of cleaner production practices and initiatives could be fostered by interconnected industrial symbiosis networks leading this way to waste and pollution prevention.

Ferreira et al. (2019) posit that the notion of industrial symbiosis encompasses a range of practices that facilitate the establishment of linkages between regional industrial systems and industrial processes. These practices entail the reciprocal exchange of resources and the concurrent utilisation and commercialization of production waste, which can serve as additional materials for processing. By developing a case study that examines the network associated with the commercialisation of fluidised bed sands in the pulp and paper industry in Portugal, Ferreira et al. (2019) assert that effective communication between parties involved in industrial symbiosis, together with the expansion of knowledge, is vital for achieving success.

Arguments to emphasise the importance of industrial symbiosis are distinguished by Álvarez and Ruiz-Puente (2017) when considering the optimising of resource flow and the acquisition of additional value generated based on the logic of producing substantial collective industrial gains versus individual benefits that produce this way synergistic effect. Ferreira et al. (2019) explain the importance of an industrial symbiosis network by pointing out that this network enables actors' actions and the exchange of resources. According to Martin and Harris (2018), industrial symbiosis encompasses various techniques that integrate industries within a regional or local industrial system.

According to Song et al. (2018), a symbiotic relationship can be defined by considering all elements of the nodes, which are the stakeholders in the network. This includes the related attributes, such as the type of company or organisation, industry sector, physical location, and type of waste generated, as well as the links, which represent the nature of the relationship between the stakeholders. Another interesting view is proposed by Schlüter et al. (2020), who use the analogy with the processes that occur at the biological systems to propose and describe a conceptual model of industrial symbiosis network by highlighting the principal reproduction modes such as brooding, broadcast spawning, and budding. Schlüter et al. (2020) explain that the model of industrial symbiosis reproduction represents a valuable tool and brings new insights regarding developing industrial symbiosis networks that describe the dependencies and connections between new industrial symbiosis linkages and existing ones.

Researchers have analysed industrial symbiosis as a concept strictly related to circular economy (Boons, Spekkink, and Mouzakitis 2011). Martin et al. (2015) define industrial symbiosis as a concept corresponding to industrial ecology, focused on creating a network of symbiotic activities inter-firms, where the

industries that have historically been segregated collaborate in order to enhance the efficiency of material cycles and energy flows, analogous to the functioning of natural ecosystems. Other scholars, such as Kobayashi (2018), emphasise that the notion of industrial symbiosis encompasses more than just enhancing resource efficiency. It also comprises establishing mutually beneficial outcomes for all corporate entities engaged in the transactions.

Merli et al. (2018) identify industrial symbiosis as a CE component incorporated into business models supporting the circular economy. The changing patterns of industrial symbiosis were analysed by Boons et al. (2011) through the proposal of a conceptual framework that identifies the antecedents, such as sector number and size of companies, specific issues related to the location of actors that need to interact, specific issues related to businesses, precise stimuli for growth; mechanisms that enable the interaction including transmission mechanisms such as projects, government interest, imitation, coercion, training and professionalisation, and institutional capacity building. The authors explain that the final results are reflected and distributed in the ecological and social system (Boons et al. 2011).

Academics provide a theoretical structure for creating a facility-scale industrial symbiosis (Facility-IS) that tackles the difference between the technological and sociocultural aspects of industrial development (Mulrow et al. 2017)as a subfield of industrial ecology, is concerned with cooperation among industrial firms in managing resources, particularly by-products, such that the waste of one firm becomes the input of another. This "closed-loop" pattern also lies at the heart of the concept of the circular economy (CE. This framework delineates the necessary prerequisites for the planning, facilitation, and expansion of Facility-IS and three distinct approaches for its implementation: anchor manufacturer, project organiser, and business incubator. To address the necessity of circular economy and industrial symbiosis to bridge the gap between sociocultural and technical aspects of industrial development, Mulrow et al. (2017)as a subfield of industrial ecology, is concerned with cooperation among industrial firms in managing resources, particularly by-products, such that the waste of one firm becomes the input of another. This "closed-loop" pattern also lies at the heart of the concept of the circular economy (CE propose that the Facility-IS framework allows small-scale businesses to effectively adopt circular economy (CE) solutions by providing operational clarity.

With the progress in knowledge-based economics and management, Grant et al. (2010) have employed a knowledge-based framework in order to evaluate the prospect of information and communication technology (ICT) in developing industrial symbiosis, emphasising ICT's importance in supporting the industrial symbiosis revolution. Other scholars, such as Turken and Geda (2020), focused their investigation on examining self-organised and assisted industrial symbiosis

within the strategic and tactical levels of supply chains. The authors assert that the examination of a company's institutional capacity, which impacts the capability of businesses to get resolutions, is a pivotal focal point in scholarly investigations pertaining to symbiotic supply chains. (Turken and Geda 2020).

Liu et al. (2015) applied a three-level investigation approach, including individual firm, interfirm, and regional levels, to explain how incorporating cleaner production could lead to improvement opportunities in an industrial zone. Their research output found that companies that applied the audit of cleaner production achieved environmental and economic benefits, that a symbiotic network enabled the outputs, and that potential symbiotic links existed at both the interfirm and regional levels.

Cecelja et al. (2015) have pioneered the use of ontology engineering to bring a novel approach to industrial symbiosis. By combining implicit knowledge from experts in Industrial Symbiosis with explicit insights from participants in Industrial Symbiosis, semantics has been effectively linked with a system engineering methodology. The approach being proposed presents a well-organized framework that aims to support the investigation of innovative concepts and original solutions. Additionally, a comprehensive methodology has been developed to enhance industrial symbiosis networks. This methodology utilises a multilingual web service to facilitate the formation of industrial symbiosis communities and to incorporate small and medium-sized enterprises that are currently marginalised from development (Cecelja et al. 2015).

Conclusions and prospect research agenda

The adoption of a circular economy presents firms with the potential to fundamentally reshape their business model in accordance with the principles of renewable eco-industrial growth and the well-being of both human beings and the environment, specifically from an ecological standpoint (Leppänen et al. 2020). Effective management of scarce resources utilised by firms requires adopting a systems approach that recognises the significance of interconnectedness and holism. According to the resource-based concept, the circular economy signifies a shift from ownership-centric economic models to performance-oriented models. Resource-based theory, which centres on the administration and utilisation of limited resources, is integrally connected to the ideas of the circular economy (Desing et al. 2020). The circular economy seeks to decrease the consumption of primary resources, energy consumption, and trash generation by implementing the 3R principles: Reduce, reuse, and recycle. (Ünal, Urbinati, and Chiaroni 2019).

Industrial symbiosis endeavours in the conceptual framework of networks seek to establish connections between different sectors on a big scale and various firms on a small scale. The goal is to gain environmental and economic advantages by exchanging resources. It encompasses several elements, such as materials, water, energy, and by-products. As Lombardi et al. (2012) assert however, there is a growing body of academic literature on industrial symbiosis, and the European Commission (Domenech et al. 2019)despite having attracted less attention in the literature, have been significant, driven both by public and private initiative. This paper provides an updated overview of IS activity in Europe, with a mapping of key networks, and a study of prevailing typologies of networks, size, geographical distribution and main streams/ resources traded. The analysis is based on a combination of desk research, gathering of primary data from case studies, a survey to IS network facilitators (n = 22 has recently acknowledged industrial symbiosis as a crucial instrument for resource efficiency and green growth, significant work remains to be accomplished in order to enhance the theoretical framework and practical understanding of industrial symbiosis. Based on this logic, industrial symbiosis remains a priority research area within the circular economy framework, where further research needs to focus on both further analysis of the existing body of knowledge, case studies illustrating applications of industrial symbiosis in different contexts, and quantitative research oriented toward identifying indicators that measure the performance of industrial symbiosis models.

Comparative research would have a crucial contribution to expanding the extant literature because case studies represent a certain individual level of analysis by defining a contribution that relates to specific countries. Meanwhile, patterns of industrial symbiosis can be better and more deeply identified by distinguishing differences and similarities in different economic, institutional, and cultural contexts. Research areas about industrial symbiosis and circular economy in specified contexts encompass examining various factors. These factors include the importance of social trust, norms and networks, the influence of cultural attitudes and values, the incorporation of Industry 4.0 technology, the consequences of governmental policies and institutional frameworks, and the interconnection between human and social capital in environments with limited resources. Within the realm of social capital, a potential research field can focus on examining the importance of social trust, norms, and networks to establish industrial symbiosis and implement circular economy practices(Klapper, Upham, and Kurronen 2018).

An additional domain of inquiry could involve examining the influence of cultural attitudes and values on the acceptance of these activities and the possibility of behavioural modifications to facilitate their adoption (Klapper et al. 2018). Regarding technological improvements, a significant area of research could involve the use of Industry 4.0 technologies, including the Internet of Things (IoT)

and Artificial Intelligence (AI), to optimise the allocation of resources and improve the effectiveness of industrial symbiosis networks. This may also encompass an examination of the obstacles and prospects posed by these technologies within the framework of circular economy ideas.

Examining the governmental and institutional context constitutes a significant domain of investigation. It may be necessary to analyse the influence of policies and frameworks on the progress of industrial symbiosis and circular economy initiatives. Additionally, it could investigate the possibility of using public-private partnerships to promote these projects. Within the realm of social capital, a potential research domain might focus on the correlation between human and social capital, specifically about entrepreneurship and commercial operations in situations with limited resources. This may involve examining how social capital might be used to offset financial and manufactured capital constraints, specifically within the sustainable business framework.

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