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Circular Economy Framework on the Solar Energy Industry: Unlocking the Potential Towards Circular Economy Transition

Dinar Ari Prasetyo*, Yuliani Dwi Lestari, Santi Novani

School of Business and Management, Institut Teknologi Bandung, Indonesia

Abstract *- The rapid expansion of the solar energy industry has led to increased resource consumption, waste generation, and carbon emissions. International Renewable Energy Agency, substantial volumes of annual waste from the solar energy industry are anticipated as early as the 2030s, potentially reaching 78 million tons by 2050. Transitioning to a Circular Economy (CE) represents a promising pathway to achieve long-term economic and environmental sustainability. However, advancing circularity within the solar energy sector remains complex and faces multiple challenges. This study seeks to identify potential for CE transition in the solar energy industry by analyzing topical research data using Boolean searches in the Scopus database, processed through VOSviewer for visualization. Network analysis reveals a framework comprising four interrelated clusters: emission reduction strategies (Cluster 1), end-of-life and waste management (Cluster 2), enabling governance and policy instruments (Cluster 3), and environmental assessment methodologies such as Life Cycle Assessment (Cluster 4). Density visualization indicates that only a limited number of keywords appear with high frequency, suggesting that the research field remains niche or emerging, with a specialized thematic focus. Meanwhile, overlay visualization points to the need for future research to examine the transition toward circularity in the solar energy sector through a product-based approach.*

Keywords *- Circular Economy, Solar Energy, Transition.*

I. INTRODUCTION

The energy transition has consistently been a prominent subject of discourse at recent state meetings. Nationally Determined Contributions (NDCs) submitted by numerous countries in accordance with international climate obligations under the COP21 Paris Agreement emphasize solar energy as a pivotal element of renewable energy expansion strategies, positioning solar as a primary alternative energy source for sustainable development. Driven by supportive regulations in numerous countries, solar photovoltaic deployment has witnessed a significant increase, with worldwide installed capacity tripling from 2018 to 2023, achieving unparalleled growth levels [1]. Escalating supply chain operations have increased resource consumption and therefore resulted in increased waste production and carbon emissions[2]. The International Renewable Energy Agency projects that significant quantities of annual waste from the solar energy sector, encompassing panels, batteries, and associated electrical equipment, may emerge as early as the 2030s, potentially escalating to 78 million tons by 2050.[3][4]. Specifically, an estimated 8 million tons of solar panels are expected to reach end-of-life by 2030, with the total projected to rise to approximately 80 million tons by 2050 [5]. The most promising strategy to achieve economic and environmental sustainability is to transition to a Circular Economy (CE) [6]. The concept of Circular Economy is based on a system of cradle-to-cradle processes, beginning with design and extending through production, distribution, consumption, and replication stages. In the renewable energy sector, particularly within the solar energy industry, the primary goal of a circular economy is to create closed loops of material flow throughout the entire economic system [7], [8]. However, the transition towards circularity in the solar photovoltaic (PV) sector faces several challenges, including issues in the supply chain such as material constraints, technology limitations, and methodologies, as well as behavioral factors among stakeholders compounded by ineffective stakeholder collaboration, limited coordination, and varying power-interest dynamics.[9], [10], [11]

This aim of this research is to explore the application of the Circular Economy Framework within the solar energy industry, with the objective of assessing the potential for transitioning to a circular economy in the sector. Additionally, the study seeks to identify the challenges and opportunities associated with implementing the Circular Economy in the solar energy industry. This study will examine prior research that integrates the Circular Economy Framework inside the solar energy sector, employing co-occurrence analysis to determine significant themes and insights. This study will elucidate opportunities for future research by analyzing the current literature.

*Corresponding author. Email: dinar_prasetyo@sbm-itb.ac.id

II. LITERATURE REVIEW

Over the past decade, research on the circular economy has grown substantially, driven by a shift away from the linear economic model and closely aligned with global agendas such as the Sustainable Development Goals (SDGs), particularly in promoting sustainable consumption and production, waste management, and resource efficiency [12], [13]. Circular economy practices throughout supply chains must strategically harness technological innovation to drive resource conservation while generating value across the triple bottom line of economic performance, social responsibility, and environmental sustainability [14]. Initially based on the three core principles of reduce (minimizing the use of primary resources), reuse (utilizing by-products across production stages), and recycle (reprocessing materials into the production cycle), the circular economy framework has since evolved into a comprehensive 9R model: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover [15], [16]. The adoption of the circular economy framework in the solar energy sector demands a comprehensive evaluation of the relevance of circular economy objectives, considering the viewpoints and interests of all pertinent stakeholders within the industry.[11]

To assure research rigor, the author systematically initiates the literature review by Boolean searching using keywords that relates to Circular Economy and Solar Energy. This study is using Scopus database in order to get the best peer review literature of previous research. The data are further analyzed using the co-occurrence method in VOS Viewer software to examine the relationships between articles and the approaches taken by prior scholars on the research topic. VOS viewer is a software application developed for the creation and visualization of bibliometric maps, facilitating in-depth analysis of maps derived from co-citation, keywords, and co-occurrence data, especially advantageous for maps with large numbers of items[17]. The keyword used by author is **"circular economy"** AND **"solar energy"**. Circular economy is a multidisciplinary topic, so the choosing of the keywords is one of the boundaries to keep the scope relevancy of this study. The author subsequently restricts the scope of analysis to publications within selected subject areas, namely *Energy, Social Sciences, Business, Management and Accounting, Economics, Econometrics and Finance, and Decision Sciences—in alignment with the cluster results identified through the mapping analysis.*

III. ANALYSIS AND RESULT

To date, the result from Boolean searching of the keywords in Scopus database to date shows 249 documents, the majority of publications are articles, comprising 55.02% of the total, followed by reviews at 20.48%, conference papers at 11.65%, and book chapters at 10.84%. The top three subject categories contributing to the literature are Energy with 119 publications (20.77%), followed by Environmental Science with 111 publications (19.37%), and Engineering with 92 publications (16.06%). In contrast, subject areas such as Social Sciences, Business, Management and Accounting, Economics, Econometrics and Finance, and Decision Sciences appear to be comparatively underrepresented in the results.

The publication years range from 2009 to 2025, with the highest volume recorded in 2024; however, projections suggest that 2025 may surpass this figure, indicating a continued upward trend in the popularity of this research theme. Top countries in publishing this topic are India (40 documents), Spain (29), United Kingdom (26), China (25), and United States (20). While the sources in publishing the articles are Solar Energy (160 documents), Circular Economy (151), Sustainable Development (61), Solar Power Generation (42), and Sustainability (42).

The initial set of 249 documents was subsequently refined to include only English-language articles and limited to the subject categories of Energy, Social Sciences, Business, Management and Accounting, Economics, Econometrics and Finance, and Decision Sciences, resulting in a final dataset of 146 documents selected for identification through the mapping analysis.The 146 documents were subsequently extracted and analyzed using VOSviewer software to generate a clustered co-occurrence map of author keywords. From a total of 1,523 keywords, 72 met the minimum threshold of appearing at least five times. Following the elimination of irrelevant terms and those with low link strength, 54 keywords (as presented in Table 1) were retained and mapped into four distinct clusters (Figure 1).

The data from the VOS viewer software illustrates color clustering of terms relevant to circular economy study, highlighting several themes correlated with solar energy and their relationships within the literature. The data reveals that research on the circular economy within the solar energy sector is predominantly centered on sustainable development. Each cluster represents a different aspect of the study of circular economy concepts, particularly within the context of solar energy

A. NETWORK VISUALIZATION

To explain the network visualization of the four clusters presented in Figure 1, a descriptive analysis will be conducted using VOSviewer, supported by an interpretation of the visualized co-occurrence of keywords.

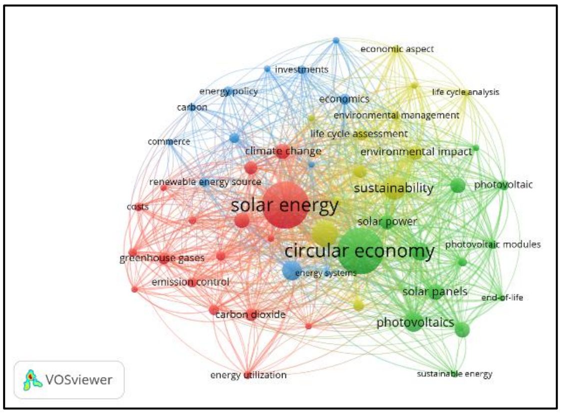

Figure 1 Network Visualization

Cluster 1 with the red color shows the keywords related to Renewable energy, carbon emissions, energy efficiency, and climate change. The high occurrence of key keywords such as solar energy, renewable energy, greenhouse gases, carbon footprint, and energy efficiency reflects a concentrated research focus on the role of circular economy practices in mitigating emissions and enhancing energy efficiency.

Table 1 Keywords Results from Co-Occurrence Analysis

Clusters (color)	Keywords	Co-Occurrence Results		
		Occurrence	Link	Link Strength
Cluster 1 (red)	Bioenergy	5	24	33
	Carbon dioxide	12	32	81
	Carbon footprint	8	27	54
	Climate change	16	45	110
	Costs	7	25	42
	Emission control	9	29	56
	Energy efficiency	9	26	45
	Energy utilization	6	22	33
	Environmental	6	20	42
	Gas emissions	7	29	61
	Geothermal energy	5	20	34
	Global warming	13	39	88
	Greenhouse gases	11	34	84
	Renewable energy	17	38	85
	Solar energy	90	53	494
	Solar power plants	5	29	40
	Waste disposal	5	27	40
Cluster 2 (green)	Circular economy	88	53	413
	End of lives	16	31	102
	End-of-life	5	24	51
	Photovoltaic (PV)	9	29	69
	PV Modules	7	29	67
	PV system	7	33	64
	Photovoltaics	24	40	148
	Recycling	22	41	163
	Solar panels	18	30	93
	Solar photovoltaics	5	22	38
	Solar power	15	43	109
	Sustainable energy	5	15	24
	Waste management	16	36	105
Cluster 3 (blue)	Carbon	6	20	36
	Commerce	5	17	24
	Decarbonisation	5	24	36
	Decision making	5	20	34
	Economics	10	31	69
	Energy	24	45	137
	Energy policy	8	26	44
	Energy systems	5	20	28
	Energy transitions	5	23	33
	Fossil fuels	9	38	58
	Investments	7	27	51
	RE source	7	23	34
Cluster 4 (yellow)	Electricity generation	5	26	37
	Energy storage	10	33	73
	Environmental impact	15	44	140
	Env- management	7	34	58
	Env -sustainability	5	25	53
	Life cycle	13	44	120
	Life cycle analysis	5	23	45
	Life cycle assessment	11	31	69
	Sustainability	31	48	189
	Sustainable Dev-	37	52	235

Cluster 2 with the green color shows the keywords related to Circular economy, photovoltaic (PV) technologies, life cycle, waste, and recycling. This cluster highlights a significant concentration of research focused on the application of circular economy principles within solar energy systems, particularly in relation to photovoltaic (PV) technologies. The prominence of terms such as recycling and waste management underscores the growing importance of end-of-life strategies for solar panels. The high link strengths associated with circular economy (413) and recycling (163) reflect a well-established research domain centered on sustainable material flows and policy-driven approaches to waste reduction in the context of the renewable energy transition.

Cluster 3 with the blue color shows the keywords related to Decarbonization, energy policy, economic instruments, and carbon management. This cluster focuses on the policy and economic dimensions of transitioning toward low-carbon energy systems. Keywords such as energy policy, investments, and commerce reflect the role of governance frameworks and market mechanisms in supporting circular economy practices. It emphasizes that circularity in the energy sector is not purely technological but also deeply embedded in macroeconomic strategies and regulatory agendas.

Cluster 4 with the yellow color shows the keywords related to environmental impact analysis, system efficiency, and life cycle thinking. This cluster underscores the significance of using Life Cycle Assessment (LCA) as a methodological tool to evaluate the sustainability of energy systems and circular economy strategies. Keywords like environmental impact and sustainable development (37 occurrences, link strength: 235) indicate a strong focus on data-driven assessments and holistic resource management frameworks. The high interconnectivity within this cluster highlights the integration of sustainability metrics into energy planning and circular design.

B. OVERLAY VISUALIZATION

The overlay visualization in VOS viewer emphasizes the publishing years of study. The gradient shading in the visualization represents the chronological distribution of publications, effectively illustrating the temporal evolution of research activity within the field. Darker tones correspond to earlier publications, enabling a clear interpretation of how scholarly focus has shifted and developed over time.

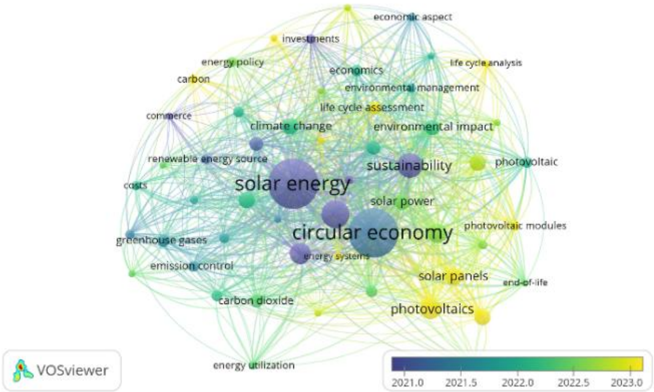

Figure 2 Overlay Visualization

Darker shades of blue in the visualization correspond to earlier publications, primarily from 2021 or before. Keywords such as carbon footprint, carbon dioxide, greenhouse gases, and emission control reflect long-standing environmental themes that have traditionally formed the foundation of scholarly discourse on circular economy and solar energy.

The green hue signifies keywords that have experienced increasing scholarly attention in recent years, representing emerging areas of interest that, while relatively new, have not yet reached the level of novelty associated with the most recent developments shown in bright yellow. These terms reflect key interdisciplinary concepts that connect long-standing environmental issues with evolving technological advancements. Notable keywords such as sustainability, solar power, solar energy systems, and environmental impact illustrate their role in linking foundational research themes with emerging innovations in the field.

The lighter shades, particularly yellow, indicate more recent research activity, with keywords such as photovoltaics, solar panels, end-of-life, and photovoltaic modules pointing to a rising focus on both the technical and socio-environmental dimensions of the circular economy transition in solar PV products. These terms highlight an increasing scholarly emphasis on lifecycle management and sustainability within circular economy frameworks applied to solar technologies.

C. DENSITY VISUALIZATION

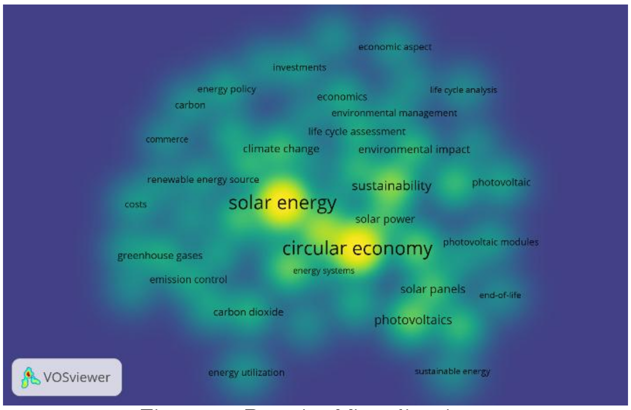

Figure 3 Density Visualization

The density visualization generated by VOSviewer offers a clear depiction of the prominence and distribution of keywords within the research corpus. Variations in shading (ranging from lighter to darker areas) indicate differing levels of keyword frequency, effectively illustrating the intensity of scholarly focus across thematic areas represented in the data.

Lighter shades, particularly yellow, denote high-frequency keywords within the dataset. Apart from circular economy and solar energy, few terms fall into this high-density category, suggesting that current research on this topic remains relatively niche or emerging topics or segmented in focus. Nevertheless, keywords such as sustainability and photovoltaics also emerge as prominent, reflecting their growing relevance within the broader discourse.

The green-shaded areas represent regions of moderate keyword density. Keywords such as photovoltaics, greenhouse gases, and environmental impact fall within this range, reflecting their consistent yet less dominant presence compared to high-density terms. These moderately frequent keywords highlight key interdisciplinary linkages, particularly in relation to environmental management, life cycle assessment, and renewable energy systems.

The darker blue regions signify areas of lower keyword density, indicating that while these terms are referenced less frequently, they still contribute meaningfully to the broader research landscape and thematic structure of the field. Terms like carbon dioxide, energy utilization, renewable energy source, and photovoltaic modules fall on the edges with lower intensity, indicating niche or emerging topics with more specialized focus.

IV. FINDINGS AND DISCUSSION

The analysis conducted using the VOSviewer application provides a structured and in-depth perspective on the centrality of the keywords solar energy and circular economy, highlighting their pivotal role within the research landscape. The four clusters derived from the dataset analysis in VOSviewer represent groups of interdisciplinary research issues published in relation to the Circular Economy within the Solar Energy sector.

Cluster 1 encompasses keywords associated with renewable energy, carbon emissions, energy efficiency, and climate change. The frequent appearance of key terms such as solar energy, renewable energy, global warming, greenhouse gases, carbon footprint, and energy efficiency underscores a strong research focus on the role of circular economy strategies in reducing emissions and addressing the broader challenges of climate change. Within this cluster, research related to the application of circular economy principles in the solar energy sector spans both macro-level and micro-level perspectives. At the macro level, studies emphasize the importance of enabling policy windows to support the extension of the solar energy lifecycle, an essential tenet of circular economy frameworks. These policies are identified as critical to facilitating systemic adoption of circular practices in the renewable energy domain[18]. Additionally, research highlights the need for dedicated financial mechanisms to achieve circular economy objectives aimed at carbon emission reduction. Innovative financing instruments tailored to circular economy initiatives, such as green bonds based on circular economy frameworks, are explored as solutions to the high capital costs associated with sustainable infrastructure and technology deployment[19]. At the micro level, the cluster also includes studies on product and process design that align with circular principles and contribute directly to climate change mitigation. This includes the development of eco-design approaches and life cycle-based production systems for solar energy technologies, which are designed to minimize environmental impact while enhancing the sustainability of solar power generation [20].Overall, Cluster 1 reflects an integrated research agenda focused on leveraging circular economy strategies, through policy, finance, design, and production, to reduce emissions and accelerate the transition to climate-resilient solar energy systems.

Cluster 2 is characterized by keywords linked to the circular economy, photovoltaic (PV) technologies, life cycle analysis, waste, and recycling. This cluster reflects a concentrated body of research dedicated to integrating circular economy principles into solar energy systems, with a strong emphasis on PV technologies. The recurring presence of terms such as recycling, end-of-life, and waste management underscores the growing academic focus on sustainable end-of-life strategies for solar panels, highlighting the critical need for effective material recovery and lifecycle optimization. Research within this cluster is primarily concerned with how the solar energy sector can minimize waste generated during both the production process and the end-of-life phase of solar products. Several studies explore the adoption of recycling practices aligned with circular economy principles. One such example includes a comprehensive review of end-of-life (EOL) solar PV panel management, which assesses methods for estimating PV waste and proposes strategies for its mitigation[21]. Case-based research also features prominently in this cluster. For instance, a study on photovoltaic electronic waste in Brazil investigates the challenges, opportunities, and barriers associated with implementing circular economy models for PV waste management [22]. Similarly, research focused on reverse logistics network design in the context of managing solar PV panel waste in Saudi Arabia exemplifies country-specific strategies for operationalizing circular practices[23]. Beyond case studies, several papers investigate technological innovations in waste management. These include the use of smart technologies to enhance energy efficiency, promote the use of sustainable resources, and support advanced waste management systems[24]. Moreover, the cluster features research on methodological advancements such as the implementation of a novel intuitionistic fuzzy decision-making framework for the sustainable siting of solar panel recycling facilities[25].

Cluster 3 encompasses keywords related to decarbonization, energy policy, economic instruments, and carbon management. It emphasizes the critical role of policy and economic frameworks in steering the transition toward low-carbon energy systems. Keywords such as energy policy, investments, and commerce reflect the significance of regulatory mechanisms and market-based tools in enabling and scaling circular economy practices. This cluster includes studies such as Understanding Policy Windows for Solar Energy Lifecycle Extension, which explores policymaker perspectives in developing regions of Asia, highlighting the importance of strategic policy timing and support[18]. Furthermore, the concept of a Just Transition is addressed within the context of renewable and solar energy deployment—stressing the need for inclusive, equitable frameworks that ensure all stakeholders benefit from the transition[26]. In addition, research within this cluster examines mechanisms such as carbon capture, carbon trading, and carbon offsetting, positioning them as vital components for accelerating the shift toward a circular economy[27], [28].

Cluster 4 encompasses keywords linked to environmental impact assessment, system efficiency, and life cycle perspectives. This cluster emphasizes the pivotal role of environmental impact assessment as a methodological foundation for evaluating the sustainability of energy systems and guiding the implementation of circular economy strategies.

Several studies within this cluster apply environmental impact assessment, particularly Life Cycle Assessment (LCA), methodologies through case-based approaches, examining specific systems such as grid-connected multi-crystalline silicon photovoltaic systems, solar thermal installations in Spain, and flexible plastic packaging alternatives. These cases offer context-specific insights into environmental trade-offs and system performance [20], [29], [30]. Additionally, this cluster includes research focused on advancing life cycle thinking within the solar sector, such as the study Promoting a Circular Economy in the Solar Photovoltaic Industry Using Life Cycle Symbiosis. This work introduces the concept of Life Cycle

Symbiosis (LCS), an extension of Industrial Symbiosis (IS), proposing it as a strategic framework for circularizing the photovoltaic industry by fostering interconnected resource flows and minimizing environmental impact across product lifecycles [31].

Overall, the four clusters of keywords identified in this study are highly interrelated and demonstrate significant interdependencies, collectively forming a comprehensive framework for understanding the transition to a circular economy in the solar energy sector.

Cluster 1 addresses the urgent need for climate change mitigation and decarbonization, establishing the environmental imperative that drives circular initiatives.

This directly links with Cluster 2 which operationalizes emission reduction through end-of-life strategies and recycling systems, ensuring that material flows are maintained within sustainable boundaries.

Cluster 3 functions as the enabling governance mechanism that connects these environmental and operational goals. Through policy instruments and stakeholder engagement, it provides the institutional architecture required to scale circular economy strategies across solar energy systems (multilevel perspectives).

Cluster 4 offers the evaluative and methodological lens, particularly through tools like Life Cycle Assessment (LCA), that measure and validate the environmental sustainability of practices emerging from the other clusters.

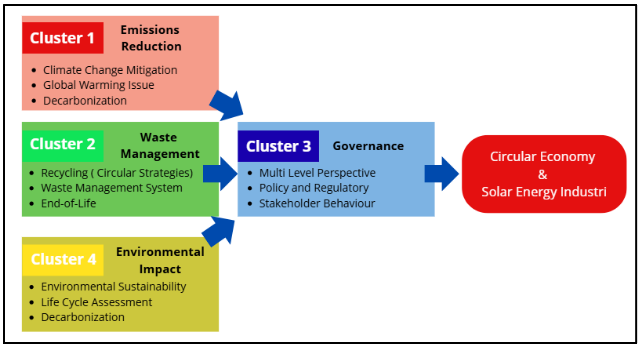

Figure 4 Circular Economy - Solar Energy Framework

V. CONCLUSION

The overall research trend, as evidenced by the distribution of publication years (the highest volume recorded in 2024 and projections indicating a further increase in 2025) demonstrates sustained and growing scholarly interest in this topic. This is further supported by the overlay visualization presented in Fig. 2, which reveals the thematic evolution of research within the field. In the earlier phases, scholarly focus centered predominantly on foundational environmental concerns, as indicated by frequently occurring keywords such as carbon footprint, greenhouse gases, and emission control, which have long underpinned academic discourse on circular economy and solar energy. However, recent research activity shows a discernible thematic shift toward more nuanced and applied dimensions of the circular economy transition, particularly in relation to solar photovoltaic (PV) technologies. Emerging keywords such as photovoltaics, solar panels, end-of-life, and photovoltaic modules reflect a growing academic emphasis on lifecycle management, technical innovation, and socio-environmental integration. These developments underscore an increasing recognition of the importance of embedding sustainability principles throughout the entire value chain of solar energy systems within circular economy frameworks.

Based on the findings from the network and overlay visualizations, as well as the density map, it is evident that only a limited number of keywords exhibit high density. This suggests that the topic remains relatively niche or represents an emerging field with a specialized research focus. Consequently, future research should explore the transition of the solar energy industry toward circular economy frameworks through a product-based lens, as indicated by emerging keywords such as photovoltaics, solar panels, end-of-life, and photovoltaic modules. Adopting a multi-level perspective is particularly relevant, refers niche character of current research themes revealed in the density analysis. Referring to the four-cluster structure identified in the network visualization, Cluster 1 highlights the strategic relevance of circular economy practices in supporting climate change mitigation and decarbonization objectives within the solar energy sector. This opens opportunities for further inquiry in the field of management science, particularly in relation to the taxonomy of innovative green financial instruments (including green bonds, green sukuk, blended finance, and public-private partnership (PPP) schemes) that are designed to support decarbonization agendas. Additionally, research on circular economy roadmaps tailored to specific industries may serve as a valuable reference for structuring transitions toward sustainability in the solar energy value chain.

Cluster 2 emphasis on recycling, end-of-life, and waste management reflects a growing scholarly interest in sustainable end-of-life strategies for solar panels. Future research should expand toward comparative cross-national studies that assess the effectiveness of policy frameworks, infrastructure readiness, and socio-economic barriers influencing end-of-life (EOL) management in diverse contexts. Other significant potential theme is technological innovation, particularly through the integration of Artificial Intelligence (AI), to enhance waste management systems and support the implementation of circular economy strategies across the solar energy value chain. Future research within Cluster 3, aligned with themes of governance and economic instruments, should prioritize the quantitative modeling of carbon pricing mechanisms, including carbon trading, carbon taxation, and offset markets. Additionally, advancing studies that examine equity and inclusion within the framework of a Just Transition will be critical to ensuring fair and socially responsible energy transitions under circular economy principles. For Cluster 4, which centers on environmental impact, future investigations should focus on the integration of circular economy principles into Life Cycle Assessment (LCA) methodologies. This integration has the potential to establish a new standard for environmental impact assessments within corporate and industrial practices, enabling more holistic and sustainable decision-making frameworks.

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REFERENCES

[1] IEA, "Renewables 2023," 2024.
[2] T. Roy, J. A. Garza-Reyes, V. Kumar, A. Kumar, and R. Agrawal, "Redesigning traditional linear supply chains into circular supply chains–A study into its challenges," Sustain Prod Consum, vol. 31, pp. 113–126, May 2022, doi: 10.1016/j.spc.2022.02.004.
[3] S. Weckend, A. Wade, and G. Heath, "IRENA IEAPVPS End-of-Life Solar PV Panels 2016," 2016.
[4] A. Atalay, S. Duran, and L. N. Van Wassenhoe, "The Dark Side of Solar Power," Harvard Business Review, 2021.
[5] G. A. Heath et al., "Research and development priorities for silicon photovoltaic module recycling to support a circular economy," Nat Energy, vol. 5, no. 7, pp. 502–510, Jul. 2020, doi: 10.1038/s41560-020-0645-2.
[6] F. Pomponi and A. Moncaster, "Circular economy for the built environment: A research framework," J Clean Prod, vol. 143, pp. 710–718, Feb. 2017, doi: 10.1016/j.jclepro.2016.12.055.
[7] H. Winkler, "Closed-loop production systems—A sustainable supply chain approach," CIRP J Manuf Sci Technol, vol. 4, no. 3, pp. 243–246, Jan. 2011, doi: 10.1016/j.cirpj.2011.05.001.
[8] J. Finn, J. Barrie, E. João, and G. Zawdie, "A multilevel perspective of transition to a circular economy with particular reference to a community renewable energy niche," International Journal of Technology Management & Sustainable Development, vol. 19, no. 2, pp. 195–220, Jun. 2020, doi: 10.1386/tmsd_00022_1.
[9] J. A. Tsanakas et al., "Towards a circular supply chain for PV modules: Review of today's challenges in PV recycling, refurbishment and re-certification," Progress in Photovoltaics: Research and Applications, vol. 28, no. 6, pp. 454–464, 2020, doi: 10.1002/pip.3193.
[10] T. Radavičius, S. N. Groesser, and M. Tvaronavičienė, "Assessment of constraints in the European Union photovoltaics circular supply chain for enhanced circularity," J Clean Prod, vol. 489, Jan. 2025, doi: 10.1016/j.jclepro.2025.144682.
[11] Y. Arıöz, İ. Yılmaz, and A. Yıldızbaşı, "Unlocking circularity: A stakeholder theory approach to the 10Rs in the solar PV supply chain," Renew Energy, vol. 250, Sep. 2025, doi: 10.1016/j.renene.2025.123254.
[12] L. A. B. da Rosa, M. Cohen, W. Y. Y. Z. Campos, L. V. Ávila, and M. C. M. Rodrigues, "Circular economy and sustainable development goals: main research trends," Revista de Administração da UFSM, vol. 16, no. 1, p. e9, Mar. 2023, doi: 10.5902/1983465971448.
[13] A. Alcalde-Calonge, F. J. Sáez-Martínez, and P. Ruiz-Palomino, "Evolution of research on circular economy and related trends and topics. A thirteen-year review," Ecol Inform, vol. 70, p. 101716, Sep. 2022, doi: 10.1016/j.ecoinf.2022.101716.
[14] M.-L. Tseng, R. R. Tan, A. S. F. Chiu, C.-F. Chien, and T. C. Kuo, "Circular economy meets industry 4.0: Can big data drive industrial symbiosis?," Resour Conserv Recycl, vol. 131, pp. 146–147, Apr. 2018, doi: 10.1016/j.resconrec.2017.12.028.
[15] J. Potting, M. P. Hekkert, and E. Worrell, "CIRCULAR ECONOMY: MEASURING INNOVATION IN THE PRODUCT CHAIN," 2017. [Online]. Available: https://www.researchgate.net/publication/319314335
[16] A. Vasiljevic-Shikaleska, B. Gjozinska, and M. Stojanovikj, "The circular economy - a pathway to sustainable future. ," J Sustain Dev, vol. 7, no. 17, pp. 13–30, 2017.
[17] N. J. van Eck and L. Waltman, "Software survey: VOSviewer, a computer program for bibliometric mapping," Scientometrics, vol. 84, no. 2, pp. 523–538, Aug. 2010, doi: 10.1007/s11192-009-0146-3.
[18] S. Y. Kweon, Y. H. Ha, S. Chang, Y. Kim, and R. Math, "Understanding policy windows for solar energy lifecycle extension: Policymaker perspectives in developing Asia," Energy Res Soc Sci, vol. 126, Aug. 2025, doi: 10.1016/j.erss.2025.104130.
[19] M. Ghasemi, G. Heravi, and M. R. Heidari, "A green bond based circular economic framework to develop decentralized solar plants," J Clean Prod, vol. 520, Aug. 2025, doi: 10.1016/j.jclepro.2025.146192.
[20] J. Albertí et al., "Life Cycle Assessment of a solar thermal system in Spain, eco-design alternatives and derived climate change scenarios at Spanish and Chinese National levels," Sustain Cities Soc,

vol. 47, May 2019, doi: 10.1016/j.scs.2019.101467.
[21] O. Capraz, Z. O. Bogar, and A. Gungor, "A Review on the Management of End-of-Life Solar Photovoltaic Panels," 2025, pp. 1–52. doi: 10.4018/979-8-3693-7383-5.ch001.
[22] N. M. De Sousa, C. B. Oliveira, and D. Cunha, "Photovoltaic electronic waste in Brazil: Circular economy challenges, potential and obstacles," Jan. 01, 2023, Elsevier Ltd. doi: 10.1016/j.ssaho.2023.100456.
[23] M. T. Islam, A. Ali, S. A. Qadir, M. Shahid, and A. Alzahrani, "Reverse Logistics Network Design for Waste Solar PV Panels in Saudi Arabia," in Transportation Research Procedia, Elsevier B.V., 2025, pp. 315–322. doi: 10.1016/j.trpro.2025.03.078.
[24] S. Nižetić, N. Djilali, A. Papadopoulos, and J. J. P. C. Rodrigues, "Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management," Sep. 10, 2019, Elsevier Ltd. doi: 10.1016/j.jclepro.2019.04.397.
[25] B. Yildirim, E. Ayyildiz, and N. Aydin, "A novel intuitionistic fuzzy decision-making framework for sustainable site selection of solar panel waste recycling facilities," J Clean Prod, vol. 521, Aug. 2025, doi: 10.1016/j.jclepro.2025.146195.
[26] D. Mulvaney, "Solar power and the just transition," in The Routledge Handbook of Sustainable Cities and Landscapes in the Pacific Rim, London: Routledge, 2022, pp. 486–494. doi: 10.4324/9781003033530-41.
[27] C. Zhang and B. Lin, "Impact of introducing Chinese certified emission reduction scheme to the carbon market: Promoting renewable energy," Renew Energy, vol. 222, p. 119887, Feb. 2024, doi: 10.1016/j.renene.2023.119887.
[28] J. Böttcher, Ed., Carbon Free. De Gruyter, 2025. doi: 10.1515/9783110784299.
[29] B. Tunçok-Çeşme, E. Yıldız-Geyhan, and G. A. Çiftçioğlu, "Environmental Life Cycle Assessment of Two Types of Flexible Plastic Packaging under a Sustainable Circular Economy Approach," Sustainability, vol. 16, no. 8, p. 3149, Apr. 2024, doi: 10.3390/su16083149.
[30] E. Santoyo-Castelazo, K. Solano-Olivares, E. Martínez, E. O. García, and E. Santoyo, "Life cycle assessment for a grid-connected multi-crystalline silicon photovoltaic system of 3 kWp: A case study for Mexico," J Clean Prod, vol. 316, p. 128314, Sep. 2021, doi: 10.1016/j.jclepro.2021.128314.
[31] N. Mathur, S. Singh, and J. W. Sutherland, "Promoting a circular economy in the solar photovoltaic industry using life cycle symbiosis," Resour Conserv Recycl, vol. 155, p. 104649, Apr. 2020, doi: 10.1016/j.resconrec.2019.104649.