Sustainability And the Metaverse Economy: Mapping Research Trends in Green Digital Transformation

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Abstract

The rapid development of digital technologies has positioned the metaverse as a key driver of global economic transformation, while also raising sustainability concerns due to its high energy demands. This study applies bibliometric analysis to publications from 2015 to 2025 retrieved from Google Scholar using the keywords "metaverse economy," "sustainability," and "green digital transformation." Results show a significant surge in publications since 2022, peaking in 2024 with 348 articles. Major contributors include MDPI (146 articles) and Springer (136 articles). Citation analysis highlights influential works on strategic management, metaverse security and privacy, blockchain, smart cities, and the digital transformation of education and healthcare. Keyword network visualisation reveals five main clusters: green business strategy, sustainable tourism, consumer behaviour, technological infrastructure (IoT, smart cities), and SME adaptation. These findings indicate that while the metaverse has the potential to support green transformation through virtual collaboration and simulations, its rising energy consumption may worsen the global carbon footprint. The study emphasises the need for energy-efficient infrastructure, renewable-powered data centres, and sustainable business models to ensure the metaverse becomes a catalyst for achieving the United Nations Sustainable Development Goals (SDGs).

Keywords : *bibliometric analysis, green digital transformation, metaverse economy, sustainability*.
JEL Codes : Q01, O33, Q55

INTRODUCTION

The development of digital technology over the past two decades has transformed the way people work, interact, and conduct economic activities. One of the most prominent innovations is the metaverse, a virtual space that enables users to interact, transact, and create within immersive three-dimensional environments. This concept is not merely a technological trend but is projected to become a new foundation for the global digital economy. At the same time, the world faces serious challenges in the form of climate crisis and environmental degradation. The Legg (2021) report emphasizes that the increase in global temperature cannot be separated from industrial activities and fossil-based energy consumption. Therefore, sustainability has become a central issue influencing global policy, business strategy, and even lifestyle choices. One strategic approach that has been widely adopted is green digital transformation, a form of digital transition that not only emphasizes efficiency and innovation but also reduces environmental impact and supports the achievement of sustainable development goals (Kraus et al., 2021).

The relationship between the metaverse and sustainability is paradoxical. On the one hand, the metaverse can support green agendas. For example, business meetings and conferences can be shifted to virtual spaces, reducing the need for air travel, which is a major contributor to carbon (Allam et al., 2022). The fashion industry has also begun adopting digital fashion, allowing consumers to purchase virtual clothing for avatars, thereby reducing physical production that consumes significant resources (Dowling, 2022). Furthermore, XR-based simulations have the potential to accelerate research and training across various sectors without requiring substantial material resources.

On the other hand, the metaverse also has negative environmental impacts. The digital infrastructure that underpins it, from data centers and 5G networks to immersive hardware, requires large amounts of energy. Research indicates that global electricity consumption to support metaverse data centers could reach 2.4–3.2% of total world energy consumption by 2030, equivalent to the annual energy needs of an industrialized country such as Japan Moreover, a single blockchain-based transaction in the metaverse

can consume up to 200 times more energy than a simple internet search (Sedlmeir et al., 2020). These findings raise concerns that the growth of the metaverse could worsen the global carbon footprint if not managed sustainably.

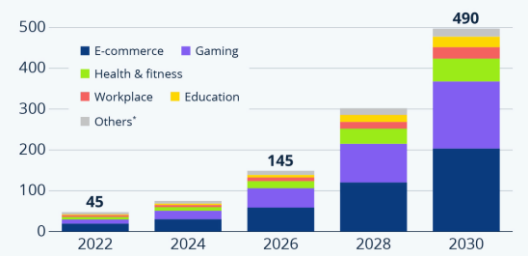

Figure 1. How the Metaverse is Making Money

Beyond the issue of sustainability, it is also important to understand the economic potential of the metaverse itself. Data from show that metaverse market revenues are projected to grow sharply from USD 45 billion in 2022 to USD 490 billion in 2030. This growth is driven by various sectors, with e-commerce and gaming as the main contributors, followed by health and fitness, workplace, education, and other categories such as virtual assets, advertising, AR/VR hardware, digital media, and live entertainment. This visualization demonstrates that metaverse growth is not limited to digital entertainment but extends across multiple aspects of social and economic life (Buchholz, 2023).

The implication is that the broader and faster expansion of the metaverse may become a major driver of the global economy, but at the same time increases pressure on digital energy consumption. Without sustainable strategies, this growth may create an imbalance between economic benefits and environmental burdens. Conversely, if companies and policymakers embed green digital transformation principles, the metaverse may function as an essential tool to speed up the realization of sustainable development goals. In other words, market data such as that presented by Buchholz (2023) should be read critically, not only as an economic opportunity but also as a reminder of the urgent need to integrate sustainability into the design and implementation of metaverse technologies.

Recent industry surveys further reinforce this ambivalence. A joint study by EY and Nokia found that 41% of companies planning to implement metaverse projects see sustainability as a key benefit. This figure rises to 51% among companies already adopting the metaverse. The most significant sustainability-related benefits identified include remote robotic operations (74%), virtual workplaces (64%), and XR-based research (61%). These findings indicate that despite energy challenges, many industry players view the metaverse as a means of enhancing efficiency and reducing environmental impact (McKinsey & Company, 2022).

The implications of this trend are threefold. First, technological design innovations and regulatory policies supporting green digital transformation are needed, such as adopting renewable-energy-powered data centers or energy-efficient blockchain models (proof-of-stake). Second, companies should integrate sustainability principles into their metaverse business strategies, including the use of green hosting, energy efficiency mechanisms, and consumer education on digital consumption (Centobelli et al., 2018). Third, the metaverse can serve as an educational medium to raise environmental awareness through simulations, immersive learning spaces, and promotion of circular economy practices.

Based on this background, the purpose of this study is to map research trends on sustainability within the context of the metaverse economy, by reviewing existing literature, identifying main themes, and exploring gaps that remain unanswered. This research also aims to provide insights into how the metaverse can be positioned both as an opportunity and as a challenge in the agenda of green digital transformation. Thus, the results of this study may serve as a valuable reference for academics, practitioners, and policymakers in designing strategies to optimize the benefits of the metaverse for sustainable economic development.

LITERATURE REVIEW

Concept of the Metaverse Economy

The metaverse is generally defined as a persistent, shared, and immersive virtual environment in which individuals interact through digital avatars (Mystakidis, 2022). It integrates technologies such as virtual

reality (VR), augmented reality (AR), blockchain, and artificial intelligence (AI). The metaverse economy refers to the economic activities taking place within this ecosystem, including digital commerce, virtual labor markets, and creative industries. According to Kumar et al., (2020), the metaverse has the potential to reshape business models and consumer experiences, thereby creating new opportunities for economic value creation. Similarly, the metaverse economy may evolve into a parallel digital society, blurring the boundaries between online and offline economic activities (Lee et al., 2024).

Sustainability and Green Digital Transformation

Sustainability is commonly understood as a form of development that fulfills current needs while ensuring that the capacity of future generations to meet their own needs remains uncompromised. (Brundtland & Mansour, 2010). In the digital era, sustainability is often associated with the concept of green digital transformation, which refers to the integration of digital technologies to achieve both efficiency and environmental objectives (Kraus et al., 2021). Empirical studies show that digital transformation can support environmental sustainability by reducing resource consumption, enabling smart energy management, and fostering circular economy practices (Centobelli et al., 2018). For example, George et al., (2021)emphasize that digital technologies can drive innovation in green business models, while Jose & Ghosh (2025) underscore their function in integrating corporate strategies with the UN Sustainable Development Goals (SDGs).

Bibliometric Analysis in Research Mapping

Bibliometric analysis is a quantitative method used to map, measure, and analyze research trends in a specific field of study (Donthu et al., 2021). Through this approach, researchers can identify the most influential publications, key authors, institutional collaborations, and emerging topics. In the context of the metaverse economy and green digital transformation, bibliometric analysis is crucial as it provides a comprehensive overview of how sustainability issues have been integrated into metaverse-related research. Previous studies have employed bibliometric methods to map literature in the fields of digital transformation and sustainability yet studies specifically connecting these domains with the metaverse economy remain scarce (Aria & Cuccurullo, 2017; Kraus et al., 2021). Therefore, applying bibliometric analysis in this study is expected to produce a comprehensive knowledge map of the evolution, research gaps, and future directions in this area.

RESEARCH METHOD

Research Design

This research applies a descriptive quantitative design with bibliometric mapping as the main approach. A descriptive quantitative approach is appropriate because it allows the researcher to describe publication patterns and research trends using numerical data such as publication counts, citation frequencies, and network structures.

Type of Data

These articles were collected through Google Scholar, which is one of the most accessible and comprehensive academic search engines. The choice of Google Scholar ensures a wide coverage of peer-reviewed journal articles, conference papers, and book chapters relevant to the research themes. While Scopus and Web of Science provide more standardized metadata, their narrower coverage may result in the omission of relevant publications, especially for emerging and interdisciplinary topics such as the metaverse economy and sustainability.

Data Collection Procedure

Data collection was conducted using a structured keyword search, including terms such as “metaverse economy,” “sustainability,” and “green digital transformation.” Boolean operators (AND, OR) were applied to refine search results. The time frame was set from 2015 to 2025 to capture the most recent decade of research. This period was chosen because sustainability became a global priority after the launch of the UN Sustainable Development Goals (SDGs) in 2015, and interest in the metaverse grew rapidly after Facebook rebranded to Meta in 2021. The Publish or Perish (PoP) software was used to extract bibliometric metadata such as title, author, publication year, journal, and number of citations.

Techniques of Analysis

In line with this study Donthu et al., (2021) applies two main bibliometric techniques, namely performance analysis and science mapping. Performance analysis is used to evaluate the productivity and impact of research outputs by examining indicators such as publication trends, citation frequencies, most cited authors, and key journals. Science mapping is employed to explore the intellectual structure and thematic development of the field through keyword co-occurrence, co-citation analysis, and bibliographic coupling. These techniques are complemented by visualization mapping using bibliometric software tools (e.g., VOSviewer), which allow the construction of network maps that illustrate relationships among authors, keywords, and citations. Together, these approaches provide a comprehensive understanding of the research landscape on the metaverse economy and sustainability.

RESULTS AND DISCUSSION

Bibliometric analysis is a method used to measure and understand the development of scientific knowledge through academic publications. It provides not only the number of publications over time but also shows research trends, emerging topics, and contributions from authors or institutions.

Table 1. Descritive General Data of the Included Studies

General Information About Data	*Results*
Time Interval	2015-2025
Sources (Journl, Books, etc)	968
Citations	21611
Cites/Year	2161.1
Cites/Paper	22,33
Cites/Author	8420,55
Papers/Author	497,67
Author/Paper	2,92
h-index	68
g-index	131
HI, norm	41
HI, Annual	4.1
Ha-index	50

The bibliometric indicators covering the period 2015–2025 reveal that the field has experienced both substantial growth and significant scholarly impact. With 968 sources and a total of 21,611 citations (an average of 2,161 citations per year), the topic demonstrates strong visibility within the academic community. The average of 22.33 citations per paper reflects high relevance, while the h-index of 68 and g-index of 131 suggest both consistent scholarly influence and the presence of highly cited landmark publications. An average of nearly three authors per paper (2.92) indicates a moderate level of collaboration, although the fragmented structure suggests that research networks are not yet fully consolidated. The very high values of citations per author (8,420.55) and papers per author (497.67) point to unequal contributions, with a small number of prolific researchers dominating the output. Meanwhile, the normalized h-index (41), annual h-index (4.1), and Ha-index (50) confirm sustained research productivity and long-term citation impact. Overall, the data portray a rapidly developing field characterized by high scholarly impact but also uneven distribution of contributions and relatively limited collaboration.

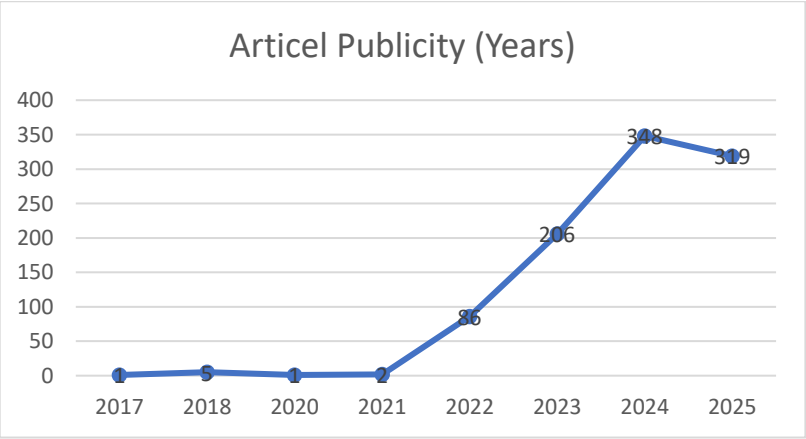

Figure 2. Articel Publicity (Years)

The number of published articles from 2017 to 2025 shows a highly dynamic development. In the early period, from 2017 to 2021, publications were still very low and relatively stagnant, ranging only from 1 to 5 articles per year. A significant surge began in 2022 with 86 articles, followed by a sharp increase in 2023, reaching 206 articles. The peak of productivity occurred in 2024 with a total of 348 articles. Although there was a slight decline in 2025 with 319 articles, the figure remained considerably higher compared to the initial years. Overall, the data indicates a rapid growth in the number of published articles since 2022, reflecting a substantial increase in research activity and academic productivity.

Table 2. Number of Articles and Citations (Years)

Years	*Number Of Articles*	*Number of Citations*
2017	1	11
2018	5	38
2020	1	598
2021	2	1022
2022	86	9225
2023	206	9360
2024	348	3937
2025	319	1357
Total	**968**	**21611**

The distribution of publications and citations between 2017 and 2025 shows a sharp acceleration in research activity and impact beginning in 2022. In the initial phase (2017–2021), publication output remained minimal, with fewer than five articles per year, yet some works from this period achieved disproportionately high citation counts, for instance, the 2020 and 2021 publications received 598 and 1,022 citations, respectively, indicating the presence of early influential studies. A turning point occurred in 2022, when output surged to 86 articles accompanied by a dramatic rise in citations (9,225), reflecting a breakthrough in scholarly attention. This momentum continued in 2023 with 206 publications and 9,360 citations, marking the peak of citation impact within the observed period. Although publication volume reached its highest level in 2024 with 348 articles, citation growth did not keep pace, suggesting that many contributions were too recent to accumulate substantial citations. By 2025, output remained high (319 articles), but citations dropped to 1,357, further supporting the time-lag effect between publication and citation accumulation. Overall, the data reveal that research on this topic experienced slow beginnings, followed by explosive growth in both productivity and influence after 2022, with evidence of a citation delay for the most recent works.

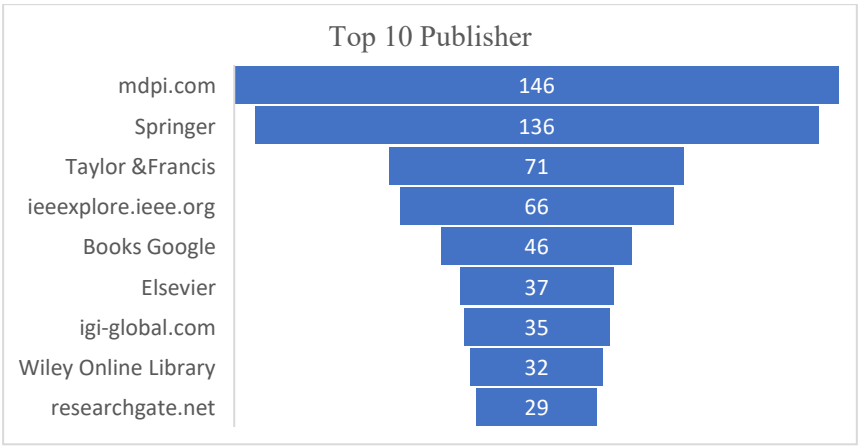

Figure 3. Top 10 Publisher

Based on Figure 1, it can be seen that mdpi.com and Springer dominate the number of publications, with 146 and 136 articles respectively, indicating a significant influence in disseminating research in the related field. Following them, publishers such as Taylor & Francis and ieeexplore.ieee.org also show considerable contributions, with 71 and 66 publications each, highlighting their important role in providing relevant and up-to-date scientific literature. Meanwhile, other publishers like Books Google, Elsevier, igi-global.com, Wiley Online Library, and researchgate.net, although having fewer publications, still make important contributions to the diversity of information sources and accessibility of research. Overall, this distribution shows that while most publications are concentrated among a few major

publishers, there is still a broad publishing ecosystem that supports the global dissemination of knowledge.

Table 3. Top 10 Citations Of Publications

No	Citations	Authors	Tittle	Year
1	5872	DA Aaker, C Moorman	"Strategic market management"	2023
2	1741	Y Wang, Z Su, N Zhang, R Xing, D Liu	"A survey on metaverse: Fundamentals, security, and privacy"	2022
3	1740	YE Rachmad	"Impact of Viral Marketing dan Gimmick Marketing Terhadap Transformation of Customer Behavior melalui Influencer Marketing"	2024
4	788	Z Allam, A Sharifi, SE Bibri, DS Jones, J Krogstie	"The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures"	2022
5	529	A Koohang, JH Nord, KB Ooi, GWH Tan	"Shaping the metaverse into reality: a holistic multidisciplinary understanding of opportunities, challenges, and avenues for future investigation"	2023
6	501	TR Gadekallu, T Huynh-The, W Wang	"Blockchain for the metaverse: A review"	2022
7	441	B George, O Wooden	"Managing the strategic transformation of higher education through artificial intelligence"	2023
8	361	G Bansal, K Rajgopal, V Chamola, Z Xiong	"Healthcare in metaverse: A survey on current metaverse applications in healthcare"	2022
9	310	S Park, S Kim	"Identifying world types to deliver gameful experiences for sustainable learning in the metaverse"	2022
10	255	SE Bibri	"The social shaping of the metaverse as an alternative to the imaginaries of data-driven smart Cities: A study in science, technology, and society"	2022

Based on the ten most-cited publications, research appears to be concentrated on strategic management, the metaverse, and advanced technological applications. The article by DA Aaker and C Moorman on *Strategic Market Management* dominates citations, emphasizing the importance of a managerial perspective in understanding modern market dynamics. Meanwhile, several studies focus on the technical and applied aspects of the metaverse, such as security, privacy, blockchain, and the transformation of education and healthcare sectors, reflecting attention to the integration of digital technology into real-world contexts. In addition, some research explores the interaction between the metaverse and concepts like sustainable smart cities, influencer marketing, and game-based learning, indicating a multidisciplinary trend that combines technology, social, and economic dimensions.

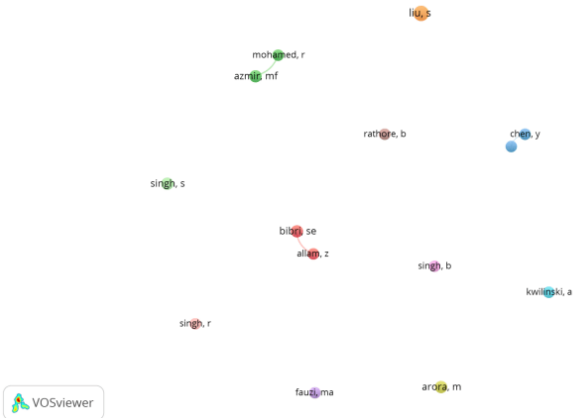

Figure 4. CO-Authorship Network

Based on Figure 3, each circle represents an author, with the size of the circle indicating the number of publications or contributions by that author. Different colors represent groups or clusters of collaboration formed based on co-authorship links. The connecting lines between circles show collaboration relationships—thicker lines indicate stronger co-authorship ties. The image shows that only a few pairs of authors collaborate closely (for example, azmir, mf with mohamed, r and bibri, se with allam, z), while

most authors appear isolated without strong collaboration links. This suggests that the collaboration network is still fragmented and not widely interconnected.

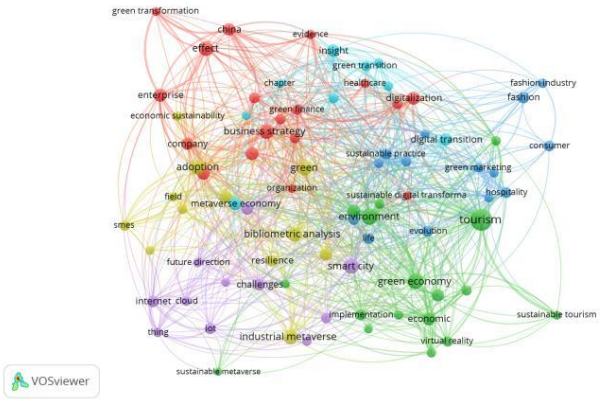

Figure 5. Network Visualization

The VOSviewer network visualization of keywords reveals distinct clusters reflecting key research themes in the intersection of sustainability, technology, and economic applications. The red cluster emphasizes business strategy, digitalization, green finance, enterprise adoption, and economic sustainability, highlighting organizational approaches to integrating green and digital strategies. The green cluster centers on tourism, environment, green economy, virtual reality, and sustainable tourism, indicating a focus on environmentally conscious economic applications. The blue cluster encompasses fashion, consumer behavior, sustainable practices, hospitality, and digital transition, reflecting consumer-oriented sustainability efforts across industries. The purple cluster, featuring IoT, internet, cloud, industrial metaverse, smart cities, and associated challenges, represents technological infrastructure and smart city/metaverse development. Meanwhile, the yellow cluster highlights SMEs, resilience, and metaverse economy, suggesting small- and medium-sized enterprises' adaptation to green and digital economic models.

Key nodes such as "green," "environment," "tourism," "digitalization," and "business strategy" appear larger, indicating their centrality and high citation within the network, while the "metaverse economy" node connects technological and economic clusters. Dense interconnections among clusters suggest strong interdisciplinary relationships, particularly between green economy, digital transformation, business strategy, and technological adoption. Overlaps between clusters show that topics like sustainable tourism, green finance, and digital transformation serve as bridges across research domains. Overall, the network underscores a convergence of research at the nexus of sustainability, emerging technologies, and economic applications, highlighting growing interest in leveraging innovations such as the metaverse and IoT to support sustainable economic practices.

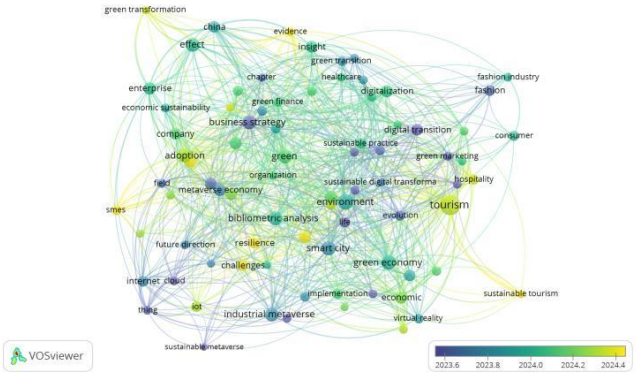

Figure 6. Overlay Visualization

Based on the keyword and cluster visualization, distinct yet interconnected research focuses can be observed. The green/yellow cluster in the top-left, containing keywords such as "green transformation," "economic sustainability," and "adoption," emphasizes business strategy, green finance, and organizational adoption, with yellow keywords like "adoption" indicating a growing interest in

sustainable business practices. The blue/green cluster in the bottom-left, including keywords such as "industrial metaverse," "IoT," and "internet cloud," relates to industrial applications of metaverse technologies and the Internet of Things, while the blue color suggests these concepts were explored earlier in the research timeline.

At the center, the green cluster with keywords like "environment," "green economy," and "digitalization" connects environmental sustainability with digital transformation, with green keywords reflecting current research focus. Meanwhile, the yellow cluster on the right, containing keywords such as "tourism," "hospitality," and "sustainable tourism," highlights sustainable tourism and consumer-related practices, with the yellow color indicating these are emerging topics gaining attention in 2024. Overall, the colors in the visualization represent temporal research trends (blue = older research, yellow = emerging topics), while the central position of keywords indicates high centrality and strong interconnection, representing core themes dominating the research field.

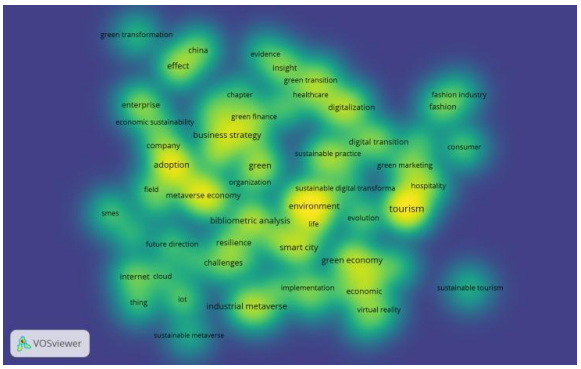

Figure 7. Density Visualization

The visualization highlights the distribution and relationships of keywords in the research domain, providing insights into key thematic areas. The color scheme indicates density, with dark blue representing low-density regions, green and cyan showing moderate density, and yellow marking high-density areas where keywords frequently appear and are highly interconnected. Larger keywords reflect higher occurrence, while smaller ones indicate less frequent topics. Spatial clustering reveals related concepts, such as "tourism," "hospitality," and "sustainable tourism," which form a cluster focused on sustainable tourism studies. Similarly, "business strategy," "green finance," and "adoption" cluster together, emphasizing research on organizational sustainability and green business practices. Another prominent cluster includes "metaverse economy," "industrial metaverse," and "smart city," highlighting technology-driven research.

Emerging topics such as "digitalization," "digital transition," "sustainable digital transformation," "green transformation," and "green economy" suggest a growing interest in the convergence of digital innovation and sustainability. Additionally, technology-related keywords like "IoT," "virtual reality," "internet cloud," and "smart city" cluster near sustainability topics, indicating interdisciplinary research connecting technology, environment, and business. Overall, the visualization reveals that research is concentrated on three main domains sustainable business and green finance, tourism and hospitality with a sustainability focus, and metaverse-driven digital transformation and smart cities while highlighting emerging intersections between technology, environment, and sustainable business practices.

CONCLUSION AND SUGGESTION

Conclusion

This study shows that research on the metaverse economy and sustainability has expanded rapidly since 2022, indicating strong momentum but also revealing a field still in its formative stage. Bibliometric evidence highlights three dominant clusters—sustainable business and green finance, tourism and hospitality with a sustainability orientation, and metaverse-driven digital transformation and smart cities. However, the apparent growth is not evenly distributed: publication dominance by a few publishers and fragmented collaboration networks suggest that knowledge production may be concentrated and lacking inclusivity, particularly from underrepresented regions and disciplines. Moreover, while the metaverse is often framed as a tool for reducing physical resource use and enabling green innovation, this narrative

risk overlooking its own energy-intensive infrastructure, which could exacerbate carbon emissions if not critically managed. Thus, the metaverse embodies both opportunity and paradox: its potential to advance sustainable development is contingent not on technological expansion alone but on how critically and ethically sustainability principles are embedded in its governance, design, and application.

Suggestion

Moving forward, research and practice must take a more critical stance toward the "green potential" of the metaverse. Interdisciplinary collaboration should not only be strengthened but also diversified to include voices from the Global South, small and medium enterprises (SMEs), and communities directly affected by digital transitions. Technology providers and corporations must be held accountable for adopting energy-efficient infrastructure, renewable-powered data centres, and verifiable low-carbon blockchain systems; otherwise, sustainability claims risk remaining rhetorical. Furthermore, future studies should interrogate the long-term energy trade-offs of immersive technologies and critically evaluate whether metaverse-driven business models genuinely contribute to sustainability or merely repackage existing consumption patterns in digital form. Policy frameworks and regulatory mechanisms will play a decisive role in preventing "greenwashing" and ensuring that metaverse development aligns with planetary boundaries. In this way, the metaverse can move beyond a speculative promise and become a verifiable contributor to global sustainability goals.

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