

Full Length Research Paper

Defining green economy aspects for eco-friendly industrial approaches; their linkages across the sustainable innovation paradigm

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Green economy is a sustainable concept that has set the pace for industrial innovations across the globe. This is reflected in manufacturing, processing, and production industrial processes. There is a paradigm shift in the definition and understanding of green economy (GE) linkages to industrial symbiosis (IS), industrial ecology (IE) and clean development mechanism (CDM). We hypothesize in this study by responding to the question, "How is green economy defined in the model of eco-friendly industrial processes and their links to circularity?" "We use systematic review design with the reporting system reviews and meta-analysis (PRISMA) and the Publish or Perish review tool for qualitative analytical synthesis. A total of (N = 1264) review articles were screened, and from the total, only (n = 56) articles were qualitatively synthesized. Based on previous research, we believe there are significant linkages and paradigms along the industrial symbiosis and circularity aspects. We conclude by recommending that research should explicitly inculcate incompatibilities of the green economy nexus on industrialization, the development of industrial policies that foster circularity and the combination of multiple solutions that inculcate sustainable innovations in industrial circularity.

Key words: Industrial ecology, Industrial symbiosis, circularity, clean development mechanisms, green economy.

INTRODUCTION

Green growth and a sustainable economy are indicators of economic growth with effective use of natural capital. The goal is to evolve towards an economy that benefits

people, reduces inequities, and environmental risks (Tawiah et al., 2021). The United Nations' (UN) 17 Sustainable Development Goals (SDGs) were announced

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in 2015, and they refocused the world's attention on the pressing need for coordinated action from a wide range of societal actors (United Nations, 2019). According to D'Amato and Korhonen (2021), macro-level discourse on sustainability, along with policy, academic research, and business, frequently uses narratives such as "green economies," "circular economies," and "linear economies," respectively. The common goal of balancing economic, environmental, and social objectives binds these concepts together despite their obviously divergent assumptions and operationalization strategies. It is imperative to assert that while the circular economy focuses on reusing and repurposing resources, the green economy recognizes the importance of all natural systems (Lavrinenko et al., 2019).

The term "green industrial production" was coined in the late 1980s, but the term "green economy" has been mainstreamed since the Rio de Janeiro 2012 conference on sustainable development (Hanumante et al., 2019). Conservation of the environment and poverty alleviation are the two main goals of this initiative. A green economy, according to the United Nations Environment Program (UNEP), is one that enhances human well-being and social equity while reducing negative environmental effects and ecological scarcity (Yermolenko et al., 2022). Simply put, according to the United Nations Department of Economic and Social Affairs (UNDESA), a green economy is a model of industrialization that is low carbon, resource efficient, and socially inclusive (UNDESA, 2012). This ideally posts those ecosystems (or natural capital) that delivers a variety of natural assets to the economic structure, many of which are often overlooked or undervalued.

METHODOLOGY

Defining green economy, industrial symbiosis and circular economy concepts

Transitioning to environmental sobriety and a sustainable world is enveloped in green industrial approaches. In this review, we limit our focus to the linkages and definitions of green aspects that inculcate innovations across the sustainable paradigm. We summarize existing works as well as environmentally friendly industrial descriptive concepts.

Review inclusion and exclusion criteria

From 2012 to 2022, a systematic review approach was used to study circular economy, industrial ecology, and industrial symbiosis in order to better understand the connections between green economy and eco-industrial models. Other added reference materials, which were limited to 300 documents as of November 4, 2021, for the systematic review procedure, a primary search in Scopus, which is considered an extensive online database for the screening of abstracts and citations of different thematic customized scientific literature, was used (Aghaei et al., 2013).

For further analysis, the systematic review technique was employed to obtain satisfactory research that was free of bias. For data compilation, we used the evidence-based approach specifically

for critical assessment and reporting system reviews and meta-analysis (PRISMA) guidelines,¹ which congregated interrelated data from various sources (Selçuk, 2019). A schematic summary of the studies that were included and omitted for analysis at various levels of the PRISMA is shown in Figure 1. Furthermore, the review study was carried out with the help of Publish or Perish,² an academic literature retrieval and analysis tool that search multiple databases for relevant terms in academic literature (Muthee et al., 2022).

RESULTS AND DISCUSSION

Green economy aspect in industries

The green economy concept was first used in 1989 to advise on the application fields, infrastructure improvements, policies, and initiatives of a sustainable development report (D'Amato et al., 2017). Due to the fact that it is a new concept, the term "green economy" has yet to be consistently defined (Gusmerotti et al., 2019). Among the proposed definitions, UNEP provides the most widely accepted and authoritative definition of the green economy. A "green economy" is defined as an economic model that improves human well-being and social equity while lowering environmental risks and scarcity (UNDESA, 2012). In the last decade, the concept of a green economy has emerged as a policy framework for long-term growth and poverty reduction through the use of ecologically responsible industrial operations (Abbasi et al., 2022; Mustapha, 2015).

Various aspects of the green economy in business can be observed where environmental and social considerations should be integrated into the operations of businesses as a green economy facet (Hajjari et al., 2017). Thanks to eco-industrial green approaches, industry can be upgraded and productive capacity increased without increasing resource use or pollution (Behera et al., 2012; Ghisellini et al., 2016). This needs the inculcation of green skills that are fundamental for these smooth transitions. By 2030, the green economy is expected to generate 24 million new jobs around the world (Shulla et al., 2021). This demonstrates how important a green economy is to the production and manufacturing industries, job creation, and the global economy's gross domestic product (GDP).

Linkages on industrial symbiosis, industrial ecology and clean development mechanisms

Synergistic connections between one company's waste output and another company's input are sought through a cross-organizational perspective in industrial symbiosis, which is empowered by inter-firm coexistence through resource and information dissemination (Rens, 2021; Yeo et al., 2019; Lopes and Farinha, 2019). It is possible for

¹ PRISMA (prisma-statement.org).

² Publish or perish on Microsoft Windows (harzing.com).

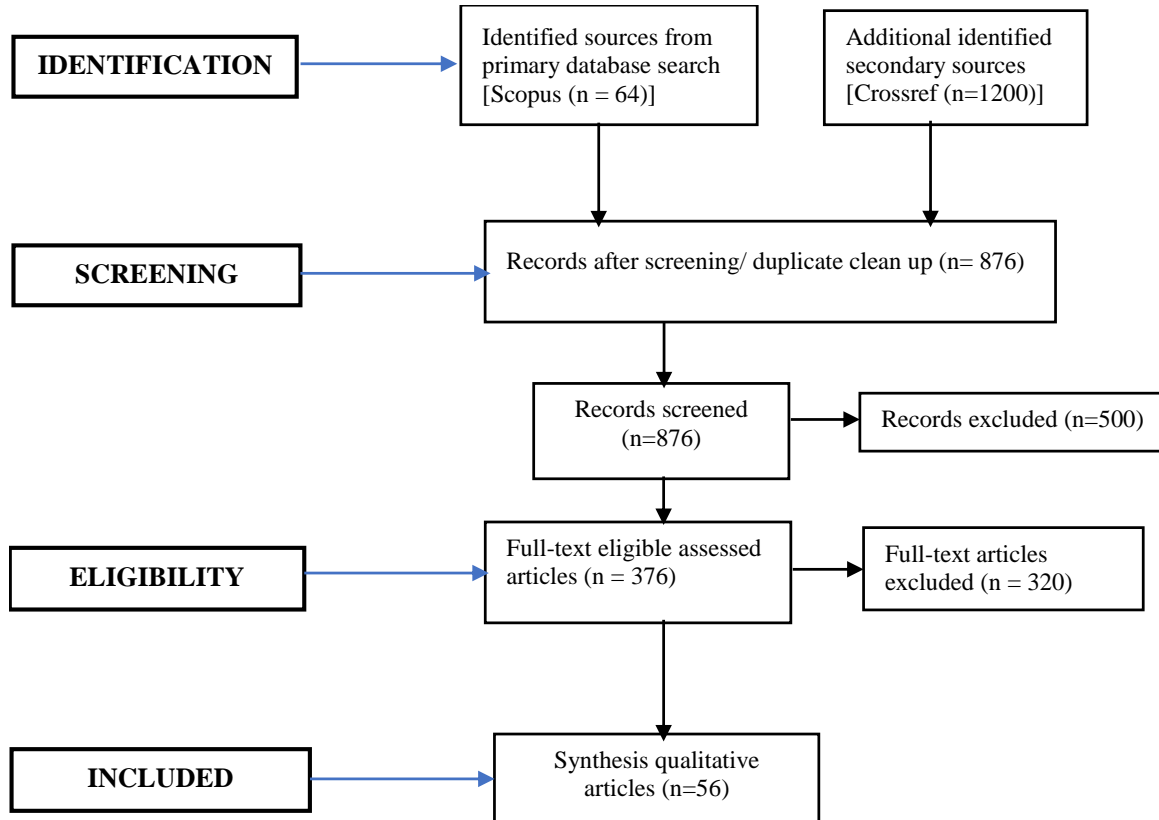


Figure 1. Summary of synthesized PRISMA guideline studies.
Source: Adapted from Moher et al. (2009).

companies that have traditionally been separated to work together and share resources through industrial symbiosis (Neves et al., 2019). Additional advantages include environmental and economic benefits, as well as social and community benefits. Despite the fact that several measures have been implemented to promote industrial ecology, the main impediment is the dissemination and exchange of confidential industrial symbiosis data among industries (Cervo et al., 2020; Henriques et al., 2021).

"Industrial Ecology" (IE) is the specialized branch of natural ecosystems that aims to change the structure and design of industrial consumption and production systems from linear to cyclical (Mishenin et al., 2018). To ensure long-term social, environmental, and economic well-being, ecological and human systems must be brought into harmony in order to achieve true sustainability. When one process produces waste or byproducts, it can be used as an input into another process. This is similar to how natural ecosystems work (Mulrow et al., 2017). Industrial Ecology (IE) interacts with natural ecosystems and attempts to move from a linear to a cyclical or closed loop system. Just like natural ecosystems, industrial ecology is in a continual state of flux (Zeng and Li, 2021).

According to Article 12 of the Kyoto Protocol, a country can agree to implement an emission-reduction project in

third world countries through Clean Development Mechanism (CDM) (Mangku, 2021). The certified emission reduction (CER) credits, which are the metric equivalent of one metric ton of carbon dioxide (CO₂), can be earned through such initiatives and applied toward meeting the Kyoto Protocol's reduction targets. There has never been a program like this before. Industrial symbiosis, industrial ecology, and CDM are interlinked in various ways. An eco-industrial park and other similar initiatives have their roots in a combination of environmental responsibility and profit maximization in industry (Ronoh, 2020). In an ideal world, this would bring the concept of IE to the industrial sector by utilizing the unutilized or residual reserves (materials, energy, water, assets, logistics, and expertise) of another company in a resource-efficient manner (Ali et al., 2019). The goal is to improve environmentally friendly production while reducing waste generation and greenhouse gas emissions, both of which are directly related to CDM. Economic rewards for all actors in industrial production processes tilt towards the availability of effective business models. Industrial Symbiosis, a circular economy approach, is the synergistic connections between enterprises where one's waste(s) can be used as input(s) of another, including materials, energy, services, and

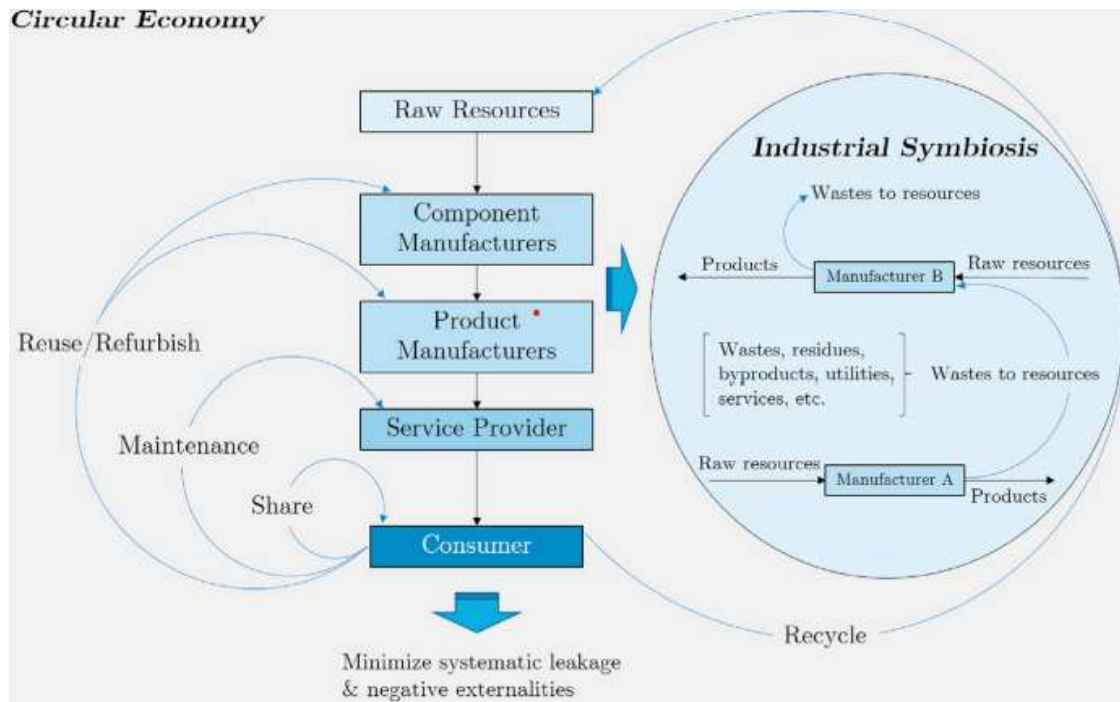


Figure 2. Schematic linkages of Circular and Industrial symbiosis.
Source: Adapted from Yu et al. (2021) and de Abreu and Ceglia (2018).

facilities (Yu et al., 2021) (Figure 2)

Circularity and industrial symbiosis

For the green economy and circular economy to be realized, symbiosis between industries is necessary (Lahane and Kant, 2022). Industrial ecology uses the analogy that "nothing is wasted in nature" to posit that one factory's waste can be an asset to another manufacturing unit (Tao et al., 2019). Sophisticated symbiosis is a way for businesses and organizations that are traditionally separated to collaborate with each other on shared resources in an effort to increase sustainability (Viswanathan et al., 2021; Neves et al., 2020). The circular economy has been around for quite some time. It is estimated that the concept has spread since the late 1970s (Geissdoerfer et al., 2017).

First introduced by Pearce and Turner (1990), the circular economy is based on the economics of the natural assets in our environment (Desmond and Asamba, 2019; Fraccascia et al., 2021; Gusmerotti et al., 2019). In today's economy, natural resources are both a source of input and a sink for output, which they examine in great detail (waste). The work of Boulding (1966) demonstrates once again that the Earth is a closed loop with limited capacity to absorb exciting technologies (Lopes and Farinha, 2019). The Ellen MacArthur Foundation coined the term "circular economy" in 2013 to

describe a "regenerative system in which resource input is reduced by easing, closing, and reducing material and energy loops" that reduces waste and emissions (Kopnina, 2018). Long-term planning, upkeep, repair, repurposing, remanufacturing, and recycling can aid in this endeavor. The United Nations defines "circular economy" as a system in which products and services are bartered in closed systems or cycles with the intent of retaining the maximum value of products, parts, materials, and resources (United Nations, 2019). Industrial ecology (IE) and industrial metabolism (IM) were concepts developed in the 1970s and 1980s as a result of a reexamination of industrial processes.

Historically, the concept of a "circular economy" was popularized in the 1990s, and it is framed in such a way that economic actors have no net impact on the environment (Kovacic et al., 2019). Designing the product's life cycle to have as little input as possible and produce as little system "waste" as possible helps achieve this goal. Net reductions are achieved at both the organizational distribution chain and the industrial level in this system. In order to achieve the underlying goal of transforming a byproduct of one industry into a resource for another, cross-functional and cross-dynamics cooperation are paramount (Gao and Bryan, 2017). At the same time, circular strategies could help developing countries alleviate some of the massive pressures they face by reducing air, water, and soil pollution and increasing economic productivity. At the same time, these

strategies could help developing countries relieve pressures by reducing air, water, and soil pollution and increasing economic productivity (Gusmerotti et al., 2019).

Circularity is becoming increasingly important in the world because it aids in the fight against resource depletion and climate change (Lakatos et al., 2021). The industry's value chain will become more efficient and less resource-intensive if it adopts a circular approach. Symbiosis between industries is often viewed as a major element in the transition to a circular economy. It promotes the use of production-process waste as a replacement for the productive resources of a different sector. The emergence of the circular economy in industry segments facilitates the collection and selection of products for reuse at the end of their useful lives (Atlason et al., 2017). A variety of industrial circularity models, including circumferential supplies, in which inputs can be continually reused and repurposed. This involves developing closed-loop recycling design concepts in which discarded products can be reused; and finally, a product life extension model, which aims to extend the life cycle of products through repairing, upgrading, and remanufacturing (Kouhizadeh et al., 2020).

There are many advantages to a circular economy over its linear counterpart, which appears to take and discard raw materials. As a result, the use of biological and technical loops can yield benefits for the economy, society, and the environment (Geisendorf and Pietrulla, 2018). Reuse, rethink, repair, refurbish, remanufacture, repurpose, recycle, and recover are the principles of circularity (Velenturf and Purnell, 2021). Industries that use secondary raw materials and primary raw material inputs, as well as new ideas for products and the supply chain, marketing and sales, and services. The value of materials is embedded and circulated through circularity principles.

In an industrial symbiosis, one company's waste can be used as a raw material by another. Because of the scarcity of resources, the unintentional byproducts of a company's production chain may be transformed into valuable alternative inputs (Park and Behera, 2014). Inter-organizational relationships based on utility sharing and the swap of energy and materials between co-located companies are a primary goal of industrial symbiosis (IS) (de Abreu and Ceglia, 2018). As a result of pooling the needs and resources of participants, such as facilities sharing and collective waste management, it is possible to achieve more efficient solutions. In addition, the principle of recycling waste materials and energy underpins the exchange of both materials and energy. Industrial symbiosis can help businesses make more money, cut costs, and make less of an impact on the environment (Wang et al., 2022).

Reorganizing material handling processes at both the company and intercompany tiers is often necessary to

implement industrial mechanisms (Lawal et al., 2021). The ability to share and exchange information is also hampered by cultural differences. Sensitive information and confidentiality in production plants may dissuade companies from considering opportunities from other corporations, and a sense of honesty and information exchange about the energy and material flows between companies may limit industrial symbiosis.

Policies and paradigm shifts along green economy and industrial symbiosis

Environmental issues like global warming and species extinction necessitate a focus on sustainable regional development (Jovovic et al., 2017). However, the conditions for the development of a green industrial path vary from region to region. From preexisting regional industrial specialization models, designers need to create a development plan (Mahmoud et al., 2019). In light of recent innovation studies on policies for revolutionary change, this lays the groundwork for identifying the place-based policy implications of growing clean industries in various regions (De Santis et al., 2021).

Predicting long-term trends in technology and marketing strategy is the goal of industrial policy. As a result, a country's economy is incentivized to change its structure in order to benefit from the shift (UN Environment, 2014). It is imperative that environmental concerns be incorporated into industrial policymaking as addressing climate change and other ecosystem challenges has a greater impact on the future of economic development (Tao et al., 2019). No one can say with certainty where industrial green policy ends and environmental policy begins when it comes to green industrial policymaking. Protecting and utilizing our natural resources is the goal of environmental policies. Even if these policies are not meant to have a structural effect, they can still have a big effect. In addition, policies aimed at enhancing the economic and employment gains associated with the green transformation are included. This includes any government action that aims to speed up the structural transformation of the economy toward a low-carbon, resource efficient economy in a way that also facilitates economic growth (Neves et al., 2019). To be more specific, green industrial policy is also distinct from traditional industrial policy. In at least six significant ways, it goes above and beyond the conventional notion of industrial policy (Gusmerotti et al., 2019). A supplemental and particularly harmful market failure is the emphasis on environmental consequences.

- i. The ability to predict the environmental impacts of various technologies, so that investment decisions can be made in a socially agreed-upon direction.
- ii. Increased ambiguity as a result of long-term transformations and policy shifts.

- iii. Greater interdependencies between policies and the need for comprehensive policy coordination.
- iv. National interests may not always be aligned with long-term sustainable management of the global commons.

Conclusion

To achieve green growth, all stages of production must integrate green parameters like resource efficiency. This will aid in the creation of a circular economy. Sustainability transformations post-Covid-19 necessitate the development of a more holistic, system-wide, and integrative approach to research into competing or complementary sustainability narratives.

A comparison of the green, circular, and linear economies in accordance with their different and combined global net sustainability potentials reveals a lot. Interpreted in light of their other inclusive conceptualization, the complementary contributions of the three narratives could be stated as follows: for a more sustainable, equitable, and just world, the circular, green, and linear economies all call for a new global economy and society based on renewable, biodiversity-based, and biodiversity-beneficial processes capable of providing tangible and intangible benefits to all people now and in the future, across all regions of the globe. According to the three narratives, problem displacement, cascading effects, and problem shifting may occur if the three narratives are implemented without considering global net sustainability. As a result of this, effective actions may be hindered or even eliminated. These three narratives, while complementary, may still be incomplete or insufficient for advancing toward global net sustainability despite their complementary nature. Researchers, managers, consultants, policymakers, and other decision-makers at local, national, and international levels, from a global north and south perspective, frequently use sustainability narratives such as "green economy," "circular economy," and "linear economy" to frame sustainability challenges and operationalize solutions.

Recommendations

- i. The interrelations and incompatibilities of green, circular, and linear economic remedies must be explicitly addressed and acknowledged in further research. If we want to pick the right narratives or constructs to add to and improve mainstream solutions for post-COVID-19 sustainability transformations, we need to do exploratory analyses.
- ii. Encouraging industry stakeholders to understand how they can incorporate the principles of industrial symbiosis into their processes is an important part of fostering circularity models and industrial symbiosis in their

operations. These narratives should be framed in terms of global net sustainability, whether they are used individually or together. A more holistic approach to environmental impact is needed when identifying and investigating undesirable or suboptimal outcomes.

- iii. There should be an emphasis on integrating multiple compatible solutions, such as circularity, bio-based and other conservation innovations, ecosystem stewardship, and nature-based solutions. Developing coherent decision-making strategies, actions, and indicators that take into account alternatives based on a variety of sustainability narratives.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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