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Research Status and Development Trends of Energy Investment Cooperation under the "Dual Carbon" Goals: A Knowledge Map Analysis Based on CiteSpace

Jieyu Liu

School of Business, Xi'an University of Finance and Economics, Xi'an, China
Email: liujieyu2022@163.com

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Abstract

Currently, against the backdrop of the dual carbon goals, energy investment cooperation has gradually become a key pathway and important lever for driving green and low-carbon transformation across nations. To clarify the research progress and evolving trends in energy investment cooperation, this article utilizes the Web of Science database and employs methods such as bibliometrics, knowledge mapping, and inductive summarization to review 286 relevant publications from 2000 to 2024. The CiteSpace knowledge mapping analysis tool is applied to visualize research literature in the field of domestic and international energy investment cooperation. The analysis examined the temporal distribution of core papers, collaborative networks among researchers, keyword co-occurrence clustering, and sudden outbreak detection of hot topics. Results indicate: 1) Publication volume exhibits exponential growth, progressing through three developmental stages: nascent, developmental, and flourishing. 2) Key research keywords include renewable energy, economic growth, policy impact, innovation, climate change, and China. 3) Research hotspots shifted from early themes like sustainability, concentrated solar power, energy, policy, and cooperation mechanisms to later focus on power generation, systems, and energy security. 4) The research hotspot of energy security remains prominent to this day.

Keywords

"Dual Carbon" Goal, Energy Investment Cooperation, CiteSpace, Knowledge Graph, Visualization Analysis

1. Introduction

The proposal of the "dual carbon" goal (achieving carbon peak by 2030 and carbon neutrality by 2060) marks a wide and profound systemic transformation in China's social development (Zhang et al., 2023). As the main source of carbon emissions, the green and low-carbon transformation of the energy system is the key to achieving the "dual carbon" goal (Song et al., 2025). However, energy transformation faces multiple challenges, such as technology, funds, resources, and international relations, and it is impossible for a single country or enterprise to complete it independently (Tian et al., 2024). Energy investment cooperation refers to the integration of resources by different entities—including nations, public and private sectors, and enterprises—through joint ventures, public-private partnerships, technology sharing, and other forms to jointly invest in green energy projects. In this context, strengthening energy investment cooperation has become an inevitable choice to gather innovative resources, reduce financing costs, optimize resource allocation, and jointly address climate change. Therefore, systematically reviewing the research trends and hotspots of energy investment cooperation at home and abroad is of great practical significance for promoting theoretical and practical innovation and facilitating the smooth and efficient realization of China's "dual carbon" goal.

Currently, the academic community has conducted extensive discussions on "carbon neutrality" and energy investment cooperation, indicating that scholars have paid close attention to issues related to energy investment cooperation. Feng and Li studied how Chinese energy enterprises, in their investment layout for clean power projects in "Belt and Road" countries, can formulate corresponding measures to reduce investment risks and expand returns in terms of financing channels, international cooperation mechanisms, and risk management and control (Feng & Li, 2024). Bai and Zhao analyzed the current situation of energy investment cooperation between China and Africa, arguing that both sides have a good foundation for cooperation and strong complementarity (Bai & Zhao, 2025), but China still faces multiple challenges, such as policy support, financing, and energy competition pressure in its energy investment cooperation. These research results have laid a solid foundation for conducting research on energy investment cooperation, but further expansion in research methods and scope is still possible. Firstly, in terms of research methods, most studies focus on systematically presenting the current situation and development trends of China's energy investment cooperation from a theoretical perspective, while few scholars use the CiteSpace bibliometric method to systematically present the overall research dynamics and trends (Guo & Ji, 2021); Secondly, in terms of research perspectives, few studies focus on how the research paradigm and hotspots of energy investment cooperation change under the "carbon neutrality" target; Finally, in terms of research content, the current themes mainly focus on the analysis of the current situation of energy investment cooperation (Sun et al., 2023), path optimization (Su et al., 2025), risk identification and response (Liu & Wang, 2024; Ding et al., 2024). Research on this energy investment

cooperation using the big data bibliometric method for systematic analysis and trend prediction still needs to be carried out.

However, the existing studies are unable to comprehensively and intuitively present the dynamic changes and research hotspots of energy investment cooperation research. In view of this, this paper introduces the CiteSpace scientific knowledge mapping tool, aiming to present the current situation of energy investment cooperation, including the publication trends of literature, core authors and institutional cooperation networks, research hotspots and frontiers. This study, grounded in global literature data, offers conclusions with direct implications for China's pursuit of its dual carbon goals. Global research hotspots provide China with a repository of cutting-edge technological insights and policy experiences, aiding in the optimization of its domestic transition pathways. The common challenges identified—such as grid stability and supply chain security—are precisely the core issues China must urgently address. Furthermore, the global cooperation network map offers critical guidance for China to define its role and engage in targeted international collaboration.

The innovation of this paper lies in: methodologically, using CiteSpace to conduct quantitative analysis of the core literature in Web of Science, converting the subjective literature review into an objective knowledge map to achieve the visualization presentation of the research status; content-wise, accurately capturing the research hotspots and frontiers of energy investment cooperation research driven by the "dual carbon" goals, revealing their internal logic and development laws, and providing references for subsequent theoretical research and policy formulation on related topics. The research results show that energy investment cooperation research is in a stage of rapid development, and in the future, it has broad research prospects in aspects such as cross-border cooperation mechanisms, investment risk management, and policy coordination.

2. Data Collection and Research Methods

2.1. Data Collection

This study utilizes the global Web of Science database, as the trends it reveals directly pertain to the core challenges and policy requirements for China to achieve its dual carbon goals. The critical technological bottlenecks (such as energy storage and hydrogen energy) and massive funding gaps highlighted by global research represent common challenges for China's transition. Issues like international carbon barriers pose direct risks to China. Therefore, analyzing global trends provides deeper insight into the global context and strategic requirements China faces in achieving its dual carbon goals. To ensure that the selected literature is of high quality and scientific nature, the documents chosen for this study are SCI/SSCI English-language publications. In order to conduct a systematic study on the literature in the field of enterprise energy investment cooperation management, using the search terms "Energy investment" and "Energy cooperation" in the Web of Science Core Collection database, with the time range set from 2000 to 2024, up

to December 31, 2024, and with the language set as English, document type as (article & review), a total of 268 SCI/SSCI publications were retrieved. After eliminating duplicate documents, a total of 268 documents were obtained, including 242 articles (article) and 26 review articles (review).

2.2. Research Methods

This paper employs bibliometric analysis and scientific knowledge mapping methods to analyze the progress of enterprise energy investment cooperation research. The bibliometric method focuses on the characteristics of relevant literature on enterprise energy investment cooperation, based on mathematical statistics, covering aspects such as the number of published papers, core authors, timeline, and research hotspots, to objectively evaluate the research status and development history of different authors, institutions, regions, and countries in this field (Zhou & Liu, 2025). The scientific knowledge map is formed through the induction of core words and keywords, revealing the development trends of related research in this field, predicting the cutting-edge of disciplinary development, and enabling scholars to have a clear understanding of the research subject.

CiteSpace has the advantage of facilitating information retrieval and can conduct network analysis, network visualization, and timeline analysis to study the research trajectory of relevant literature. Therefore, we used the CiteSpace 6.3R1 version for quantitative analysis, using "topics + abstracts + keywords" as the content of the software analysis, analyzing core authors, institutions, and keywords, and sorting out the trends and frontiers of energy investment cooperation research.

3. Current Status of Energy Investment Cooperation Research

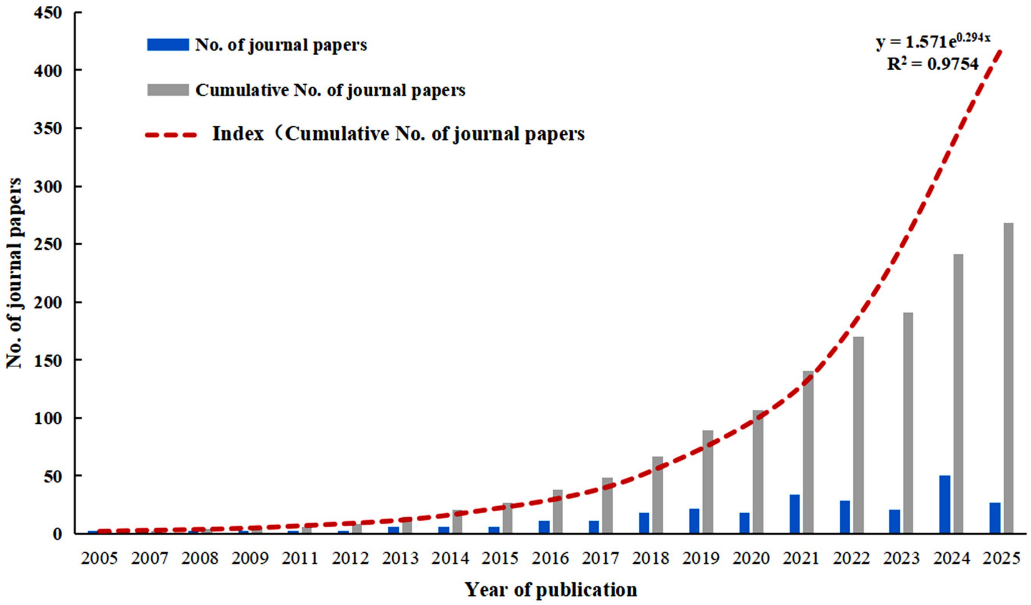
3.1. Analysis of Publication Trends

Based on data from 268 literature entries retrieved via the WOS platform, this paper conducts a systematic analysis of publication trends in the field of energy investment cooperation. The cumulative publication growth curve fitted using statistical methods reveals a pronounced exponential growth pattern (R^2 = 0.9754), indicating a well-fitted model consistent with exponential growth dynamics. Notably, between 2016 and 2021, the actual cumulative publication volume exceeded theoretical projections, with growth accelerating particularly after 2021. This indicates that energy investment cooperation was a hot research topic during this period and continues to attract widespread scholarly attention. This phenomenon reflects the urgent need for research on investment cooperation mechanisms amid the global low-carbon energy transition, offering significant theoretical innovation opportunities and research prospects for scholars in related fields.

Overall, the volume of publications in the field of energy investment cooperation exhibits an increasing trend, indicating that research on this topic is widely

recognized by scholars and continues to gain momentum. Based on the trend in annual journal article counts, we categorize research in this field into three phases, as shown in Figure 1.

First came the embryonic stage (2005-2015). Research on energy investment cooperation began to take shape, marking a period of slow development. The number of publications gradually increased, though at a modest pace. Next was the developmental stage (2016-2020). Research on energy investment steadily rose, growing from 11 papers in 2016 to 18 in 2020, with a stable increase in publication volume. Then came the boom phase (2021-2025). Following China's announcement of its "carbon peak and carbon neutrality" strategic goals in September 2020, global attention on carbon reduction surged. Research in energy investment cooperation experienced explosive growth, marking a period of rapid expansion. Publication volume accelerated sharply, rising from 34 papers in 2021 to 50 papers by 2024.



Source: Statistical data released by the WOS platform.

Figure 1. Statistical analysis of published papers on energy investment cooperation from 2005 to 2025.

3.2. Network Analysis of Scientific Research Collaboration

3.2.1. Author Co-Occurrence Analysis

Using the CiteSpace software, authors and institutions with an occurrence frequency greater than 3 were extracted to draw a graph (Figure 2). In this graph, the number of publications by authors or institutions represents the key research topics, while the co-occurrence relationships indicate their collaboration situations. The larger the font size of the nodes, the more publications the author has. The thickness of the lines represents the strength of the connection between the authors. From the perspective of author collaboration, a cooperation team mainly composed of Karakosta Charikleia and Shahbaz Muhammad was formed. They

have outstanding publication volumes in the field of energy investment and have formed a close cooperation network (Karakosta & Askounis, 2010; Karakosta et al., 2012; Shahbaz et al., 2024; Riveros & Shahbaz, 2024; Ahmed et al., 2024). There is not much cooperation among the team members, and the cooperation intensity is not high. Overall, the team collaboration shows the characteristics of "overall dispersion and local concentration". This structure indicates that while the field has established some stable research teams conducive to in-depth specialization, it also faces the challenge of "knowledge fragmentation" due to sparse connections between teams. This hinders the formation of a unified cognitive framework for energy investment cooperation. Therefore, the key to future development in this field lies in breaking down team barriers, strengthening academic exchange and collaboration, and driving the integration of dispersed knowledge points into a systematic theoretical framework.

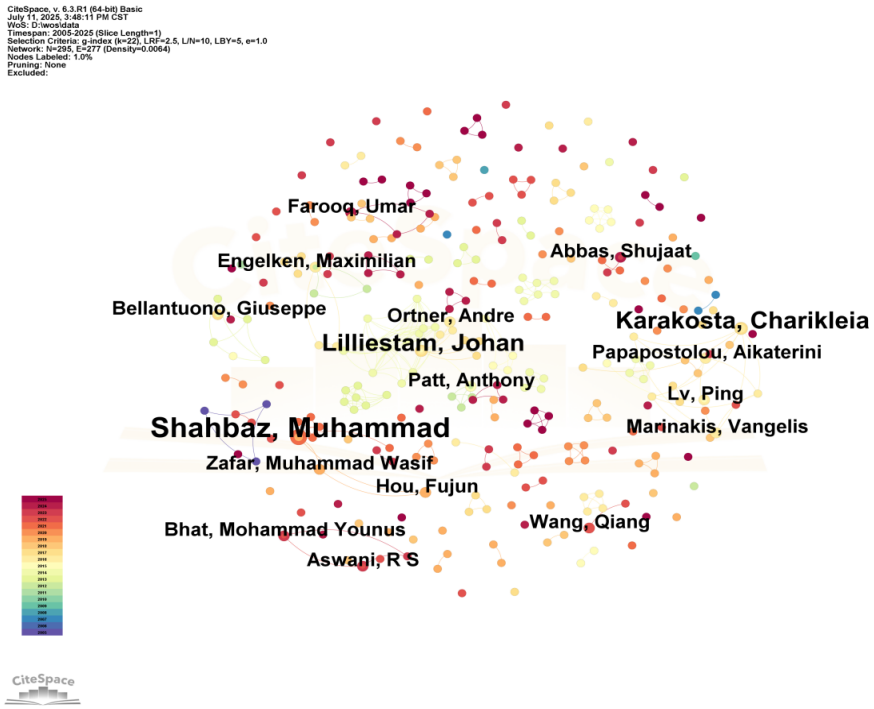


Figure 2. Author collaboration network.

3.2.2. Institutional Collaboration Analysis

In CiteSpace, node size and intermediary centrality are used to highlight cutting-edge research hotspots in this field. Research on energy investment cooperation has formed highly productive research teams represented by the Beijing Institute of Technology, China University of Petroleum, ETH Zurich, and COMSATS University Islamabad (CUI), indicating that universities are the primary driving force in this field (as Figure 3). Among these, the Beijing Institute of Technology published 6 related papers, while China University of Petroleum, ETH Zurich, and COMSATS University Islamabad (CUI) each published 4. Publication counts and detailed information for other institutions are shown in Table 1 below. It is im-

portant to note that connections between these research institutions are not dense, and no large-scale collaborative clusters have yet formed. Instead, collaboration exhibits localized clustering with overall dispersion. Consequently, significant potential for cooperative exchange exists among research institutions in the field of energy investment cooperation.

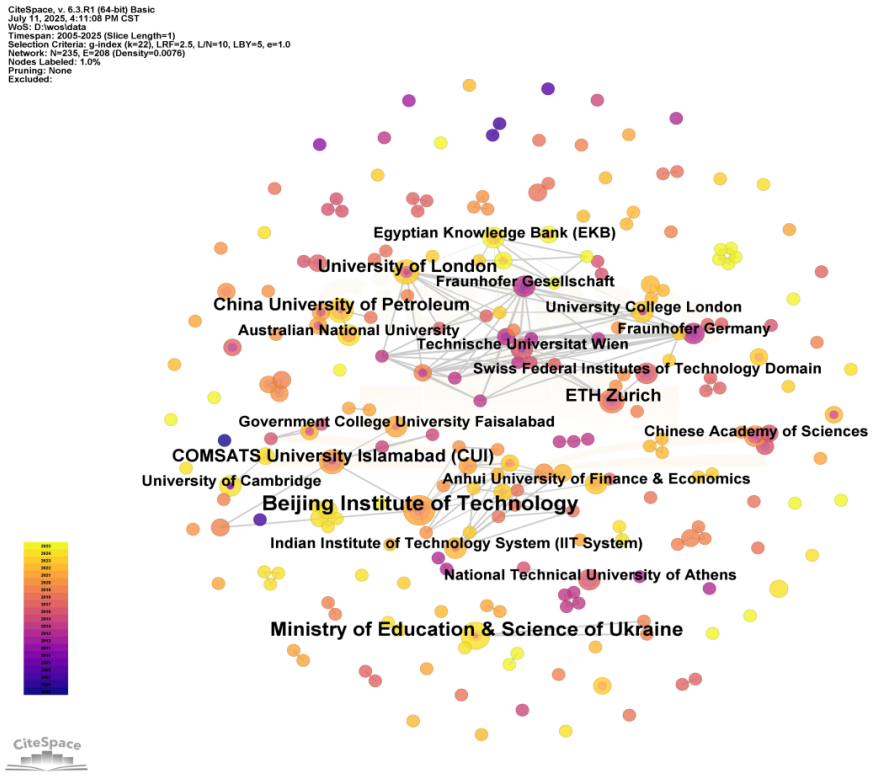


Figure 3. Institutional collaboration network.

Table 1. Frequency table of institutions.

Number	Institution	Count	Centrality	Year
1	Beijing Institute of Technology	6	0.01	2019
2	China University of Petroleum	4	0	2018
3	ETH Zurich	4	0	2015
4	COMSATS University Islamabad (CUI)	4	0	2015
5	University of London	3	0.01	2014
6	Fraunhofer Gesellschaft	3	0.01	2012
7	Fraunhofer Germany	3	0.01	2012
8	Technische Universitat Wien	3	0.01	2013
9	National Technical University of Athens	3	0	2016
10	Government College University Faisalabad	3	0	2018
11	University of Cambridge	3	0	2009
12	Swiss Federal Institutes of Technology Domain	3	0	2015
13	Ministry of Education & Science of Ukraine	3	0	2024

Continued

14	University College London	3	0.01	2014
15	Indian Institute of Technology System (IIT System)	3	0	2018
16	Australian National University	3	0	2021
17	Anhui University of Finance & Economics	3	0	2021
18	Egyptian Knowledge Bank (EKB)	3	0.01	2023
19	Chinese Academy of Sciences	3	0	2015

3.2.3. National Cooperation Analysis

Research on energy investment cooperation is primarily concentrated in China, the United Kingdom, the United States, and India, with these nations exhibiting high intermediary centrality, indicating their pivotal role in international scientific collaboration. According to Table 2, in terms of quantity, China contributed 71 papers, the United Kingdom 27, the United States 22, and India 20. In terms of publication volume, China holds a significant position in global energy investment cooperation research. Particularly since proposing the dual carbon goals, China has demonstrated high enthusiasm for energy investment and cooperation within the context of energy transition. China leads the world in installed capacity for green energy sources such as hydropower, wind power, and photovoltaic power generation, which has further intensified Chinese scholars' research focus in this field.

Table 2. Number of national documents issued in energy investment cooperation fields.

Number	Country	Count	Centrality	Year
1	CHINA	71	0.46	2013
2	ENGLAND	27	0.39	2009
3	USA	22	0.24	2005
4	INDIA	20	0.24	2014
5	GERMANY	18	0.1	2012
6	PAKISTAN	17	0.06	2015
7	AUSTRALIA	15	0.06	2015
8	ITALY	14	0.03	2008
9	RUSSIA	13	0.01	2016
10	U ARAB EMIRATES	12	0.07	2012
11	TÜRKIYE	10	0.07	2016
12	SAUDI ARABIA	10	0.02	2019
13	NETHERLANDS	10	0.02	2007
14	FRANCE	9	0.08	2013

3.3. Keyword Clustering and Timeline Analysis

3.3.1. High-Frequency Keyword Analysis of Energy Investment Cooperation Research

Keywords reflect the primary content and research focus of scholarly literature,

serving as crucial references for academic retrieval and knowledge clustering. To better understand and grasp the hot topics and cutting-edge issues in energy investment cooperation research, this paper maps the knowledge graph of keywords in this field (in Figure 4). Larger nodes indicate higher frequency of occurrence and stronger relevance to the topic, while the thickness of connecting lines represents the strength of co-occurrence relationships.

In the collinear network of energy investment cooperation research, the top ten keywords by frequency are: renewable energy (127 occurrences), economic growth (54 occurrences), impact (34 occurrences), policy (27 occurrences), innovation (23 occurrences), climate change (20 occurrences), and China (14 occurrences). Frequency counts, centrality values, and peak years are detailed in Table 3 below. Centrality represents the importance of a node. Values greater than or equal to 0.1 are often regarded as significant inflection points in keyword maps, indicating current research hotspots in the field. All keywords ranked in the top ten by frequency exhibit centrality values exceeding 0.1. These top keywords serve as pivotal nodes within the network. As illustrated in the diagram, "renewable energy", "economic growth", and "impact" constitute the foundational pillars of the energy investment cooperation network, representing the foremost frontier research topics among scholars. Notably, "renewable energy" possesses a centrality of 0.36, playing a critically pivotal role in sustaining the entire network.

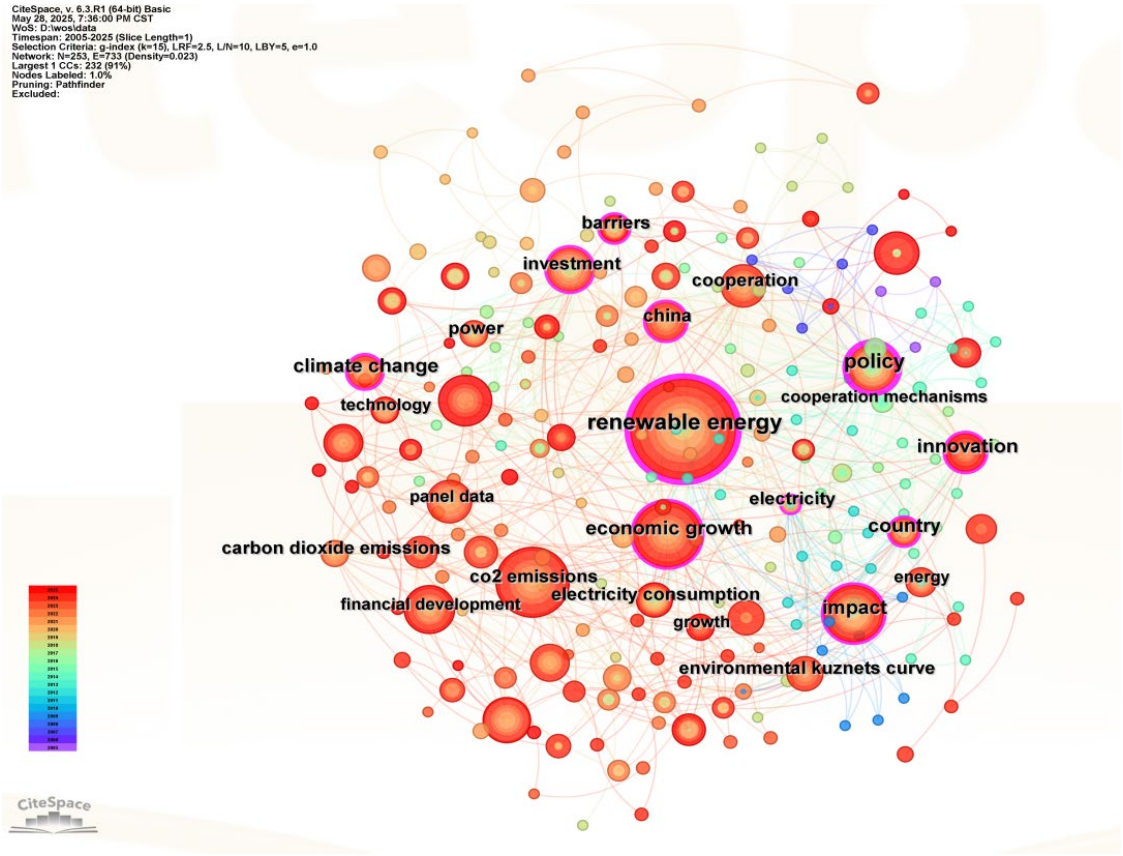


Figure 4. Keyword map.

Table 3. Top ten high-frequency terms in energy investment cooperation.

Number	Keywords	Count	Centrality	Year
1	renewable energy	127	0.36	2008
2	economic growth	54	0.12	2013
3	impact	34	0.15	2012
4	policy	27	0.21	2007
5	innovation	23	0.17	2012
6	climate change	20	0.16	2014
7	investment	16	0.1	2017
8	china	14	0.17	2020
9	country	9	0.14	2012
10	electricity	5	0.12	2009

3.3.2. Keyword Timeline Analysis of Energy Investment Cooperation Research

To more clearly illustrate the temporal evolution of research on energy investment cooperation, we constructed a timeline map using high-frequency keywords and employed the LLR algorithm to detect prominent keywords, as shown in Figure 5. Nodes in the figure represent keywords, with node size proportional to keyword frequency. When a keyword appears exceptionally frequently, it forms a circle. Connecting lines of different colors denote keywords from distinct years, while node positions indicate the year of first occurrence. The right side of the map displays clusters ("hashtag words") generated based on keyword frequency, representing distinct research domains. Keywords on the same timeline share common research themes. This analysis yielded 11 distinct clusters. The Modularity Q-value of 0.6178 exceeds the threshold of 0.3, indicating a statistically significant clustering structure. The Mean Silhouette S-value of 0.8201 surpasses the 0.7 benchmark, confirming the clusters' validity.

The map reveals that most major intersections of research themes occurred between 2010 and 2015. Prominent nodes include renewable energy, economic growth, impact, policy, innovation, climate change, and China. The high density of connections surrounding these keywords reflects their centrality, indicating their significance in energy investment cooperation research. We marked densely connected areas with black boxes (see "R1", "R2", and "R3" in Figure 5), which partially reflect the evolution of energy investment cooperation research. The specific analysis of the clustering results is as follows:

"R1" encompasses the clusters #0 Financial Development, #1 Environmental Quality, #2 Sustainable Development, and #3 Belt and Road Initiative Regions, featuring keywords such as electricity, consumption, foreign direct investment, energy, China, barriers, and growth. The highly dense lines indicate concentrated bursts of different themes within the energy investment cooperation field, reflecting strong interconnections among these documents—particularly regarding electricity, consumption, foreign direct investment, energy, and China. Notably, nodes

like barriers and climate change are highlighted in purple on the outer ring, indicating their high intermediary centrality. This signifies that investment barriers and climate change serve as crucial bridges for subsequent energy investment cooperation research, carrying significant importance. The prominence of the "#3 Belt and Road Region" cluster profoundly reflects the global perspective and inherent need for international cooperation inherent in the dual carbon goals, guiding China's participation in global climate governance. Through green energy cooperation, China and Belt and Road countries complement each other's strengths, representing a strategic choice to serve their own dual carbon objectives, optimize global investment layouts, and fulfill green commitments. Since the launch of the Belt and Road Initiative, research on energy investment cooperation has intensified. As such cooperation expands, scholars have extensively studied its impacts on economic development, environmental quality, and sustainable development. This cluster indicates that academia has keenly recognized the Belt and Road region as the pivotal international stage where China achieves its dual carbon goals and demonstrates global climate leadership.

"R2" encompasses the clusters #4 economic stability, #5 energy security, and #6 cooperation mechanism, featuring keywords such as policy, innovation, renewable energy, impact, electricity, and country. This cluster focuses on researching policy innovations in renewable energy across nations and their impact on the transformation of the electricity sector, particularly examining how policy-driven technological innovation propels changes in power structures and their socioeconomic and environmental implications. As global climate change accelerates, economic conditions become increasingly intertwined with energy systems. The environmental impacts of traditional energy sources are growing, prompting nations to enact policies that drive technological innovation and accelerate energy transition. Notably, the outer rings of the renewable energy and policy nodes appear purple, indicating these concepts possess high intermediary centrality and exert significant influence on the trajectory of research directions.

"R3" is the closest cluster to the present, encompassing groups such as #7 impact, #8 community-based, #9 energy sector, and #10 energy transition. Keywords include but are not limited to: power investment, technology, and cooperation mechanisms. The research themes primarily focus on power investment, energy technology, and energy investment cooperation mechanisms. This section emphasizes development models that prioritize safety, reliability, low-carbon efficiency, and innovation-driven collaboration, concentrating on how policy design and international cooperation can jointly advance the low-carbon transformation of global power systems. Notably, the outer layer of the "power investment" node is colored purple, indicating its high intermediary centrality and significant influence on subsequent research directions. China's dual carbon goals, proposed in 2020, established a clear transition timeline for its energy system, closely tied to the formation of the core cluster "#10 Energy Transition". This top-level design directly spurred extensive research addressing the question of "how to achieve an

efficient transition", explaining the high frequency of keywords such as "technology" and "cooperation mechanisms".

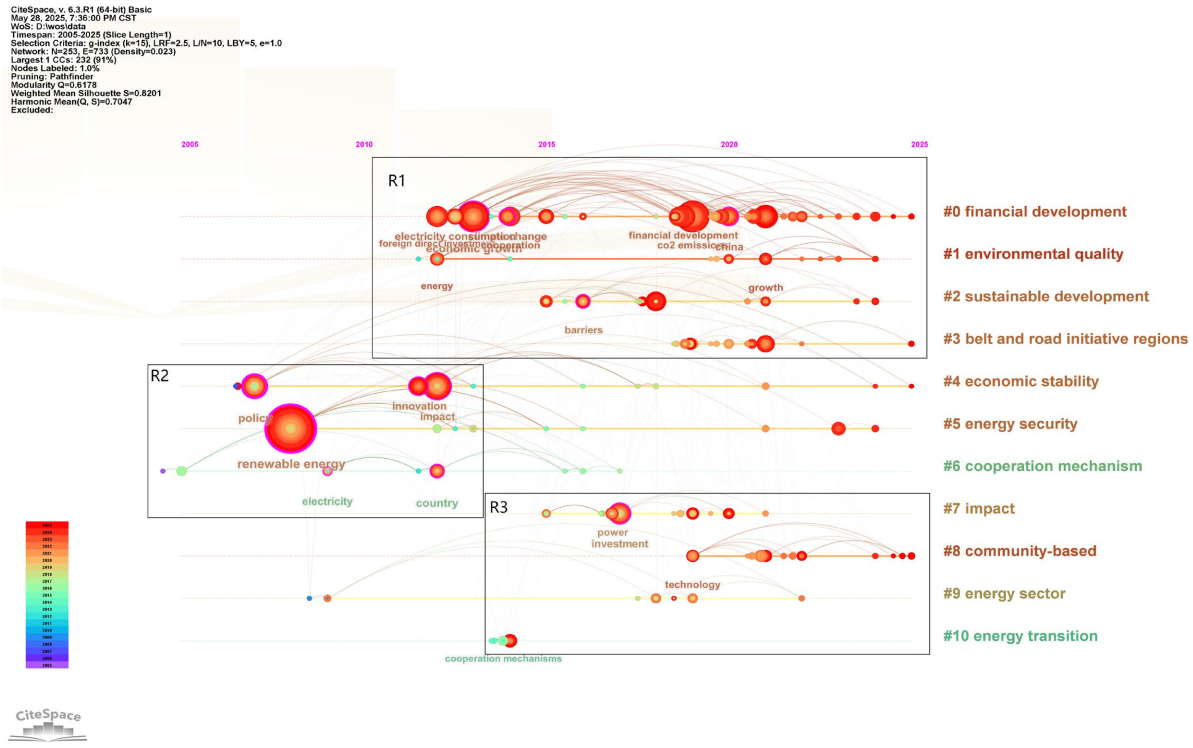


Figure 5. Keyword clustering timeline chart.

Keyword clustering comprises 11 categories, with the clustering coefficient for each category indicating the quality of clustering. Detailed information is presented in Table 4. Overall, the clustering results are satisfactory.

Table 4. Summary of the 11 clusters.

Cluster ID	Cluster	Size	Silhouette	Mean (year)
0	financial development	50	0.744	2019
1	environmental quality	25	0.715	2020
2	sustainable development	22	0.75	2019
3	belt and road initiative regions	21	0.819	2020
4	economic stability	21	0.96	2014
5	energy security	20	0.853	2015
6	cooperation mechanism	20	0.952	2011
7	impact	16	0.844	2017
8	community-based	16	0.726	2022
9	energy sector	13	0.953	2012
10	energy transition	8	0.967	2014

3.4. Emergent Word Analysis in Energy Investment Cooperation Research

To further analyze shifts in emerging research hotspots within energy investment cooperation, we employed a keyword outbreak map with a γ value set at 0.5, identifying eight outbreak keywords as shown in Table 5. Each research focus will become an outbreak trend within a short timeframe, and as international circumstances and national policies evolve, these hotspots will continuously transform. Based on keyword frequency, centrality, and outbreak analysis, this study reveals that research hotspots in energy investment cooperation have shifted from initial themes like sustainability, concentrated solar power, energy, policy, and cooperation mechanisms to current focus areas such as power generation, systems, and energy security. Notably, the research intensity surrounding energy security remains sustained to this day.

Specifically, the emergence of key terms in energy cooperation research began in 2005, primarily centered on "sustainability". Research activity remained high until 2017, after which scholarly interest in these topics began to wane. During this period, emergent terms such as "concentrating solar power", "energy", "policy" and "cooperation mechanisms" also emerged successively, becoming research hotspots at the time. The term "power generation" emerged in 2019; "systems" in 2021; and starting in 2023, "energy security" emerged, indicating that this research topic is currently a hot topic in the field of energy investment cooperation research. The three most prominent emergent terms were "energy security", "concentrating solar power", and "policy" with prominence scores of 3.85, 3.64, and 3.58, respectively. These research themes are likely to remain at the forefront of China's energy cooperation studies both currently and in the foreseeable future. For instance, in 2024, the National Development and Reform Commission and the National Energy Administration convened a symposium in Beijing to thoroughly implement the new energy security strategy. The meeting emphasized seizing opportunities and addressing challenges in energy security to advance high-quality energy development in the new era. Under the premise of safeguarding national energy security, efforts will be intensified to strengthen international energy cooperation and promote high-quality global energy development.

Table 5. Top 8 keywords with the strongest citation bursts.

Keywords	Year	Strength	Begin	End	2005-2025
sustainability	2005	3.3	2005	2017	
concentrating solar power	2012	3.16	2012	2018	
energy	2012	2.27	2012	2014	
policy	2007	3.58	2013	2018	
cooperation mechanisms	2014	3.64	2014	2017	
power generation	2019	3.17	2019	2021	
systems	2021	2.79	2021	2022	
energy security	2023	3.85	2023	2025	

4. Conclusion and Reflections

4.1. Research Findings

This study analyzes research literature on international energy investment cooperation indexed in the Web of Science database. Utilizing CiteSpace software, it examines the timeline of journal articles, key authors and journals, research institutions and countries, keywords, and research hotspots related to energy investment cooperation. The primary findings are as follows: First, in terms of publication volume, research on energy investment cooperation has experienced exponential growth, progressing through three developmental stages: an embryonic phase, a developmental phase, and a period of prosperity. Core research in this field began in 2005, with publication growth accelerating significantly starting in 2016. The current peak in energy investment cooperation research is closely linked to China's proactive implementation of policies such as the 13th Five-Year Plan for Energy. Second, based on author and institutional data, current research on energy investment cooperation exhibits dispersed author distribution and institutional collaboration, with research teams represented by Karakosta Charikleia and Shahbaz Muhammad emerging as prominent. Institutional collaboration in this field remains fragmented, with cross-institutional cooperation requiring further enhancement. Third, keyword clustering and timeline analysis reveal current research hotspots encompassing renewable energy, economic growth, policy impacts, frameworks, power systems, supply chains, and techno-economic analysis. Nevertheless, China's energy development continues to face significant challenges, including substantial demand pressures, multiple supply constraints, and the arduous task of achieving a green and low-carbon transition.

4.2. Research Outlook

Against the backdrop of the dual carbon goals, energy investment cooperation research is shifting from traditional project-evaluation approaches toward more systematic and forward-looking directions. Innovative thinking can also be applied in aspects such as research methodology. Therefore, future research should consider the following aspects: 1) From "Single Projects" to "Systemic Resilience": Building a New Cross-Border Investment Paradigm to Safeguard Regional Energy Security. Future research should move beyond isolated assessments of individual project economics and focus on exploring how diverse investment and financing entities—including governments, international institutions, and the private sector—can collaborate through platform-based models to effectively share and mitigate geopolitical and operational risks facing critical energy infrastructure. This collaborative approach will foster the development of more resilient regional energy supply systems; 2) Advancing investment decision-making models by embedding dynamic carbon pricing and multi-objective optimization into evaluation frameworks to enhance project carbon resilience and comprehensive benefits; 3) Conducting combined quantitative and qualitative analyses for energy investment

cooperation studies to ensure more objective and impartial evaluation outcomes; 4) Establishing a "Just Transition" cooperation model for countries with collaborative needs, integrating China's technological advantages in energy infrastructure with financial resources and capacity-building support. This approach aims to advance synergistic governance of biodiversity and climate change, offering new pathways toward building a more resilient, equitable, and efficient global energy governance system.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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