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Bibliometric Analysis on Green Workforce Readiness

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ABSTRACT

This study presents a bibliometric analysis of the scholarly literature on green workforce readiness, a critical area in the transition toward sustainable and low-carbon economies. Using data extracted from the Scopus database and analyzed through VOSviewer, the study maps key publication trends, co-occurring themes, leading authors, and international collaboration networks. The results indicate that "sustainable development" serves as the conceptual core of this research domain, with closely linked themes including green economy, workforce training, environmental protection, and green manufacturing. Temporal analysis reveals a shift from foundational concepts like education and environmental policy to more recent emphases on technological and industrial transformations such as renewable energy and circular economy. Author and country collaboration networks underscore the dominance of scholars from the United States, China, and India, alongside increasing contributions from emerging economies. Despite the field's growth, the study identifies research gaps in regional coverage and interdisciplinary integration. The findings offer valuable insights for academics, policymakers, and practitioners aiming to align workforce development strategies with sustainability goals.

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1. INTRODUCTION

In the face of mounting environmental challenges, climate change, and unsustainable consumption patterns, the global economy is undergoing a fundamental transformation toward sustainability. This transition requires not only new technologies and green innovations but also a reconfiguration of human capital capable of supporting low-carbon, resource-efficient economic models [1]. Consequently, the concept of a "green workforce" has emerged, referring to the pool of workers who possess the knowledge, skills, values, and attitudes necessary to contribute meaningfully to environmentally sustainable development [2], [3]. This workforce spans a wide range of sectors, including renewable energy, sustainable agriculture, green construction, waste management, and environmental services.

The readiness of the workforce to participate in this green transition is now seen as a critical determinant of a nation's capacity to achieve its environmental and economic goals. Green workforce readiness encompasses not only technical skills but also

adaptability, environmental literacy, and the ability to work across multidisciplinary teams [4]. Educational institutions, vocational training systems, and labor policies are all under increasing pressure to integrate sustainability competencies into their curricula and frameworks [5]. The World Economic Forum has underscored that green skills will be among the most in-demand competencies over the next decade, as industries reshape their operations in response to climate-related policies and global sustainability commitments [6].

Scholarly interest in the green workforce has grown considerably over the past decade, with researchers exploring diverse topics such as green skill gaps, policy frameworks, labor market transitions, and educational reforms. However, the body of literature remains dispersed across disciplines such as environmental science, education, human resource management, and economics [7]. As a result, it has become increasingly necessary to map the intellectual structure of this growing field. Bibliometric analysis provides a robust quantitative method to examine research trends, influential authors, key journals, and thematic clusters, thereby offering a clearer understanding of how the concept of green workforce readiness is being developed and disseminated in the academic community.

Bibliometric mapping allows researchers to visualize the evolution of scientific literature, trace scholarly networks, and identify knowledge gaps. It helps synthesize complex research landscapes and inform policymakers and practitioners about emerging topics and underexplored areas [8]. In the case of green workforce readiness, such an analysis can reveal whether research is aligned with the urgent demands of sustainable development goals (SDGs), especially SDG 8 (decent work and economic growth) and SDG 13 (climate action). Additionally, this approach supports the identification of regional disparities in research focus and collaborations, highlighting which countries or institutions are leading the discourse.

Given the urgent call for workforce transformation and the fragmented nature of the current academic discourse, a comprehensive bibliometric review becomes essential to synthesize existing knowledge and guide future inquiry. Despite the proliferation of publications in green human capital and labor market transformation, there remains a lack of systematic mapping that focuses specifically on workforce readiness for the green economy. Addressing this gap will support the formulation of targeted educational strategies, labor policies, and cross-sectoral initiatives that are evidence-based and future-oriented.

Although green workforce readiness has emerged as a key element in achieving global sustainability goals, existing research is scattered and lacks a coherent structure that connects theoretical development, policy discourse, and practical implementation. Many studies focus on isolated aspects, such as green education or skill demand in specific industries, without establishing integrative frameworks that could support holistic workforce development. Moreover, no bibliometric studies to date have consolidated the global body of literature on this topic, resulting in limited insights into publication trends, dominant themes, and research frontiers in this rapidly growing domain. This study aims to conduct a bibliometric analysis on the topic of green workforce readiness.

2. METHODS

This study employed a quantitative bibliometric analysis approach to systematically map the development and intellectual structure of scholarly research on green workforce readiness. Bibliometric analysis is a statistical method used to analyze academic literature quantitatively, enabling the identification of publication trends, influential sources, leading authors, and thematic clusters [8]. The methodological framework focused on analyzing co-authorship, co-citation, and keyword co-occurrence networks to uncover the relationships and patterns among the research constituents. This approach provides a

structured overview of the existing knowledge base and supports the discovery of emerging areas of interest within the field.

The data for this analysis were extracted from the Scopus database, which was selected due to its comprehensive coverage of peer-reviewed academic publications across disciplines. The search strategy included keywords such as "green workforce," "green jobs," "green skills," "workforce readiness," and "sustainable employment" in article titles, abstracts, and keywords. The search was limited to publications from 2000 to 2024 to capture the recent evolution of the field. Only journal articles, conference papers, and reviews published in English were included to ensure quality and consistency. The raw data were exported in CSV and RIS formats, which were then processed using VOSviewer for bibliometric mapping and network visualization.

In conducting the analysis, three core techniques were used: co-authorship analysis to examine collaboration networks among researchers and countries; co-citation analysis to identify influential articles and the theoretical foundation of the field; and keyword co-occurrence analysis to uncover major themes and research trends. VOSviewer was used to generate visual maps, showing the density and clustering of key terms and entities.

3. RESULTS AND DISCUSSION

3.1 Keyword Co-Occurrence Network

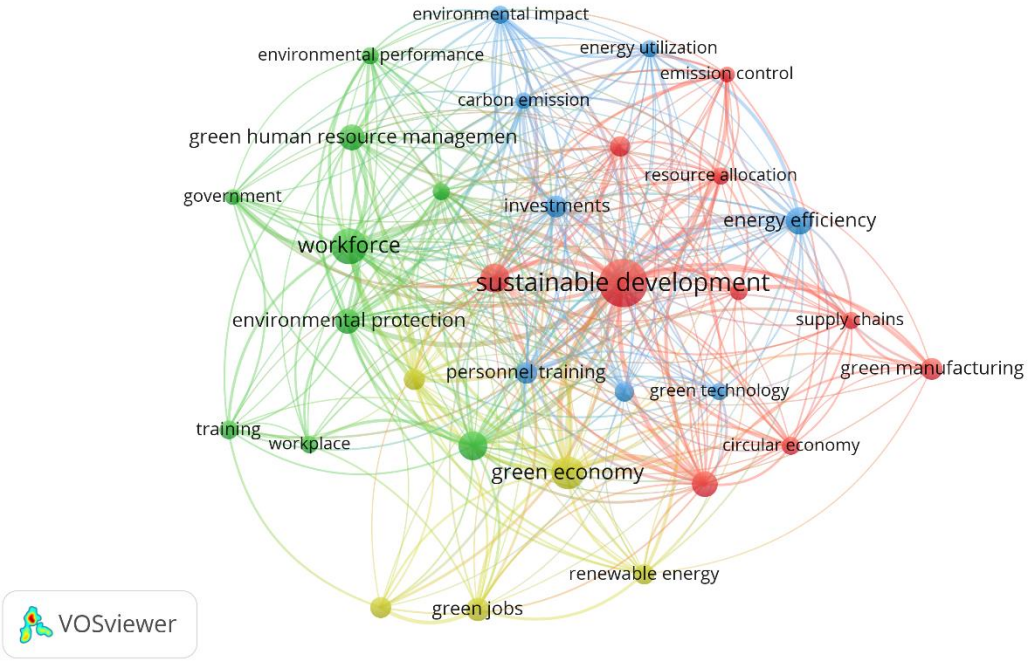

Figure 1. Network Visualization
Source: Data Analysis Result, 2025

Figure 1 represents a keyword co-occurrence network within the literature on green workforce readiness. The map identifies the most frequently co-occurring terms and organizes them into thematic clusters, each represented by a different color. The size of each node reflects the frequency of the keyword's appearance in the literature, while the thickness of the connecting lines indicates the strength of the co-occurrence relationship between terms. At the center of the network, "sustainable development" emerges as the most prominent and central term, signaling its role as the conceptual anchor that integrates various subtopics across the field.

The green cluster focuses on workforce-centric concepts, such as "workforce," "green human resource management," "training," "government," "environmental protection," and "workplace." This grouping suggests a strong thematic focus on the preparation of human capital for sustainability transitions. The prominence of terms like "training" and "personnel training" indicates a growing emphasis on upskilling and reskilling strategies, while "green human resource management" underscores the integration of environmental concerns into organizational HR practices. The co-occurrence with "government" also highlights the influence of policy in shaping workforce development in the context of green economy goals.

The yellow cluster revolves around the term "green economy" and includes closely related keywords like "green jobs," "renewable energy," and "personnel training." This suggests that discussions on green workforce readiness are strongly associated with broader economic restructuring efforts aimed at decarbonization and sustainability. The presence of "green jobs" in this cluster indicates a growing literature on labor market transformations and employment opportunities tied to environmental goals. The interconnectedness between this cluster and both the workforce and sustainable development clusters suggests a multidimensional relationship among policy, employment, and environmental progress.

The red cluster, on the other hand, centers on more technical and industrial aspects of sustainability, including "green manufacturing," "supply chains," "energy efficiency," "circular economy," and "green technology." This cluster reflects the intersection between workforce readiness and technological or operational shifts in production systems. The strong link between "green manufacturing" and "supply chains" indicates that discussions of labor transformation are extending into the value chain and production process reengineering, where new competencies are needed to implement eco-efficient practices.

The blue cluster contains terms like "environmental performance," "carbon emission," "energy utilization," and "emission control," indicating a research stream focused on the environmental outcomes of workforce and industrial transformations. This cluster bridges the policy, technological, and environmental monitoring domains. The presence of "investments" suggests attention to the economic and infrastructural support necessary for transitioning toward sustainable practice.

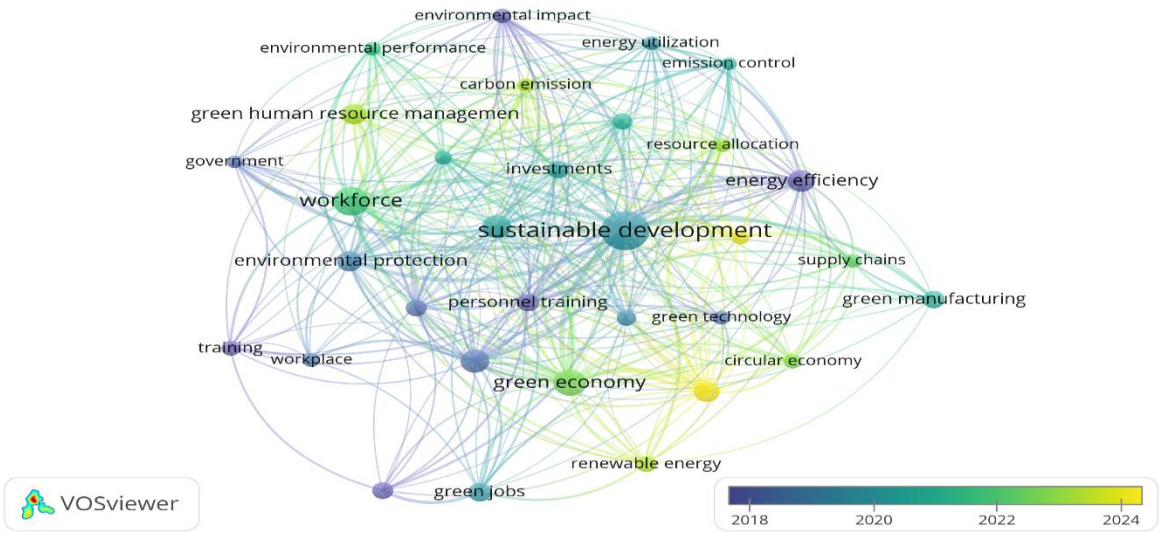

Figure 2. Overlay Visualization

Source: Data Analysis Result, 2025

Figure 2 provides a temporal perspective on keyword co-occurrence in green workforce readiness literature. The color gradient, ranging from blue (older publications, around 2018) to yellow (more recent, up to 2024), illustrates the evolution of research topics over time. Central terms such as **"sustainable development"**, **"green economy"**, and **"workforce"** remain consistently prominent, suggesting their foundational role throughout the years. However, newer trends are visible in terms like **"circular economy"**, **"renewable energy"**, and **"green manufacturing"**, which appear in shades closer to yellow, indicating increased scholarly attention in the most recent years. This shift reflects a growing academic and policy interest in practical implementation and industrial adaptation for sustainability.

In contrast, earlier research—denoted in blue, focused more heavily on **"training," "workplace,"** and **"environmental protection"**, indicating that initial discussions centered on foundational human capital development and environmental values. The gradual transition from these conceptual and capacity-building concerns toward more technical and systemic topics such as **"resource allocation"**, **"energy efficiency"**, and **"supply chains"** suggests that the field is maturing.

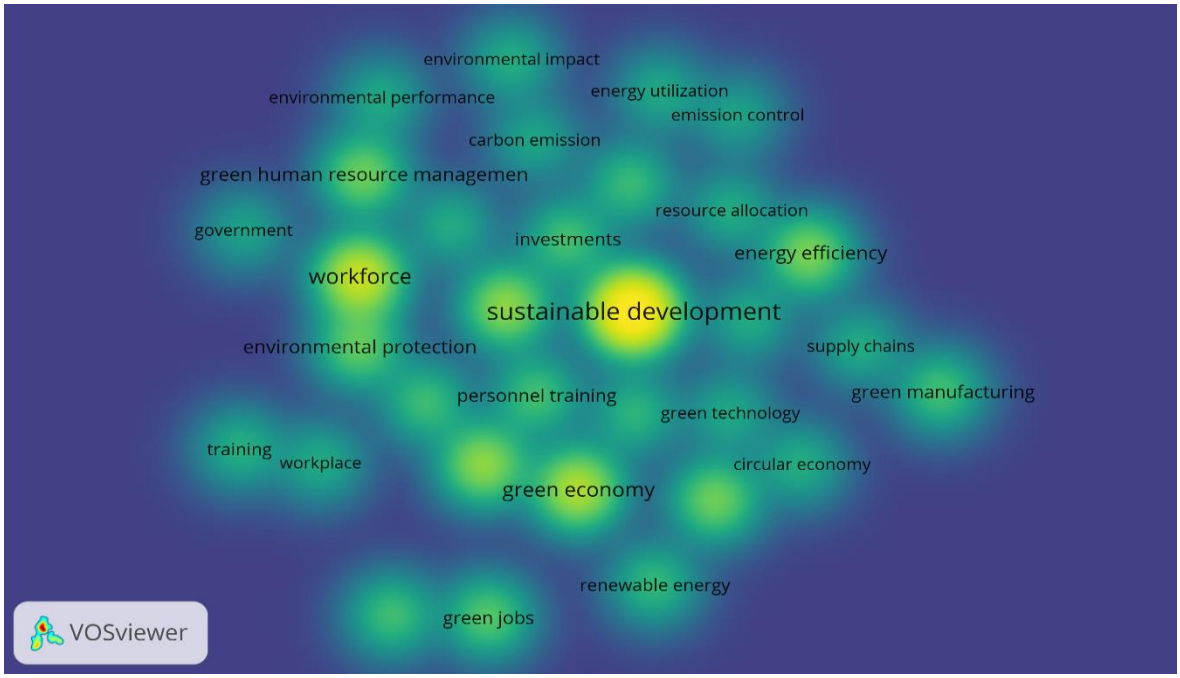

Figure 3. Density Visualization

Source: Data Analysis, 2025

Figure 3 above illustrates the intensity of research attention within the domain of green workforce readiness. The color scale, ranging from blue (low density) to bright yellow (high density), indicates the frequency and significance of keyword co-occurrences in the literature. At the core, "sustainable development" appears as the most intensively studied and central concept, shown by its bright yellow color. Surrounding this central theme are high-density terms such as "workforce," "green economy," and "environmental protection," indicating that these topics are also frequently explored and closely linked to the overarching sustainability discourse.

The peripheral areas of the map, which are more green or blue in tone, represent emerging or less frequently addressed topics such as "green manufacturing," "supply chains," "circular economy," and "energy utilization." Although these terms are connected to central themes, their lower density suggests that they

offer potential opportunities for further research and exploration. Notably, topics like "green jobs" and "renewable energy" also show moderate density, indicating a growing but still underdeveloped body of literature in workforce preparation for green sectors.

3.2 Co-Authorship Network

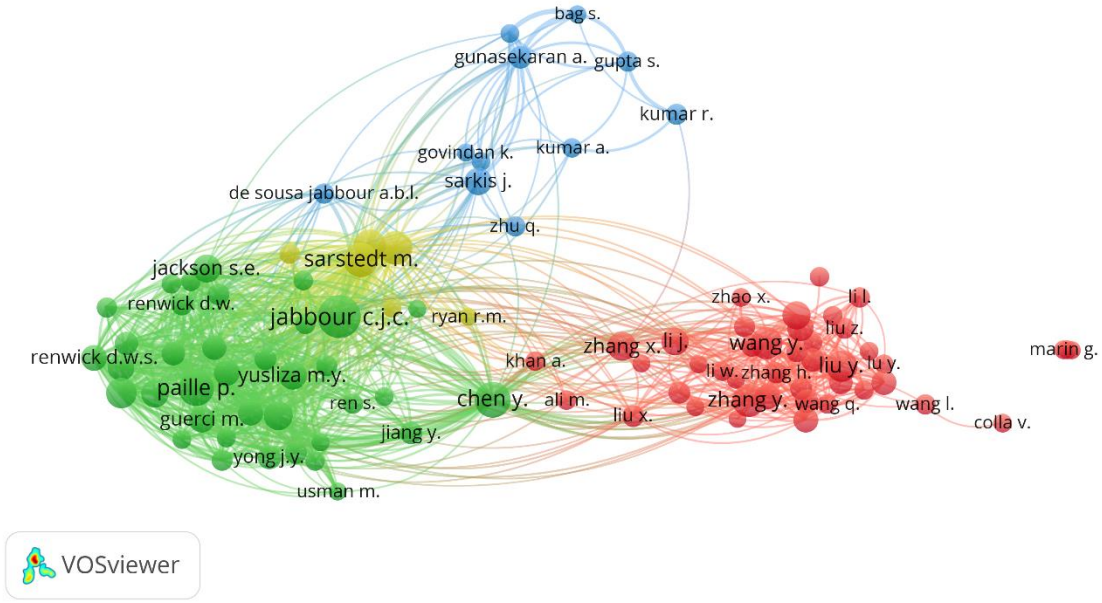

Figure 4. Author Collaboration Visualization

Source: Data Analysis, 2025

Figure 4 illustrates the collaborative structure among leading scholars in the field of green workforce readiness and related sustainability studies. Nodes represent individual authors, while the size of each node indicates their publication volume or citation influence. The different colors represent distinct clusters of collaboration—indicating thematic or regional research communities. The green cluster, which includes influential figures such as *Jabbour C.J.C.*, *Paillé P.*, and *Renwick D.W.S.*, appears to dominate the literature, suggesting a strong and cohesive research community focused on green human resource management and organizational sustainability. The red cluster, containing authors like *Wang Y.*, *Liu Y.*, and *Zhang Y.*, likely represents a body of work centered on environmental performance, circular economy, or green manufacturing—potentially with a strong East Asian research base. Meanwhile, the blue cluster, involving *Bag S.*, *Gunasekaran A.*, and *Gupta S.*, seems to align with topics in supply chain sustainability and operations management.

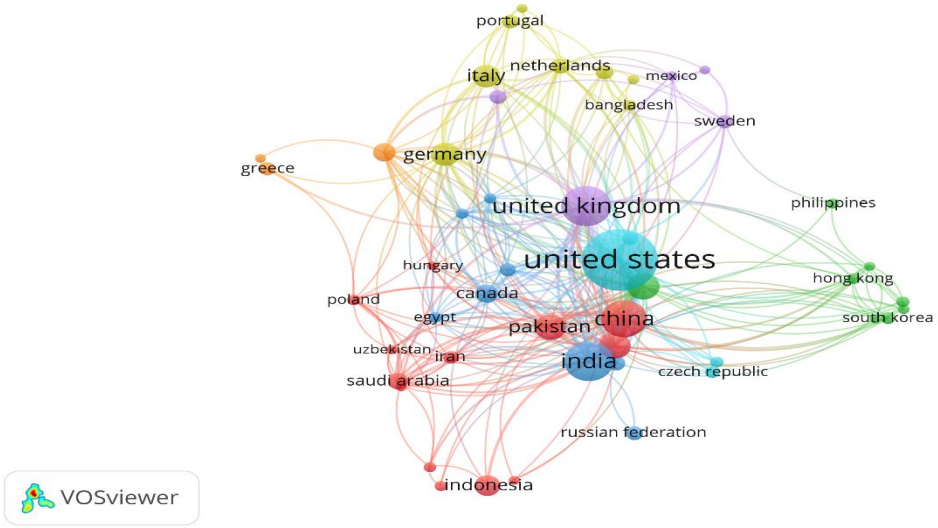

Figure 5. Country Collaboration Visualization

Source: Data Analysis, 2025

This country collaboration network visualizes international research partnerships in the field of green workforce readiness. The **United States** emerges as the most prominent and central node, reflecting its leading role in both research output and global collaborations. Strong ties are observed with other major contributors like **China**, **India**, **United Kingdom**, and **Germany**, which are also sizable nodes, indicating their substantial influence and active participation in this research domain. The color-coded clusters suggest regional research groupings—such as the red cluster (Asia and Middle East), the yellow cluster (Southern and Western Europe), and the green cluster (East and Southeast Asia). Countries like **Indonesia**, **Pakistan**, and **Saudi Arabia** are actively integrated into broader international collaborations, suggesting growing contributions from emerging economies.

3.3 Citation Analysis

Table 1. Top Cited Research

Citations	Authors and year	Title
313	[9]	Managing supply chains for sustainable operations in the era of industry 4.0 and circular economy: Analysis of barriers
296	[10]	The relationship between lean operations and sustainable operations
281	[11]	A comparison of occupant comfort and satisfaction between a green building and a conventional building
234	[12]	Green human resource management: A comparative qualitative case study of a United States multinational corporation
223	[13]	Green technology innovation development in China in 1990–2015
193	[14]	The implications of new information and communication technologies for sustainability
175	[15]	Convolutional neural networks: Computer vision-based workforce activity assessment in construction
173	[16]	Effect of green human resource management practices on organizational sustainability: the mediating role of environmental and employee performance

Citations	Authors and year	Title
173	[17]	Green employee empowerment: a systematic literature review on state-of-art in green human resource management
161	[18]	Exploring the linkage between greenness exposure and depression among Chinese people: Mediating roles of physical activity, stress and social cohesion and moderating role of urbanicity

Source: Scopus, 2025

Discussion

The findings of this bibliometric study shed light on the evolving structure, thematic orientation, and collaborative networks in the scholarly literature on green workforce readiness. As the world moves toward low-carbon, sustainable economic systems, there is growing academic interest in preparing a workforce capable of supporting this transition. The bibliometric maps presented here, based on co-occurrence, temporal trends, density visualization, co-authorship networks, and country collaborations, offer insights into how the academic community is responding to this urgent need.

First, the keyword co-occurrence network reveals that *"sustainable development"* acts as the conceptual anchor of green workforce research. It is intricately connected to clusters such as *"green economy," "workforce," "environmental protection,"* and *"green manufacturing."* This centrality reflects a systems-oriented understanding of green workforce readiness as a pillar supporting multiple dimensions of sustainability, from policy to industry. Keywords like *"training," "green jobs," "personnel training,"* and *"green human resource management"* indicate a strong focus on human capital development, affirming the role of education, upskilling, and organizational transformation in driving sustainable growth. This aligns with prior literature that emphasizes workforce adaptation as a critical factor in implementing climate and environmental policy [19]–[21].

The thematic clustering further highlights the breadth of this interdisciplinary field. The green cluster centers on organizational and workforce development, with emphasis on *HR practices, government policy,* and *environmental literacy*. This suggests that much of the literature is rooted in management sciences, public administration, and environmental policy. The red cluster, on the other hand, is more focused on production and industrial transformation, reflected by terms like *"green manufacturing," "supply chains,"* and *"circular economy."* These keywords point to a shift in how industries are redefining roles, requiring new competencies in operational sustainability, lean practices, and lifecycle design. The presence of keywords such as *"green technology"* and *"energy efficiency"* in both the red and yellow clusters indicates a convergence between technological innovation and human capital.

Temporal analysis through the overlay visualization shows an important trend: the field is rapidly evolving. Earlier research (pre-2020) primarily concentrated on foundational topics like *training*, *environmental protection*, and *green HRM*, as denoted by blue and green colors. More recent years (2022–2024) have seen a pivot toward technical and systemic challenges such as *green manufacturing*, *circular economy*, and *renewable energy*. This shift suggests that academic inquiry is increasingly addressing real-world implementation of sustainability transitions, focusing on equipping workers with the skills necessary to thrive in new green sectors. This finding supports the view that while green workforce readiness initially revolved around awareness-building and policy framing, it is now extending into applied research with tangible economic and industrial impacts [22].

The density visualization reinforces the dominance of *sustainable development*, *green economy*, and *workforce* as core themes with high research intensity. These hotspots indicate areas of scholarly saturation and

maturity, while peripheral but connected terms such as *resource allocation*, *emission control*, and *green technology* reveal emerging niches that merit further exploration. Interestingly, terms like *workplace* and *green jobs*, while present, appear less dense, suggesting potential research gaps in connecting green workforce readiness to actual job design, occupational safety, and inclusive employment practices.

Author collaboration networks provide additional insights into the intellectual structure of the field. Scholars such as **Jabbour C.J.C., Paillé P., Renwick D.W.S., and Sarstedt M.** form the core of a green-colored cluster that is prolific in green HRM and workforce sustainability. These authors, mainly from Europe and Latin America, have contributed significantly to shaping the managerial and organizational perspective on green readiness. In contrast, a red cluster featuring **Wang Y., Liu Y., and Zhang Y.** appears to represent a more East Asian focus on industrial sustainability and environmental performance. The blue cluster, including **Bag S., Gunasekaran A., and Govindan K.**, bridges supply chain management and environmental logistics. The relative separation of these clusters suggests thematic fragmentation, highlighting the need for greater interdisciplinarity across green workforce, operations, and policy domains.

The international collaboration network reinforces the United States' position as the dominant contributor to this body of literature. It acts as a central hub for partnerships with countries like China, India, and the United Kingdom. The prominence of these countries is not surprising, as they possess large and diverse labor markets undergoing green transformation due to both domestic policies and global economic pressures. What is particularly notable, however, is the increasing involvement of emerging economies such as Indonesia, Pakistan, Bangladesh, and the Philippines, which are forming regional linkages and contributing to the global discourse. This reflects a broader recognition that workforce readiness for sustainability must be addressed globally, not just in the Global North. However, the weaker presence of African and South American countries suggests a regional research gap that future studies should address, especially considering the environmental vulnerabilities and labor transitions occurring in these regions.

The convergence of academic attention on green human capital, organizational change, and sectoral transformation underscores the multidimensional nature of workforce readiness. As this study shows, research is no longer limited to education or policy—it now includes systemic redesign of industries and technologies. This trend mirrors broader developments in the global economy where ESG (Environmental, Social, Governance) metrics, digitalization, and sustainability are reshaping labor markets. Nevertheless, several challenges remain. The first is the integration of green workforce planning into national labor strategies, particularly in low- and middle-income countries. The second is the lack of longitudinal studies measuring the actual effectiveness of green training programs and the employability of green job graduates. And third, there is a need to explore the social justice dimension of the green transition, ensuring that new green economies are not only efficient but also equitable.

4. CONCLUSION

This bibliometric study provides a comprehensive overview of the intellectual landscape surrounding green workforce readiness, revealing a dynamic and interdisciplinary field that plays a pivotal role in advancing global sustainability goals. The analysis highlights "sustainable development" as the central thematic anchor, closely linked to clusters such as green economy, environmental protection, and workforce training. Over time, the literature has evolved from foundational discussions on education and policy to more applied themes like green manufacturing and circular economy. Key authors and institutions have shaped distinct research trajectories, while

collaboration networks show increasing global participation, particularly from the United States, China, India, and emerging economies like Indonesia and Pakistan. However, gaps remain in regional representation, interdisciplinary integration, and empirical validation. Moving forward, greater collaboration across sectors and countries, as well as a stronger focus on inclusive and measurable outcomes, will be essential to ensure that workforce systems are adequately prepared to support a just and effective green transition.

REFERENCES

[1] R. Budiarto, W. P. Sari, D. Novitasari, and A. R. Izzati, "Toward a just transition: Assessing green employment readiness in Indonesia," in *AIP Conference Proceedings*, AIP Publishing LLC, 2024, p. 30003.

[2] W. Rahmaningtyas, H. N. Purasani, N. Farliana, and R. Widhiastuti, "Greening the Workforce: A Roadmap for Sustainable Employment in the Era of Environmental Challenges," in *International Conference of Economics Business and Economics Education Science (ICE-BEES-24)*, Atlantis Press, 2024, pp. 736–748.

[3] O. H. Ebini, "Fostering Workforce Readiness for the Green Hydrogen Economy through People-Centric Training Programs," *Volume*, vol. 9, pp. 773–788.

[4] A. Talaja and S. Golem, "Adoption of Green Skills: Examining the Role of Higher Education in Addressing Change Readiness and Resistance," in *Lifelong Learning for Green Skills and Sustainable Development: Southern European Perspectives*, Springer, 2024, pp. 101–110.

[5] G. R. Dantes, I. M. A. Pradnyana, and M. D. Arthajaya, "The Readiness Level of Universitas Pendidikan Ganesha in Implementing Green IT Referring to The G-Readiness Framework," in *2024 Ninth International Conference on Informatics and Computing (ICIC)*, IEEE, 2024, pp. 1–6.

[6] J. Cleary and A. Kopicki, "Preparing the workforce for a 'green jobs' economy," *Rutgers, NJ John J. Heldrich Cent. Work. Dev.*, 2009.

[7] P. M. P. Chandrasekara, M. Wickramaratne, and A. Senarathna, "Employee Readiness Level on Implementing Green Human Resource Management Practices in Public Sector Organizations," 2020.

[8] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," *J. Bus. Res.*, vol. 133, pp. 285–296, 2021.

[9] P. Kumar, R. K. Singh, and V. Kumar, "Managing supply chains for sustainable operations in the era of industry 4.0 and circular economy: Analysis of barriers," *Resour. Conserv. Recycl.*, vol. 164, p. 105215, 2021.

[10] N. Piercy and N. Rich, "The relationship between lean operations and sustainable operations," *Int. J. Oper. Prod. Manag.*, vol. 35, no. 2, pp. 282–315, 2015.

[11] W. L. Paul and P. A. Taylor, "A comparison of occupant comfort and satisfaction between a green building and a conventional building," *Build. Environ.*, vol. 43, no. 11, pp. 1858–1870, 2008.

[12] J. Haddock-Millar, C. Sanyal, and M. Müller-Camen, "Green human resource management: a comparative qualitative case study of a United States multinational corporation," *Int. J. Hum. Resour. Manag.*, vol. 27, no. 2, pp. 192–211, 2016.

[13] Q. Wang, J. Qu, B. Wang, P. Wang, and T. Yang, "Green technology innovation development in China in 1990–2015," *Sci. Total Environ.*, vol. 696, p. 134008, 2019.

[14] C. Fuchs, "The implications of new information and communication technologies for sustainability," *Environ. Dev. Sustain.*, vol. 10, no. 3, pp. 291–309, 2008.

[15] H. Luo, C. Xiong, W. Fang, P. E. D. Love, B. Zhang, and X. Ouyang, "Convolutional neural networks: Computer vision-based workforce activity assessment in construction," *Autom. Constr.*, vol. 94, pp. 282–289, 2018.

[16] F. Amjad *et al.*, "Effect of green human resource management practices on organizational sustainability: the mediating role of environmental and employee performance," *Environ. Sci. Pollut. Res.*, vol. 28, no. 22, pp. 28191–28206, 2021.

[17] S. Tariq, F. A. Jan, and M. S. Ahmad, "Green employee empowerment: a systematic literature review on state-of-art in green human resource management," *Qual. Quant.*, vol. 50, no. 1, pp. 237–269, 2016.

[18] Y. Liu, R. Wang, Y. Xiao, B. Huang, H. Chen, and Z. Li, "Exploring the linkage between greenness exposure and depression among Chinese people: Mediating roles of physical activity, stress and social cohesion and moderating role of urbanicity," *Health Place*, vol. 58, p. 102168, 2019.

[19] S. K. Ooi, A. Amran, S. Goh, and M. Nejati, "Perceived Importance and Readiness of Green HRM in Malaysian Financial Services Industry.," *Glob. Bus. Manag. Res.*, vol. 9, 2017.

[20] J. Winterton and J. J. Turner, "Preparing graduates for work readiness: an overview and agenda," *Educ. Train.*, vol. 61, no. 5, pp. 536–551, 2019.

[21] S. Simbolon and D. M. Simbolon, "Sustainable workforce in a green era: Indonesia's energy sector transition," *Int. J. Energy Econ. Policy*, vol. 14, no. 3, pp. 702–710, 2024.

[22] N. Berber and M. Aleksic, "Green human resource management: Organizational readiness for sustainability," in *International Scientific Conference the Priority Directions of National Economy Development, Faculty of Economics, University of Niš*, 2016, pp. 271–282.