
Unveiling the Relationship between Circular Economy and Energy Systems: Towards the Conceptual Framework of Circular Energy

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Abstract: Circular Economy and Energy Systems have emerged as two prominent and increasingly debated research domains over the last decade. Although these research domains have generally evolved along parallel trajectories, an emerging body of literature reveals interesting relationships between them. These relationships suggest the need for a unified conceptual framework capable of capturing the dynamics of Energy Systems through the lens of Circular Economy, or vice versa. Building on this premise and through a systematic literature review, this paper investigates the relationships between Circular Economy principles and Energy Systems characteristics, aiming to advance the conceptual framework of Circular Energy. The study frames Circular Energy as a system-level concept that goes beyond energy production and transition, focusing instead on the circularity of energy flows. The proposed framework highlights the mechanisms through which circular strategies interact with energy flow systems and clarifies the contextual enabling the emergence of a Circular Energy configuration.

Keywords: Circular Economy; Energy Systems; Circular Energy; Energy flows; Energy efficiency; Energy cascading; Circular business models

1 Introduction

Over the last decades, Circular Economy and Energy Systems have emerged as two prominent and largely independent research domains. On the one hand, Circular Economy focuses on replacing linear take–make–dispose models with closed-loop systems that retain resources in productive use for longer periods, thereby increasing value creation and reducing waste (Urbinati et al., 2017). Circular Economy initiatives increasingly emphasize resource efficiency, recovery and industrial symbiosis, yet energy is often treated as a secondary component rather than a core circulating resource (Fraccascia et al., 2021). On the other hand, the concept of Energy Systems addresses the production,

conversion, delivery and use of energy to meet societal needs within complex socio-technical structures (Groscurth et al., 1995). Current Energy Systems are still predominantly linear, characterized by centralized infrastructures, fossil fuel dependency and significant energy losses through exhausts, chimneys and inefficient distribution networks (Önnered & Bravić, 2024).

Given their parallel development, the integration between Circular Economy and Energy Systems remains limited and fragmented. Indeed, a few scientific evidence shows how Circular Economy principles, such as resource efficiency, recovery and industrial symbiosis, can play a significant role in shaping energy-related practices, particularly through waste heat reuse, fuel substitution and bioenergy production (Fraccascia et al., 2021). In addition, existing literature shows that large amounts of energy are currently dispersed into the environment and could be recaptured through cascading, heat exchangers and cross-sectoral integration (Önnered & Bravić, 2024). Accordingly, emerging business models, such as the one of energy-as-a-service, can support more service-oriented and decentralized energy configurations, although they remain conceptually fragmented (Muthumala et al., 2022).

The study adopts a systematic literature review methodology following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines, which ensure transparent, complete and reproducible reporting (Liberati et al., 2009). Academic articles were collected from the major scientific database, i.e. Scopus, combining keywords related to Circular Economy and Energy Systems through Boolean operators. The final sample consisted of peer-reviewed journal articles published in English and belonging to the Business & Management area.

This paper aims to contribute to the management literature by integrating the fragmented scientific evidence between Circular Economy and Energy Systems literatures. While previous research addressed Circular Economy mainly through business models and mass flows (Urbinati et al., 2017) and Energy Systems through technical and linear economic approaches (Groscurth et al., 1995), this study positions energy as a circulating flow rather than a linear input and introduces a system-level lens that captures cross-sectoral energy flows. In addition, by advancing the Circular Energy concept, the study offers a novel contribution to sustainability-oriented innovation management studies.

This paper is structured as follows. After the Introduction, the conceptual foundations of both Circular Economy and Energy Systems are presented in Section 2. In Section 3, the research methodology is described, detailing the systematic literature review process. Section 4 presents the results of our study. In Section 5, the paper concludes by summarizing the main findings, outlining theoretical and managerial implications and suggesting directions for future research.

2. Topics conceptualization

This research is grounded on two fundamental research domains: Circular Economy and Energy Systems. The following subsections outline and examine their core principles and underlying characteristics, with particular attention to their integration within the hybrid perspective of Circular Energy.

Circular Economy: definition and key principles

The Circular Economy (CE) literature defines CE as a transformation of traditional linear production systems into closed-loop models that enable the reuse and prolonged circulation of resources (Urbanati et al., 2017). Several influential organizations are committed to spreading CE principles. For example, the Ellen MacArthur Foundation defines CE as “an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and aims for the elimination of waste through the superior design of materials, products, systems and, within this, business models” (Ellen MacArthur Foundation, 2013). This definition emphasizes the systemic nature of CE and its focus on regenerative design, renewable energy and waste elimination through improved product and system design (Geissdoerfer et al., 2017).

At the macro level, CE is strongly connected with the concept of sustainability (Kristensen & Mosgaard, 2020; Merli et al., 2018). Their relationship involves partial alignment, synergies and trade-offs: although often conflated, CE primarily focuses on resource efficiency and economic value creation, while sustainability encompasses broader social and environmental objectives and explicitly addresses trade-offs with economic growth; consequently, CE can support sustainability goals but may also produce adverse effects if pursued without adequate social and environmental consideration (Pieroni et al., 2019).

At the meso level, the Circular Economy is interpreted from a systemic and inter-organizational perspective, focusing on the coordination of firms and stakeholders within industrial and regional systems. This level emphasizes eco-industrial parks and industrial symbiosis initiatives, where geographically proximate organizations collaborate to optimize resource use, exchange by-products and energy flows and enhance collective circular performance across value networks (Kirchherr et al., 2017).

At the micro level, research has largely focused on business models, material flows, customer value propositions and value networks, highlighting how firms reorganize internal activities and supply chain relationships to implement circularity. A significant portion of the literature emphasizes the role of innovative business models in facilitating the transition towards circular strategies, which reflect the operationalization of CE at the micro-level (Lewandowski, 2016; Suchek et al., 2021).

Research shows that recycling is the most mentioned CE strategy, featured in 79% of definitions, while reuse (74–75%) and reduce (54–55%) are also frequently mentioned (Kirchherr et al., 2017). To further structure CE strategies, a comprehensive framework, known as R-strategies, has been developed that identifies ten main key actions to apply CE principles (Potting et al., 2017). These strategies are synthesized in Table 1.

Table 1 R-strategies of Circular Economy (Morseletto, 2020).

<i>Objectives</i>	<i>Strategies</i>	<i>Description</i>
Smarter product use and manufacture	R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product

	R1 Rethink	Make product use more intensive (e.g. through sharing products or by putting multi-functional products on the market)
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources.
Extend lifespan of product and its parts	R3 Re-use	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function.
	R4 Repair	Repair and maintenance of defective product so it can be used with its original function
	R5 Refurbish	Restore an old product and bring it up to date
	R6 Remanufacture	Use parts of discarded product in a new product with the same function
	R7 Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9 Recover	Incineration of materials with energy recovery

Energy Systems: socio-technical configurations and main characteristics

Energy Systems can be broadly defined as complex socio-technical configurations composed of natural resources, technologies, infrastructures, institutions and social practices that enable the production, conversion, distribution and use of energy (Allwood et al., 2014; Orecchini, 2006). Rather than being purely technical arrangements, Energy Systems emerge from the interaction between physical components and social, economic and institutional structures, which jointly shape how energy is generated and consumed (Akella et al., 2009). The systemic perspective behind the anatomy of Energy Systems highlights the interdependencies among actors, technologies and governance mechanisms, as well as the central role of energy flows in sustaining economic and societal activities.

Energy Systems can be further characterized according to the types of energy they produce or transform, their infrastructural configuration, modes of energy transport and distribution and their environmental implications. From a functional perspective, Energy Systems manage multiple energy forms — including thermal, electrical, chemical, nuclear and mechanical energy — which are converted and exchanged across interconnected processes (Gerard M. Crawley, 2013). Structurally, they may evolve from linear and centralized architectures toward increasingly decentralized and complex configurations, reflecting technological innovation and changing governance models (Li et al., 2023a). Energy transport can rely either on continuous network infrastructures, such as electricity grids and gas pipelines, or on more fragmented systems based on transportable energy carriers like hydrogen or synthetic fuels (Abdin et al., 2020). Moreover, Energy Systems differ significantly in their environmental impact depending on the predominance of renewable or non-renewable energy sources, which strongly influences their sustainability performance and transition pathways (Wang et al., 2019).

Historically, Energy Systems have been dominated by fossil fuel-based resources and large-scale, centralized infrastructures; this configuration has contributed to significant path dependencies and lock-in effects, making structural transformations towards alternative energy pathways particularly challenging (Önnered & Bravić, 2024). Such lock-ins are reinforced by long investment cycles, established regulatory frameworks and existing business interests, which collectively slow down the diffusion of innovative technologies and alternative system architectures (Trencher et al., 2020). At the same time, global energy demand has increased dramatically: global energy consumption more than doubled between 1960 and 2014, driven by population growth and rising per capita energy use, and it continues to expand, particularly in emerging economies (Ganivet, 2020).

Energy Systems can also be interpreted through a macro-meso-micro perspective, which offers a useful lens for capturing their socio-technical complexity across different analytical scales (Schenk et al., 2007). At the macro level, they appear as highly aggregated configurations, whose overall functioning is shaped by broad policy orientations and long-term structural dynamics. From this perspective, system transformation depends on the co-evolution of households, firms, governments, technologies and ecosystems within wider social, economic, technological and ecological conditions (Li et al., 2023b) which is closely linked to the integrated socioeconomic, environmental and energy policies that steer the direction of the transition (Chatzinikolaou & Vladoš, 2025). At the meso level, the focus moves to the intermediate domain in which technologies, infrastructures, institutions and groups of actors become dynamically interconnected, generating interdependencies, feedback and organized sectoral patterns (Schenk et al., 2007). This is also the level at which micro-level fluctuations are translated into broader systemic reconfiguration through self-organizing and adaptive processes and where regional energy ecosystems, localized governance, innovation hubs, industrial clusters and energy communities concretely emerge (Chatzinikolaou & Vladoš, 2025). At the micro level, Energy Systems are expressed through localized actors and basic units, such as firms, consumers, devices and specific technologies, whose behaviours are heterogeneous, context-dependent and partly uncertain. More specifically, this is the scale at which variation, path dependence and stochastic change originate (Li et al., 2023b), as well as the level in which firm strategies, technologies and managerial practices shape adaptive responses to transition pressures.

Building on these premises, the main characteristics of Energy Systems can be operationalized as in the following Table 2.

Table 2 Main characteristics of Energy Systems.

<i>Perspective</i>	<i>Characteristics</i>	<i>Description</i>
Macro	<ul style="list-style-type: none"> Aggregated system configuration Energy mix and environmental implications Policy and transition pathways Long-term structural dynamics 	Energy Systems are shaped by long-term transition pathways, policy conditions and the predominance of renewable or non-renewable energy sources (Chatzinikolaou & Vladoš, 2025; Wang et al., 2019)

Meso	<p>Energy infrastructures</p> <p>Centralized vs decentralized configurations</p> <p>Regional energy ecosystems</p> <p>Systems interdependences and feedback</p>	<p>Energy Systems rely on infrastructural and organizational architectures, including centralized or distributed configurations, grids, pipelines and transportable energy carriers (Abdin et al., 2020; Schenk et al., 2007; Vanek et al., 2008)</p>
Micro	<p>Localized actors and technologies</p> <p>Energy management and efficiency</p> <p>Process-level energy conversion and use across multiple energy forms (thermal, electrical, chemical, mechanical and nuclear)</p>	<p>Energy Systems produce, convert, store and use multiple forms of energy through localized technological units (Gerard M. Crawley, 2013; Schenk et al., 2007)</p>

Hybrid perspective of Circular Energy

The Circular Economy literature has traditionally focused on material flows and product circulation within economic systems, while energy has often been treated as an enabling input rather than as a flow subject to circular strategies. As a result, the research discussion about Circular Economy has only marginally addressed energy flows generated by industrial and residential activities and their potential recirculation within circular business models. Existing studies on the contribution of the Circular Economy to the energy production and transition has largely concentrated on isolated applications, particularly waste-to-energy solutions such as waste heat recovery, municipal solid waste valorisation and biowaste-to-energy pathways (Andrade & Selosse, 2024). In addition, energy-based industrial symbiosis has been identified as an effective approach to reducing the reliance on traditional fuels by enabling the reuse of waste energy and by-products across industrial processes (Liu et al., 2017). In this context, energy cascading, fuel substitution and bioenergy production allow excess or residual energy from one process to be valorised in another, thereby reducing overall primary energy demand (Fraccascia et al., 2021). Within this emerging stream, applications have been explored at different scales, including urban systems (Su & Urban, 2021) and residential sector decarbonization (Businge & Mazzoleni, 2023).

Building on the research at the intersection between Circular Economy and Energy Systems, the paper is aimed to conceptualise in a framework the hybrid perspective of Circular Energy, as also illustrated in Figure 1, which represents the systemic integration of the two research domains under investigation.

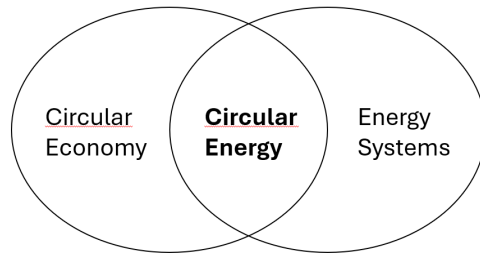


Figure 1 Hybrid perspective of Circular Energy.

The above perspective provides the theoretical foundation for the following systematic literature review and will guide the development of the Circular Energy framework.

3. Research methodology

To investigate the relationship between Circular Economy and Energy Systems, a systematic literature review was carried out adopting the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) procedure (Liberati et al., 2009). Systematic literature reviews rely on a transparent and replicable procedure that enables an objective comparison and synthesis of existing studies, thereby strengthening the robustness of knowledge development within a research domain (Tranfield et al., 2003).

Data collection

First, a systematic search was performed using the Scopus database, selected as the primary source due to its extensive journal coverage and its recognition as one of the most comprehensive citation databases available (Farah et al., 2026). An initial set of keywords was derived from existing literature reviews on Circular Economy and Energy Systems. Different combinations and synonyms of keywords related to these two approaches – such as “circular”, “economy”, “energy” and “systems” – were formulated using Boolean operators.

The restriction to the business subject area was intentionally adopted to ensure alignment with the managerial and system-level perspective of this study. To ensure both quality and relevance, the search results were restricted to peer-reviewed journal articles and review papers published in English, without temporal limitations. The data collection phase was completed at the end of February 2026. All retrieved articles were then independently screened by the authors to assess their alignment with the research objectives; studies not explicitly addressing the relationship between Circular Economy and Energy Systems were excluded. More specifically, studies were included if they (i) explicitly addressed the intersection between Circular Economy and Energy Systems, (ii) adopted a managerial, organizational or system-level perspective and (iii) provided conceptual or empirical insights into the circularity of energy flows.

The screening process followed a sequential approach: titles and abstracts were first examined, followed by full-text analysis when eligibility could not be determined at the preliminary stage. In the second stage, hand-searching was conducted to reduce the risk of omitting relevant contributions, particularly those grounded in alternative theoretical or methodological perspectives. Given the practical relevance of the investigated topic, this complementary step allowed the inclusion of additional sources, thereby strengthening both analytical rigor and theoretical plurality. The overall data collection procedure is illustrated in Figure 2.

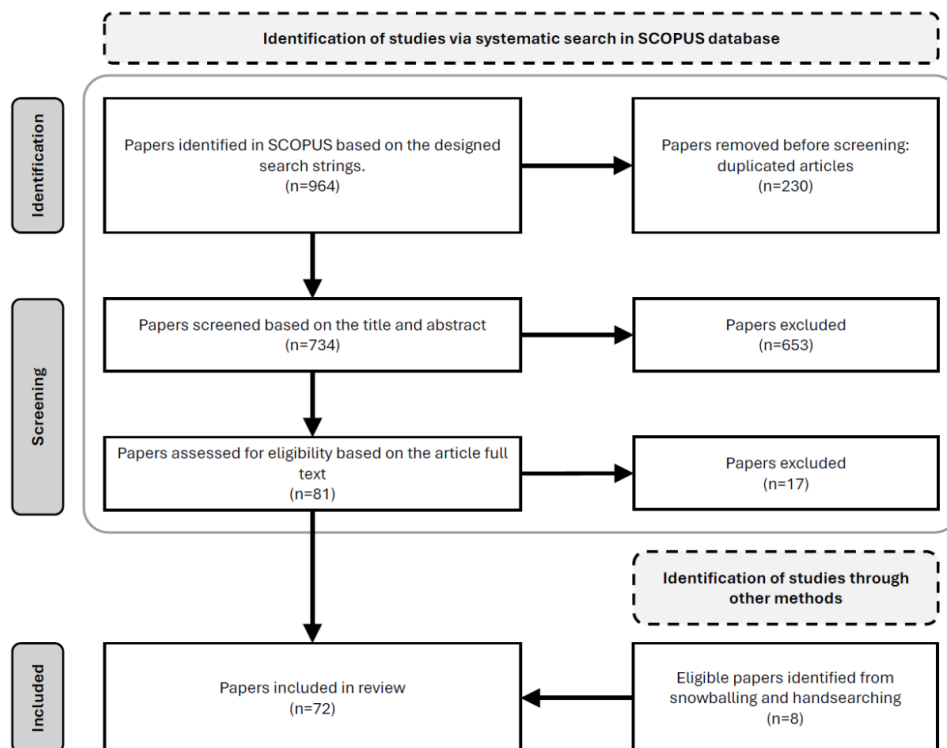


Figure 2 Data collection process based on PRISMA procedure.

The systematic search conducted in the Scopus database yielded an initial dataset of 964 documents identified through the designed search strings. Overall, the selection procedure led to a final sample of 72 articles included in the review.

An overview of the collected data

A first descriptive insight emerges from the temporal distribution of publications, as reported in Figure 3, which highlights a clear and progressive increase in scholarly attention towards the intersection between Circular Economy and Energy Systems starting from 2016. The observed acceleration reflects the growing recognition of energy as a strategic resource within circular configurations and the increasing relevance of systemic sustainability transitions in both academic and policy debates (Ng & Chen, 2026).

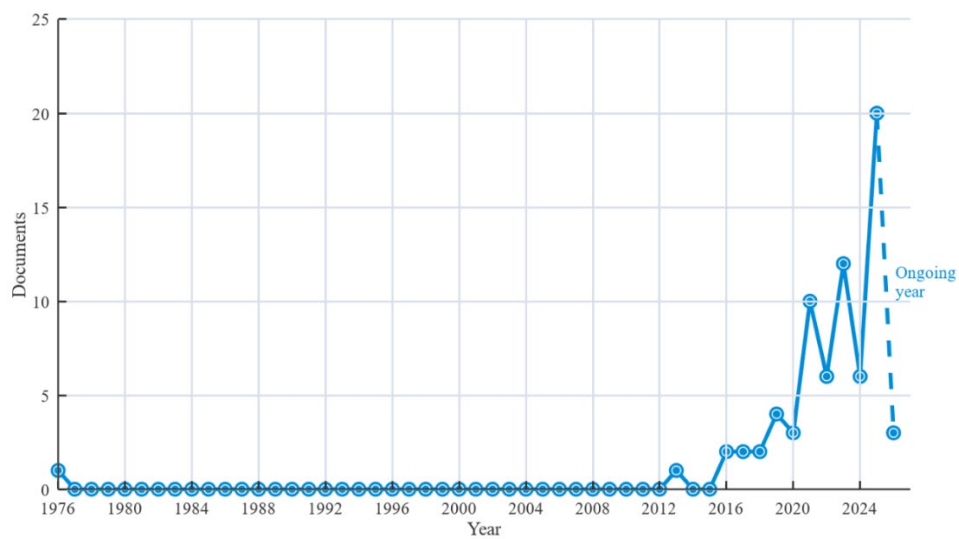


Figure 3 Historical series of published papers in Circular Economy and Energy Systems research domains.

From a geographical perspective (Figure 4), the scientific production is predominantly concentrated in China, the European Union and India.

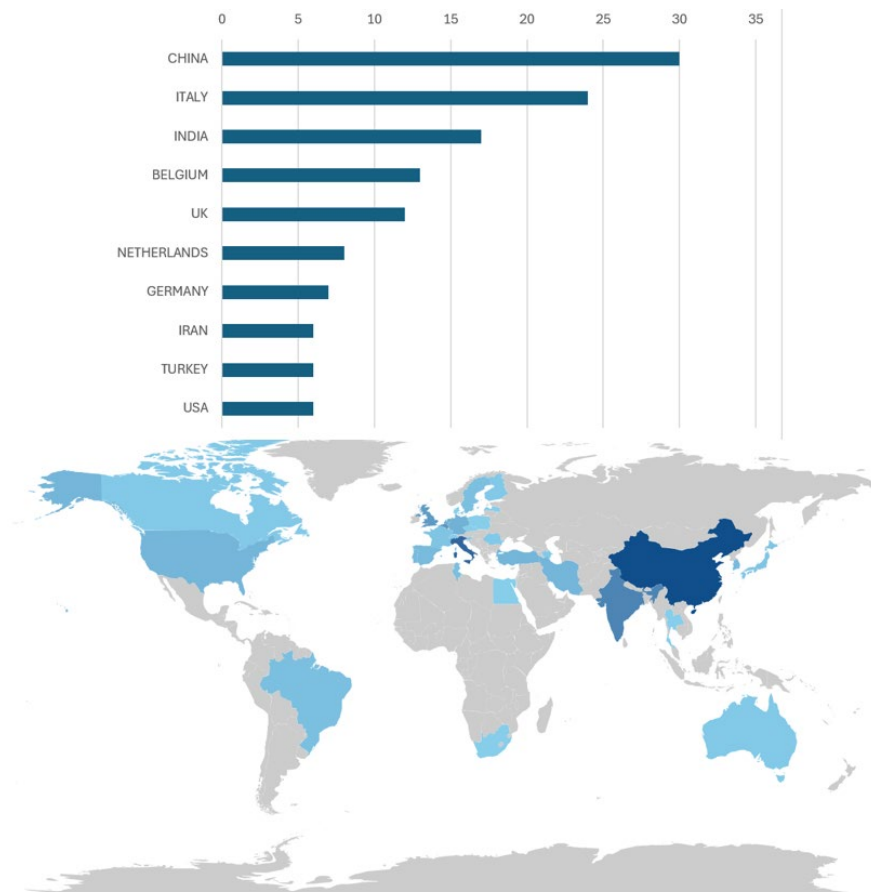


Figure 4 Country scientific production.

Regarding publication outlets (Figure 5), the analysis reveals a marked concentration of contributions in the “Journal of Cleaner Production”, which emerges as the dominant journal within the dataset.

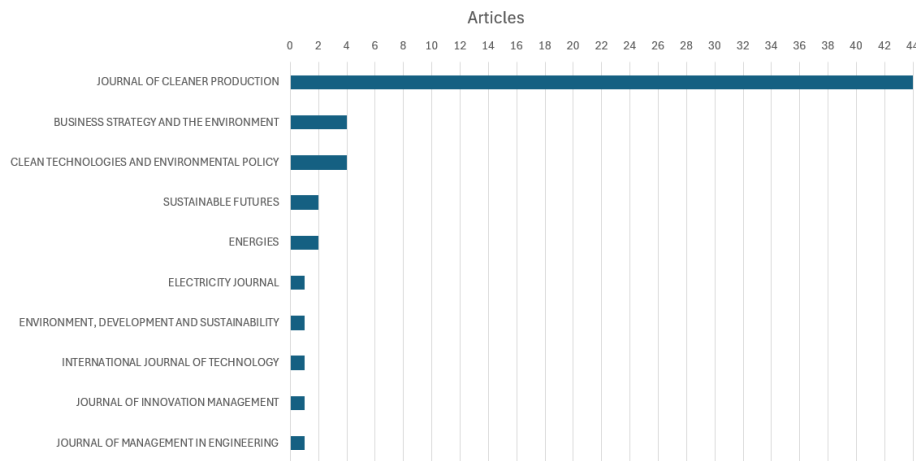


Figure 5 Top ten journals.

Finally, the VOSviewer keyword co-occurrence analysis reported in Figure 6 reveals four main thematic clusters, capturing the multidimensional nature of the Circular Economy–Energy Systems nexus. More specifically, the map highlights a cluster centred on waste management and waste-to-energy, a second one related to renewable energy and energy transition, a third focused on sustainability and a fourth revolving around environmental impact.

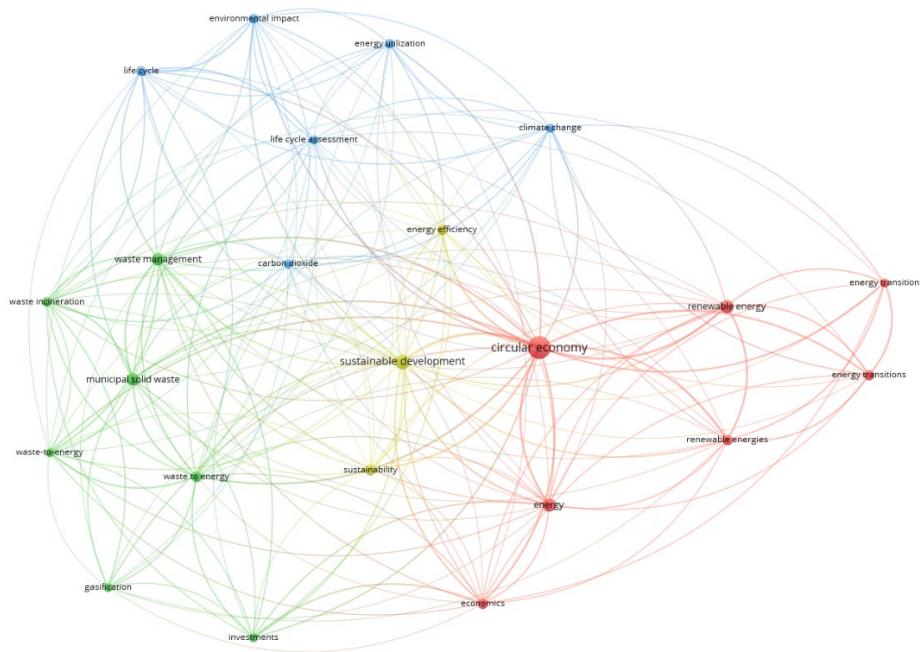


Figure 6 Co-occurrence network of keywords in the Circular Economy and Energy Systems research domains.

4. Results

This section presents the results of the systematic literature review, organized according to the hybrid perspective of Circular Energy introduced in Figure 1. The findings are articulated across three analytical perspectives – macro, meso and micro – which represent the levels through which both Circular Economy principles and Energy Systems characteristics can be observed.

Macro perspective

The macro perspective represents the institutional and infrastructural space where Circular Economy principles and Energy Systems characteristics converge, shaping how energy flows are produced, shared and reintegrated across sectors. Historically, Energy Systems have largely evolved according to a linear logic based on the extraction of primary resources, centralized energy production and final consumption (Önnered & Bravić, 2024). From a Circular Economy perspective, this configuration can be reconsidered as a broader resource metabolism in which energy flows are not only consumed but can also be redistributed, cascaded and valorized across interconnected sectors. In this sense, Circular Energy reflects a systemic transformation of Energy Systems in which energy is treated as a circulating flow within the broader economic system.

One of the earliest and most widely discussed points of interaction between Circular Economy and Energy Systems emerges in the institutional coupling of waste management and energy production (Gatto, 2023). Over the past decades, several countries have progressively promoted Waste-to-Energy pathways capable of converting residual municipal solid waste into usable energy carriers. Technologies such as incineration with heat recovery, pyrolysis and gasification have therefore been deployed within broader policy frameworks aimed at reducing landfill dependence while simultaneously contributing to energy supply (Antunes & Ha L Ter, 1976; Haraguchi et al., 2019). Nevertheless, from a Circular Economy perspective, Waste-to-Energy remains primarily a downstream recovery strategy operating at the end-of-life stage of products. Rather than reorganizing the systemic circulation of energy across economic sectors, it extracts residual energy from material flows that have already exited productive cycles (Bosmans et al., 2013).

Recent research highlights the role of Circular Economy policies in supporting the broader decarbonization and restructuring of Energy Systems. In particular, the development of renewable energy infrastructures and alternative energy carriers, such as hydrogen and methanol (Hampp et al., 2023) has been increasingly discussed as a key mechanism for enabling the circulation of energy across industrial sectors. Through sector coupling, renewable energy can be transferred and reused across multiple sectors via intermediate energy carriers, thereby enabling a more flexible and circular usage of energy flows within the broader Energy System. For instance, recent studies emphasize the strategic role of green hydrogen in decarbonizing energy-intensive industries when supported by coordinated investments in infrastructure development, research and regulatory frameworks (Baglieri, 2024). These developments indicate a structural transition in which Energy Systems evolve from linear supply infrastructures into circulatory architectures, a

transformation largely shaped by policy frameworks and infrastructure investments that enable the redistribution and cascading of energy across sectors.

The literature highlights several systemic barriers that hinder the large-scale emergence of Circular Energy configurations at the macro perspective. A first limitation concerns the infrastructural and technological lock-ins embedded in existing Energy Systems, which have historically evolved around centralized production infrastructures and long-lived capital assets. These structural characteristics generate strong path dependencies, making the reconfiguration of energy infrastructures towards cross-sectoral energy flows particularly difficult (Seto et al., 2016). The circulation of energy flows requires substantial investments in new infrastructures, storage systems and the production of energy carriers, while existing regulatory frameworks and market mechanisms are typically designed for linear energy supply models, thereby limiting the scalability of circular energy practices (A. Karaeva et al., 2023). Furthermore, the transition towards Circular Energy systems must be understood within the broader dynamics of socio-technical energy transitions, where technological innovation interacts with institutional structures, policy frameworks and market arrangements. These complex interactions contribute to slow transformation processes and require significant institutional adaptation before new systemic configurations can fully emerge (Sovacool, 2016).

Meso perspective

While the macro perspective concerns the institutional and infrastructural conditions that shape the transition, the meso perspective is the scale at which circularity becomes operational through collaboration among firms, communities, utilities, intermediaries and local networks. In this sense, energy is no longer interpreted as a linear input to be supplied, consumed and dissipated, but as a flow that can be exchanged, cascaded, recovered, shared and managed collectively across interconnected organizations and users (Önnered, 2023).

A first and foundational expression of this meso convergence is represented by industrial symbiosis, especially when symbiotic exchanges involve not only materials and by-products, but also heat, steam, process energy and residual energy streams. In these configurations, the circularity of energy does not depend exclusively on technological recoverability, but on the possibility of aligning heterogeneous demand profiles, spatial proximity, temporal synchronization and governance arrangements among multiple actors. The literature suggests that industrial symbiosis can significantly reduce primary energy demand and fossil fuel dependence, while improving energy security and resource productivity across industrial ecosystems (Fraccascia et al., 2021).

More than a mere outcome of industrial symbiosis, energy cascading constitutes an autonomous meso-level mechanism of Circular Energy, through which residual energy is strategically redirected across organizations, processes and local uses according to its quality, timing and functional suitability, thus allowing energy value to persist within coordinated territorial systems rather than being prematurely dissipated.

This inter-organizational dimension is further reinforced by the fact that at the meso-level Circular Energy requires enabling conditions that are not purely technical. Financial constraints, technological uncertainty, fragmented regulation, institutional inertia and limited coordination capabilities still act as major barriers to the development of robust energy exchange networks (Fraccascia et al., 2021). The challenge, therefore, is not only

to recover energy, but to organize the relationships, incentives and infrastructures that make such recovery stable, scalable and economically viable. From this viewpoint, Circular Energy can be interpreted as a governance problem as much as an engineering one.

A further and particularly promising expression of the intersection between Circular Economy and Energy Systems at the meso level is represented by smart energy grids. These grid configurations can be understood as advanced, digitally enabled energy networks that rely on real-time data, automated control and bidirectional communication to coordinate the generation, distribution, storage and consumption of energy. Smart energy grids constitute the enabling infrastructure through which the circularity of energy flows can be organized across multiple actors and territorial nodes. Indeed, by connecting utilities, firms, communities, prosumers and distributed assets within responsive and decentralized configurations, they allow energy surpluses to be valorized locally, losses to be reduced, renewable intermittency to be balanced and flexibility to be shared across the system.

Within this broader inter-organizational space, community ownership models represent one of the clearest expressions of Circular Energy at the meso level. In these arrangements, energy assets are collectively owned, governed and managed within local value networks, enabling a more equitable distribution of costs, risks and benefits. Their relevance lies in the fact that they embed energy circulation within shared governance structures, thus extending the notion of circularity beyond resource recirculation alone and linking it to participatory governance and local resilience (Boulanger et al., 2021).

Alongside these community-based forms, the intersection between the meso and micro perspectives reveals distributed energy coordination models that bridge inter-organizational configurations and localized energy management. A particularly relevant case is represented by aggregators, which pool distributed energy resources and manage them as coordinated portfolios. By orchestrating distributed generation, storage and flexibility, aggregators enable the collective valorization of assets that would otherwise remain fragmented, thereby increasing the circular use of locally available energy resources and reducing dissipation across the network (Leewiraphan et al., 2024).

Micro perspective

While the macro and meso perspectives address respectively institutional infrastructures and inter-organizational configurations, the micro dimension concerns how firms organize their internal energy use, conversion processes, technological systems and service-based energy business models in ways that reduce dissipation and enhance the productive value of energy resources.

A key conceptual challenge arises at this level. Energy flows are governed by the fundamental laws of thermodynamics, which limit their circularity. In particular, the second law of thermodynamics implies that every energy conversion is irreversible and generates entropy, meaning that part of the useful energy is inevitably degraded into low-grade heat that can no longer perform work (Gerard M. Crawley, 2013). Consequently, energy cannot be perfectly recirculated within economic systems. This thermodynamic constraint creates a fundamental difference between material and energy circularity: several Circular Economy strategies originally developed for material flows therefore cannot be directly applied to energy systems. Strategies such as reuse, repair, refurbish,

remanufacture and repurpose rely on the persistence of a physical product whose functionality can be restored or extended. In the energy domain, however, the product is a flow that is irreversibly transformed during use.

Despite these constraints, existing literature suggests that several Circular Economy strategies can still be adapted to energy flows when interpreted through the lens of resource efficiency and process optimization (A. Karaeva et al., 2023). Five strategies — refuse, rethink, reduce, recycle and recover — appear particularly relevant for the energy sector. Refuse (R0) concerns the avoidance of unnecessary energy inputs through the redesign of processes or the substitution of fossil fuels with renewable sources. Rethink (R1) refers to the reconfiguration of production systems and energy use patterns to increase the productivity of energy inputs, for example through process integration or renewable self-generation. Reduce (R2) focuses on improving efficiency in energy production, conversion and consumption, thereby lowering the amount of primary energy required per unit of output. Finally, recycle (R8) and recover (R9) relate to the valorization of waste streams within energy systems, through the conversion of waste materials into energy carriers or the recovery of energy from waste streams such as in waste-to-energy processes.

Beyond the adaptation of R-strategies, an important micro perspective manifestation of Circular Energy concerns energy cascading within industrial processes. Energy cascading refers to the practice of redirecting residual energy generated in one stage of production to supply another process requiring a lower level of energy quality. This mechanism is particularly relevant in industrial environments, where thermodynamic transformations continuously degrade high-quality energy into lower-temperature heat that is often dissipated through exhaust gases, cooling systems or industrial chimneys. Empirical studies highlight the scale of dissipative energy flows in modern energy systems. It is estimated that around 72% of global primary energy consumption is lost after conversion, with a large share occurring as low-temperature waste heat (below 100 °C), particularly in electricity generation, transportation and industry (Forman et al., 2016). Importantly, the valorization of waste heat can also extend beyond the boundaries of a single firm. Residual industrial heat can be transferred to nearby buildings through district heating networks, enabling meso-level circular configurations in which industrial energy surpluses supply urban heating demand (Bühler et al., 2017). In this perspective, energy cascading connects the micro and meso perspectives of Circular Energy.

Closely related to cascading mechanisms is the broader theme of energy efficiency and demand-side optimization, which represents one of the most immediate expressions of Circular Energy at the micro level. Because energy cannot be perfectly recirculated, circularity often emerges through strategies aimed at minimizing unnecessary consumption and improving the productivity of energy inputs.

A further dimension of Circular Energy at the micro-level concerns the role of energy storage technologies, which introduce a temporal form of circulation within Energy Systems. Unlike materials, energy cannot be physically recirculated once used, but it can be temporarily accumulated and reintroduced into the system at a later moment. Storage technologies make this possible by capturing surplus energy that would otherwise be dissipated or curtailed and preserving it for future use (Zakeri & Syri, 2015). In this way, the energy flow is not immediately exhausted after production but is held within the system and released when demand arises: technologies such as batteries, thermal energy storage, hydrogen storage and pumped hydro systems therefore create a form of temporal

circularity, allowing the same energy to generate value across different moments in time rather than being consumed instantaneously.

Another major manifestation of Circular Energy at the micro perspective concerns the emergence of service-oriented energy business models, which originate at the intersection between localized energy management and meso-level community-based and inter-organizational configurations. In other words, the servitization of energy creates the organizational conditions through which circularity can extend from materials to energy flows. Within this logic, several emerging business models can be interpreted as concrete vehicles of Circular Energy, in particular: (i) energy-as-a-service (Muthumala et al., 2022), where providers deliver integrated energy solutions while retaining technical and operational responsibility; (ii) pay-as-you-go (Yadav et al., 2019), which enables incremental and flexible access to decentralized energy systems through service-based and digitally enabled payment arrangements; and (iii) rooftop-as-a-service (Leewiraphan et al., 2024), which allows users to access photovoltaic performance as a managed service rather than through direct asset ownership.

5. Conclusions

This paper addresses a central gap at the intersection between Circular Economy and Energy Systems, namely the lack of a unified explanation of how Circular Economy principles and Energy Systems characteristics intersect across energy flows, infrastructures, and related organizational configurations.

Through a systematic literature review, the paper advances Circular Energy as a multi-level configuration emerging from the interaction between Circular Economy principles and Energy Systems characteristics. More specifically, the study highlights how Circular Energy takes shape through enabling conditions at the macro perspective, orchestration mechanisms at the meso perspective and operational mechanisms at the micro perspective.

The paper contributes to Circular Economy literature by extending its analytical focus beyond material and product loops and by conceptualizing energy as a strategic flow of value whose circulation, coordination and productive extension deserve explicit theoretical attention, rather than being treated as a secondary enabling input (Fraccascia et al., 2021). At the same time, it contributes to Energy Systems literature by complementing predominantly technical and linear interpretations with a system-level and organizational perspective that highlights how institutional conditions, inter-organizational arrangements and firm-level practices shape the emergence of more circular energy dynamics (Önnered & Bravić, 2024). More broadly, the study shows the value of a business and management perspective for integrating these two research domains into a unified conceptual framework, since this perspective makes it possible to connect technologies and infrastructures with governance mechanisms, business models, coordination processes and strategic choices across macro, meso and micro levels. In this sense, the Circular Energy provides scholars with a common conceptual language through which the intersection between Circular Economy and Energy Systems can be interpreted not as a set of isolated technical applications, but as a multi-level process of systemic alignment through which energy flows are organized, valorised and progressively reoriented towards more circular configurations.

From a managerial perspective, the study highlights the need for firms, policymakers and infrastructure designers to move beyond isolated efficiency measures and promote coordinated strategies that align enabling conditions, inter-organizational orchestration and firm-level operational mechanisms for the emergence of Circular Energy. At the same time, this study has some limitations. The review focuses on English-language journal articles indexed in Scopus and mainly positioned within the business and management domain, thus ensuring coherence with the managerial orientation of the study while leaving aside potentially relevant contributions from adjacent technical and policy-oriented fields. Moreover, the research is conceptual and therefore calls for further empirical validation across sectors and territorial contexts. Overall, the paper suggests that the transition towards more sustainable systems requires not only cleaner energy production, but also a deeper rethinking of how energy is organized, circulated and valorised. In this sense, Circular Energy offers a promising lens for understanding and advancing the systemic transformation of Energy Systems through the principles of Circular Economy.

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