Business Ethics and Leadership, Volume 7, Issue 1, 2023
ISSN (online) – 2520-6311; ISSN (print) – 2520-6761

Innovation and Management of Smart Transformation Global Energy Sector: Systematic Literature Review

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Type of manuscript: research paper

Abstract: *The acceleration of globalisation processes and increasing countries' energy interdependence are required to ensure national energy security and independence. That demands investigating and developing processes and approaches for sustainable transformation of the global energy sector. The article aims to perform a complex review and investigation of the academic environment to analyse the trends and features of scientific publications devoted to new trends and tendencies in the smart energy industry transformation. To provide a categorical and theoretical background on the key scientific publications' trends, the paper conducted a bibliometric analysis of scientific publications about smart energy management and sustainable energy sector. The subject of investigation is publications on smart energy management and the sustainable energy sector. The article represented the results of bibliometric analysis using the Scopus tools analytics and VOSViewer tools. The investigation answered the central question of the key academic and research tendencies in the smart energy development and sustainable transformation field. Thus, qualitative, and quantitative trends describe the academic tendencies to spread smart and sustainable technologies in the energy industry. Using the Scopus scientometric database, a system of more than 5000 academic texts in the determined area was created from 2001 to 2022. Such countries as India, China, the USA, the UK, Germany, Italy, Canada, South Korea, France represent the analysed scientific area. Describing the key trends and clusters has allowed understanding and systemised the dominant trends in the development of scientific publications in the field of management of sustainable development processes, spreading the IOT processes, and renewable energy.*
Keywords: energy sector, sustainable development, smart transformation, energy management, efficiency.
JEL Classification: O30, Q41, Q42.

Received: 23 January 2023 **Accepted:** 28 February 2023 **Published:** 31 March 2023

Funding: This research was funded by the Ministry of Education and Science of Ukraine, grants "Innovative transformations in energy for sustainable development and national security: smart technologies and environmental responsibility", "Economic and mathematical modeling and management technologies of cross-border energy security in the conditions of military operations and post-war reconstruction".
Publisher: Academic Research and Publishing UG (i.G.) (Germany)
Founder: Sumy State University and Academic Research and Publishing UG (i.G.) (Germany)

Cite as: Chygryn, O., Bektas, C., & Havrylenko, O. (2023). Innovation and Management of Smart Transformation Global Energy Sector: Systematic Literature Review. *Business Ethics and Leadership, 7*(1), 105-112. http://doi.org/10.21272/bel.7(1).105-112.2023.

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Introduction

The International Energy Agency (IEA, 2022) offers three scenarios for transforming the global energy system − basic, ambitious and "Zero emissions by 2050". Their implementation depends entirely on the readiness of the governments of individual countries to implement previously declared goals. Thus, all three scenarios predict an increase in the share of electricity in final global consumption. For the basic scenario, this share will be 28% in 2050; for the ambitious scenario, it will be 40%. To implement the "Zero Emissions by 2050" plan, the share of electricity must exceed 50%. Intellectualisation has become dominant in the energy development strategy. The basis is defined as ensuring inseparability and coherence of actions in the following key directions: energy supply (uninterrupted supply of electrical energy of appropriate quality), energy availability (energy saving and affordable price of electricity) and energy acceptability (minimum impact on the environment) (Andrișan et al., 2022; Djalilov, 2022; Mlaabdal et al., 2021). These directions are highlighted as the basis for transitioning to implementing modern ones and promising "intelligent" technologies (Koibichuk et al., 2022). This implementation of innovative technology networks will contribute to integrating renewable energy sources into the power grid. The article aims to perform a complex review and investigation of the academic environment to analyse the trends and features of scientific publications devoted to new trends and tendencies in the smart energy industry transformation.

Literature Review

Optimization of resource use, the introduction of renewable sources, digitalization, and the gradual application of more and more technologies will inevitably lead to the transformation of the energy sector in each country. Using a wide range of methods and tools for implementing sustainable development and renewable energy projects and stimulating CO2 emissions reduction characterizes the global transformational processes in the energy industry. The main ones include legislative norms and restrictions, supporting energy security (Kolosok et al., 2022), implementation of the environmental management system (Dobrowolski et al., 2022; Ziabina et al., 2022), use of emissions trading systems by countries (El Amri et al., 2020), fiscal and tax mechanisms and tools (Bardy et al., 2022; Khalatur et al., 2022), support of ecologically oriented innovative entrepreneurship (Saher et al., 2022); introduction of green investments and taxes (Pimonenko et al., 2018; Vostrykov et al., 2022), environmental standardization and certification; development of sustainable energy consumption (Yang et al., 2021), forming green awareness and sustainable society culture (Kyrychenko et al., 2021; Louis, 2022; Vakulenko et al., 2022). Thus, quite important to investigate the existing scientific environment of developing smart energy sector transformation.

Methodology and Research Methods

The analysed tendencies are connected with smart energy and sustainable energy sector development and were published in the authoritative scientific journals chosen based on the Scopus CiteScore System (Table 1).

Table 1. The TOP-10 Journals Based on Scopus CiteScore 2022

Journal Title	CiteScore	SNIP	SJR
IEEE Communications Surveys and Tutorials	69,4	13,519	11,315
Renewable and Sustainable Energy Reviews	28,5	3,678	4,535
IEEE Transactions on Industrial Informatics	21,3	4,333	3,471
Applied Energy	20,4	3,062	2,652
IEEE Transactions on Consumer Electronics	10,2	2,105	1,602
Energy Policy	8,3	1,562	2,034
IET Renewable Power Generation	7,3	1,132	1,174
Sensors (Switzerland)	6,4	0,803	1,420

Sources: Compiled by the authors on the base of Scopus

Represented academic journals described by high-level CiteScore, that estimate the citations received per document. Thus, in the described subject field the highest CiteScore belongs to the IEEE Communications Surveys and Tutorials journal (CiteScore Rank − 69,4), which was established in 1998. Simultaneously, SCImago Journal Rank assess the weighted citations obtained by the journal. They are determined by the

sphere and subject area and citing indicators. IEEE Communications Surveys and Tutorials journal has the highest level (SJR – 11,315). One more indicator (Source Normalised Impact per Paper) evaluates the number of citations received compared to citations foreseen for the journal's scientific subject area. IEEE Communications Surveys and Tutorials journal also has the highest SNIP Rank – 13,519. Described tendencies characterise the relevance of the chosen for investigations scientific publications.

The proposed bibliometric analysis includes investigating quantitative and qualitative indicators of the academic papers investigating issues connected with smart energy development and management. Such an approach is assumed to assess and determine the main subject areas in smart energy development and management. They provide the possibility to systemise and structure scientific papers on the key research areas to cluster the main spheres of scientific activity. EViews software allows creating of bibliometric maps, built-on information from the Scopus base, that illustrate the trends in co-citation and co-occurrence analysis.

Results

The study of global trends in publishing activity dedicated to the smart transformation of the energy industry and approaches to effective management made it possible to identify and analyse the relevant trends. Figure 1 shows the dynamics of the publications dedicated to developing the sustainable energy sector and smart energy transformation for 2000-2022. The Scopus analytics tools can review and analyse scientific publications from the scientific base considering a wide range of indicators: by scientists, their citing number and ranks, affiliation, subject area, type of publications, countries, funding institutions, etc. The dynamic of publications in the figure shows a steady growth trend in the number of relevant scientific works and significant growth has been observed since 2010.

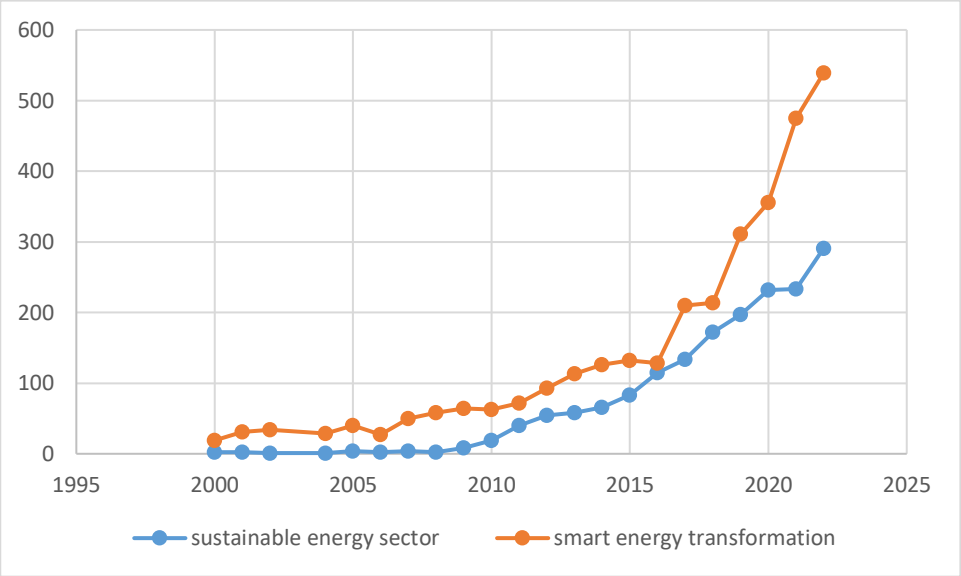


Figure 1. The Dynamics of the Publications Dedicated to the Development of the Sustainable Energy Sector and Smart Energy Transformation

Sourse: Compiled by the authors on the basis of Scopus base

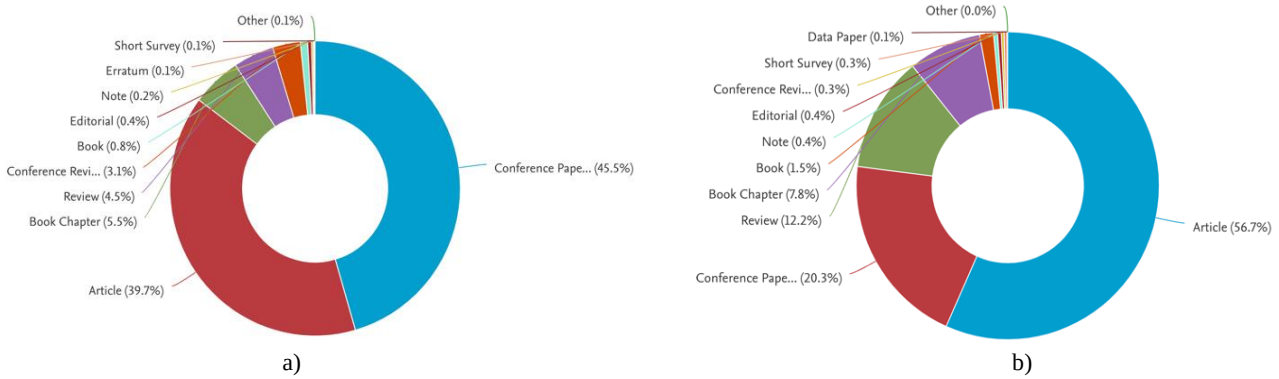
Correlation analysis was used to determine the degree of relationship between indicators of the number of publications (Table 2).

Table 2. Descriptive Statistics

Pirson coef.	n sampl.	Fisher coef.	Stand. dev.	cvantil, 95%	lower 95% limit, zL	upper 95% limit, zU	lower 95% limit, rL	upper 95% limit, rU
0,7995	22	1,0974	0,2294	1,9599	0,6477	1,5470	0,5701	0,9133

Sourse: Compiled by the authors on the basis of Scopus base

The correlation coefficient and its confidence interval were evaluated, namely, the lower and upper bounds. Thus, the sample correlation coefficient is 0.88, and the range from 0.57 to 0.91 is the true value of the correlation coefficient for the general population. Figure 2 shows the structure of two groups of publications, which cover conference papers, articles, book chapters, reviews, conference reviews, books, editorials, notes etc.

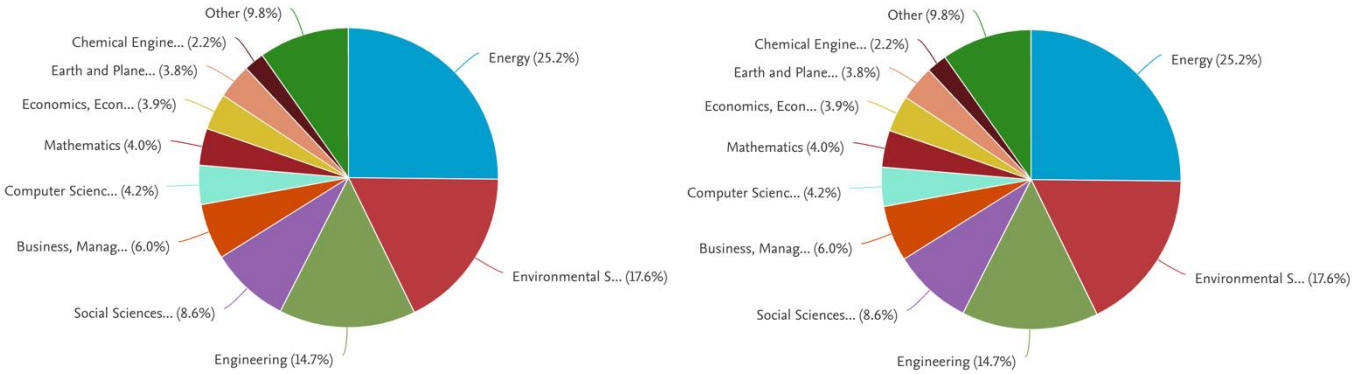


a) b)

Figure 2. The Structure of Scientific Papers on Smart Energy Transformation (a) and Development of the Sustainable Energy Sector (b)

Source: Compiled by the authors on the basis of Scopus base

The presented structure of subject industries indicates an approximately equal distribution for all groups of scientific publications. The structure of the subject area for smart energy transformation publications has the following character: Engineering (988 publications), Computer Science (784 publications), Energy (690 publications), Mathematics (330 publications), Environmental Science (208 publications), Social Sciences (148 publications), Decision Sciences (132 publications), Physics and Astronomy (102 publications), Materials Science (91 publications), Business, Management and Accounting (74 publications). The structure of a group of publications on the sustainable development of the energy industry has a slightly different structure, namely, publications on the economic direction have significant specific weight. The distribution of publications has the following form: Energy (1781 publications), Environmental Science (1246 publications), Engineering (1044 publications), Social Sciences (608 publications), Business, Management and Accounting (426 publications), Computer Science (299 publications), Mathematics (281 publications), Economics, Econometrics and Finance (278 publications), Earth and Planetary Sciences (268 publications), Chemical Engineering (156 publications), Agricultural and Biological Sciences (142 publications), etc.



a) b)

Figure 3. The Structure of Publications According to the Subject Area (Smart Energy Transformation (a), Development of the Sustainable Energy Sector (b))

Sourse: Compiled by the authors on the basis of Scopus base

The main funding institutions are the Horizon 2020 Framework Programme, the National Natural Science Foundation of China, the European Commission, Horizon 2020, Engineering and Physical Sciences Research Council, the European Regional Development Fund, the National Research Foundation of Korea, the Seventh Framework Programme, Korea Institute of Energy Technology Evaluation and Planning, National Key Research and Development Program of China, Fundamental Research Funds for the Central Universities, etc. These findings show that most scientific publications explore a wide range of methods and approaches for implementing smart energy models and approaches, with a preference for investigating the tendencies of innovative smart technologies for reducing power consumption and supporting the development of sustainable technologies in the energy sphere. These trends align with the most high-cited papers, as shown in Table 3.

Table 3. The TOP-10 Most-Cited Papers

Title	Author (s)	Journal Title	Year of publication	Number of Citation
Smart grid - The new and improved power grid: A survey	Fang X., Misra S., Xue G., Yang D.	IEEE Communications Surveys and Tutorials 14(4),6099519, pp. 944-980	2012	2135
Demand side management: Demand response, intelligent energy systems, and smart loads	Palensky P., Dietrich D.	IEEE Transactions on Industrial Informatics 7(3),5930335, pp. 381-388	2011	2135
Smart energy management system for optimal microgrid economic operation	Chen C., Duan S., Cai T., Liu B., Hu G.	IET Renewable Power Generation 5(3), pp. 258-267	211	777
A review on optimized control systems for building energy and comfort management of smart sustainable buildings	Shaikh P.H., Nor N.B.M., Nallagownden P., Elamvazuthi I., Ibrahim T.	Renewable and Sustainable Energy Reviews 34, pp. 409-429	2014	573
Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors	Hargreavesn T., Nye M., Burgess J.	Energy Policy 38(10), pp. 6111-6119	2010	547
Smart home energy management system using IEEE 802.15.4 and zigbee	Han D.-M., Lim J.-H.	IEEE Transactions on Consumer Electronics 56(3),5606276, pp. 1403-1410	2010	543
Big data driven smart energy management: From big data to big insights	Zhou K., Fu, C., Yang S.	Renewable and Sustainable Energy Reviews 56, pp. 215-225	2016	486
DC Microgrid Technology: System Architectures, AC Grid Interfaces, Grounding Schemes, Power Quality, Communication Networks, Applications, and Standardizations Aspects	Pop C., Cioara T., Antal M., (...), Salomie I., Bertoncini M.	Sensors (Switzerland) 18(1),162	2018	414
A smart home energy management system using IoT and big data analytics approach	Al-Ali A.R., Zualkernan I.A., RashidM., Gupta R., Alikarar M.	IEEE Transactions on Consumer Electronics 63(4),8246800, pp. 426-434	2017	360
Review and prospect of integrated demand response in the multi-energy system	Wang J., Zhong H., Ma Z., Xia Q., Kang C.	Applied Energy 202, pp. 772-782	2017	342

Sources: Compiled by the authors on the base of Scopus

Academic papers in that field mainly relate to the managerial, economic, IT, and technological aspects. The notes from the descriptions and abstracts of the papers suggest that the managerial, social, and economic perspectives of smart energy development are also relevant. VOSviewer 1.6.13 tools help describe the biggest clusters of the investigated area, which significantly affect the theory of smart energy development (Figure 4).

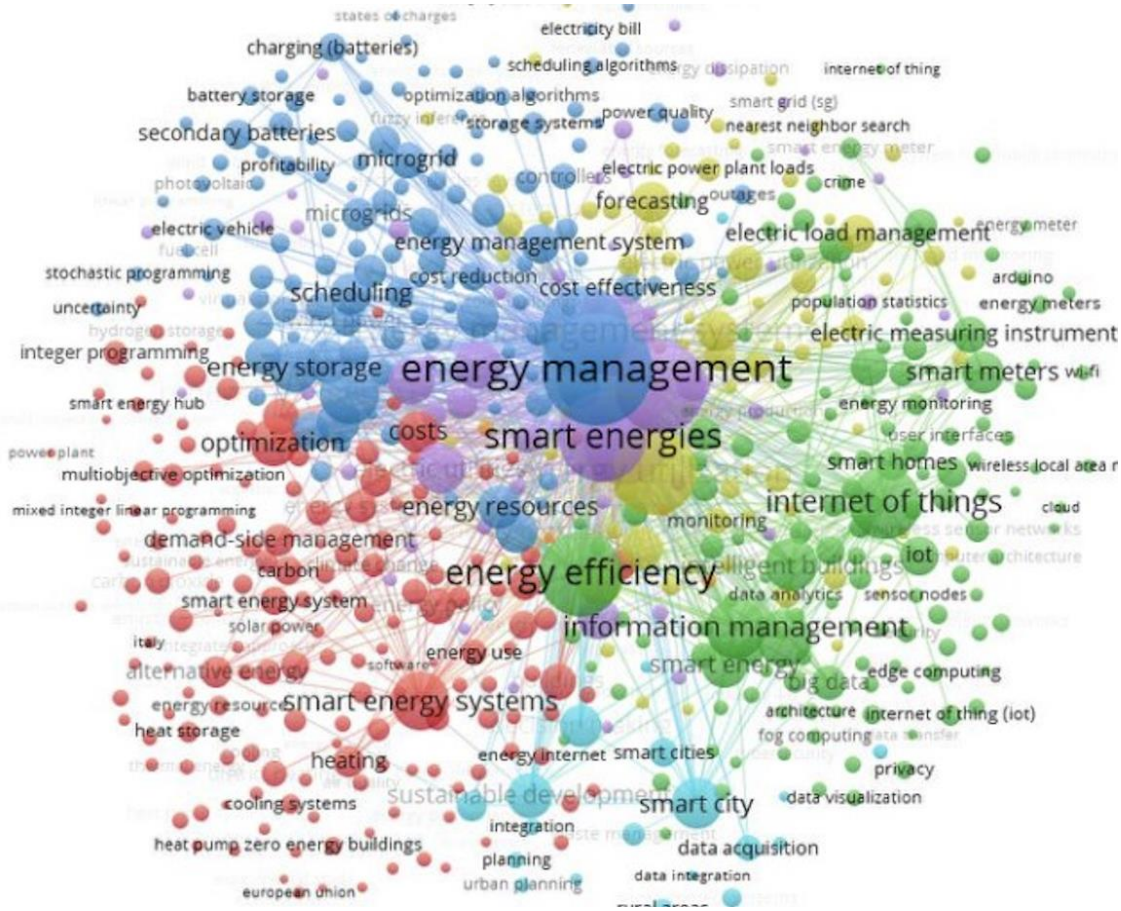


Figure 4. The Results of the Co-Citation Analysis of the Theory of Smart Energy Development

Sources: Compiled by the authors on the base of Scopus and VOSviewer tool

As shown in Figure 4, many publications focused on energy management practices, smart energy technologies, energy efficiency, energy storage, the internet of things, smart energy systems and smart city. Also, many studies deal with renewable energy, sustainable development, optimisation, and information management.

The co-citation analysis revealed the eight significant clusters of academic pools that had the most significant influence on the theory of smart energy development, and it is management (Figure 4). The biggest blue cluster includes the categories (more than 160 items) connected with alternative energy, building energy management, climate change, carbon emission, carbon footprint, electricity generation, emission control, energy hubs, energy networks, energy security, energy transition, sustainable energy, smart energy systems, sustainable energy systems, zero energy buildings, etc. The next significant violet cluster explained spreading the IT technologies in the energy sector: cyber security, cloud computing, energy efficiency, energy grids, energy monitoring, green computing, home energy management, industry 4.0, innovations, intelligent energy management, internet of things, network security etc. The following green cluster emphasizes the trends in the energy sector and the economic mechanisms of their implementation. It includes energy efficiency, information management, artificial intelligence, green computing, energy optimization, renewable energy etc. Figure 5 demonstrates the cluster analysis results of the main keywords dealing with the theory of smart energy development.

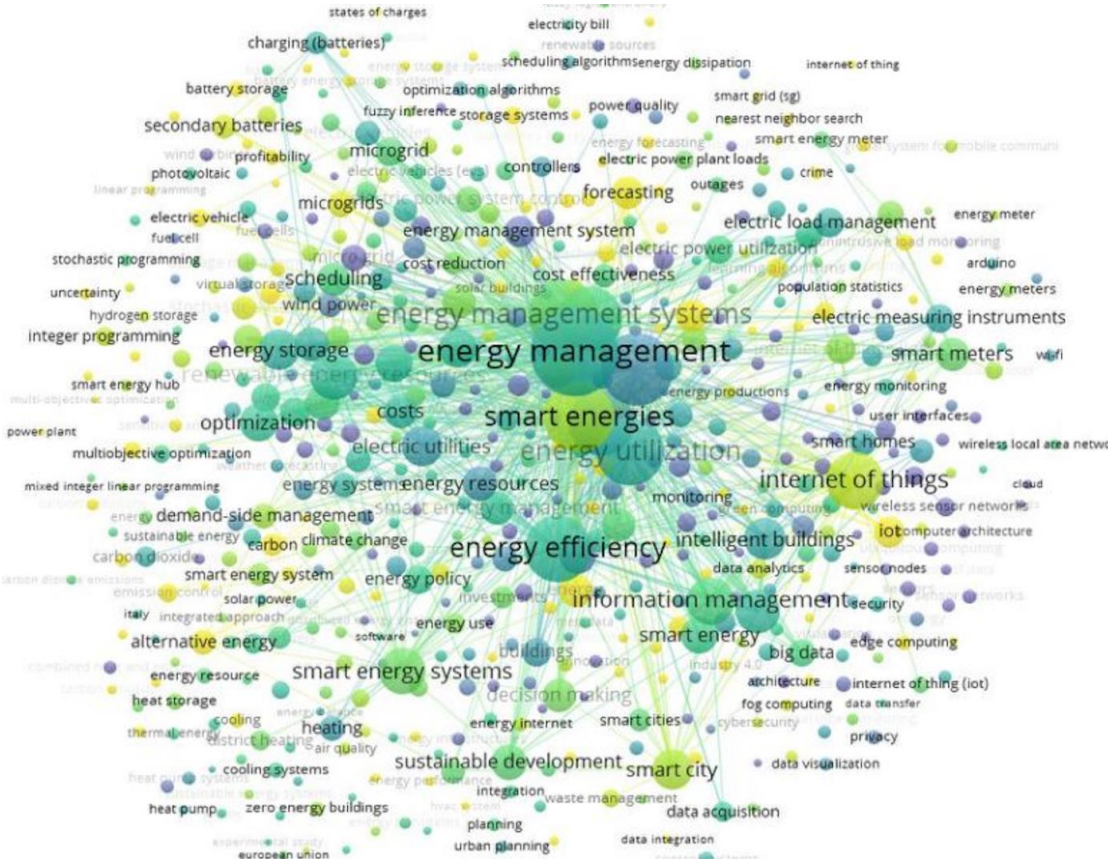


Figure 5. The Results of the Keywords Cluster Analysis on the Theory of Smart Energy Development

Sources: Compiled by the authors on the basis of Scopus and VOSviewer tool

The results of the keywords cluster analysis devoted to the theory of smart energy development outlined the significant growth in publication activity since 2018. Moreover, the results of the bibliographic coupling analysis between countries determined leaders in co-citation, particularly India, China, USA, UK, Germany, Italy, Canada, South Korea, France etc.

Conclusions

The analysis of scientific publications and their bibliometric analysis made it possible to determine the characteristic trends in the development of publishing activity, which characterize the development of the theory of smart transformation of the energy industry. The analysis results indicate a steady growth trend in publications since 2005. The main subject areas are energy, the science of sustainable development, engineering, etc. During this period, the world economy is entering a new stage of technological development, in which not the volumes of used resources (including fuel and energy) but their effective management will become the main dominant factor. Due to the application of intelligent industrial technologies, the industry will undergo large-scale revolutionary transformations. Such a process is primarily characteristic of the energy sector, where smart transformations occur.

Author Contributions: Conceptualization: Olena Chygryn, Oleksii Havrylenko; methodology: Olena Chygryn, Cetin Bektas; software: Olena Chygryn; validation: Olena Chygryn, Oleksii Havrylenko; formal analysis: Olena Chygryn, Cetin Bektas; investigation: Olena Chygryn; resources: Oleksii Havrylenko; data curation: Olena Chygryn; writing-original draft preparation: Olena Chygryn, Cetin Bektas; writing-review and editing: Olena Chygryn; visualization: Oleksii Havrylenko; supervision: Olena Chygryn, Cetin Bektas; project administration: Olena Chygryn; funding acquisition: Olena Chygryn.

Conflicts of Interest: Authors declare no conflict of interest.

Data Availability Statement: Not applicable.

Informed Consent Statement: Not applicable.

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