

Article

Bibliometric Literature Analysis of a Multi-Dimensional Sustainable Development Issue: Energy Poverty

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Abstract: Energy plays a critical role in building a sustainable future—economically, socially, and environmentally. Energy poverty holds a similarly prominent position and covers certain economic, social and environmental issues that are underlined by the United Nations’ Sustainable Development Goals. Due to its multidimensional role in plans for achieving sustainable development, there is a growing body of literature focusing on various aspects of energy poverty. This study conducts a bibliometric analysis of this literature by utilizing more extensive data from the Web of Science, covering all information on energy poverty studies. The analysis reveals how energy poverty has attracted attention over time, who the leading authors are, which studies constitute outstanding contributions to the literature, which different sides of the research topic stand out, and also highlights the potential research gaps. The results reveal all the network flows among researchers, publications, journals, keywords, organizations, co-cited publications, and bibliographic coupling for energy poverty studies. The findings confirm the increasing popularity of energy poverty as a topic and demonstrate the increasing awareness of the issue in academia over time.

Keywords: energy poverty; fuel poverty; energy deprivation; fuel deprivation; bibliometric analysis



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1. Introduction

The term “energy poverty” usually refers to the lack of affordability or of access to basic energy services to meet one’s most common needs, such as lighting, cooking, heating and cooling [1]. Bouzarovski and Petrova [2] define energy poverty as “the inability to attain a socially and materially necessitated level of domestic energy services”. However, in other definitions, the phrase generally refers to a lack of or limited access to the electricity and fuel required to sustain basic human needs that may differ because of climatic conditions, technological improvements, and country-specific social, cultural, political and environmental conditions [3,4]. Furthermore, the literature also extends the concept to cover meeting a variety of needs requiring energy, such as information and communication technologies, entertainment, education, transportation, commercial activities, and the running of home appliances [5–7]. Although these needs are caused by various dynamics and arise in different forms, in each case the affordability problem mainly stems from the lack of energy efficiency, low income levels, and high energy prices, all of which are major causes of energy poverty, as well as being related to the availability of energy sources [8,9].

Energy poverty is a social, economic, environmental and health problem that is being accentuated by the economic crisis, climate change and advances in technology, resulting in a paradigm shift in production in general, and household energy consumption in particular. Due to this paradigm shift, the post-pandemic era seems to be adding new dimensions to energy services. Thus, energy poverty may well include a lack of

socialization in circumstances where social media predominate as the means of interaction and communication between people, as well as inequality in education, as almost all means of education have been moved partly online and away from conventional methods in both developed and developing countries. Thus, energy poverty has become a critical challenge for sustainable development and intersects with the sustainable development objectives of the UNDP [10]. There is no doubt that energy poverty has now become the main agenda of many governments, as well as of “the international sustainable development agenda” [3].

One initial reflection on how energy poverty is treated in the literature is the growth of research in how to close the gap between the lack of knowledge regarding the drivers of energy poverty and efficient energy policies. The concept of energy poverty was initially introduced by Isherwood and Hancock [11] at a time when the number of vulnerable households affected by economic crises grew, following the oil shock of the early 1970s. The first popular and agreed definition, the well-known “10% indicator”, was suggested by Boardman [12] and was based on utility bills.

One reason for the knowledge of this topic failing to produce efficient energy policies is the lack of a consensus over how to define energy poverty and, thus, the difficulty of tracking and monitoring it. There is little doubt that policies mitigating energy poverty will require a manageable and functional definition of energy poverty in order to be translated into policy development. In the EU, only five countries, the UK, France, Cyprus, Ireland and Slovakia, have official definitions of energy poverty and strategies to mitigate it [13]. Other countries have neither a definition of energy poverty nor a policy for dealing with it.

Various indicators are employed to measure, track, analyze and evaluate energy poverty in households. The 10% indicator [14], 2M indicators [15], minimum income standards [16], low-income-high-cost [17], after fuel cost poverty indicator [16,18] and hidden energy poverty [19] are based on household bills for various expenses [13]. There are also two indicators based on the self-reporting of household conditions, namely, the “EU survey on income and living conditions” and the “Survey on perceptions and statements from households” [13] (see [20] for a review). In examining previous studies, there is a need to identify the most influential studies, authors and journals that are active in this area, as well as the most frequently used keywords. Our aim in this paper is to contribute to the convergence of the literature on a functional definition of energy poverty, for the purposes of policy formation.

Therefore, the purpose of this paper is to carry out a bibliometric analysis (also called scientometric analysis) on energy poverty to determine and identify the leading journals, authors, papers, keywords, institutions, countries, co-authorship, co-citation, co-occurrence, and bibliographic couplings. Such exercises enable existing and future researchers to explore new dimensions of the related topic and to acquire deeper perspectives on it by providing a broader assessment of the available sources and their intellectual structures, thus establishing a feasible way to track knowledge flows and the diffusion of ideas [21,22]. Due to its power of visualization and synthetization, this research method has been widely used in various research fields [23,24] and has become a frequently employed analytical tool for researchers focusing on different aspects of energy-related issues (e.g., [25–30]).

There are some remarkable studies reviewing the energy poverty literature [3,4,13,20,31–34], but none of them performed a scientometric analysis to reveal networks among publications in terms of global and local citation counts, citing and cited references, co-citation, bibliographic coupling, co-authorship, and co-occurrence. Moreover, the network analysis in this study is based on a larger and more comprehensive dataset covering all information on energy poverty studies, stored in the Web of Science. Therefore, this study is expected to contribute to the literature by revealing the bibliometric properties of publications on energy poverty and synthesizing them.

The rest of the paper is organized as follows. Section 2 explains the data used in bibliometric analyses and introduces the methodology. Section 3 presents and discusses a wide range of results by means of tables and figures. Finally, Section 4 provides some concluding remarks.

2. Materials and Method

Before proceeding to introduce materials and methods, a brief overview of the literature in terms of subject categories and methodologies will shed light on our understanding of the various aspects of energy poverty studies. It should first be pointed out that Sovacool [6], Bouzarovski and Petrova [2], Pelz et al. [3], Streimikiene et al. [4], Urquiza et al. [33], Pachauri et al. [35], Thomson et al. [36], Nussbaumer et al. [5], Pachauri and Spreng [37], Practical Action [38], Charlier and Legendre [39], and Churchill et al. [40] all describe conceptual frameworks and multidimensional ways of measuring energy poverty. Various indicators are employed to measure, track, analyze and evaluate energy poverty in households. The 10% indicator [14], 2 M indicators [15], minimum income standards [16], low-income-high-cost [17], after fuel cost poverty indicator [16,18] and hidden energy poverty [19] are based on household bills and various other expenses [13]. There are also two indicators based on self-reporting household conditions, namely the “EU survey on income and living conditions” and the “Survey on perceptions and statements from households” [13]. Finally, it should be noted that energy or fuel poverty may change, based on subjective and objective measurements, and may lead to different results, as reported by Price et al. [41] and Llorca et al. [42].

These seminal studies are important in observing various countries’ problems with energy poverty. On the one hand, although the subject of poverty is comprehensively covered by the economic aspect of sustainable development [43–49], it is also considered to be a precursor of problems in health and education, since it causes a deterioration in people’s living conditions [31,50–53]. Furthermore, the topic has been investigated in terms of its various links with, for example, inequalities and differences in income [54–57], gender [58–65] and race [8,66–69], the nexus of renewable energy, smarter technology, energy efficiency and its alleviation [70–78], energy prices, energy security and energy dependence [79–83] and the relationship between CO₂ emissions, climate change and energy poverty [84–89].

In order to examine the energy poverty issue, some researchers focus on a single country’s experience by using statistical data and methodologies, while others address regional or cross-country samples. Of these, Pachauri et al. [35] analyzed the issue in India by using household survey data, based on changes in energy distribution patterns, and concluded that this approach can be a good complement to monetary measures of energy poverty. Using microdata gathered by the Rural Energy Survey of Bangladesh, Barnes et al. [90] ran the OLS estimator to determine the socio-economic dynamics of energy consumption and calculated that 58% of rural households are energy-poor. Szabo et al. [91] conducted a spatial economics analysis using a wide range of geographical information for Sub-Saharan Africa and proposed rural electrification options to reduce energy poverty. Pereira et al. [54] analyzed the impact of rural electrification on the mitigation of energy poverty in Brazil by examining 23,000 rural domiciles or rural properties and observed a close relationship between them. Papada and Kaliampakos [92] conducted a survey of energy expenses and subjective perceptions of housing conditions and found that 58% of Greek households are energy-poor. By using Indian household data based on various energy indicators, Sadath and Acharya [93] showed that energy poverty is widespread in India and occurs in tandem with decreasing incomes and social breakdown. Based on household data from various regions in Indonesia, Andadari et al. [94] showed that substitution among energy sources may be useful in alleviating extreme energy poverty, but not for reducing energy poverty overall. Thomson et al. [50] examined 32 European countries using quality-of-life survey data and found that energy poverty, poor health and poor living conditions are distributed differently in different countries. Bouzarovski and Herrero [95] also used microdata collected from household budget surveys and analyzed post-communist states in eastern and central Europe. They concluded that geographical factors may drive energy poverty to a considerable extent. Like the studies in the literature that have already been mentioned, microdata gathered from household surveys are the main input for calculation and comparison purposes regarding energy poverty in much of this research [96–102].

Energy poverty has been analyzed using several alternative concepts [2]. Although referring mainly to the need to heat homes, “fuel poverty” is the second most widely used term in the literature. “Energy deprivation” or “fuel deprivation” are other, alternative keywords in similar studies [103]. Although it is used officially in French documents, some studies treat “energy precariousness” or “fuel precariousness” in a similar manner [104,105]. In light of the discussion of these terms in Bouzarovski and Petrova [2], we selected keywords to determine studies that directly focus on energy poverty or fuel poverty. Then we searched each keyword by using the Web of Science database as the primary source of bibliometric data. In order to consider studies related to energy poverty and fuel poverty, we first limited the keyword search to titles, only because other search types, such as searching the topic, produced hundreds of irrelevant papers whose main focal points were remote from energy poverty. Later, we searched the keywords in abstracts and topics, which gave us publications related to energy poverty and/or fuel poverty. In this search, no restrictions of time were imposed, and thus all Web of Science-indexed sources were retrieved from the database as of 10 January 2021 (accessed on 10 January 2021). The descriptive statistics for the collected data are as shown in Figure 1:

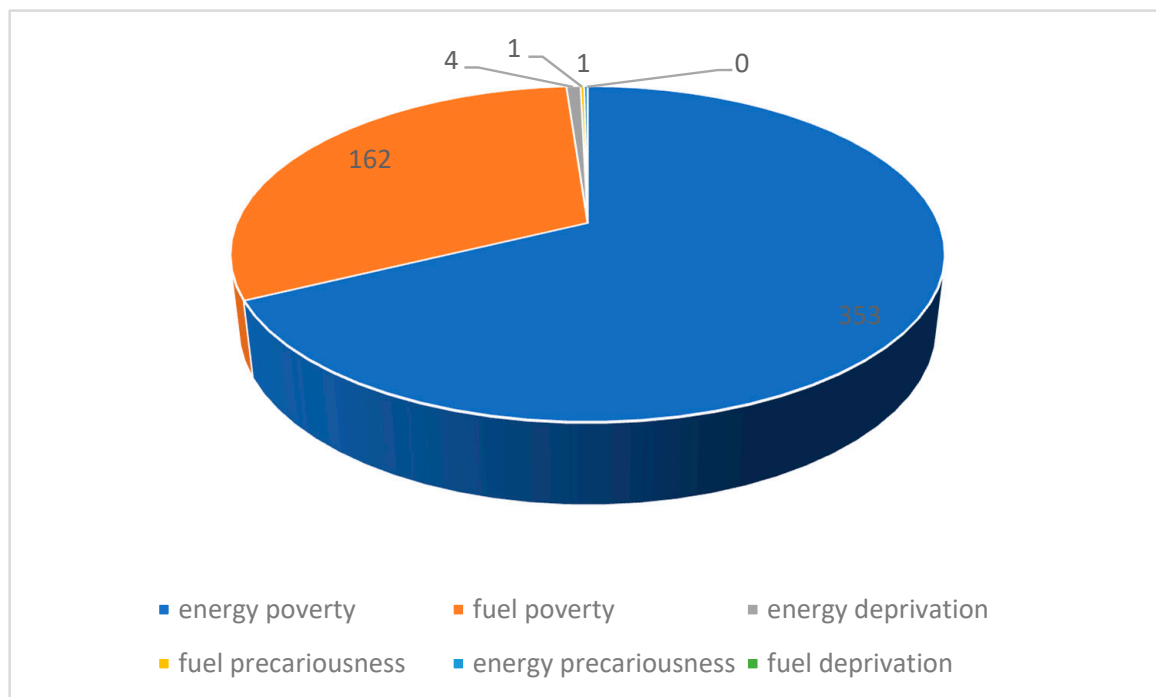


Figure 1. The number of studies with alternative keywords.

Given the search restrictions, the database provided 521 items with different types of research in which the terms “energy poverty” and “fuel poverty” were preferred by a great majority of the papers, as shown in Figure 1. Interestingly, 125 out of 521 studies, which corresponds to about a quarter of the publications obtained for this study, were published in 2019 (see Figure 2).

Figure 2 reveals that, in the last five years, the popularity of energy poverty as a research topic has been increasing. In line with the increasing number of publications, the number of citations followed an upward trend in the last decade and reached its maximum in 2020. Some structured information on the bibliometric data used in this study can also be tracked through the PRISMA outline in Appendix A. The selected publications have been cited 8006 times so far, as shown in Table 1. A distinctive difference arises between citation counts according to the language of the items in the table, confirming the advantages of visibility and accessibility when publishing studies in the English language.

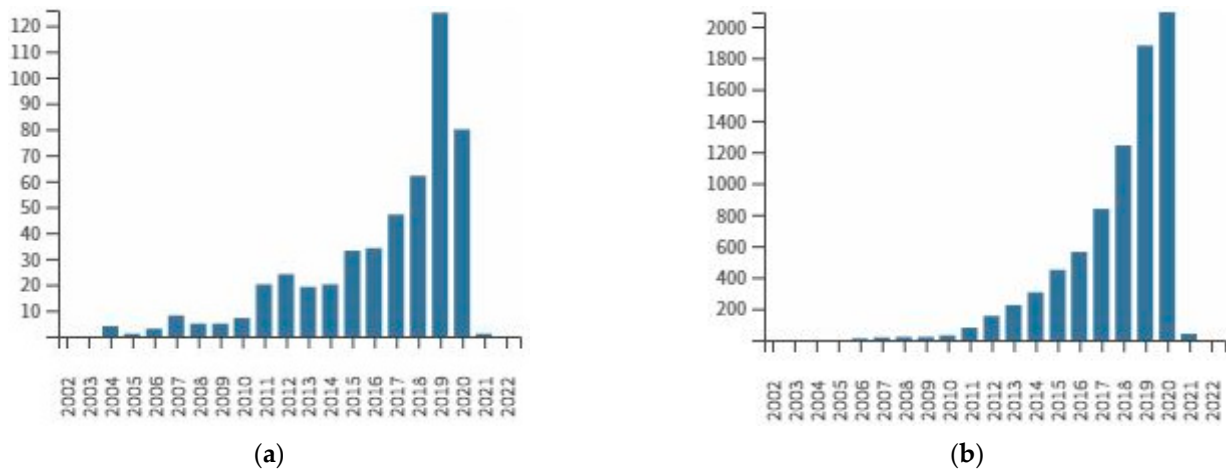


Figure 2. The number of studies (a) and citations (b).

Table 1. The number of items and citations by language.

Language	Number of Publications	Number of Citations	Average Citation per Item
English	509	7978	15.67
Spanish	8	9	0.88
Czech	2	0	0
German	1	11 Formun Altı	11
Italian	1	8	8
Total	521	8006	15.36

Finally, Table 1 shows that the average citation per item is 15.36 for energy poverty studies.

Figure 3 shows that a significant proportion of total publications are articles, followed by book chapters, proceedings, reviews, editorial materials and book reviews.

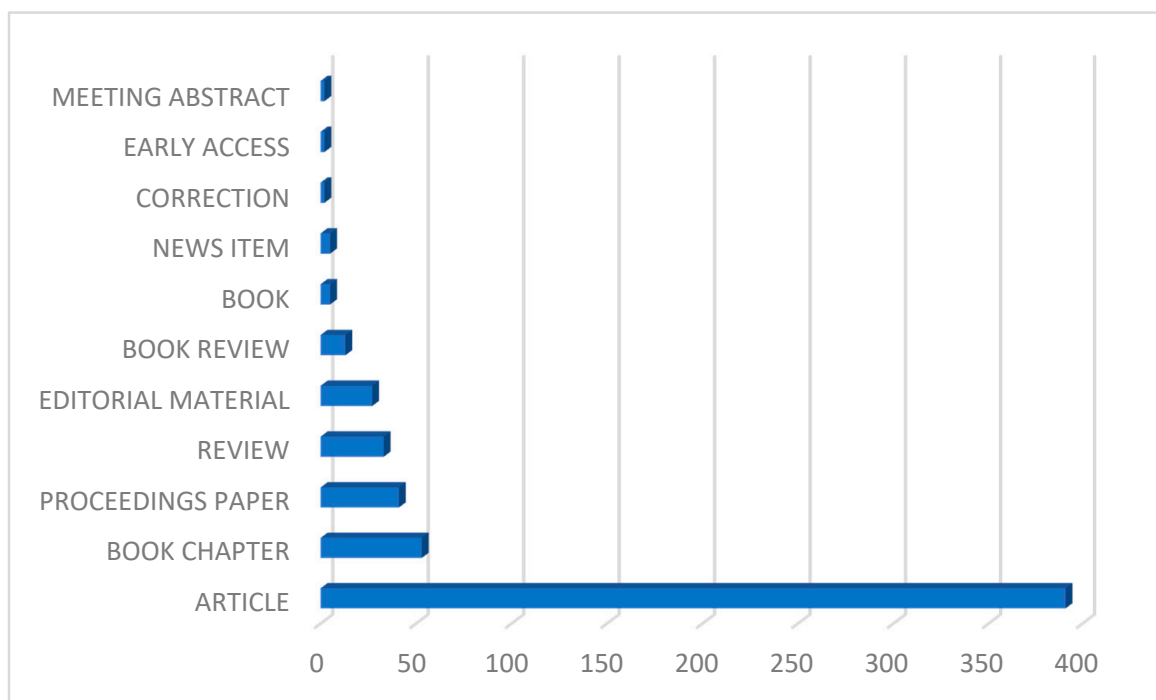


Figure 3. Publication types.

Having obtained all information provided by the Web of Science core collection database, this study applies a bibliometric analysis that clusters and visualizes the most striking items, journals, keywords, authors, institutions, countries, co-authorship, co-citation, co-occurrence and bibliographic coupling as a research method by using HistCite 12.03.17 and VOSviewer 1.6.15. This research method is also called “scientometric analysis”. More broadly, it can be conducted for a group of countries, organizations, publications and scholars with reference to connections and similarities [106]. In this way, it provides researchers, editors, journals and organizations, according to the research focus, with a variety of information about how relevant research topics have attracted attention over time and who the leading authors are, as well as which studies have made outstanding contributions to the literature and which different aspects of the research topic stand out. Therefore, it highlights how future studies may capture the gap in the current literature [22–24]. This advantage of such studies makes bibliometric analysis a popular research tool in the energy literature, making it one of the most rapidly increasing research fields (e.g., [25–30]).

In the analysis, the VOSviewer is a powerful tool used to determine the links among publications by considering citing and cited references, co-citation, bibliographic coupling, co-authorship and co-occurrence. It first creates a similarity matrix that reflects the power of the relationship between items (the similarity between i and j , that is, between publications), as shown in Equation (1):

$$\text{similarity}_{i,j} = \frac{c_{i,j}}{w_i w_j} \quad (1)$$

where the similarity of the i th and j th items are based on the ratio of c and w , and where c represents the number of co-occurrences for i and j , while w_i and w_j stand for total numbers of occurrence and co-occurrence for the items being considered [107]. Subsequently, the visualization is established by ordering items according to similarity, in which a higher level of similarity means the pairs in the diagram are closer. The mapping procedure is based on a weighted sum of the squared Euclidean distances between all pairs of items. In this phase, a weighted sum of the squared Euclidean distances is minimized, and a restriction is applied, such that the average distance between any two items must be equal to 1 to avoid the inconsistency that may occur, due to having the same location by items:

$$V(L_1, \dots, L_N) = \sum_{i,j} \text{similarity}_{i,j} \|L_i - L_j\|^2 \quad (2)$$

where L_i is a vector $L_i = (L_{i1}, L_{i2})$, and it specifies the place of the related item in the diagram. The term in vertical lines $\|L_i - L_j\|$ is the Euclidean norm. Then, based on Equation (3), minimization is obtained by applying Equation (2):

$$\frac{2}{N(N-1)} \sum_{i < j} \|L_i - L_j\| = 1 \quad (3)$$

Since this procedure does not yield a globally optimum solution, the software conducts a transformation through principal component analysis and determines the reflection of the solution to place it in a vertical or horizontal axis, according to the median value of items (e.g., $L_{11}, \dots, L_{N1} > 0$ or < 0). The procedure also uses a Gaussian kernel function with the item density, calculated by the adjacency of items and their weights. Thus, the small distance and larger area for items mean a strong relationship based on calculations and weightings.

3. Results and Discussions

In order to obtain bibliometric results, HistCite 12.03.17 and VOSviewer 1.6.15 were employed by utilizing the full recorded data with the cited references. HistCite software is more powerful in producing statistical tables with useful columns that enable us to see

local and global citations. However, the VOSviewer is more successful in mapping and visualizing bibliometric searches and indicating connections between items [106,107].

The results for the most productive authors are listed in Table 2. Our bibliometric analysis discovered 981 authors with at least one publication on energy poverty. Among the top thirty authors according to the number of papers, the most productive researcher seems to be Stefan Bouzarovski, with nineteen. The table also provides information on “the total number of citations to a paper in the Web of Science” (TGCS) and “the count of citations to a paper within the collection” (TLCS).

Table 2. Most productive authors.

Author	NPR	TLCS	TGCS	AVG	Author	NPR	TLCS	TGCS	Formun Üstü	AVG
Bouzarovski S	19	376	704	37.05	Perez-Fargallo A	6	0	47		7.83
Wei YM	14	17	28	2.00	Boardman B	5	131	264		52.80
Liao H	13	10	34	2.62	Boemi SN	5	15	26		5.20
Santamouris M	10	14	122	12.20	Castano-Rosa R	5	0	31		6.20
Snell C	10	186	341	34.10	Gouveia JP	5	20	54		10.80
Thomson H	10	178	311	31.10	Herrero ST	5	80	213		42.60
Sovacool BK	9	81	322	35.78	Katsoulakos N	5	18	37		7.40
Kaliampakos D	8	69	100	12.50	Lindley S	5	38	51		10.20
Papada L	8	69	100	12.50	Marrero M	5	0	31		6.20
Petrova S	8	219	427	53.38	Morris C	5	176	343		68.60
Robinson C	8	39	57	7.13	Bazilian M	4	89	198		49.50
Rubio-Bellido C	7	0	61	8.71	Gillard R	4	78	166		41.50
Howden- Chapman P	6	0	110	0.14	Walker G	4	136	383		1.25
Liddell C	6	189	361	18.33	Middlemiss L	4	91	166		41.50
Pachauri S	6	87	300	50	Simcock N	4	62	147		36.75

NPR: number of publications recorded; TLCS: “total local citation score”; TGCS: “total global citation score”, AVG: average TGCS per publication.

Stefan Bouzarovski is also a leading researcher, according to his local and global citation counts, making him the most influential scholar in the energy and fuel-poverty literature. His paper, entitled: “A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary” [2], is frequently cited in the Web of Science Core Collection and is among the nineteen publications of his that are listed in Table 2. Following Stefan Bouzarovski, Yi-Ming Wei, Hua Liao, Mat Santamouris, Carolyn Snell, Harriet Thomson, Benjamin Sovacool, Dimitris Kaliampakos, Lefkothea Papada and Saska Petrova are the top ten authors according to the number of publications.

However, it is also important to pay attention to the highest number of citations scored by authors, since they form a basis and reveal gaps for subsequent studies. In this case, Chris Morris, Brenda Boardman, Shonali Pachauri and Saska Petrova are the researchers who have attracted the greatest amount of attention, in terms of average citations per publication. Apart from the general statistical outlook, authors’ relationships based on citation networks are visualized in Figure 3, where they are clustered into five groups or “clubs”, marked by different colors.

Figure 4 presents the group of authors who form clusters according to the citation network and who have a minimum of four publications on energy poverty. Accordingly, the yellow club is at the center of the diagram and consists of Stefan Bouzarovski, Saska Petrova, Neil Simcock, Gordon Walker and Sergio Herrero. The green club shines out, with Carolyn Snell, Harriet Thomson, Christine Liddell and Chris Morris. In the red club, Benjamin Sovacool, Shonali Pachauri, Morgan Bazilian and Philippa Howden-Chapman are the key names among the other club members. The other clubs in the Figure are

signified by smaller bubbles since they are relatively weak. However, Ross Gillard and Lucie Middlemiss, in the blue club, and Lefkothea Papada in the purple club, are other names who have become prominent.

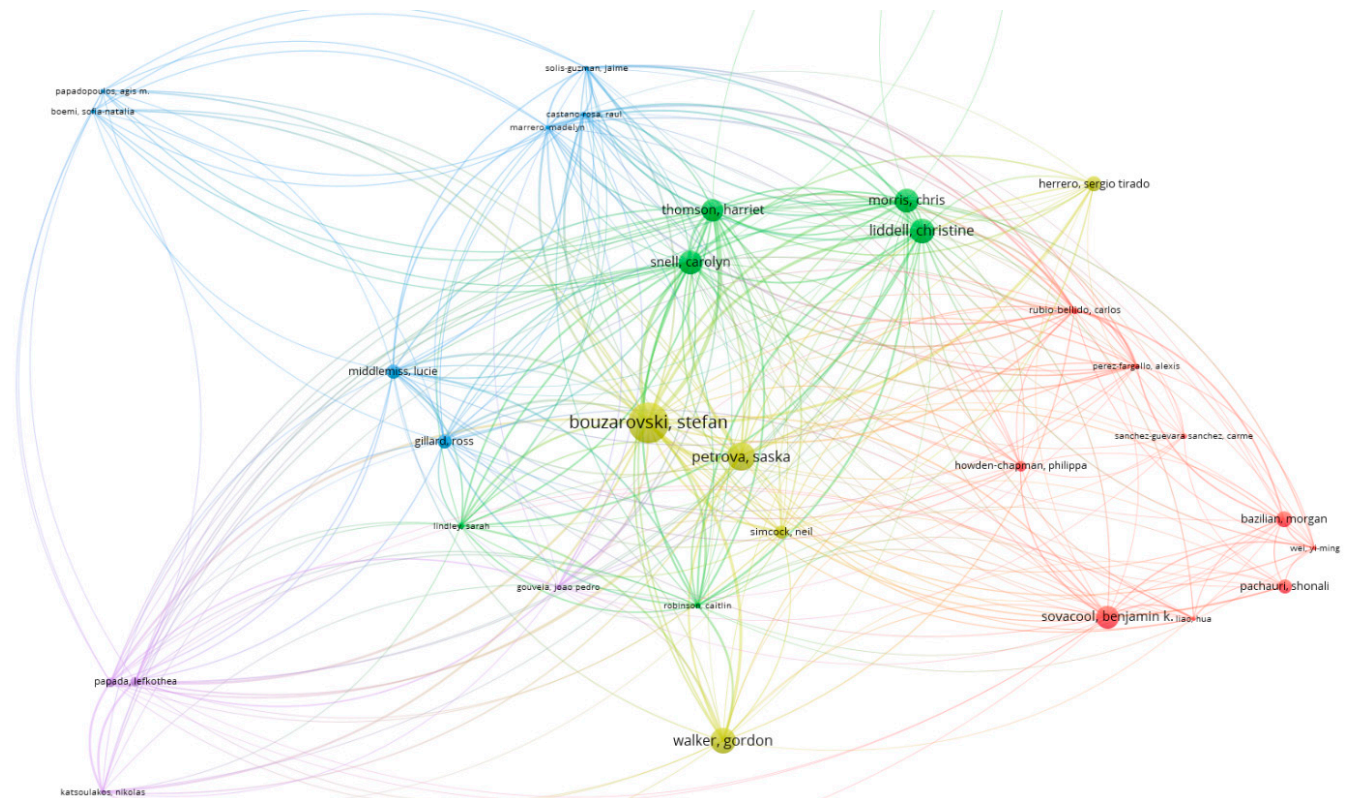


Figure 4. Author networks according to citations.

One striking output in the visualization of authors' clubs according to citation networks is Brenda Boardman, who has not found a place in any club despite her rank in terms of average citations per publication. Her publications are among the third most frequently cited papers on average, as shown in Table 2. This output led us to deepen our search upon acquiring some additional information about her publications. She has five publications in line with the keywords search of our analysis, which were published in 2012 (1), 2010 (2), 2009 (1) and 1993 (1). Four of her papers (1993, 2010, 2010, 2012) focus on fuel poverty and one on energy poverty (2009). The papers published in 1993, 2010 and 2012 were cited 6, 183 and 75 times respectively, although her other two papers have not been mentioned in any other study as yet. Therefore, they may have a weak connection with more recent publications in the heavy network, which is why she was not included in any of the clubs. Besides, it is important to note that the visualization changes when her publications are considered independently according to the citation network, as shown in subsequent figures. This is one of the strong aspects of the VOSviewer's clustering algorithm and shows why we need to reveal citation networks, co-citation networks and co-occurrence networks in the bibliometric analysis.

The author clubs in Figure 4 can be evaluated by considering their institutions and countries, thus enabling us to view the spatial distribution of author-citation networks. Accordingly, outside the UK, only Sergio Tirado Herrero from the Autonomous University of Barcelona is in the first club. All the other members are from the UK: Stefan Bouzaroski and Saska Petrova from the University of Manchester, Neil Simcock from John Moores University in Liverpool and Gordon Walker from Lancaster University.

The green club consists only of authors from the UK: Carolyn Snelli from the University of York; Harriet Thomson from the University of Birmingham; Chris Morris and Christine

Liddell from the University of Ulster; Sarah Lindley from the University of Manchester; and Robinson Caitlin from the University of Liverpool.

In the red club are Benjamin Sovacool from the University of Sussex (UK); Shonali Pachauri from the International Institute for Applied Systems Analysis (Austria); Yi-Ming Wei from the Beijing Institute of Technology (China); Morgan Bazilian from the Colorado School of Mines (USA); Philippa Howden-Chapman from the University of Otago (New Zealand); Carmen Sánchez-Guevara from the University of Madrid (Spain); Alexis Perez Fargallo from the Universidad del Bío-Bío (Chile); Carlos Rubio-Bellido from the University of Seville; and Hua Liao from the Beijing Institute of Technology (China).

The blue club shows an equal distribution in terms of country and institution, with Agis Papadopoulos and Sofia-Natalia Boemi from the Aristotle University of Thessaloniki (Greece); Lucie Middlemiss and Ross Gillard from the University of Leeds (UK); and Jaime Solís-Guzmán and Madelyn Marrero from the University of Seville (Spain).

Finally, the purple club has two members from Greece and one member from Portugal: Lefkothea Papada and Nikolas Katsoulakos are Greek scholars at the National Technical University of Athens, while João Pedro Gouveia is a Portuguese scholar from the Nova University of Lisbon.

Given the 981 authors with at least one publication on energy poverty, it can be seen that there is a vast pool of researchers who are spatially distributed among 66 countries. Figure 5 illustrates the number of publications by each country of the researchers. With 144 publications, the UK has the highest score; Spain with 54 publications, the US with 40 publications, Greece with 36 publications and Australia with 35 publications are also among the top five countries. Interestingly, the results indicate that researchers in Africa have paid less attention to energy poverty studies, although the continent suffers greatly from energy poverty and needs improvements to combat the problem. From the continent, South Africa (17), Nigeria (10), Ethiopia (3), Ghana (3), Mozambique and Sierra Leone (1) are the countries that find a place in the figure.

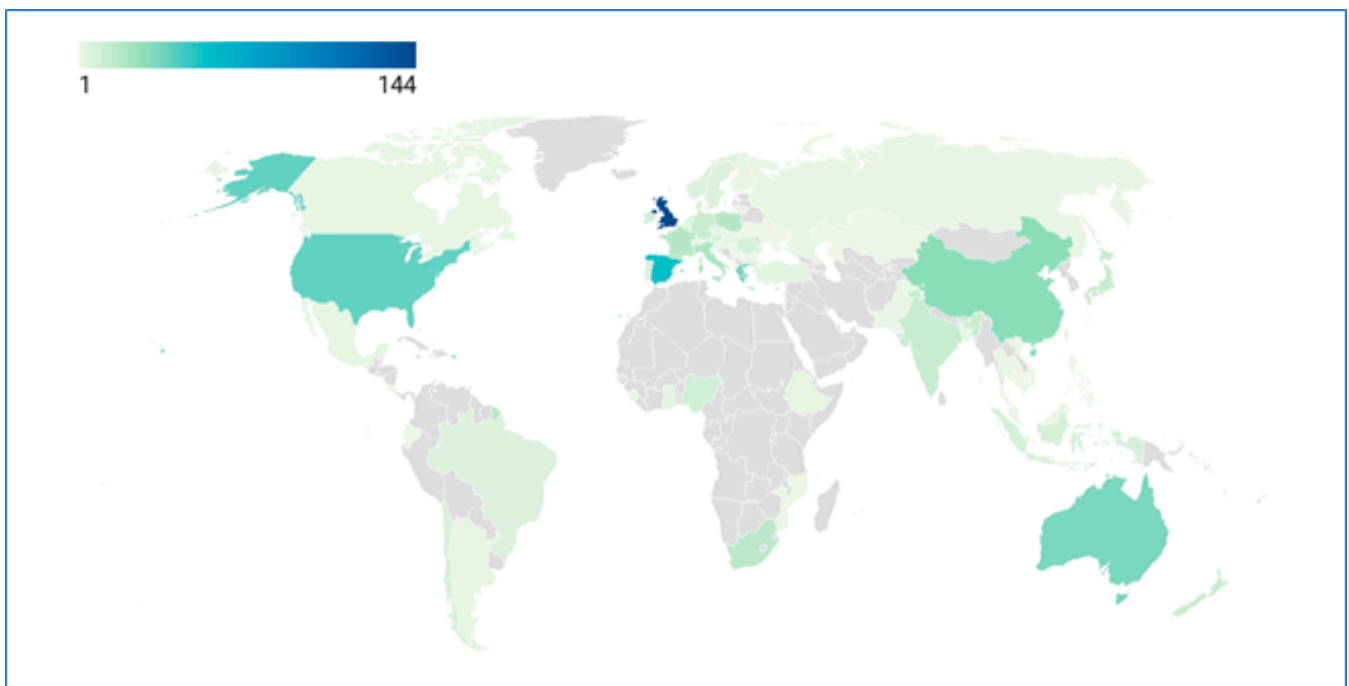


Figure 5. Spatial distribution of energy poverty publications.

The results also provide information on the distribution of publications and citations among institutions as tabulated in Table 3 (restricted to at least five publications). The University of Manchester in the UK, the University of New South Wales in Australia,

the University of Seville in Spain, the National Technical University of Athens and the University of Otago in New Zealand appear to be among the top five institutions.

Table 3. Leading institutions by publications.

Institution	NPR	TLCS	TGCS	Institution	NPR	TLCS	TGCS
Univ. Manchester	19	338	640	Univ. Coll Dublin	6	84	376
Univ. New South Wales	13	4	51	Univ. Dundee	6	0	1
Univ. Seville	13	9	113	Univ. Lancaster	6	139	388
Nat. Tech. Univ. Athens	12	103	156	Univ. Nottingham	6	18	70
Univ. Otago	12	14	205	Univ. Sussex	6	23	102
Univ. Athens	11	14	122	Univ. Ulster	6	189	361
Beijing Inst. Technol.	10	0	0	Univ. Zaragoza	6	36	93
Cyprus Inst.	9	2	6	Vermont Law Sch.	6	61	257
Univ. Leeds	8	105	212	Aarhus Univ.	5	19	89
Univ. Oxford	8	79	165	Aristotle Univ. Thessaloniki	5	15	26
Univ. York	8	183	331	Beijing Inst. Technol.	5	27	69
Univ. Birmingham	7	207	473	Bolzano Univ.	5	0	1
Columbia. Univ	6	79	209	Brunel Univ. London	5	0	1
Nat. Univ. Singapore	6	1	7	Metropolitan Univ. London	5	0	1
Univ. Bio Bio	6	0	47	CRES Greece	5	0	1

Moving on to the essential sources of these publications, the journal *Energy Policy* predominates with 88 publications, which corresponds to 17 percent of the total publications obtained in this study. This share is even more remarkable, considering that more than half the other journals contribute 1 percent or less.

In line with the number of publications, the highest local and global citation scores belong to the *Energy Policy* journal, followed by *Energy Research & Social Sciences*, *Renewable & Sustainable Energy Reviews*, *Energy and Buildings*, *Energy for Sustainable Development*, *Energy, Indoor and Built Environment*, *Energy Economics* and *Solar Energy* journals, each with citation scores (TGCS) of over a hundred. Additionally, *Renewable & Sustainable Energy Reviews* has the highest average citation per publication. Although it has only 2 percent of the total per publication, with 11 items (i.e., eight times fewer than the number in the first row of Table 2), the publications of this journal are highly influential. This may be due to its having the highest impact factor among other journals with the exception of *Nature Energy*, which may be considered an outlier in Table 4. However, only three publications in *Nature Energy* are directly related to energy poverty. One important point is that nearly all the journals in Table 4 are within the first quartile (Q1) ranking of Web of Science. Table 4 also shows the publishers for journals, most of which are published by Elsevier (13 journals), Taylor & Francis (6 journals), MDPI (3 journals) and SAGE (3 journals). In Table 4, Elsevier's journals have relatively higher impact factors than the others, as well as fitting the energy scope directly. This also guarantees greater visibility and accessibility, even though most of them provide access to articles by subscription. Therefore, researchers might have been attracted to publishing in those journals.

Figure 6 illustrates the citation size and flow among journals with at least three publications on energy poverty. The size of the circles shows citations to journals, while the lines represent the citation networks they are a part of. The same colors indicate the same cluster for journals. Thus, the red cluster includes *Energy Policy*, *Energy*, *Energy Economics*, *Applied Economics* and the *Energy Journal*. The second cluster in green covers *Energy & Environment*, *Energy and Buildings*, *Energy Sources Part B*, *Indoor and Built Environment* and *Sustainable Cities and Society*. The third cluster in blue consists of *Energy Research and Social Sciences*, *Energies*, *Nature Energy* and *Renewable Energy*. The fourth cluster in yellow contains *Applied Energy*, *Housing Studies* and *Local Environment*. The fifth cluster in purple includes *Renewable & Sustainable Energy Reviews*, *Sustainability*, and the *Journal of Energy in Southern Africa*.

Table 4. The number of publications and citations from Journals.

JOURNAL/PUBLISHER	NPR	TLCS	TGCS	AVG	% of TP	IF
ENERGY POLICY/ELSEVIER	88	1178	2838	32.25	0.17	5.04
ENERGY AND BUILDINGS/ELSEVIER	38	92	302	7.95	0.07	4.86
ENERGY RESEARCH & SOCIAL SCIENCE/ELSEVIER	30	334	762	25.40	0.06	4.77
SUSTAINABILITY/MDPI	16	12	94	5.88	0.03	2.57
ENERGIES/MDPI	13	0	29	2.23	0.02	2.70
RENEWABLE & SUSTAINABLE ENERGY REVIEWS/ELSEVIER	11	139	684	62.18	0.02	12.11
ENERGY SOURCES PART B-ECONOMICS PLANNING/T&F	10	17	38	3.80	0.02	1.75
ENERGY ECONOMICS/ELSEVIER	9	75	136	15.11	0.02	5.20
ENERGY FOR SUSTAINABLE DEVELOPMENT/ELSEVIER	9	65	289	32.11	0.02	3.61
INDOOR AND BUILT ENVIRONMENT/SAGE	9	90	146	16.22	0.02	1.90
ENERGY/ELSEVIER	5	70	152	30.40	0.01	6.08
GEOFORUM/ELSEVIER	5	25	57	11.40	0.01	3.09
LOCAL ENVIRONMENT/T&F	5	12	34	6.80	0.01	1.85
OIL & GAS JOURNAL/NA	5	0	1	0.20	0.01	0.05
ENERGY JOURNAL/IAEE	4	33	76	19.00	0.01	2.39
ENVIRONMENT AND PLANNING A-ECONOMY/SAGE	4	45	78	19.50	0.01	3.03
JOURNAL OF ENERGY IN SOUTHERN AFRICA/NA	4	9	40	10.00	0.01	1.10
RENEWABLE ENERGY/ELSEVIER	4	11	70	17.50	0.01	6.27
APPLIED ECONOMICS/T&F	3	9	13	4.33	0.01	1.10
APPLIED ENERGY/ELSEVIER	3	1	83	27.67	0.01	8.84
ENERGY & ENVIRONMENT/SAGE	3	0	0	0.00	0.01	1.77
HOUSING STUDIES/T&F	3	1	18	6.00	0.01	2.25
INT. GAS ENGINEERING AND MANAGEMENT/NA	3	0	0	0.00	0.01	0.01
INT. J. OF ENV RESEARCH AND PUBLIC HEALTH/MDPI	3	0	35	11.67	0.01	2.84
NATURE ENERGY/NA	3	6	23	7.67	0.01	46.49
SOLAR ENERGY/ELSEVIER	3	14	134	44.67	0.01	4.60
SUSTAINABLE CITIES AND SOCIETY/ELSEVIER	3	6	68	22.67	0.01	5.26
AUSTRALIAN JOURNAL OF SOCIAL ISSUES/T&F	2	9	37	18.50	0.00	0.91
BUILDING AND ENVIRONMENT/ELSEVIER	2	11	36	18.00	0.00	4.97
DEVELOPMENT IN PRACTICE/T&F	2	1	1	0.50	0.00	NA

NPR: number of publications recorded; TLCS: "total local citation score"; TGCS: "total global citation score", AVG: average TGCS per publication; % of TP: the share of publications from the journal in total publications; IF: current impact factor of the journal according to Journal Citation Reports (Clarivate Analytics, 2020). T&F: Taylor & Francis; NA: Not Available.

The sixth cluster in neon blue consists of *Energy for Sustainable Development*, *Geoforum* and *Solar Energy*. Finally, the seventh cluster in orange contains only the *International Journal of Environmental Research and Public Health*. The clustering is based on the links among the publications for their citing and cited references, co-citations, bibliographic couplings, co-authorships, and co-occurrences.

The occurrence of keywords is another way to reveal how the available studies consider the various aspects of energy poverty. Although energy poverty appears to be a problem caused by low income, according to the various definitions, it has intersecting issues regarding the Sustainable Development Goals, based on the three pillars of environmental, economic and social sustainability. Therefore, an extensive set of keywords in which each term is repeated at least five times in energy poverty publications was detected, as shown in Figure 7.

The figure shows that the clustering algorithm enlarged the energy- and fuel-poverty bubbles by placing them at the center of the co-occurrence network. Among 27 keywords that were found at least five times in the analyzed publications, the terms "energy efficiency", "energy access" and "energy policy" are the most frequently used of the main searched keywords. "Energy deprivation" and "fuel deprivation" do not meet the search criteria of the analysis, but the term "deprivation" without the words "energy" or "fuel" was used in the keyword list in seven publications. In terms of readjusting the search with at least one publication, we detected three publications that used "energy deprivation". In this readjusted search, no publications using "energy precariousness" or "fuel precariousness", or only the term "precariousness", were found. Considering the network of the

keywords in Figure 7, seven clusters formed by the VOSviewer leap to the eye. The terms climate change, energy, energy justice, poverty and sustainable development were covered by the first cluster in red. Energy access, energy affordability, energy consumption and rural electrification were included in the second cluster in green. Energy efficiency, energy vulnerability, fuel poverty and residential buildings were located in the third cluster in blue. Electricity access, energy poverty, energy transition and renewable energy fall into the fourth cluster, in yellow. Adaptive comfort, energy policy, social housing and thermal comfort found places in the fifth cluster, in purple. Deprivation, health and multidimensional energy poverty index entered the sixth cluster. Finally, the seventh cluster in orange embraced energy services, indicators, and vulnerability.

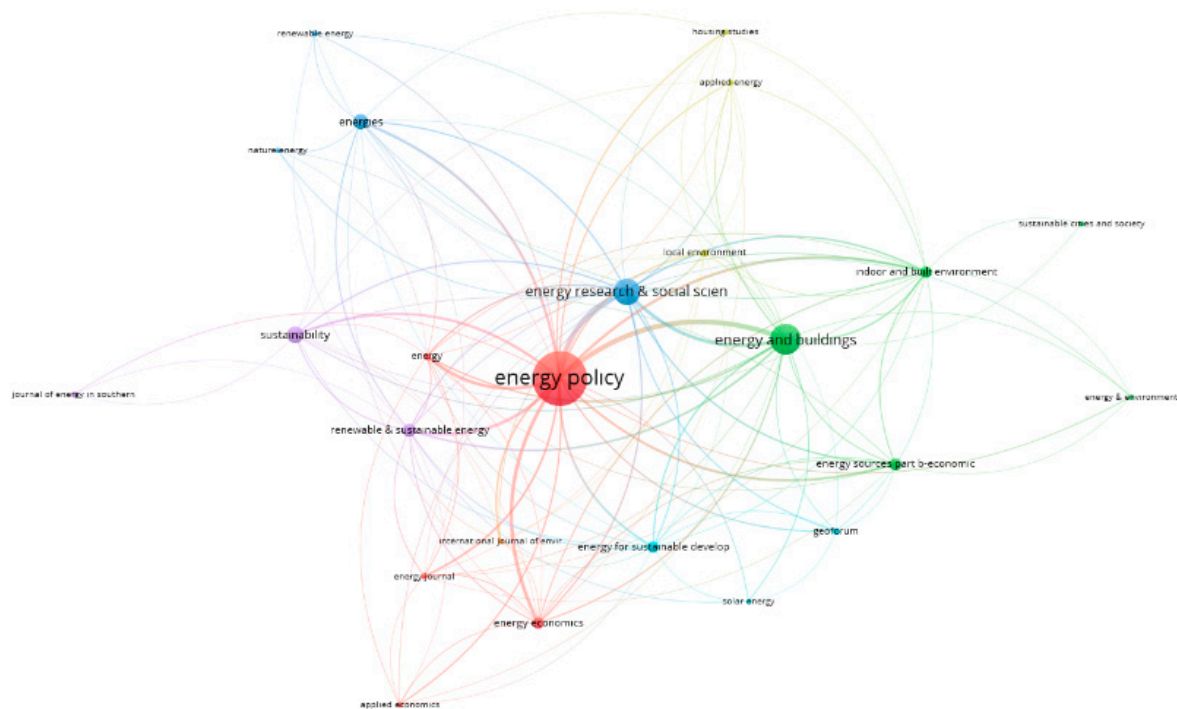


Figure 6. Citation and journal connections.

It is possible to see which studies come to the surface, regarding the number of times they were cited together when diving more deeply into data, as reflected in the density diagram in Figure 8.

Publications that were cited at least 25 times were used to construct the density diagram in which increasing redness (going from blue to red) and closeness signify the power of co-citation relationships for publications. Thus, co-cited publications and their close relationship can be seen in Figure 8. The diagram also gives additional information (e.g., journal name or some words from titles) along with the author and year of publication, in order to crystallize the publications concerned. The most prominent publications in this inquiry are located at the center of each red area, with the closest co-cited partners who find a place in the same cluster. Boardman [14], Bouzarovski et al. [108], Buzar [109], Fahmy [110], Walker and Day [111], Liddell and Morris [112], Healy and Clinch [113] and Dubois [114] are the authors of some of the publications in the first cluster. Boardman [115], Liddell et al. [116], Bouzarovski [117], Bouzarovski and Petrova [2], Moore [16], Middlemiss and Gillard [118] and Thomson and Snell [119] authored other prominent co-cited publications from the second cluster. In the third cluster, Sovacool [6], Birol [45], Pachauri et al. [35], Pachauri and Spreng [37], Nussbaumer et al. [5], Papada and Kaliampakos [92], and Day et al. [1] all fall into the red areas. Finally, Fabbri [120], Legendre and Ricci [121], Price et al. [41], Hills [17] and Roberts et al. [122] are the most frequently co-cited authors of publications in the fourth cluster.

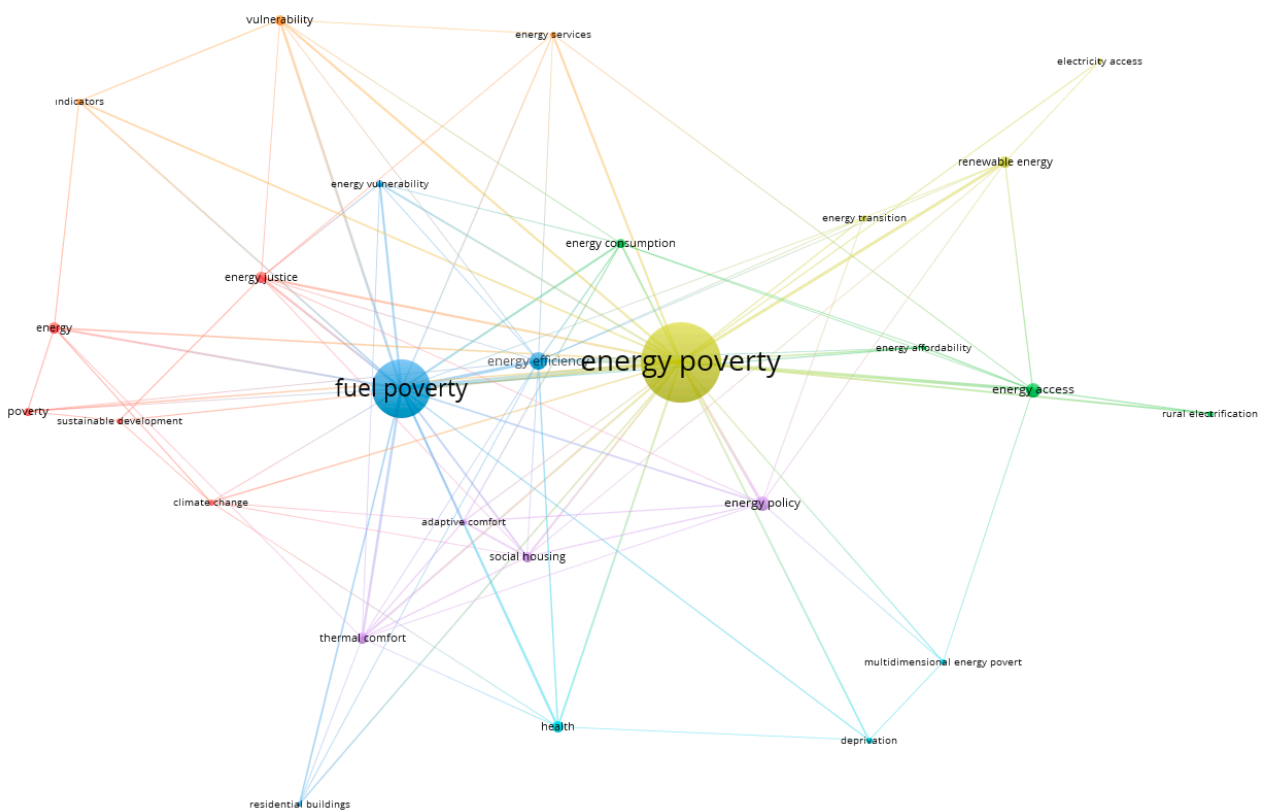


Figure 7. Keyword occurrences in publications.

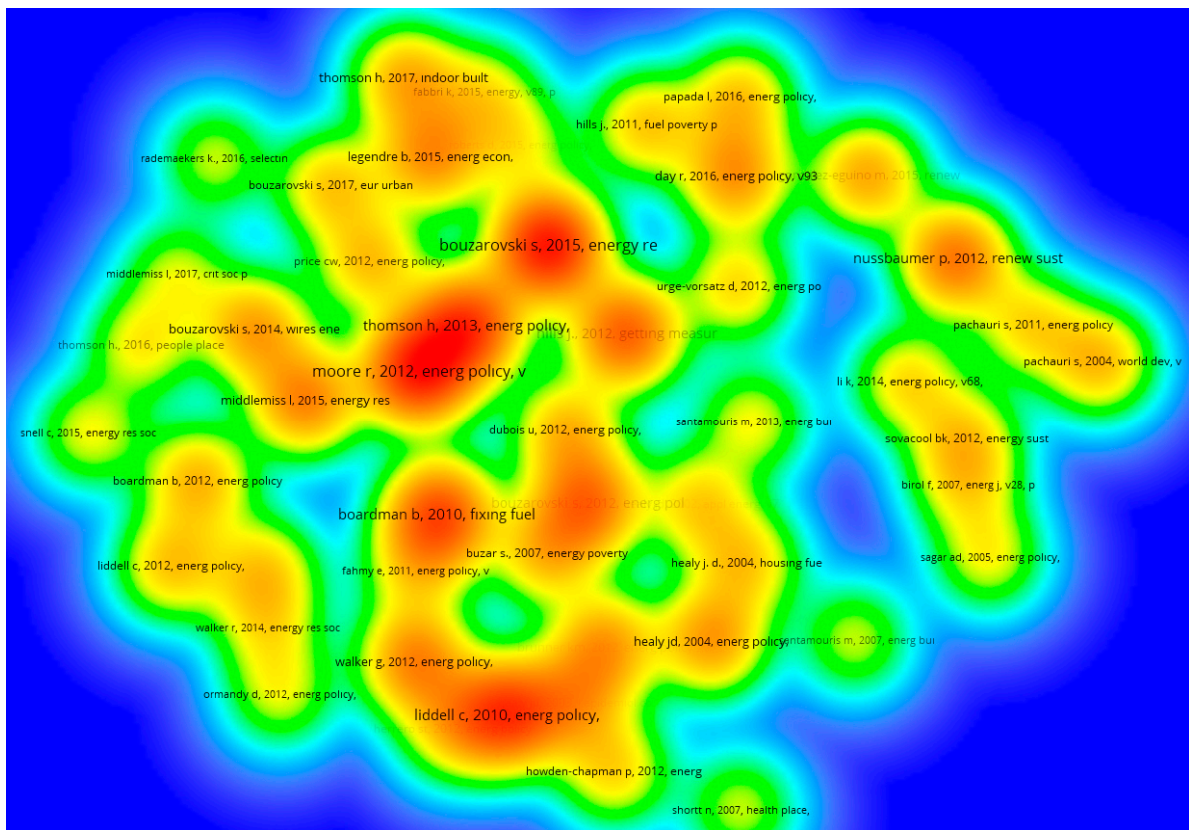


Figure 8. Co-citation density of publications.

Figure 9 shows publications falling into a cluster with a similar reference list by depicting them in the same color, with each group also pointing out alternative focal points and their most prominent publications.

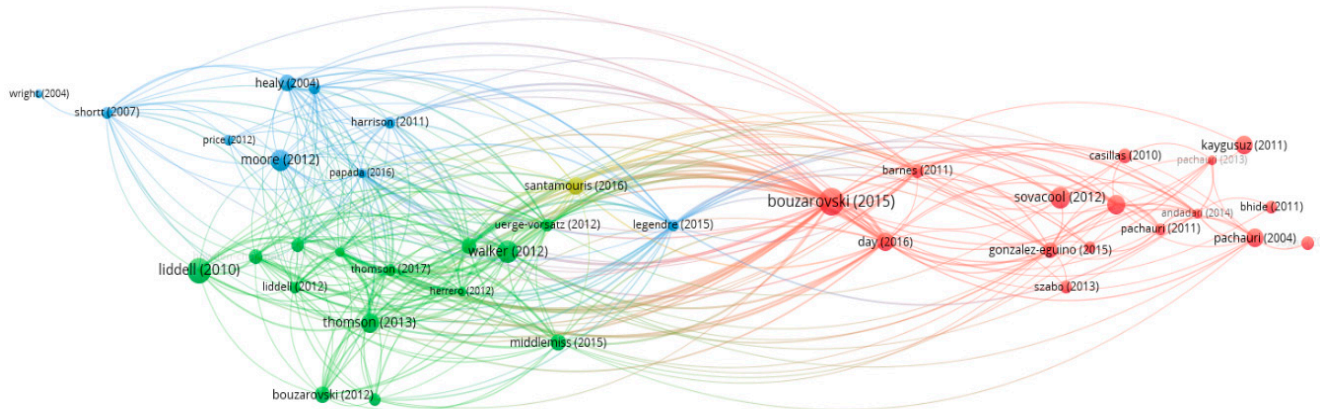


Figure 9. The bibliographic similarity of publications.

Bouzarovski and Petrova [2], Sovacool [6], Day et al. [1], Kaygusuz [53], Nussbaumer et al. [5], Barnes et al. [90], Andadari et al. [94], Bhide and Monroy [123], Casillas and Kammen [124], González-Eguino [125], Pachauri et al. [35], Pachauri and Spreng [37], Pachauri and Rao [61], Pereira et al. [54], Sagar [126], and Szabó et al. [91] published leading studies in the red cluster, all of them focusing on energy poverty.

The focal point of research in the second group of publications, those that are connected by the green bubbles, is how to tackle the fuel poverty issue. Walker and Day [111], Liddell and Morris [112], Thomson and Snell [119], Middlemiss and Gillard [118], Boardman [115], Brunner et al. [127], Herrero and Ürge-Vorsatz [128], Howden-Chapman et al. [129], Liddell et al. [116] and Sovacool [130] authored prominent publications in this group. Although they are included in the second cluster, Thomson et al. [36], Ürge-Vorsatz and Herrero [89] and Bouzarovski et al. [108] wrote the publications dealing with energy poverty.

Considering the connections between publications, Healy and Clinch [113,131], Legendre and Ricci [121], Moore [16], Price et al. [41], Shortt and Rugkåsa [132] and Wright [133] are members of the third blue cluster. Their publications also pay attention to the fuel poverty issue, as in the second cluster. Moreover, Papada and Kaliampakos [92] and Harrison and Popke [134] in this cluster also address energy poverty. Finally, Santamouris [135] wrote the only publication in the fourth cluster in yellow to highlight energy poverty.

Note that these studies, which are minor members of the second and third clusters, fall on the right-hand side of Figure 9, since they are weighted for that area in terms of the bibliographic coupling of the publications citing them. It is also important to mention that all these publications in the figure also have a connection among themselves, shown as tracked by curved lines. Therefore, it can be concluded that there is a growing body of literature on energy poverty and fuel poverty and that there are prominent publications that empower the theoretical underpinnings of these issues and motivate researchers to explore new aspects of energy poverty. Additionally, Figure 8 shows that researchers may focus independently on studies of energy poverty and fuel poverty because they diverge from each other in terms of bibliographic coupling and network power compared to each other, as well as occupying different clusters.

4. Conclusions

This study has conducted a bibliometric analysis of the literature on energy poverty by using a large and comprehensive dataset covering all information on energy poverty studies as stored in the Web of Science. The characteristics of relevant publications on energy poverty are revealed through global and local citation counts, citing and cited

references, co-citation, bibliographic coupling, co-authorship and co-occurrence. This work reveals the increasing popularity of energy poverty as a research topic in recent years. The number of citations has gradually been increasing, raising awareness of the issue in academia over time. The bibliometric data show that there is a vast researcher pool distributed spatially all over the world. The results indicate that on the one hand, the social dimensions of the energy poverty issue have been widely analyzed in the current literature, and that policy strategies are covered by the Sustainable Development Goals. On the other hand, the bibliographic characteristics of the available publications mainly them in two groups labeled “energy poverty” and “fuel poverty”. The study is expected to draw up a roadmap for researchers, by providing comprehensive information about historical trends in energy-poverty studies over nearly half a century; the main topics and keywords that researchers focus on; basic concepts, definitions and measurements; the most influential publications; the leading scholars, organizations, countries and journals; and network analysis among publications in terms of citation, co-occurrence and bibliographic coupling. The study also expects to provide a baseline for researchers by directing them toward a specific subfield of the theme of energy poverty, thus making it possible to capture potential gaps in the literature through the inclusive information that the available literature contains.

Our analysis has revealed that the issue of energy poverty has been mostly investigated in developed countries, leaving a need for investigation in respect of Asian, African and South American applications. This issue is of the greatest importance, since its solution serves the economic, social and environmental goals of sustainable development, although the Sustainable Development Goals partly consider the issue of affordable energy as a problem to which underdeveloped countries are mostly subject. However, this can be validated for both developed and developing countries, as has been shown by empirical research [36,50,92,95–102]. Therefore, the Sustainable Development Goals board should pay greater attention to the issue of energy poverty in their policy discussions and strategies. In addition, empirical investigation shows that micro-level data are required that can be gathered by household surveys and that may revise the poverty measurements, based on local dynamics and the purchasing power of people’s incomes. Therefore, underdeveloped countries should focus on alternative measurements based on their local dynamics, in order to document energy poverty, as well as developing country-specific strategies to mitigate the adverse effects of energy poverty on people. This study has delved into the energy-poverty literature by using bibliometric data. However, there is a need for macro-level data that can be used as a proxy variable to analyze the issue from the macroeconomic policy perspective and to see how energy poverty responds to macroeconomic variables. Future studies may focus on developing such a new measurement or establishing an index that can be standardized by taking country-specific factors into account.

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Appendix A

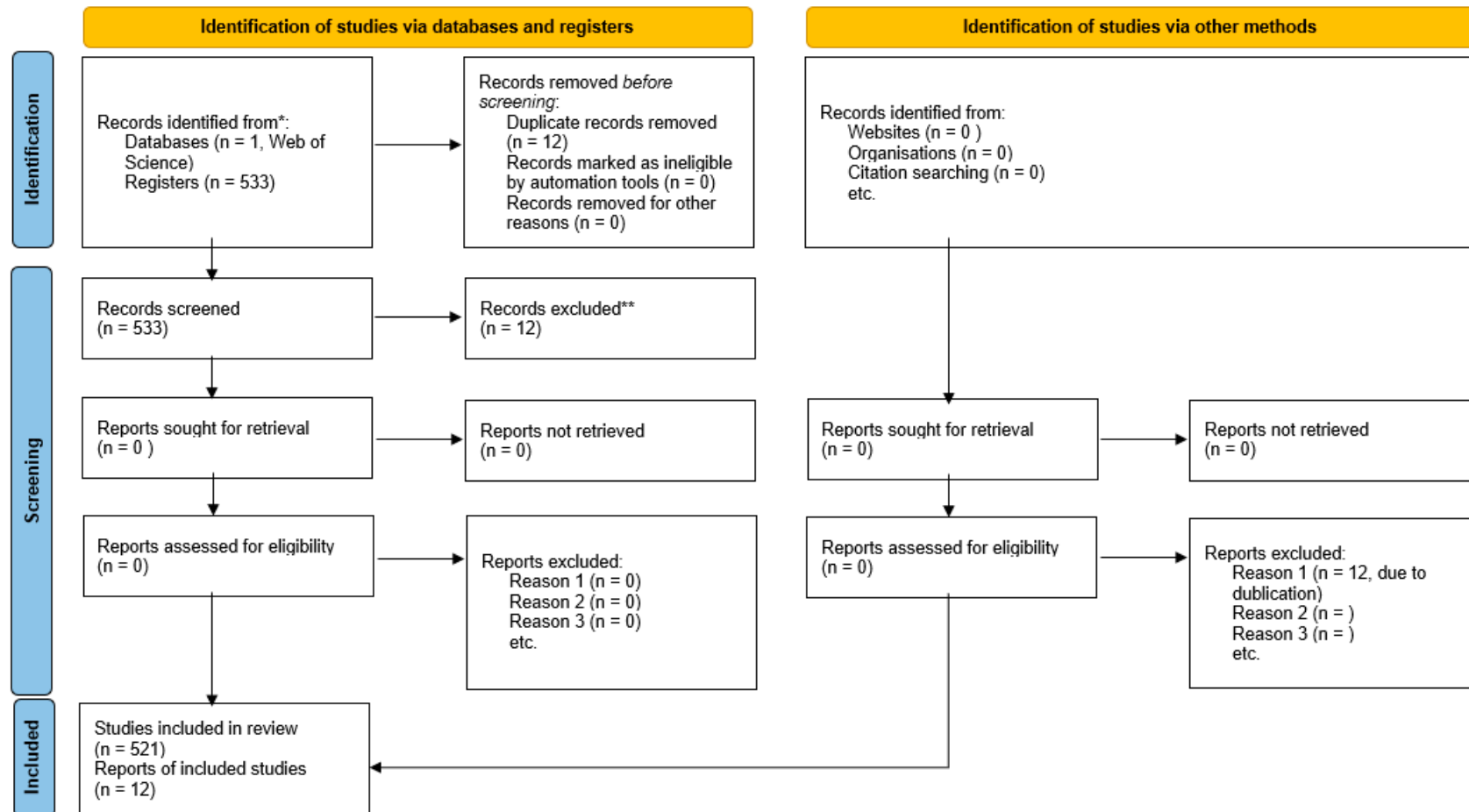


Figure A1. PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases, registers and other sources. * Consider, if feasible to do so, the possibility of reporting the number of records identified from each database or register searched (rather than the total number across all databases/register). ** If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools. Visit: <http://www.prisma-statement.org/> (accessed on 8 August 2021).

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