"Managing energy efficiency and renewable energy in the residential sector: A bibliometric study"

AUTHORS	Iryna Sotnyk (iD) ®
	Tetiana Kurbatova (iD) ®
	Oleksandra Kubatko (iD) ®
	Olha Prokopenko (iD) ®
	Marina Järvis (iD) ®

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Oleksandra Kubatko, Olha Prokopenko,
Marina Järvis, 2023

Iryna Sotnyk, Doctor of Economic
Sciences, Full Professor, Department
of Economics, Entrepreneurship
and Business Administration, Sumy
State University, Ukraine; Renewable
Energy Systems Group, Institute for
Environmental Sciences, University of
Geneva, Switzerland. (Corresponding
author)

Tetiana Kurbatova, Ph.D. in Economics,
Associate Professor, International
Economic Relations Department, Sumy
State University, Ukraine.

Oleksandra Kubatko, Ph.D. in
Economics, Associate Professor,
Department of Economics,
Entrepreneurship and Business
Administration, Sumy State University,
Ukraine.

Olha Prokopenko, Doctor of Economic
Sciences, Full Professor, Estonian
Entrepreneurship University of
Applied Sciences, Estonia; Department
of Business Economics and
Administration, Sumy State Makarenko
Pedagogical University, Ukraine.

Marina Järvis, Ph.D. in Economics,
Associate Professor, Estonian
Entrepreneurship University of Applied
Sciences, Estonia; Department of
Business Administration, Tallinn
University of Technology, Estonia.

Iryna Sotnyk (Ukraine, Switzerland), Tetiana Kurbatova (Ukraine),
Oleksandra Kubatko (Ukraine), Olha Prokopenko (Estonia, Ukraine),
Marina Järvis (Estonia)

MANAGING ENERGY EFFICIENCY AND RENEWABLE ENERGY IN THE RESIDENTIAL SECTOR: A BIBLIOMETRIC STUDY

Abstract

The recent surge in publications addressing household energy efficiency and renewable energy highlights their vital roles in managing national decarbonization and green power transition. The study aims to analyze the research trends in this field to comprehend their significance in shaping residential decarbonization changes. Bibliometric and visualization analyses are applied to bridge existing knowledge gaps by focusing on technology and managerial mechanisms for implementing energy efficiency and renewable energy concepts. Leveraging the Scopus database and VOSviewer 1.6.19 software, the study covers energy efficiency publications from 1978 to 2023 and renewable energy papers from 1984 to 2023. The study clusters academic articles in two ways: keyword co-occurrence and co-authorship analyses. The first one reveals the merging of renewable energy and energy efficiency studies, covering sustainable development, heating/cooling mechanisms, and emerging technology trends. While both topics share commonalities like smart grids and the Internet of Things, renewable energy clusters spotlight specific areas such as bioenergy and wind/solar power. Co-authorship analysis highlights a notable increase in countries considering research topics, reflecting growing international collaboration. Leading contributors include the United States, the United Kingdom, China, Germany, and India. This study equips scientists with a systematic understanding of the evolution and latest research trends in managing household energy efficiency and renewable energy transformations. It aids in identifying promising research directions, further advancing these crucial fields.

INTRODUCTION

The escalating global concerns regarding climate change and its detrimental impacts on the planet necessitate revising energy production and consumption patterns (Koval et al., 2023; Melnyk et al., 2020; Sineviciene et al., 2019; Shpak et al., 2022). Transitioning toward sustainable energy practices at the household level by implementing energy efficiency improvements and renewable power technologies can significantly contribute to a sustainable future (Olczak et al., 2022; Pu et al., 2021; Sowa, 2020). There are several environmental, economic, and social reasons for that.

Firstly, the pressing need to reduce greenhouse gas emissions is a driving force behind this urgency. The residential sector is one of the main energy consumers and carbon dioxide emitters (Sotnyk et al., 2022a). Investing in energy-efficient measures and green power sources for households can substantially decrease the global carbon footprint and mitigate the adverse effects of climate change (Fasoranti et al., 2022; Kwilinski et al., 2023a; Nekrasenko et al., 2015). This approach aligns

with international agreements like the Paris Agreement and national climate plans of the world's leading countries (Climate Action Tracker, n.d.; United Nations, n.d.), which call for urgent and ambitious action to limit global warming.

Secondly, residential energy consumption directly affects energy bills and overall economic stability. Energy-efficient measures can reduce power consumption, lowering home utility bills. Moreover, promoting renewable energy adoption creates opportunities for green jobs and stimulates economic growth in the green power sector, driving innovation and competitiveness (Janikowska & Jebreel, 2022; Lyndiuk et al., 2020; Trypolska, 2021; Vilchynska et al., 2023).

Thirdly, investing in energy efficiency and household green energy improves energy security. Over-reliance on fossil fuels can lead to geopolitical tensions and price volatility. Diversifying energy sources and encouraging decentralized green power generation enhance energy independence and resilience (Chygryn & Shevchenko, 2023; Ksonzhyk et al., 2021; Kwilinski et al., 2023c; Samusevych et al., 2021).

Furthermore, managing energy-efficient measures and renewable energy in homes addresses energy poverty and social equity issues. In many regions, vulnerable communities struggle with high energy costs, leading to difficult choices between basic needs and utility payments. Implementing energy-efficient and green power programs can alleviate the burden on low-income households and enhance their quality of life (Fasoranti et al., 2022; Mentel et al., 2018).

Lastly, tackling residential energy issues can spur behavioral change and create a culture of sustainable living. When households adopt energy-efficient and renewable energy technologies, they become role models for their communities, inspiring broader adoption of sustainable habits (Rau et al., 2020; Vakulenko & Lieonov, 2022).

Given the above, energy-efficient and green power solutions for homes have a diverse and broad impact on society. However, their implementation requires encouraging state and local managerial mechanisms that should be scientifically grounded and consider the latest research developments in the field. Therefore, the systematization of modern scholar achievements on managing energy efficiency and renewable energy issues in the residential sector, determination of the research trends, leading contributor countries, and their international cooperation ties are vital to address these challenges.

1. LITERATURE REVIEW

The number of publications on energy efficiency and green power in households in the Scopus database has increased significantly over several decades, especially in the last 20 years. Such growth suggests that scientists are considering the residential sector as an essential contributor to the decarbonization of the economy through introducing and managing energy-efficient changes and renewable energy technologies.

The most popular recent topics on energy efficiency in the residential sector cover households' energy-saving behavior (Andor & Fels, 2018; Paone & Bacher, 2018; Trotta, 2018), energy consumption management practices (Corsini et al., 2019; Kwilinski et al., 2023b; Guo et al., 2018; Wolske et al., 2020), and energy efficiency investment mechanisms (Sala et al., 2023; Sotnyk et al., 2022b; Trotta, 2018). Vital is also smart home technologies (Bastida et al., 2019; Sovacool & Furszyfer Del Rio, 2020; Tirado Herrero et al., 2018), energy justice and energy poverty (Lekavičius et al., 2020; Tirado Herrero et al., 2018; Xu & Chen, 2019), and decarbonization management issues (Goldstein et al., 2020; Vélez-Henao & García-Mazo, 2022; Wynes et al., 2018).

The research on green power in households has similar directions, such as renewable energy investment incentives (Lekavičius et al., 2020; Yoshino et al., 2019), household perception of green power technologies (Al-Marri et al., 2018; Hasselqvist

et al., 2022; Milchram et al., 2018), and justice for energy consumers and owners of renewable energy facilities (Hanke et al., 2021; Smale & Kloppenburg, 2020). In addition, there are environmental effects of green power transition (Liu et al., 2021; Razmjoo et al., 2021), prosumers' development (Luna et al., 2016; Ruiz-Cortes et al., 2019), peer-to-peer green energy trading (Cui et al., 2020; Pumphrey et al., 2020; Smale & Kloppenburg, 2020) or strategies for adopting home power storage systems (Nguyen et al., 2018; Ruiz-Cortes et al., 2019).

Therefore, modern research focuses primarily on social, ethical, economic, management, financing, and environmental issues of residential energy efficiency and renewable energy rather than on the technical side only. The latter is widely investigated within the application of information technologies in homes, including smart grids (Anjana & Shaji, 2018; Martin, 2020; Vakulenko et al., 2021), smart meters (Rausser et al., 2018; Sovacool et al., 2021), the Internet of Things (Rafsanjani & Ghahramani, 2020; X. Zhang et al., 2021), and other intelligent systems (Alsalemi et al., 2020; Gnewuch et al., 2018; Daniel et al., 2019; Razmjoo et al., 2021).

Overall, there is a great diversity of research on residential energy efficiency and green power issues. However, there is a lack of papers summarizing and systematizing current developments and managing trends in the field. In particular, Andor and Fels (2018) considered 44 international studies and analyzed the available empirical evidence on non-price interventions encouraging energy conservation behavior among private households. They confirmed that instruments like social comparison, commitment devices, goal setting, and labeling might substantially decrease home power consumption, although their effects vary significantly.

Corsini et al. (2019) performed a bibliometric analysis that utilized practice theories within sustainable energy consumption studies. The study detected the changes in the field, namely, the shift from researching 'consumer identity' to investigating the 'household energy' topic under the sharing and circular economy.

Ingeborgrud et al. (2020) studied the evolution and current developments in energy-related social sciences and humanities research. The scholars revealed that recent research concentrates on new technologies, for example, smart meters, household power demand management, energy-efficient initiatives of communities, energy poverty, energy justice, and relevant social and economic policies.

Buckley (2020) analyzed 52 studies considering the effects of different incentives for energy efficiency in households. The article indicated that despite advancements in the quality of recent studies, the analysis underscores the significance of methodological rigor when conducting and reporting the effects of incentives.

Jensen et al. (2019) reviewed 1067 Sustainable Energy Consumption Initiatives (SECIs) to curb residential power usage across 30 European nations. The authors developed a problem-framing typology, categorizing initiatives into four types: 1) technology changes, 2) individual behavior changes, 3) everyday life situation changes, and 4) complex interaction changes. The analysis revealed a bias toward technocratic and consumer behavioral strategies (75% in categories 1 and 2). Addressing and managing technology-business-culture-life interactions is proposed for more effective, lasting transformation.

Sotnyk et al. (2023) explore the progress and contemporary household energy efficiency and green power research patterns. The study identifies the nations, institutions, and authors contributing to the field alongside discerning avenues of global cooperation. Using the SciVal platform and Scopus "Analyze search results" tool, the authors highlight that the current focal areas encompass environmental, economic, and social implications, as well as management strategies to adopt pioneering energy-efficient and renewable energy technologies in households. These technologies include smart meters, grids, and the Internet of Things. However, the study focuses primarily on analyzing current research trends and general features of their evolution without a deep insight into research genesis. In addition, the intricate progression of international cooperation ties in the field has yet to be thoroughly examined in the temporal dimension.

Overall, there is a lack of papers compiling the evolution and current state of scientific developments in the residential energy efficiency and green pow-

er field. It reduces the effectiveness of sectoral strategies and policies based on disintegrated approaches to their formation. In turn, it impedes energy efficiency and renewable energy advancement in households, decreasing the social, economic, and environmental effectiveness of state and local management mechanisms. Therefore, there is a need to cover the knowledge gap in identifying the evolution trends and current and prospective research directions in managing residential energy-efficient and green power changes, as well as their main contributors worldwide.

The study aims to analyze the genesis of the research on the energy-efficient and renewable energy technologies and management mechanisms for their deployment in households and reveal the perspective directions for further consideration to combat climate change, promote economic stability, enhance energy security, and foster social equity. The paper uses publications from the Scopus database and the VOSviewer package to perform the bibliometric analysis. The novelty is to offer lucid insights into the evolution and recent trends of household energy efficiency and green power studies. Additionally, it sheds light on the most influential countries contributing to this field and the directions of international collaboration in the temporal dimension.

2. METHODS

Two publication sets downloaded from the Scopus database as of August 10, 2023, were used for the research. The first one included papers on energy efficiency in households for the period 1978–2023. The second set contained publications on renewable energy issues in the residential sector dated 1984–2023. These two arrays of documents were formed using the keyword search function in the Scopus database, namely, the "title, abstract, keywords" option. The keywords "energy efficiency" and "household" were applied to select publications on the energy efficiency topic. In contrast, the keywords "renewable energy" and "household" were used to form the dataset on the green power theme.

Initially, the publication search did not involve time constraints. However, the time frames for the selected publications were determined automatically by the availability of relevant papers in the Scopus database. To specify the formed document set, additional filters were applied to the publication type (article and conference paper), language (English), and publication stage (final). Two final paper sets included 4,544 Scopus publications on energy efficiency and 3,842 documents on renewable energy in the residential sector.

The following research stage involved the content analysis of the selected publications in VOSviewer 1.6.19 and the visualization of the results. It was applied separately for household energy efficiency and green power topics. The bibliometric study in VOSviewer was conducted in two directions: keyword co-occurrence and co-authorship analyses. The software uses the clustering method for both types of analyses. VOSviewer allows dividing a publication set into several clusters and presenting them as network and overlay dynamic maps to conduct a deeper analysis of the development

Figure 1. Research algorithm

trends in the selected field. Figure 1 illustrates the research algorithm. In addition, comparative analysis and generalization methods were used to conduct the discussion and make conclusions.

3. RESULTS AND DISCUSSION

The keyword co-occurrence analysis in VOSviewer included investigating the recent research directions on managing energy efficiency and renewable energy transformations in the residential sector and their changes over time. The co-authorship analysis studied the leading countries in energy efficiency and renewable energy research and their international cooperation ties at present and in evolutionary terms.

3.1. The co-occurrence analysis

The co-occurrence analysis used a threshold of eight keyword occurrences to cluster the publications. On the household energy efficiency research topic, VOSviewer identified six interdisciplinary

clusters (Figure 2) with 493 items, including four large (red, green, blue, and yellow) and two small (lilac and turquoise) clusters closely connected. Based on the keywords, the large red cluster consists of 137 items and could be named "Energy efficiency as part of sustainable development." It covers different aspects of sustainable energy development, like carbon emissions and global warming threats, urbanization and economic growth impacts, public health, carbon footprint, waste management, green power sources (biomass, biogas, agricultural wastes) for homes, and others. The cluster's keyword "sustainable development" has 298 occurrences and a total link strength of 2141.

The second (green) cluster combines 120 items and could be named "New trends in energy-efficient technologies." It includes issues on energy storage and utilization, smart and microgrids, the Internet of Things, intelligent buildings, smart homes, electric vehicles, photovoltaic cells, hybrid systems, and managerial and organizational aspects of their implementation in the residential sector. The most significant keywords of the clus-

Source: VOSviewer 1.6.19, the Scopus database (downloaded on August 10, 2023).

Figure 2. Network visualization of keyword co-occurrence analysis on household energy efficiency research
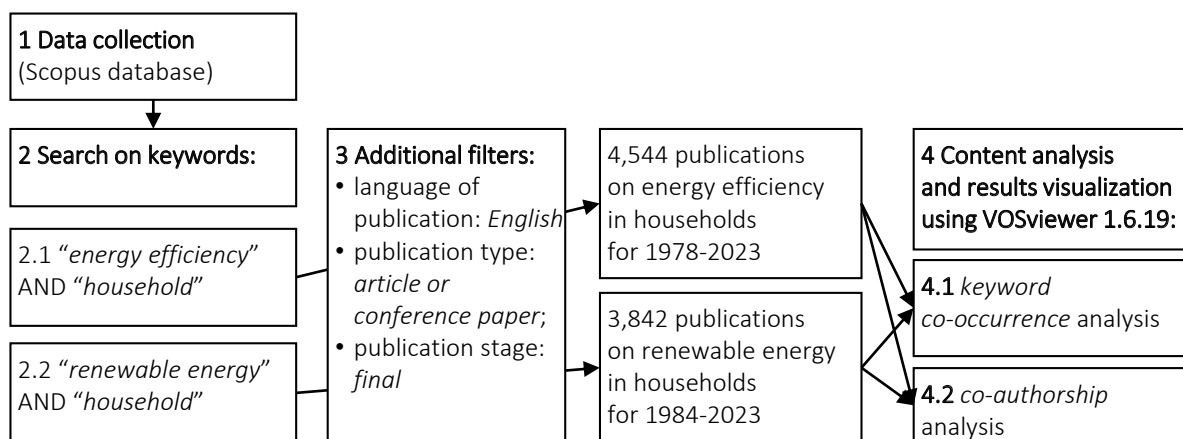
ter are "domestic appliances" (438 occurrences with a total link strength of 3165), "electric power utilization" (346 and 2702, respectively), and "energy management" (343 and 2828).

The third (blue) cluster consists of 113 items united by the topic "Energy use and policy in the residential sector." The cluster covers mostly social, economic, and management issues of home energy, such as power consumption patterns and energy-efficient behavior, power market, energy conservation, household energy demand, energy efficiency gaps, and investments. The most important keywords include "housing" (846 occurrences with a total link strength of 6870), "household energy" (785 and 6348, respectively), "energy policy" (646 and 5149), "energy conservation" (637 and 4900), and "energy use" (531 and 4413).

The fourth (yellow) cluster combines 85 items and could be named "Energy-efficient heating and cooling." It considers the technical and economic aspects of heating and conditioning in buildings, energy-efficient heating systems for homes, including using green power sources (geothermal, solar energy, heat pumps), passive house standards, lifecycle cost of energy-efficient heating projects, etc. The most significant keywords of the cluster are "energy utilization"

(1327 occurrences with a total link strength of 9928), "heating" (791 and 6151, respectively), and "air conditioning" (219 and 1790).

The fifth (lilac) cluster includes 30 items and covers power market (emphasizing electricity) issues connecting to home energy efficiency. The papers from this cluster study energy demand and its elasticity, pricing policy in the residential sector, demand-side management, electricity consumption and costs. The main keywords include "costs" (309 occurrences with a total link strength of 2686), "electricity consumption" (284 and 2252, respectively), and "demand-side management" (106 and 1007).

The last (turquoise) cluster has eight items considering energy-efficient lighting. The most significant keywords are "lighting" (91 occurrences with a total link strength of 651) and "light emitting diodes" (47 and 309, respectively).

Figure 3 visualizes the evolutionary development of the formed clusters in 2014–2019. It should be noted that before 2016, energy efficiency was primarily considered as energy conservation in reducing negative environmental impacts of carbon emissions, modernizing refrigeration technologies, involving bioenergy resources in the residential sector, etc. In 2016–2017, the range of household
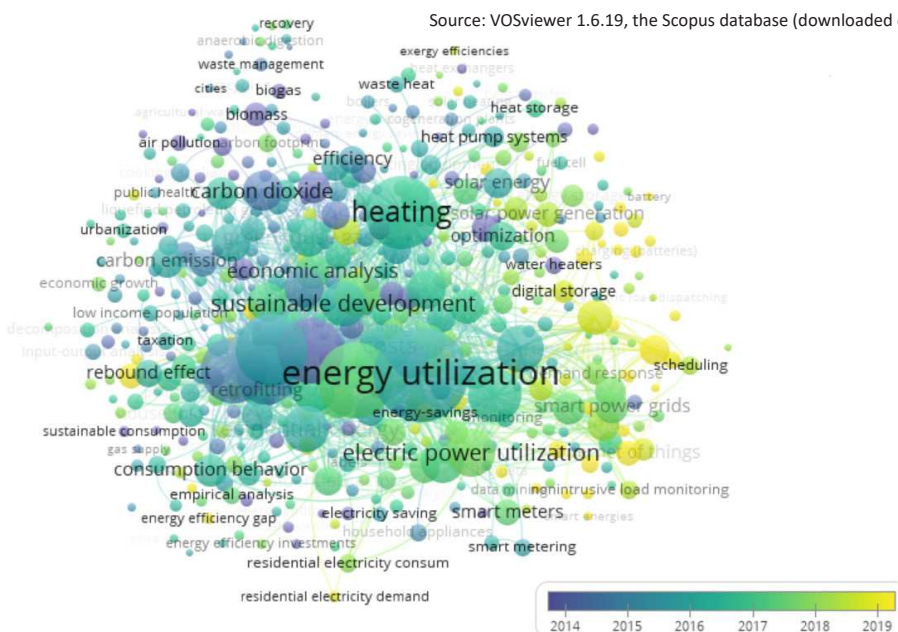
Source: VOSviewer 1.6.19, the Scopus database (downloaded on August 10, 2023).

Figure 3. Overlay visualization of keyword co-occurrence analysis on household energy efficiency research

energy efficiency studies extended to sustainable development issues, power utilization, energy-efficient optimization of heating, cooling and lighting in homes, energy management systems, solar power use, and sectoral energy policy. In 2018–2019, scholars actively investigated mechanisms of implementing new energy-efficient technologies like the Internet of Things, power storage, hybrid systems, smart grids, photovoltaic cells, etc. Along with new technologies, economic research on lifecycle cost optimization, energy-demand management, investments, and policies for energy efficiency improvements received growing attention. For example, recent studies are those on energy security, energy efficiency policy, energy poverty, and energy pricing mechanisms (Onyshchenko et al., 2018; Kostyrko et al., 2021; Buckley, 2020; Xu & Chen, 2019). The cluster analysis results on recent trends and the evolution of home energy efficiency research align with those by Andor and Fels (2018), Ingeborgrud et al. (2020), Ma et al. (2020), and Sotnyk et al. (2023).

Analyzing the keywords co-occurrence in the publications on the household green power topic, VOSviewer formed five interdisciplinary clusters (Figure 4) with 275 items. The red cluster contains 74 research papers on the economic, managerial, social, and environmental aspects of renewable energy, including those for the residential sector.

It covers various issues such as green power policy and low carbon economy development, management of energy transitions, renewable energy planning, pricing, consumption patterns, and willingness to pay for green power in households. The cluster's keyword "renewable energies" has 1011 occurrences and a total link strength of 5132. Other popular keywords include "alternative energy "(518 occurrences and a total link strength of 2751), "investment" (318 and 1851, respectively), "decision-making" (118 and 647), and "emission control" (128 and 818).

The second (green) cluster consists of 69 items focusing on different bioenergy technologies, their environmental impacts, and the mechanisms of their influence on the household sector. It includes research papers on biogas, biomass, biodiesel, wood, and wastes, and estimations of the consequences of their use for climate change, sustainable development, greenhouse gases, quality of life, regional planning, homes, etc. The main keywords of the cluster are "biogas" (193 occurrences and a total link strength of 1057), "biomass" (197 and 998, respectively), "greenhouse gases" (204 and 1307), and "sustainable development" (295 and 1502).

The third (blue) cluster combines 68 items, studying the latest trends in green power technologies

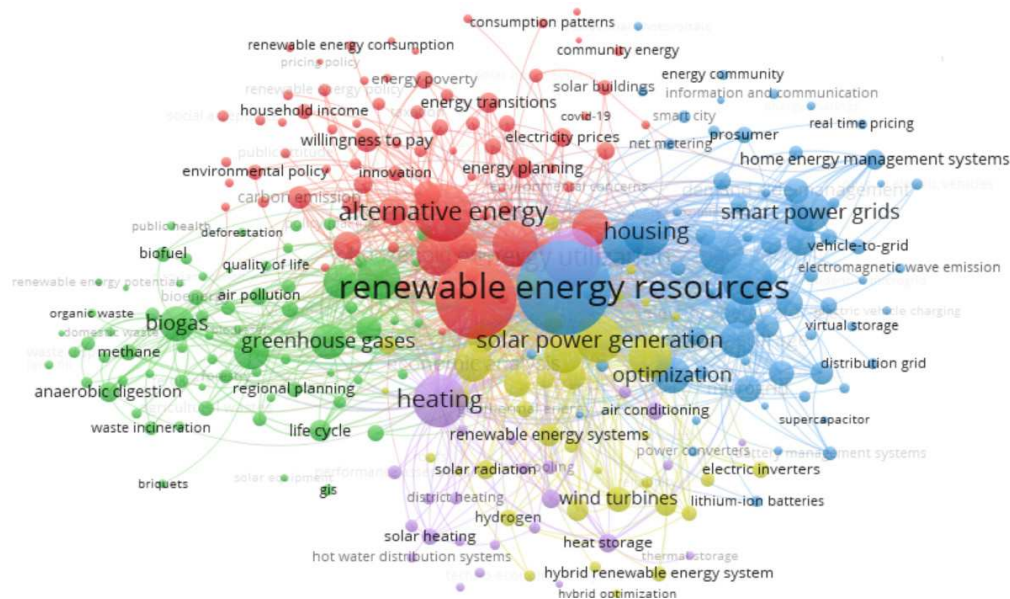Source: VOSviewer 1.6.19, the Scopus database (downloaded on August 10, 2023).

Figure 4. Network visualization of keyword co-occurrence analysis on household renewable energy research

Figure 5. Overlay visualization of keyword co-occurrence analysis
on household renewable energy research

deployment in the residential sector. The cluster covers topics on managing distributed renewable energy generation, microgrids, hybrid vehicles, smart meters and smart homes, prosumers, residential storage technologies, and home energy management systems. The most important keywords include "renewable energy resources" (1383 occurrences with a total link strength of 6761), "power transmission network" (401 and 2291, respectively), "electric smart power grids" (262 and 1463), and "energy management" (316 and 1776).

The fourth (yellow) cluster combines 39 items and focuses mainly on solar and wind energy issues. In addition, it includes papers on hydrogen, geothermal, and tidal power technologies, as well as their economic efficiency, optimization, management, and monitoring in the residential sector. The most significant keywords of the cluster are "solar power generation" (337 occurrences with a total link strength of 2038), "photovoltaic cells" (283 and 1593, respectively), "wind power" (244 and 1284), and "economic analysis" (212 and 1298).

The fifth (lilac) cluster identifies 25 items and covers home heating and cooling mechanisms using green power technologies. The latter involves solar, waste, geothermal power, and other renewable energy sources. Moreover, the cluster contains papers on decarbonization, district heating, heat storage, refrigerators, and zero-energy buildings. The main keywords include "heating" (444 occurrences with a total link strength of 2563) and "energy utilization" (537 and 2800, respectively).

Figure 5 visualizes the evolutionary development of the considered clusters on home green power in 2015–2020. In 2015–2016, the scholars' attention was paid to bioenergy technologies, wind power, and energy planning in households. In 2017–2018, the research focus moved to home photovoltaic systems, smart power grids, storage technologies, efficient green energy management, investments in renewable energy at home, etc. The latest trends include promoting microgrids, hydrogen storage, the Internet of Things, prosumers, and green energy transitions in the residential sector. For instance, recent studies consider prosumer issues, renewable energy investment optimization, green electricity transition, and renewable energy demand management (Sala et al., 2023; Sotnyk et al., 2022a, 2022b; Kulapin et al., 2022). The cluster analysis outcomes regarding recent residential green power trends and their changes over time align with (W. Zhang et al., 2021; Sotnyk et al., 2023).
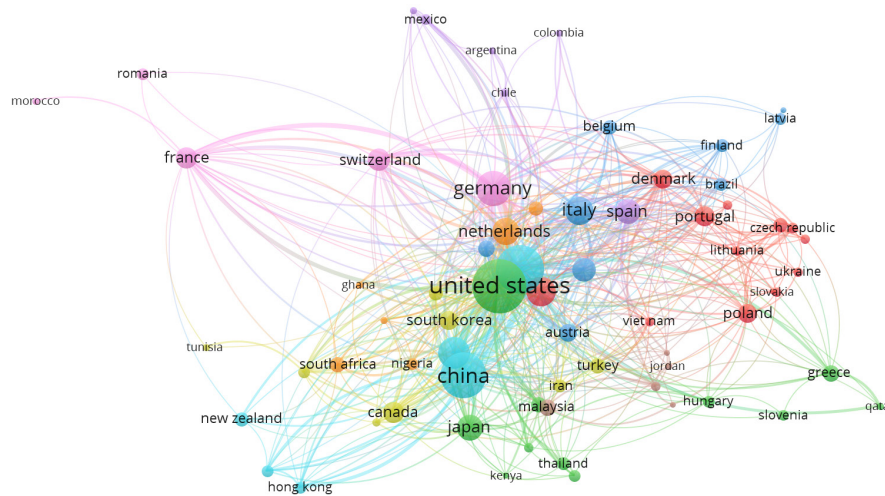
Figure 6. Network visualization of co-authorship analysis by countries in the field of household energy efficiency research

The results of the co-occurrence analysis show that some clusters for energy efficiency and green power topics are very similar. Energy efficiency and renewable energy red clusters consider the economic, managerial, social, and environmental impacts of these technologies' development. Energy efficiency green and renewable energy blue clusters include new technological trends. Energy efficiency yellow and renewable energy lilac clusters contain studies on home heating and cooling issues. Specific renewable energy clusters are those considering bioenergy and solar and wind issues.

Overall, the co-occurrence analysis in VOSviewer confirmed the outcomes obtained by Han and Wei (2021), Ma et al. (2020), W. Zhang et al. (2021), and Sotnyk et al. (2023). The study findings on household energy efficiency research trends are partially confirmed by Ziabina et al. (2021). The difference is explained by focusing on national decarbonization issues through energy efficiency in the paper instead of the residential EE.

3.2. The co-authorship analysis

The co-authorship analysis studied the leading countries in energy efficiency and green power research (with a minimum of 10 papers per country). Moreover, the leading organizations and authors, having more than four papers worldwide, were checked. In addition, the research links among the countries were studied in detail.

Concerning energy efficiency research in the residential sector, the countries' network includes all continents and is presented by nine clusters in different colors in Figure 6. The most influential are the United States, the United Kingdom, China, Germany, Australia, and India, with the largest numbers of documents, which is mostly in line with the results of Han and Wei (2021), Ma et al. (2020), and Sotnyk et al. (2023). Japan, the Netherlands, Sweden, Italy, Spain, Switzerland, France, and Poland have fewer documents but actively grow their number. The United States, Sweden, Japan, Canada, South Africa, New Zealand, Brazil, and Mexico have the most extended research history in the field, considering 2015–2019 (Figure 7). Some European countries like Germany, the Netherlands, Italy, Denmark, and Switzerland intensified their household energy efficiency research in 2016–2017, along with Hong Kong, Thailand, and Bangladesh. China, Greece, Turkey, Poland, Portugal, Spain, France, and Ukraine significantly extended their studies on energy efficiency in 2018. In 2019, Pakistan, Saudi Arabia, Qatar, Ghana, Iran, and Ecuador also progressed in this field.

The broad scientific collaboration of the United States and the United Kingdom with researchers from all continents is worth noting. However, their most extensive interactions include European partnerships. China primarily cooperates with scientists from Europe but also has close
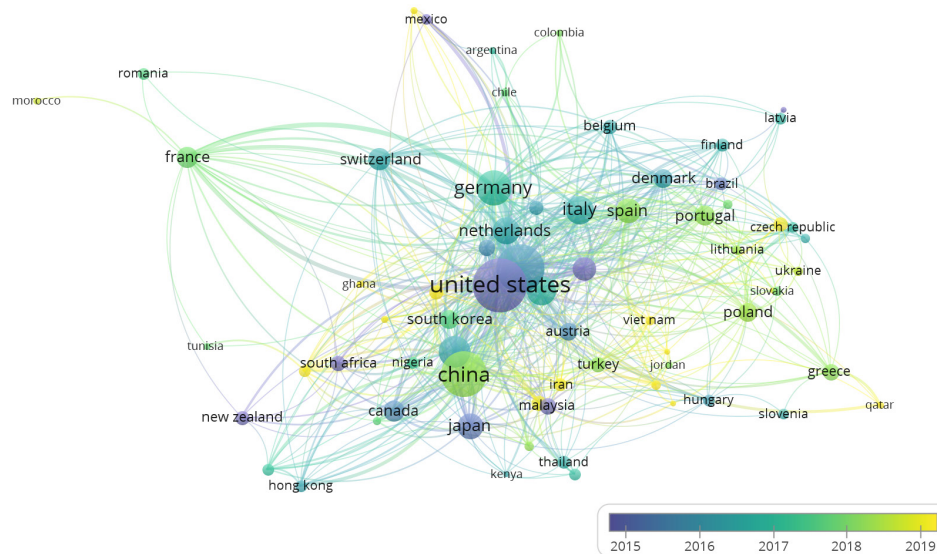
Figure 7. Overlay visualization of co-authorship analysis by countries in the field of household energy efficiency research

ties with Japan, Australia, Canada, South Korea, Turkey, Hong Kong, and others. Germany primarily works with European countries while collaborating with Mexico, Colombia, Indonesia, China, Japan, Singapore, Tunisia, Ghana, and Ethiopia. The obtained results mostly coincide with those of Ma et al. (2020). However, they contradict the outcomes of Han and Wei (2021), who indicate that China and the United States have the leading research positions and demonstrate the closest interconnection. The latter is not in line with the study findings. Nevertheless, Han and Wei (2021) confirm the research outcome about the strong collaboration of these two countries with European scholars. The divergence in results can be explained by focusing the mentioned paper on investigating household energy consumption rather than energy efficiency and green power in the residential sector.

Concerning household renewable energy research, the countries' network is presented by eight clusters indicated in different colors in Figure 8. The most influential states are the United States, the United Kingdom, China, Germany, and India, with the highest numbers of scientific publications, aligning with Han and Wei's (2021) and Sotnyk et al. (2023) findings. Poland, Australia, Japan, Spain, France, Italy, Denmark, the Netherlands, South Korea, and South Africa have fewer documents but actively grow their

number. It is worth noting that the United States, the United Kingdom, Italy, Canada, Australia, Austria, Switzerland, Belgium, Bangladesh, and Kenya are among the countries with the longest research history in the field, considering 2017–2020 (Figure 9). China intensified its renewable energy research in 2018–2019 along with South Korea, Norway, Portugal, Spain, Croatia and Romania. In 2020, Poland, Ukraine, Pakistan, Saudi Arabia, Egypt, Ghana, Iraq, and Rwanda also progressed in this field.

Analysis of countries' ties demonstrates strong links between the United States and European research organizations, namely, from Italy, Germany, France, Spain, Poland, etc. Moreover, the United States has joint publications with investigators from Canada, Asia (Malaysia, Saudi Arabia, Iraq, Taiwan), Africa (South Africa, Kenya, Ghana, Nigeria), and other regions. Chinese scientists collaborate with Asian researchers from Pakistan, Bangladesh, South Korea, and the Philippines; European colleagues from Germany, the United Kingdom, Italy, Spain, France, Denmark, and Poland; African scientists from Egypt, Ghana, Kenya, and Rwanda. The United Kingdom has the broadest collaboration network, working with scientists worldwide. For example, Ukraine collaborates mainly with colleagues from neighboring countries like Poland, Slovakia, Estonia,

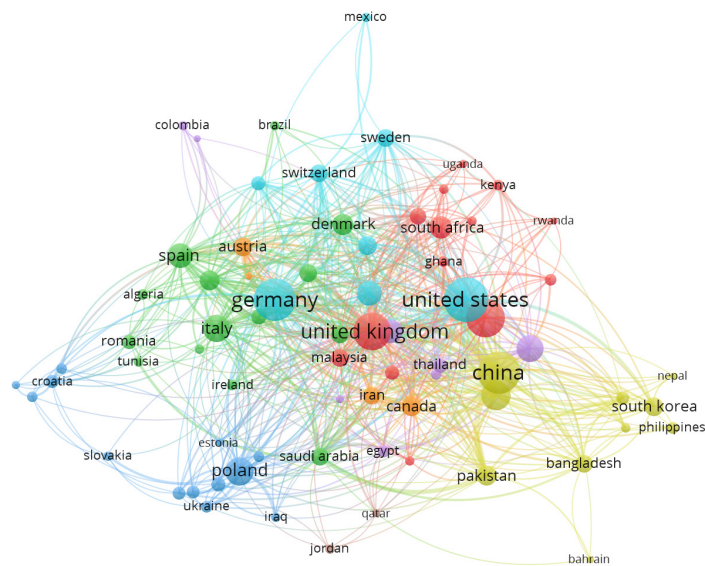**Figure 8.** Network visualization of co-authorship analysis by countries
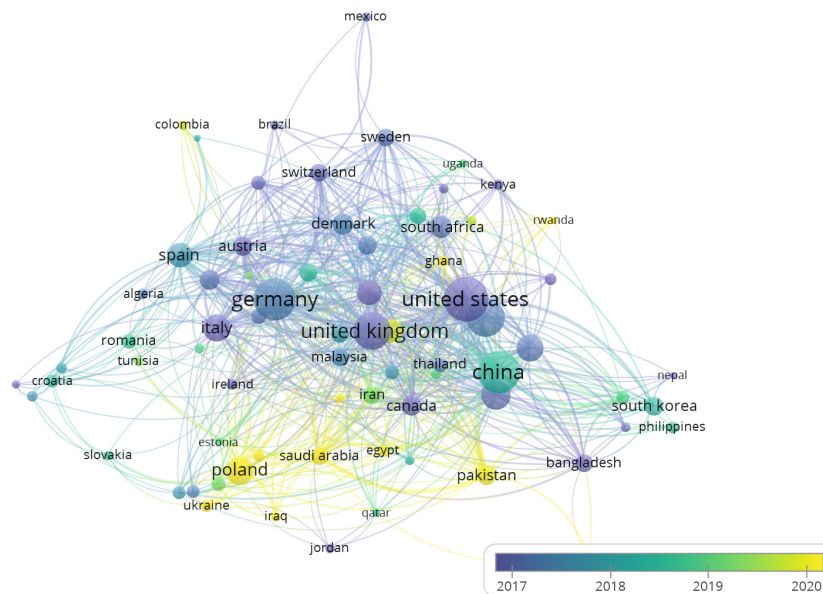in the field of household renewable energy research

Figure 9. Overlay visualization of co-authorship analysis by countries
in the field of household renewable energy research

Latvia, and Lithuania but also has joint publications with researchers from Germany, the United Kingdom, Switzerland, and China.

The study revealed a rising trend of countries participating in household energy efficiency and renewable energy research and publishing on various relevant issues. Additionally, there is a noteworthy increase in international cooperation within this field, contributing significantly to its advancement. The results confirmed the previous findings indicating that the United States, China, and European countries are leading in residential energy efficiency and green power research.

CONCLUSION

The study examines the origins of research on energy efficiency and renewable energy technologies and managing their implementation in households. It involves 4,544 publications on the residential energy efficiency topic and 3,842 papers on the home green power topic extracted from the Scopus database to perform the bibliometric analysis using the VOSviewer 1.6.19 software package. The paper provides clear insights into the evolution of studies on household energy efficiency and renewable energy issues, highlights recent trends and the leading nations contributing to this field, and unveils patterns of international collaboration over time. The conclusions are outlined below.

First, recognizing the residential sector's substantial role in managing national economies' decarbonization and green energy transition has increased the interest of researchers in investigating energy efficiency and renewable energy issues in households, especially over the last 20 years. Publication analysis reveals two key attributes characterizing many works in the field: their interdisciplinary nature and robust international collaboration. Rather than solely addressing technical aspects, the scholars prominently delve into the social, economic, managerial, and environmental dimensions of home energy efficiency and green power matters, creating international research teams. Notably, the adoption, use, and management of new information technologies to improve energy efficiency and implement renewable energy in households is the special focus of recent studies, which get the highest citing.

Second, the conducted keyword co-occurrence cluster analysis in VOSviewer showed a close interrelation of green power and energy efficiency research issues, causing similar directions in their development. For instance, both renewable energy and energy efficiency clusters contain publication sets devoted to (1) social, economic, managerial, and environmental issues (sustainable development), (2) heating and cooling, and (3) new technological trends in the field. Moreover, the latter includes the same technologies as smart grids, the Internet of Things, and electric vehicles. However, the renewable energy clusters have specific ones, considering bioenergy and wind and solar power issues.

Third, during the last eight years, evolutional changes in the prevailing directions of household energy efficiency and green power research have occurred. While the scholars focused on the environmental impacts of energy-efficient technologies and home energy conservation in 2014–2015, power optimization and residential energy efficiency policy gained popularity in 2016–2017. The latest trends include studies on new energy-efficient technologies and management mechanisms of their implementation in the household sector. As for the evolution of green power research, it moved from investigating bio-, wind energy, and renewable energy planning in homes to considering green power transition issues and innovative technologies, ensuring these changes, along with investment, demand management, and other economic and managerial mechanisms to support sustainable transformations.

Fourth, the co-authorship analysis focused on identifying prominent nations in the residential energy efficiency and renewable energy field and their interconnected relationships. The United States, the United Kingdom, China, Germany, Australia, and India emerge as the most influential contributors to the household energy efficiency domain. As for the energy efficiency research timeline of 2015–2019, the field's stalwarts include the United States, Sweden, Japan, Canada, and others. The United States and the United Kingdom exhibit widespread global cooperation, predominantly within Europe. Meanwhile, China's collaborative efforts primarily involve European researchers while maintaining significant ties with Japan, Australia, Canada, and other regions.

Finally, prominent contributors to household green power studies include the United States, the United Kingdom, China, Germany, and India, with extensive scientific publications. From 2017

to 2020, long-standing involvement in the field was evident in countries such as the United States, the United Kingdom, Canada, Australia, and others. China, South Korea, and the European Union intensified renewable energy research between 2018 and 2019. Noteworthy collaborations span the United States and European institutions, while China engages with scholars from Asia, Europe, and Africa, and the United Kingdom exhibits a globally expansive partnership network.

Future studies should acknowledge certain limitations of this analysis. First, the latter utilized publications from the Scopus database, applying co-authorship and co-occurrence analyses with the VOSviewer tool. Expanding the scope of future investigations could involve alternative review techniques and software. Second, enhancing the co-occurrence analysis could entail a broader range of keywords for comprehensive exploration or a more focused selection to delineate specific research trends. Third, this study concentrated on English-language articles and conference papers within the Scopus database. Future exploration might encompass various publication types (book chapters or reviews), languages, and databases, particularly Web of Science. The identified limitations offer promising avenues for further scholarly inquiry.

Overall, the research revealed new trends in renewable energy and energy efficiency development to consider for improving the residential sector's relevant policies and managerial mechanisms. The outputs of the keyword co-occurrence and co-authorship clustering analyses may be used for creating innovative and highly effective energy policy strategies and instruments. Broader speaking, the study's results may help build long-term management mechanisms for green power and energy efficiency deployment in many countries to reform their residential sector toward decarbonization and greening the economies.

AUTHOR CONTRIBUTIONS

Conceptualization: Iryna Sotnyk, Tetiana Kurbatova.
Data curation: Iryna Sotnyk, Oleksandra Kubatko.
Formal analysis: Iryna Sotnyk, Oleksandra Kubatko, Olha Prokopenko, Marina Järvis.
Funding acquisition: Tetiana Kurbatova, Marina Järvis.
Investigation: Iryna Sotnyk, Olha Prokopenko, Marina Järvis.
Methodology: Iryna Sotnyk, Tetiana Kurbatova.
Project administration: Iryna Sotnyk, Tetiana Kurbatova.
Resources: Oleksandra Kubatko, Olha Prokopenko, Marina Järvis.
Software: Tetiana Kurbatova, Oleksandra Kubatko, Olha Prokopenko.
Supervision: Iryna Sotnyk, Oleksandra Kubatko.
Validation: Oleksandra Kubatko, Olha Prokopenko, Marina Järvis.
Visualization: Tetiana Kurbatova, Oleksandra Kubatko.
Writing – original draft: Iryna Sotnyk, Tetiana Kurbatova, Oleksandra Kubatko.
Writing – review & editing: Iryna Sotnyk, Tetiana Kurbatova, Olha Prokopenko, Marina Järvis.

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REFERENCES

1. Al-Marri, W., Al-Habaibeh, A., & Watkins, M. (2018). An investigation into domestic energy consumption behaviour and public awareness of renewable energy in Qatar. *Sustainable Cities and Society, 41,* 639-646. https://doi.org/10.1016/j.scs.2018.06.024

2. Alsalemi, A., Himeur, Y., Bensaali, F., Amira, A., Sardianos, C., Varlamis, I., & Dimitrakopoulos, G. (2020). Achieving domestic energy efficiency using micro-moments and intelligent recommendations. *IEEE Access, 8,* 15047-15055. https://doi.org/10.1109/aCCESS.2020.2966640

3. Andor, M., & Fels, K. (2018). Behavioral economics and energy conservation – A systematic review of non-price interventions and their causal effects. *Ecological Economics, 148,* 178-210. https://doi.org/10.1016/j.ecolecon.2018.01.018

4. Anjana, K. R., & Shaji, R. S. (2018). A review on the features and technologies for energy efficiency of smart grid. *International Journal of Energy Research, 42*(3), 936-952. https://doi.org/10.1002/er.3852

5. Bastida, L., Cohen, J. J., Kollmann, A., Moya, A., & Reichl, J. (2019). Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming. *Renewable and Sustainable Energy Reviews, 103,* 455-462. https://doi.org/10.1016/j.rser.2019.01.004

6. Buckley, P. (2020). Prices, information and nudges for residential electricity conservation: A meta-analysis. *Ecological Economics, 172,* 106635. https://doi.org/10.1016/j.ecolecon.2020.106635

7. Chygryn, O., & Shevchenko, K. (2023). Energy industry development: Key trends and the core determinants. *SocioEconomic Challenges, 7*(1), 115-128. https://doi.org/10.21272/sec.7(1).115-128.2023

8. Climate Action Tracker. (n.d.). *Home.* Retrieved July 10, 2023, from https://climateactiontracker.org/

9. Corsini, F., Laurenti, R., Meinherz, F., Appio, F. P., & Mora, L. (2019). The advent of practice theories in research on sustainable consumption: Past, current and future directions of the field. *Sustainability, 11*(2), 341. https://doi.org/10.3390/su11020341

10. Cui, S., Wang, Y.-W., Li, C., & Xiao, J.-W. (2020). Prosumer community: A risk aversion energy sharing model. *IEEE Transactions on Sustainable Energy, 11*(2), 828-838. https://doi.org/10.1109/TSTE.2019.2909301

11. Daniel, M., Rivière, G., & Couture, N. (2019). Cairnform: A shape-changing ring chart notifying renewable energy availability in peripheral locations. *TEI 2019 - Proceedings of the 13th International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 275-286). https://doi.org/10.1145/3294109.3295634

12. Fasoranti, M. M., Alimi, R. S., & Ofonyelu, C. C. (2022). Effect of prepaid meters on the household expenditure on electricity consumption in Ondo state. *SocioEconomic Challenges, 6*(4), 86-96. https://doi.org/10.21272/sec.6(4).86-96.2022

13. Gnewuch, U., Morana, S., Heckmann, C., & Maedche, A. (2018). Designing conversational agents for energy feedback. In S. Chatterjee, K. Dutta, & R. Sundarraj (Eds.), *Designing for a Digital and Globalized World* (pp. 18-33). Springer. https://doi.org/10.1007/978-3-319-91800-6_2

14. Goldstein, B., Gounaridis, D., & Newell, J.P. (2020). The carbon footprint of household energy use in the United States. *Proceedings of the National Academy of Sciences of the United States of America* (pp. 19122-19130). https://doi.org/10.1073/pnas.1922205117

15. Guo, Z., Zhou, K., Zhang, C., Lu, X., Chen, W., & Yang, S. (2018). Residential electricity consumption behavior: Influencing factors, related theories and intervention strategies. *Renewable and Sustainable Energy Reviews, 81,* 399-412. https://doi.org/10.1016/j.rser.2017.07.046

16. Han, X., & Wei, C. (2021). Household energy consumption: State of the art, research gaps, and future prospects. *Environment, Development and Sustainability, 23*(8), 12479-12504. https://doi.org/10.1007/s10668-020-01179-x

17. Hanke, F., Guyet, R., & Feenstra, M. (2021). Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases. *Energy Research & Social Science, 80,* 102244. https://doi.org/10.1016/j.erss.2021.102244

18. Hasselqvist, H., Renström, S., Strömberg, H., & Håkansson, M. (2022). Household energy resilience: Shifting perspectives to reveal opportunities for renewable energy futures in affluent contexts. *Energy Research & Social Science, 88,* 102498. https://doi.org/10.1016/j.erss.2022.102498

19. Ingeborgrud, L., Heidenreich, S., Ryghaug, M., Skjølsvold, T. M., Foulds, C., Robison, R., Buchmann, K., & Mourik, R. (2020). Expanding the scope and implications of energy research: A guide to key themes and concepts from the social sciences and humanities. *Energy Research & Social Science, 63,* 101398. https://doi.org/10.1016/j.erss.2019.101398

20. Janikowska, O. J., & Jebreel, A. A. A. (2022). The effect of energy transition on the labor market. A preliminary evaluation of Poland's wind-energy industry. *Polityka Energetyczna – Energy Policy Journal, 25*(1), 109-124. https://doi.org/10.33223/epj/146412

21. Jensen, C. L., Goggins, G., Røpke, I., & Fahy, F. (2019). Achieving sustainability transitions in residential energy use across Europe: The importance of problem framings. *Energy Policy, 133,* 110927. https://doi.org/10.1016/j.enpol.2019.110927

22. Kostyrko, R., Kosova, T., Kostyrko, L., Zaitseva, L., & Melnychenko, O. (2021). Ukrainian market of

electrical energy: Reforming, financing, innovative investment, efficiency analysis, and audit. *Energies, 14*(16), 5080. https://doi.org/10.3390/en14165080

23. Koval, V., Ostapenko, O., Halushchak, O., Olczak, P., Dobrovolska, K., & Kaptalan, S. (2023). Economic and environmental dimensions of energy production with the use of renewable technologies. *Polityka Energetyczna – Energy Policy Journal, 26*(1), 5-22. https://doi.org/10.33223/epj/161355

24. Ksonzhyk, I., Lavrushchenko, Y., Oleksiuk, M., Saienko, V., & Buryk, Z. (2021). Influence of renewable "green" energy on the economic development of the EU states. *Environment and Ecology Research, 9*(5), 271-281. https://doi.org/10.13189/eer.2021.090507

25. Kulapin, O., Ivakhnov, A., Danylchenko, D., Fedorchuk, S., Hrytsenko, V., & Stanislav, D. (2022). Prospects of using prosumers to analyze the potential of demand management. *2022 IEEE 3rd KhPI Week on Advanced Technology, KhPI Week 2022 – Conference Proceedings* (pp. 1-5). Kharkiv, Ukraine. https://doi.org/10.1109/KhPIWeek57572.2022.9916321

26. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023a). Greenfield investment as a catalyst of green economic growth. *Energies, 16*(5), 2372. https://doi.org/10.3390/en16052372

27. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023b). Relationship between energy and governance efficiency. *Energies, 16*(6), 2511. https://doi.org/10.3390/en16062511

28. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023c). The effects of urbanisation on green growth within Sustainable Development Goals. *Land, 12*(2), 511. https://doi.org/10.3390/land12020511

29. Lekavičius, V., Bobinaitė, V., Galinis, A., & Pažėraitė, A. (2020). Distributional impacts of investment subsidies for residential energy technologies. *Renewable and Sustainable Energy Reviews, 130,* 109961. https://doi.org/10.1016/j.rser.2020.109961

30. Liu, J., Murshed, M., Chen, F., Shahbaz, M., Kirikkaleli, D., & Khan, Z. (2021). An empirical analysis of the household consumption-induced carbon emissions in China. *Sustainable Production and Consumption, 26,* 943-957. https://doi.org/10.1016/j.spc.2021.01.006

31. Luna, A. C., Diaz, N.L., Graells, M., Vasquez, J. C., & Guerrero, J. M. (2016). Cooperative energy management for a cluster of households prosumers. *IEEE Transactions on Consumer Electronics, 62*(3), 235-242. https://doi.org/10.1109/TCE.2016.7613189

32. Lyndiuk, O., Kalinina, S., & Buchyk, V. (2020). The development of renewable energy in Ukraine in the context of ensuring public employment. *Polityka Energetyczna – Energy Policy Journal, 23*(4), 141-154. https://doi.org/10.33223/epj/130319

33. Ma, X., Wang, M., & Li, C. (2020). A summary on research of household energy consumption: A bibliometric analysis. *Sustainability (Switzerland), 12*(1), 316. https://doi.org/10.3390/su12010316

34. Martin, R. (2020). Making sense of renewable energy: Practical knowledge, sensory feedback and household understandings in a Scottish island microgrid. *Energy Research & Social Science, 66,* 101501. https://doi.org/10.1016/j.erss.2020.101501

35. Melnyk, L., Sommer, H., Kubatko, O., Rabe, M., & Fedyna, S. (2020). The economic and social drivers of renewable energy development in OECD countries. *Problems and Perspectives in Management, 18*(4), 37-48. https://doi.org/10.21511/ppm.18(4).2020.04

36. Mentel, G., Vasilyeva, T., Samusevych, Y., & Pryymenko, S. (2018). Regional differentiation of electricity prices: Social-equitable approach. *International Journal of Environmental Technology and Management, 21*(5-6), 354-372. https://doi.org/10.1504/IJETM.2018.100583

37. Milchram, C., van de Kaa, G., Doorn, N., & Künneke, R. (2018). Moral values as factors for social

acceptance of smart grid technologies. *Sustainability, 10*(8), 2703. https://doi.org/10.3390/su10082703

38. Nekrasenko, L. A., Prokopenko, O. V., & Aranchiy, V. I. (2015). Carbon tax as an instrument of environmental management in Ukraine. *Actual Problems of Economics, 165*(3), 196-202. Retrieved from https://www.researchgate.net/publication/283125532_Carbon_tax_as_an_instrument_of_environmental_management_in_Ukraine

39. Nguyen, S., Peng, W., Sokolowski, P., Alahakoon, D., & Yu, X. (2018). Optimizing rooftop photovoltaic distributed generation with battery storage for peer-to-peer energy trading. *Applied Energy, 228,* 2567-2580. https://doi.org/10.1016/j.apenergy.2018.07.042

40. Olczak, P., Matuszewska, D., Lishchenko, A., Zhydyk, I., Koval, V., & Iermakova, O. (2022). The economic efficiency of photovoltaic energy for energy prosumers. *Polityka Energetyczna – Energy Policy Journal, 25*(4), 95-114. https://doi.org/10.33223/epj/155095

41. Onyshchenko, V. O., Zavora, T. M., & Filonych, O. M. (2018). The sociological measuring in the implementation of measures of energy efficiency and energy conservation of housing facilities. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 6,* 131-138. https://doi.org/10.29202/nvngu/2018/18

42. Paone, A., & Bacher, J.-P. (2018). The impact of building occupant behavior on energy efficiency and methods to influence it: A review of the state of the art. *Energies, 11*(4), 953. https://doi.org/10.3390/en11040953

43. Pu, R., Li, X., & Chen, P. (2021). Sustainable development and sharing economy: A bibliometric analysis. *Problems and Perspectives in Management, 19*(4), 1-19. https://doi.org/10.21511/ppm.19(4).2021.01

44. Pumphrey, K., Walker, S. L., Andoni, M., & Robu, V. (2020). Green hope or red herring?

Examining consumer perceptions of peer-to-peer energy trading in the United Kingdom. *Energy Research & Social Science, 68,* 101603. https://doi.org/10.1016/j.erss.2020.101603

45. Rafsanjani, H. N., & Ghahramani, A. (2020). Towards utilizing Internet of Things (IoT) devices for understanding individual occupants' energy usage of personal and shared appliances in office buildings. *Journal of Building Engineering, 27,* 100948. https://doi.org/10.1016/j.jobe.2019.100948

46. Rau, H., Moran, P., Manton, R., & Goggins, J. (2020). Changing energy cultures? Household energy use before and after a building energy efficiency retrofit. *Sustainable Cities and Society, 54,* 101983. https://doi.org/10.1016/j.scs.2019.101983

47. Rausser, G., Strielkowski, W., & Štreimikienė, D. (2018). Smart meters and household electricity consumption: A case study in Ireland. *Energy & Environment, 29*(1), 131-146. https://doi.org/10.1177/0958305X17741385

48. Razmjoo, A., Gakenia Kaigutha, L., Vaziri Rad, M. A., Marzband, M., Davarpanah, A., & Denai, M. (2021). A technical analysis investigating energy sustainability utilizing reliable renewable energy sources to reduce CO_2 emissions in a high potential area. *Renewable Energy, 164,* 46-57. https://doi.org/10.1016/j.renene.2020.09.042

49. Ruiz-Cortes, M., Gonzalez-Romera, E., Amaral-Lopes, R., Romero-Cadaval, E., Martins, J., Milanes-Montero, M. I., & Barrero-Gonzalez, F. (2019). Optimal charge/discharge scheduling of batteries in microgrids of prosumers. *IEEE Transactions on Energy Conversion, 34*(1), 468-477. https://doi.org/10.1109/TEC.2018.2878351

50. Sala, D., Bashynska, I., Pavlova, O., Pavlov, K., Chorna, N., & Chornyi, R. (2023). Investment and innovation activity of renewable energy sources in the electric power industry in the south-eastern region of Ukraine. *Energies, 16*(5), 2363. https://doi.org/10.3390/en16052363

51. Samusevych, Y., Vysochyna, A., Vasylieva, T., Lyeonov, S., & Pokhylko, S. (2021). Environmental, energy and economic security: Assessment and interaction. *E3S Web of Conferences, 234,* 00012. https://doi.org/10.1051/e3sconf/202123400012

52. Shpak, N., Ohinok, S., Kulyniak, I., Sroka, W., Fedun, Y., Ginevičius, R., & Cygler, J. (2022). CO_2 emissions and macroeconomic indicators: Analysis of the most polluted regions in the world. *Energies, 15*(8), 2928. https://doi.org/10.3390/en15082928

53. Sineviciene, L., Kubatko, O. V., Sotnyk, I. M., & Lakstutiene, A. (2019). Economic and environmental performance of post-communist transition economies. In M. Bilgin, H. Danis, E. Demir, & U. Can (Eds.), *Eurasian Economic Perspectives. Eurasian Studies in Business and Economics, 11/1* (pp. 125-141). Springer. https://doi.org/10.1007/978-3-030-18565-7_10

54. Smale, R., & Kloppenburg, S. (2020). Platforms in power: Householder perspectives on the social, environmental and economic challenges of energy platforms. *Sustainability, 12*(2), 692. https://doi.org/10.3390/su12020692

55. Sotnyk, I., Kurbatova, T., Blumberga, A., Kubatko, O., & Kubatko, O. (2022a). Solar energy development in households: Ways to improve state policy in Ukraine and Latvia. *International Journal of Sustainable Energy, 41*(11), 1623-1649. https://doi.org/10.1080/14786451.2022.2092106

56. Sotnyk, I., Kurbatova, T., Romaniuk, Y., Prokopenko, O., Gonchar, V., Sayenko, Y., Prause, G., & Sapiński, A. (2022b). Determining the optimal directions of investment in regional renewable energy development. *Energies, 15*(10), 3646. https://doi.org/10.3390/en15103646

57. Sotnyk, I., Kurbatova, T., Trypolska, G., Sokhan, I., & Koshel, V. (2023). Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis. *Environmental Economics, 14*(2), 13-27. https://doi.org/10.21511/ee.14(2).2023.02

58. Sovacool, B. K., & Furszyfer Del Rio, D. D. (2020). Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. *Renewable and Sustainable Energy Reviews, 120,* 109663. https://doi.org/10.1016/j.rser.2019.109663

59. Sovacool, B. K., Hook, A., Sareen, S., & Geels, F. W. (2021). Global sustainability, innovation and governance dynamics of national smart electricity meter transitions. *Global Environmental Change, 68,* 102272. https://doi.org/10.1016/j.gloenvcha.2021.102272

60. Sowa, S. (2020). The implementation of renewable energy systems, as a way to improve energy efficiency in residential buildings. *Polityka Energetyczna – Energy Policy Journal, 23*(2), 19-36. https://doi.org/10.33223/epj/122354

61. Tirado Herrero, S., Nicholls, L., & Strengers, Y. (2018). Smart home technologies in everyday life: Do they address key energy challenges in households? *Current Opinion in Environmental Sustainability, 31,* 65-70. https://doi.org/10.1016/j.cosust.2017.12.001

62. Trotta, G. (2018). Factors affecting energy-saving behaviours and energy efficiency investments in British households. *Energy Policy, 114,* 529-539. https://doi.org/10.1016/j.enpol.2017.12.042

63. Trypolska, G. (2021). Prospects for employment in renewable energy in Ukraine, 2014–2035. *International Journal of Global Energy Issues, 43*(5-6), 436-457. https://doi.org/10.1504/IJGEI.2021.118930

64. United Nations. (n.d.). *Nationally Determined Contributions Registry.* Retrieved July 10, 2023, from https://unfccc.int/NDCREG

65. Vakulenko, I., & Lieonov, H. (2022). Renewable energy and health: Bibliometric review of non-medical research. *Health Economics and Management Review, 3*(2), 44-53. https://doi.org/10.21272/hem.2022.2-05

66. Vakulenko, I., Saher, L., Lyulyov, O., & Pimonenko, T. (2021). A systematic literature review of smart grids. *E3S Web of Conferences, 250,* 08006. https://doi.org/10.1051/e3sconf/202125008006

67. Vélez-Henao, J.-A., & García-Mazo, C.-M. (2022). Environmental rebound effect of wind and solar technologies in the Colombian household sector. *Journal of Industrial Ecology, 26*(5), 1784-1795. https://doi.org/10.1111/jiec.13326

68. Vilchynska, L., Shashyna, M., Saienko, V., & Starikov, O. (2023). The impact of the COVID-19 pandemic on household expenditures in the EU countries (The case of Central and Eastern Europe). *Malaysian Journal of Consumer and Family Economics (MAJCAFE), 30,* 155-175.

69. Wolske, K. S., Gillingham, K. T., & Schultz, P. W. (2020). Peer influence on household energy behaviours. *Nature Energy, 5,* 202-212. https://doi.org/10.1038/s41560-019-0541-9

70. Wynes, S., Nicholas, K. A., Zhao, J., & Donner, S. (2018). Measuring what works: Quantifying greenhouse gas emission reductions of behavioural interventions to reduce driving, meat consumption, and household energy use. *Environmental Research Letters, 13*(111), 113002. https://doi.org/10.1088/1748-9326/aae5d7

71. Xu, X., & Chen, C.-F. (2019). Energy efficiency and energy justice for U.S. low-income households: An analysis of multifaceted challenges and potential. *Energy Policy, 128,* 763-774. https://doi.org/10.1016/j.enpol.2019.01.020

72. Yoshino, N., Taghizadeh-Hesary, F., & Nakahigashi, M. (2019). Modelling the social funding and spillover tax for addressing the green energy financing gap. *Economic Modelling, 77,* 34-41. https://doi.org/10.1016/j.econmod.2018.11.018

73. Zhang, W., Li, B., Xue, R., Wang, C., & Cao, W. (2021). A systematic bibliometric review of clean energy transition: Implications for low-carbon development. *PLoS ONE, 16*, e0261091. https://doi.org/10.1371/journal.pone.0261091

74. Zhang, X., Manogaran, G., & Muthu, B. (2021). IoT enabled integrated system for green energy into smart cities. *Sustainable Energy Technologies and Assessments, 46,* 101208. https://doi.org/10.1016/j.seta.2021.101208

75. Ziabina, Y., Pimonenko T., Lyulyov, O., Us, Y., & Proshkin, D. (2021). Evolutionary development of energy efficiency in the context of the national carbon-free economic development. *E3S Web of Conferences, 307,* 09002. https://doi.org/10.1051/e3sconf/202130709002