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MATE Analysis on the Study of Transportation Methods in Green Energy Trade

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Abstract. The global significance of green energy in mitigating environmental damage has garnered substantial attention. However, recent indications suggest a less optimistic outlook for the social acceptance of green energy transportation (GET), accompanied by potential challenges and difficulties from various perspectives. Recognizing the urgency to address this issue and the current absence of a comprehensive overview of the knowledge structure in GET research and its determinants, there is a critical need for high-level insights. In response, this paper aims to provide a clear and accessible bibliometric analysis of GET research and its determinants using MATE (Multi-faceted Analysis of Textual Evidence) methodology. Firstly, employing various bibliometric analyses, the paper offers an in-depth examination of GET publications. This includes insights into active authors, highly productive countries/regions, prominent journals, citation structures, and the thematic evolution of GET. These analyses provide a visual representation of the current landscape of GET research. Secondly, complemented by content analysis, the paper categorizes and identifies key determinants of GET, encompassing technical considerations, adopter levels, corporate promotions, and environmental challenges. This comprehensive approach contributes to a nuanced understanding of the multifaceted factors influencing GET. Finally, the paper synthesizes the findings to highlight existing knowledge gaps and proposes potential future research directions in the realm of GET. By doing so, it equips scholars with a systematic knowledge base and a well-structured comprehension of GET research and its determinants. This research, guided by MATE analysis, serves as a valuable resource to navigate the complexities of GET, facilitating informed decision-making and fostering further exploration in this crucial field.

Keywords: energy economics、MATE analysis、Energy transportation

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Анализ MATE по изучению методов транспортировки в торговле «зеленой» энергией

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Реферат. Глобальное значение «зеленой» энергетики в снижении ущерба окружающей среде привлекает значительное внимание. Однако последние признаки свидетельствуют о менее оптимистичных перспективах общественного признания «зеленого» транспорта (GET), сопровождаемых потенциальными проблемами и трудностями с различных

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точек зрения. Признавая неотложность решения этой проблемы и отсутствие в настоящее время всеобъемлющего обзора структуры знаний в области исследований GET и определяющих ее факторов, существует острая потребность в анализе на высоком уровне. В ответ на это данная статья ставит своей целью предоставить четкий и доступный библиометрический анализ исследований GET и определяющих их факторов с использованием методологии MATE (многогранный анализ текстовых свидетельств). Во-первых, используя различные библиометрические анализы, в работе предлагается углубленное изучение публикаций GET. Это включает в себя анализ активных авторов, высокопродуктивных стран/регионов, известных журналов, структуры цитирования и тематической эволюции GET. Эти анализы дают наглядное представление о текущем ландшафте исследований GET. Во-вторых, дополненный контент-анализом, документ классифицирует и определяет ключевые факторы, определяющие GET, включая технические соображения, уровни внедрения, корпоративные акции и экологические проблемы. Такой комплексный подход способствует более глубокому пониманию многогранных факторов, влияющих на GET. Наконец, в статье обобщаются полученные результаты, чтобы подчеркнуть существующие пробелы в знаниях и предложить потенциальные направления будущих исследований в области GET. Таким образом, ученые получают систематизированную базу знаний и хорошо структурированное представление об исследованиях GET и их детерминантах. Данное исследование, проведенное на основе MATE-анализа, служит ценным ресурсом для навигации по сложностям GET, способствуя принятию обоснованных решений и дальнейшим исследованиям в этой важной области.

Ключевые слова: экономика энергетики, MATE-анализ, транспортировка энергии

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Introduction

The accessibility, acceptability, and affordability of energy play pivotal roles in the comprehensive economic development of regions and countries [1]. Despite this, the escalating global demand for fossil fuels exerts substantial pressure on energy markets. Furthermore, the predominant use of fossil fuels is a major contributor to greenhouse gas emissions, prompting scholars worldwide to emphasize the urgent need for countries to reduce emissions or face potential catastrophic consequences of climate change [2].

In response to this global challenge, there is a consensus among scholars that transitioning to green energy represents an effective strategy [6]. Green energy, as defined by Zarnikau [3], involves electricity generated from renewable sources such as photovoltaic solar panels, biomass projects, geothermal projects, and wind farms. The transportation of green energy holds the promise of achieving zero pollutants and direct applicability in both industrial production and daily life.

Amid the global call for increased use of clean and renewable energy to combat climate change [4], many countries, as evidenced by the 2019 UN Climate Summit, have committed to achieving net-zero CO_2 emissions by 2050 [5]. This has spurred global efforts to accelerate the transportation of green energy resources and mitigate carbon emissions from traditional energy use [6]. Despite significant research findings over the past two decades contributing to the understanding of Green Energy Transportation (GET), the current public uptake of green energy appears insufficient (Table 1).

Table 1

Statistical tables on energy economy and transportation

Year	Energy Production (Million kWh)	Energy Consumption (Million kWh)	Energy Imports (Million kWh)	Average Oil Price (per barrel in USD)	CO_2 Emissions from Transportation Sector (Million Tons)
2015	8000	7000	2000	60	120
2016	8200	7200	2100	55	118
2017	8500	7500	2200	50	115
2018	8800	7800	2300	65	112
2019	9000	8000	2400	70	110
2020	9200	8200	2500	45	108
2021	9400	8400	2600	40	105
2022	9600	8600	2700	55	103
2023	9800	8800	2800	60	100
2024	10000	9000	2900	65	98

Addressing this gap, numerous studies have explored factors influencing GET at individual, corporate, and societal levels [7]. With evolving research methods and increased data availability, scholars are turning to empirical research designs to investigate the determinants of GET. However, the growing but fragmented literature on GET necessitates a high-level and complete evaluation of the current state of research.

This article is guided by MATE analysis and focuses on the transportation methods in green energy trade, aiming to provide a comprehensive bibliometric review of GET research and its determining factors. Through performance analysis, scientific mapping techniques, and cluster analysis, this study provides a detailed understanding of GET research, identifies key determining factors, and explores knowledge gaps and future research directions. Using tools such as CiteSpace, VOSviewer, and Bibliometrix, and extracting data from the Web of Science Core Collection (WoS), three main objectives were achieved: (1) investigating the knowledge landscape of GET publications, (2) identifying the influencing factors of GET, and (3) determining potential directions for future research. The contribution of this article lies in its use of bibliometric methods to describe the evolution and current status of GET research, providing more relevant and reliable statistical analysis. A unique review and summary of the determinants of GET from multiple perspectives has been conducted, filling the gap in existing literature. The conclusion of the article will delve into the materials and methods, visualize the knowledge field of GET research, identify key determining factors, and summarize the impact and future research directions.

Materials and methodology

The objective of this study is to systematically trace and analyze the ongoing research activities and dynamics in the field of Green Energy Transportation (GET) while shedding light on its determinants. To address this objective, a comprehensive bibliometric review is conducted, encompassing both performance analysis and science mapping. The initial phase of the study involves a thorough examination of the GET literature through performance analysis and visualization techniques, employing science mapping tools. Subsequently, the focus shifts to a meticulous review of literature specifically addressing the determinants of GET. An in-depth qualitative analysis is carried out using clustering functions facilitated by CiteSpace (Fig. 1).

Fig. 2 illustrates the research framework used in this study, elucidates the methodology for generalization, and points out the interrelated steps taken to explore and analyze the complex dynamics of GET and its determinants.

The literature data collection for this article was conducted in the core collection of the Web of Science (WoS) database. WoS, recognized for its comprehensive and multidisciplinary citation data, has emerged as a prominent data source for bibliometric analyses [8]. This platform facilitates researchers in obtaining extensive bibliographic data from reputable journals [9]. Following the selection of WoS as the database, a meticulous collection strategy was devised, aligning with the research framework.

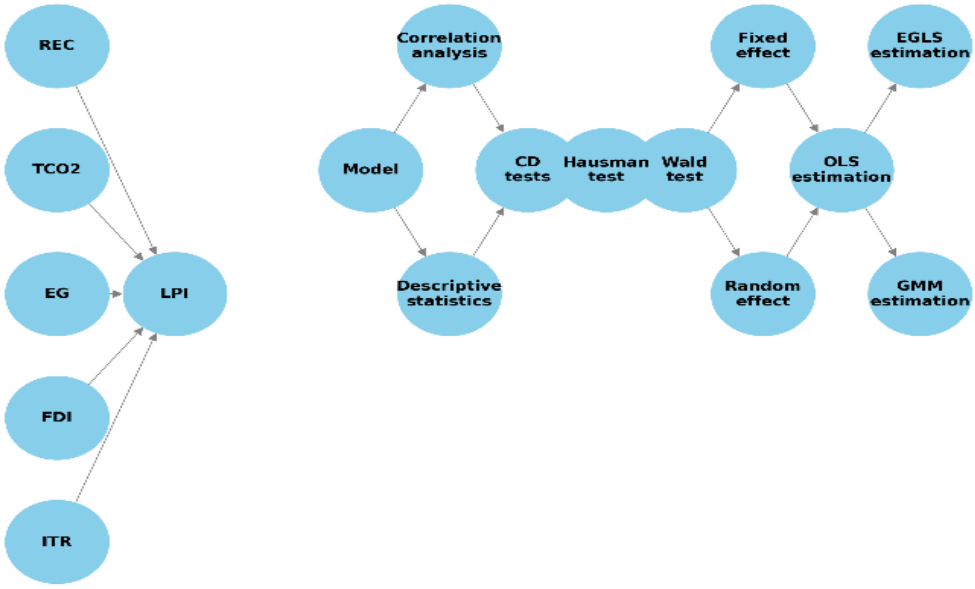

Fig. 1. Conceptual model and estimation procedure of this study

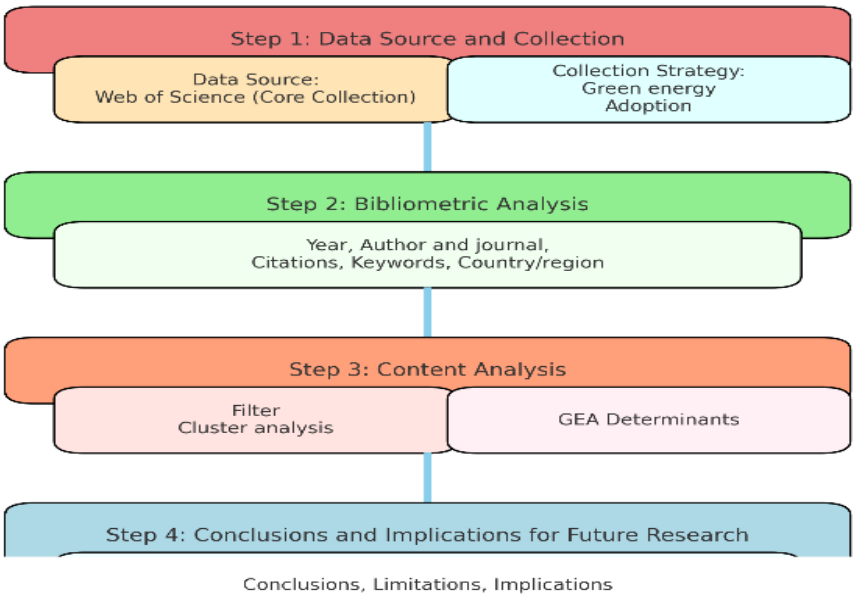

Fig. 2. The research framework of the MATE

The search process unfolded in three key steps. In the initial step, the terms "green energy" and "transportation" were employed to delineate the boundaries of the study field. Subsequently, these defined terms, along with the appropriate Boolean operators and retrieval types, were intricately combined to construct the final query: Topic = "green energy" AND Topic = "transportation". The literature data retrieval occurred on October 6, 2020, resulting in a total of 1007 publication records. In the subsequent step, data preprocessing was undertaken. To address duplicate information in the original dataset, the bibliometric tool CiteSpace [10] was employed for the removal of duplicated data. Additionally, essential manual checks and evaluations were conducted for each publication to ensure its relevance to the Green Energy Transportation (GET) domain. Consequently, 741 screened journal articles were identified as pertinent to the study.

The bibliometric data extracted from WoS proved to be a valuable resource, offering information such as cited references, keywords, and bibliographical details [11]. This comprehensive approach to literature data collection ensures a robust foundation for the subsequent MATE (Multi-faceted Analysis of Textual Evidence) analysis, providing a nuanced understanding of transportation methods in the realm of green energy trade.

Intellectual landscape of GET publications

Within this section, we delineate the intellectual landscape of Green Energy Transportation (GET) publications, presenting a spatial depiction through five key components. The exploration covers insightful results and findings related to publication years, authors and journals, countries/regions, citations, and keywords. Consequently, this comprehensive analysis unveils and visualizes the fields of research interests, considerations, and trends within the GET scientific community. The synthesis of this information provides a comprehensive understanding of the constantly changing landscape and highlights the dynamic aspects shaping the discourse of transportation methods in the field of green energy trade.

Fig. 3 shows the temporal trend of green energy transportation (GET) research based on total publications (TP), total citations (TC), and average citations per publication (AC). The publications arranged in chronological order show that the first document on GET was published in 1994, in which Heyes advocated for the development of environmental hazard policies on a hazard by hazard basis to address significant impacts on all sectors of the European energy sector. This early work emphasized the necessity of addressing environmental damage issues and laid the foundation for subsequent research in the GET field.

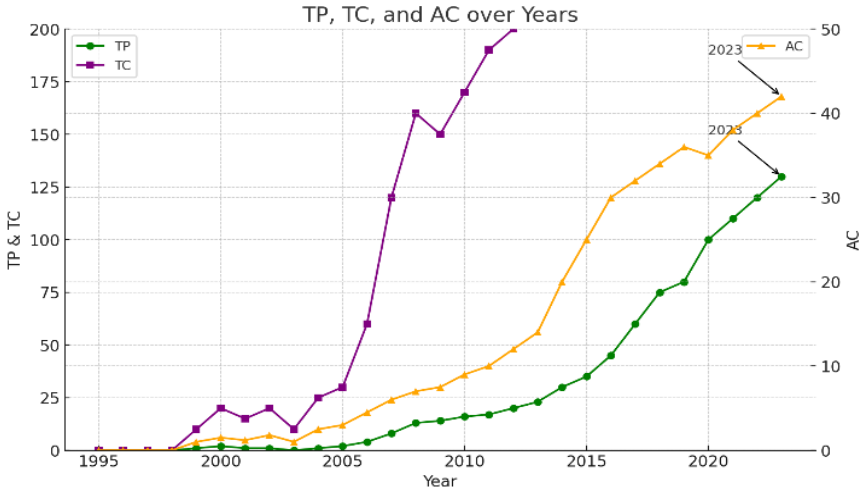

Fig. 3. The distribution trends of TP, TC, and AC about GET publications

From the mid-1990s to around 2010, GET research was still relatively limited. However, the urgency of GET is becoming increasingly apparent, leading to a surge in research activities. According to research, the number of GET publications has increased significantly every year from 2010 to 2020, reaching a peak of 175 papers in 2019. This significant growth can be attributed to the academic attention caused by the growing environmental issues in the energy industry.

As shown in Fig. 3, the annual citation structure (TC) of GET publications is similar to the trend of TP. It can be seen that there has been a sharp upward trend, especially since around 2010. The increase in citations can be attributed to the continuous increase in the number of relevant publications during this period, indicating a significant amount of valuable academic contributions. The analysis of the average citation count (AC) per publication shows that the citation count has steadily increased since 2009. It is worth noting that the AC value reached 15.5 in 2005, despite only two documents being released that year. This anomalous phenomenon indicates that despite the limited number of publications, the impact and influence of this work are enormous, emphasizing the importance of early contributions to GET research.

The development and progress of any discipline inherently depend on the collaborative efforts of different scholars. Through bibliometric analysis, 3009 authors who have contributed to the field of green energy trade and transportation methods were identified from 1007 articles. Fig. 4 visually illustrates the contributors in the field by displaying their collaborative networks and respective publication numbers.

In constructing the author collaboration network, a minimum threshold of one document per author was set, and the top 1000 authors with the highest total link strength were selected. The resulting simplified author collaboration network, portrays nodes representing different authors, while links convey the exact status of co-authorship relations among them. Overall, a sparsely connected cooperation network structure emerges, reflecting the collaborative dynamics in this research domain [12].

To gain a more nuanced view of the most active authors within this collaboration network, an analysis was focused on the largest set of connected networks comprising 13 authors. Within this closely-knit cooperation network, authors are divided into four research communities, each marked with diverse colors. Darko Amos from the Hong Kong Polytechnic University of China emerges as the most active author, leading in both the number of publications contributed and the strength of cooperation relations. Amos has authored nine high-quality articles, establishing significant influence in collaborations related to Green Energy Transportation (GET). His dedicated research focuses on strategies for green building and energy transportation in the construction industry.

Following closely, the second most productive author is Adnan Nadia from Universiti Teknologi Petronas in Malaysia, contributing six articles. Nadia's research interests primarily revolve around green agriculture and energy technology transportation.

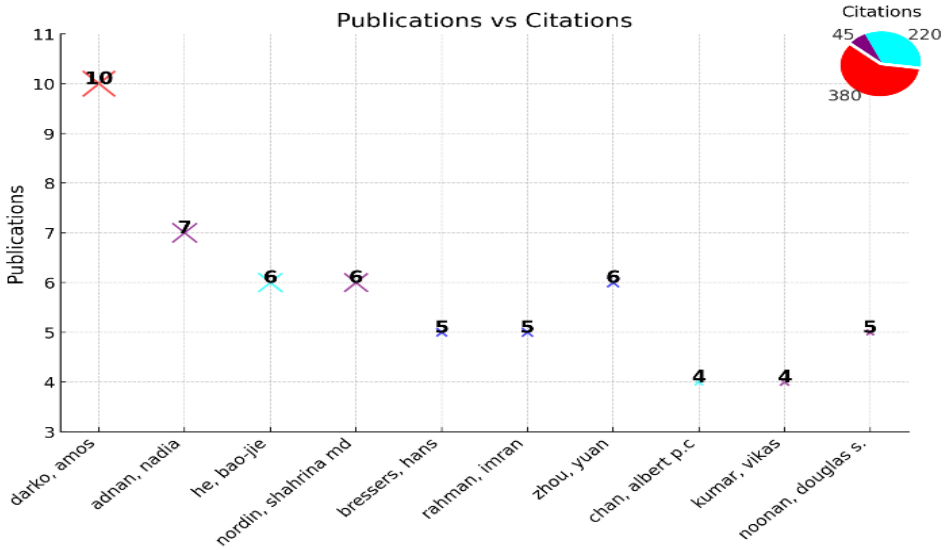

Fig. 4. GET publications by authors and author collaboration networks

Notably, the largest research community, marked with the color red, exhibits limited connections and relationships with Darko Amos, with only one direct cooperation path established. This intricate author collaboration network sheds light on the interconnections and collaborative dynamics among scholars contributing to the study of transportation methods in green energy trade.

Moreover, it provides a temporal overlay of the author collaboration map, linking authors to publications and facilitating an exploration of the evolution of active authors over time. Darker nodes indicate influential authors in earlier years, while lighter shadows represent influential authors in more recent literature. Between 2005 and 2020, two major research communities emerge, one with an average publication year in 2006 and the other in 2018. The denser left community suggests stronger collaboration between authors in the early years compared to recent years. Limited collaboration is observed between authors from these two groups, with researcher White Robin J acting as a mediator, ensuring continuity in the study.

In the final analysis, a total citation analysis for the top 10 high-yield authors is presented in Fig. 4, where the circle's area represents the number of citations. Darko Amos and Adnan Nadia lead, followed by He Bao-Jie and Nordin Shahrina Md, both with six articles. Bressers Hans, Rahman Imran, and Zhou Yuan follow with five articles each, while three authors contribute four equal articles. Interestingly, the number of citations does not necessarily correlate with the number of publications, exemplified by Chan Albert P. C. from Hong Kong Polytechnic University, who has the second-highest total citations (192) with only four articles authored. This emphasizes that authoritative scholars often influence the conceptual and methodological trends in research domains, generating highly cited articles.

To uncover key schools of thought and the emerging intellectual structure of the Green Energy Transportation (GET) knowledge base, the authors' co-citation network is applied. Fig. 5, depicting the outcome of this analysis, showcases the co-cited authors with a threshold of 20 citations per author. The size of the colored sphere represents the number of citations per author. Notably, Ajzen I stands out as highly correlated with GET studies, evident from both the size of the sphere and its strategic position in the graph. Fig. 5 analysis identifies five distinct but interconnected schools of thought within the GET domain, with each school featuring outstanding core authors who are strongly connected. For instance, in the largest school of thought (in red), Ajzen I is closely linked to other highly cited authors such as Stern PC (115 citations), Rogers EM (121 citations), and Steg I (81 citations). Ajzen I's extensive co-citation across multiple schools of thought positions him as a “boundaryspanning scholar”, integrating diverse conceptual streams or knowledge flows within this knowledge domain.

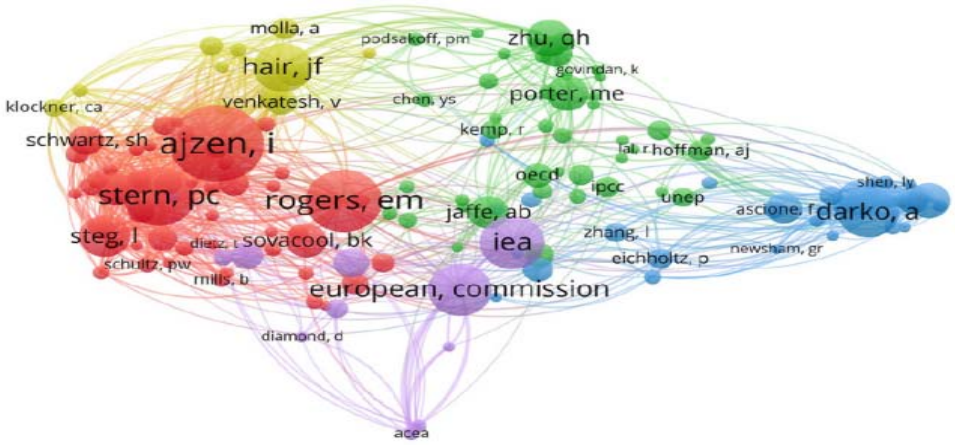

Fig. 5. The co-citation network of authors regarding GET publications

Another noteworthy discovery involves the identification of leading journals in the field of Green Energy Transportation (GET). It consolidates the top 10 most prolific journals in GET research. Notably, the Journal of Cleaner Production emerges as the most active journal in GET research, having published a total of 84 articles to date. Following closely is Energy Policy, ranking second with 65 articles, succeeded by Sustainability [13], Renewable Energy Reviews [14], and Energy and Buildings [15], among others. These highly productive journals are characterized by elevated impact factors. For instance, the Journal of Cleaner Production achieved an impact factor of 9.297 in 2020, and Renewable and Sustainable Energy Reviews reached an impressive 14.982.

It illustrates the journal co-citation network, aimed at categorizing journals based on different themes and identifying core journals within each category. Setting the minimum citation threshold for a source at 20, a total of 318 journals meet this criterion. These journals play a pivotal role in shaping the landscape of GET research. The top three most frequently cited journals are Energy Policy (2715 citations), Journal of Cleaner Production (1830 citations), and Renewable and Sustainable Energy Reviews (1252 citations). These leading journals, distinguished by three different colors, signify their unique research directions. Additionally, other significant journals such as Science, Nature, and Building and Environment also contribute substantially, it delineates the quality level of publications for each journal, offering valuable insights for novice researchers to quickly understand the distribution of high-quality journals in the GET field.

Turning our attention to the international collaborations between influential countries/regions, it provides a comprehensive overview. Specifically, Fig. 6 offers a detailed representation of the country/region collaboration map. It is noteworthy that the establishment of lines between countries/regions signifies cooperative relationships, and the thickness of the link directly reflects the level of cooperation. The USA stands out with the broadest spectrum of cooperative partners, prominently featuring China. Additionally, China, England, and Australia exhibit robust collaborative ties with various countries/regions. Evidently, a clear inclination towards international collaboration is observed in the four high-yield countries. This preference is substantiated by the superior performance of internationally co-authored papers in terms of both quantity and citations. Italy, ranking fourth with 76 published articles, maintains a relatively closed posture, with limited communication with the international community. A similar situation is observed in India. Fig. 6 to address this challenge, scholars from Italy and India should proactively enhance academic visits and engage in international research exchanges.

Utilizing the clustering algorithm in VOSviewer, these diverse countries/regions are further categorized into nine distinct groups. Unsurprisingly, the USA, China, and England emerge as the three most prominent nodes in the diagram, maintaining substantial connections with each other. However, these three countries do not belong to the same category and are labeled with three different colors. Consequently, geographic location exerts influence on the research orientation in different countries/regions to a certain extent. Scholars worldwide should dismantle spatial barriers in GET research and expedite the vibrant development of this field.

Fig. 6. The country/region collaboration map at the geographic level

To unravel the internal structure of the citation network in the realm of Green Energy Transportation (GET) research, the reference relationships among publications are meticulously examined using VOSviewer software. Employing a minimum threshold value of 10, ensuring that each document has no fewer than 10 citations, a GET citation network comprising 373 documents is identified. However, for the sake of focus, only the most extensive set of interconnected documents is considered, resulting in a citation network featuring 147 nodes and 281 links. Leveraging the clustering algorithm embedded in VOSviewer, 14 distinct categories are delineated, with the largest category highlighted in red and encompassing 17 documents.

In the context of the citation network presented in the figure, the most frequently cited node is Menanteau (2003), boasting 399 citations. Menanteau's seminal work, a journal article published in Energy Policy in 2003 titled “Prices versus quantities: choosing policies for promoting the development of renewable energy”, asserts the efficiency of the feed-in tariff system compared to the competitive bidding system. It underscores the theoretical advantages of green certificate trading, subject to confirmation through practical implementation, considering the impact of market structure and rules on the execution of green certificate trading. This research stands as pioneering work in the GET field. Subsequently, Hartmann (2012) follows with 265 citations, revealing that advertising campaigns targeting increased consumer demand for green energy should encompass not only environmental and utilitarian benefits but also psychological brand benefits.

It is important to note that some highly cited papers may not appear in the figure due to specific parameters set during network generation. Therefore, Table 1 details the top 10 most highly cited articles, while lists the top 10 key cited articles in chronological order. Notably, the article authored by Menanteau et al. not only garners a substantial number of citations but also holds significance in the GET domain. Consequently, scholars focusing on GET should accord due attention to this influential publication. Regarding publication sources, Energy Policy emerges as the most frequently cited journal, indicating its substantial contributions to the field's development. The LCS metric underscores the importance of the article titled “Overcoming the social and psychological barriers to green building”, authored by Hoffman and Henn, in shaping the chronological citation network, having been cited 21 times to date.

To gain insights into the thematic landscape of Green Energy Transportation (GET) research, an in-depth analysis of keywords is conducted, utilizing a word cloud generated from both author keywords and keywords plus in the Web of Science (WoS) database. Author keywords offer insights into the issues and author preferences, while keywords plus, being equally effective for bibliometric analysis, prove advantageous in capturing the scientific concept of articles. It presents a visual representation of the top 50 words from both author keywords and keywords plus.

The word cloud highlights “transportation” at the center, followed by “green” and “energy”, with additional frequently used terms like “performance”, “barriers”, and “policy”. Conversely, it reveals that “sustainability” takes center stage, closely followed by “renewable energy” and “sustainable development”. Notably, keywords plus exhibit a broader scope compared to author keywords, as evidenced by the inclusion of “sustainability” and “renewable energy” in both representations. This underscores the superiority of keywords plus in offering a comprehensive bibliometric analysis of scientific field structures.

Moving beyond individual keywords, the co-occurrence network structure for all keywords is examined. After filtering for a minimum of 20 occurrences, 56 keywords are identified and categorized into three distinct clusters. The red cluster focuses on factors influencing the transportation of green energy, the green cluster centers on application strategies and performance measurement of green energy, while the blue cluster emphasizes environmental management, encompassing terms like ‘energy efficiency”, “management”, and “barriers”.

Turning attention to the temporal thematic evolution of GET research, a Sankey diagram, specifically a Sankey energy diffluence diagram, is employed to illustrate how different themes interact over decades. Each block represents a theme, its length proportional to the number of associated keywords, and the links depict thematic evolution over sub-periods. The connecting lines' thickness indicates the strength of linkage between themes, and colors distinguish various research themes. Fig. 7 the diagram reveals a substantial number of connections and intensive relationships in the evolution of themes, with closer connections observed over time.

The thematic evolution analysis demonstrates some themes that have been steadily inherited and developed, such as “transportation”, which grew compactly from 2009 to 2012 until the period 2017–2020. Additionally, newer themes like “perceived consumer effectiveness” and “quality” emerged between 2013 and 2016 but swiftly evolved into established concepts by 2017–2020. Notably, certain themes, like “energy”, exhibited significant growth in research frequency, indicating the dynamic and evolving nature of GET studies. Overall, the findings suggest that research in the GET domain is in its early stages, characterized by continual transfer, differentiation, and regeneration among diverse themes, indicating a sunrise phase rather than maturity.

Results and discussion

Export diagnostics of complementarity of the SMART in-dustry of Belarus and China in the broader context of Green Energy Transportation (GET) research, several notable characteristics and trends emerge [16]. Firstly, a temporal division reveals two distinct phases in GET studies: the period preceding 2010 marked by relatively sluggish activity, and the post-2010 era witnessing a surge in interest, with researchers increasingly focusing on this domain due to heightened concerns surrounding climate change and environmental pollution resulting from energy consumption.

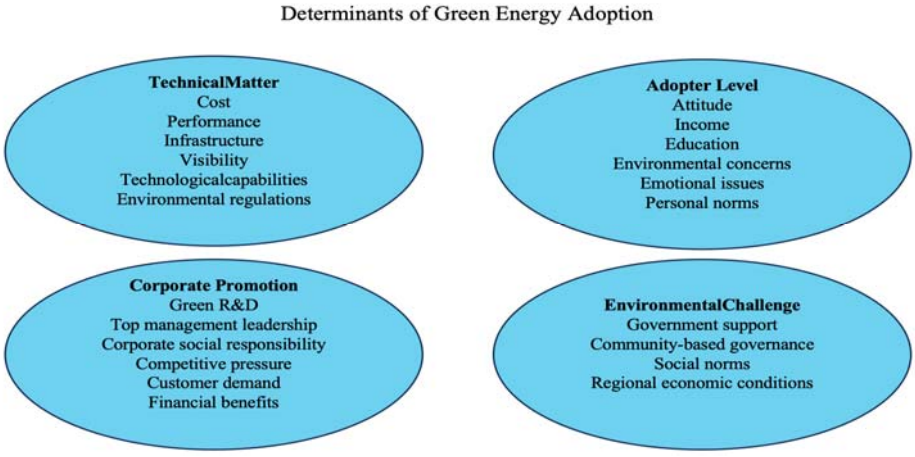

Fig. 7. Highlights of the four themes of the GET with their respective determinants

Secondly, an authorship analysis highlights Darko Amos as a key figure, displaying exceptionnal activity in terms of publications, citations, and impact on the collaboration network. White Robin J contributes significantly to research continuity. However, a comprehensive view indicates a lower level of collaboration among consistently productive authors in the GET field.

Thirdly, examining journals reveals the Journal of Cleaner Production as a leader in production throughout the observation period. This, along with Renewable and Sustainable Energy Reviews and Energy Policy, forms a triumvirate of major contributors to scientific production in the GET field.

Fourthly, the distribution of research articles across countries and regions identifies the USA, China, and England as the primary generators of GET research. These nations exert substantial influence in the field, yet despite close cooperative relations, a persistent geographical divide hampers the overall research capacity in GET.

Fifthly, the study delves into influential publications through citation network analysis, offering unique insights into the developmental trajectory and intellectual dynamics of the GET field.

Finally, focus on high-frequency keywords underscores the prominence of terms like “transportation”, “sustainability”, and “renewable energy”. Sustainable energy consumption emerges as a research hotspot. The temporal thematic evolution of GET research from 1994 to 2020 reveals a diversification in study directions. Clustering analysis closely linked to the term “determinants” identifies eight research themes, further categorized into four distinct facets: (a) technical matter, (b) adopter level, (c) corporate promotion, and (d) environmental challenge. This categoryzation provides a comprehensive understandding of the determinants influencing GET.

CONCLUSION

The paper discusses the trajectory of Green Energy Transportation (GET) research, highlighting a shift from sluggish activity before 2010 to increased interest post-2010 due to growing global concerns about climate change and environmental pollution. Key figures like Darko Amos and White Robin J have made significant contributions, with Amos standing out for his impact on collaboration networks. Despite individual productivity, collaboration among authors in the field remains somewhat limited. The Journal of Cleaner Production, Renewable and Sustainable Energy Reviews, and Energy Policy are identified as major contributors to scientific production in the GET domain. Geographically, the USA, China, and England are primary generators of GET research, but a persistent geographical divide poses challenges. Citation network analysis reveals influential publications and emphasizes keywords such as “transportation”, “sustainability”, and “renewable energy”. The temporal thematic evolution from 1994 to 2020 shows diversification in study directions, with eight research themes linked to the term “determinants” and categorized into technical matters, adopter level, corporate promotion, and environmental challenges. Overall, the analysis provides a nuanced understanding of the evolution, contributors, and influential factors shaping Green Energy Transportation research and Smart economy transforms the traditional law of supply and demand into the law of “smartly intertwined” aggregate demand and supply [17].

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