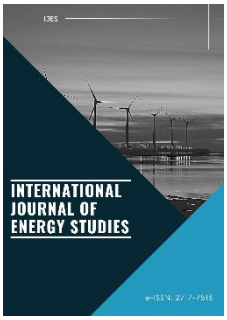
INTERNATIONAL JOURNAL OF ENERGY STUDIES

e-ISSN: 2717-7513 (ONLINE); homepage: https://dergipark.org.tr/en/pub/ijes



Research Article

Int J Energy Studies 2025; 10(1): 1245-1260

DOI:10.58559/ijes.1587039

Received : 18 Nov 2024

Revised : 25 Jan 2025

Accepted : 25 Feb 2025

An academic approach to the relationship between energy poverty and health

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Highlights

- As the demand for energy has increased, the number of studies examining the relationship between energy poverty and health has increased.
- The countries focusing on the issue are not energy-poor countries.
- It has been observed that the number of studies looking at the subject from a perspective of health is low.

You can cite this article as: Kaya M, Kandemir Türe, A. Bibliometric analysis of studies on the relationship between energy poverty and health. Int J Energy Studies 2025; 10(1): 1245-1260.

ABSTRACT

Energy poverty has emerged as a significant issue in recent years, leading to various negative consequences. One of these is its impact on health. It is widely accepted that there is a connection between energy poverty and health, which has resulted in a growing body of literature exploring this relationship. This study conducts a bibliometric analysis of this literature using comprehensive data from Web of Science, which includes many studies examining the link between energy poverty and health. It also investigates whether the countries conducting research on this issue are themselves energy-poor nations. The analysis outlines how the connection between energy poverty and health has garnered increasing attention over time, identifies leading authors and countries, highlights studies that have made significant contributions to the literature, and points out potential research gaps. The results reveal the network flows between countries, researchers, publications, organizations, keywords, and bibliographic connections in energy poverty and health studies. The findings confirm the growing interest in the energy poverty-health link but also show that the countries focusing on this issue are not energy-poor countries themselves.

Keywords: Energy poverty, Fuel poverty, Health, Well-being, Bibliometric analysis

1. INTRODUCTION

Energy poverty (EP), also called “fuel poverty” and “energy vulnerability”, is defined as the inability of a household to provide the energy service they need, both socially and financially [1-3]. With the goal of “affordable and clean energy”, which is the seventh of The Agenda 2030 for Sustainable Development Goals (SDG) adopted in 2015 by all United Nations Member States, it is aimed to “ensure access to affordable, reliable, sustainable and modern energy for all” [4]. Inability or insufficient access to modern forms of energy is a major obstacle to the success of the SDG [5-6]. Although there is no internationally accepted measure of EP, evaluations are commonly made with measures of the affordability of households' energy use or energy expenditures. According to the expenditure measure, EP occurs when people spend more than 10% of their income on energy [7].

EP is an important problem for both developed and developing countries and has a reducing effect on social welfare [8]. In recent years, there has been an increase in studies on the effects of energy use on the health and well-being of individuals [9-15]. Scientific research shows that intense energy consumption poses a danger to public health due to indoor air pollution [16]. From a health standpoint, they concentrate pollution in homes, as fuels are burned indoors in simple household cooking stoves without a chimney or hood and burn the fuel inefficiently. Such stoves are used each day when people are indoors, with serious public health, environmental and economic consequences [17].

It is estimated that 2.8 million premature deaths occur annually worldwide due to the use of solid biomass and coal for cooking, as well as the use of candles and other polluting fuels for lighting [7]. Despite significant efforts to increase renewable energy sources, improve access to electricity, and enhance energy efficiency, many countries are still falling short of achieving the goal of "affordable and clean energy." While the global access deficit decreased from 1.22 billion people in 2010 to 759 million in 2019, it is projected that 660 million people will still lack access to electricity by 2030, with the majority (555 million) living in sub-Saharan Africa. People who rely on polluting fuels and technologies are exposed to high levels of household air pollution, which has serious implications for their cardiovascular and respiratory health, making them more vulnerable to diseases, including the COVID-19 virus [18].

The issue of EP has been addressed separately in various studies using different techniques, dimensions, definitions, and solutions. The studies used different methodologies to measure EP in terms of sample sizes and regional differences [6, 19]. According to a meta-analysis study, a general EP effect size was calculated for developing economies and it was found that 71.1% of the population in the overall sample studies (30 studies) was energy poor [19]. In order for strategies and policies to be effective, it is important to measure and evaluate EP [8]. It was found that lower EP was associated with higher health and education outcomes for 50 developing countries between 1990 and 2017. As access to electricity and energy increases, life expectancy at birth increases and infant mortality rates decrease [20].

Evidence has been found that being energy poor in Australia increases the probability of being obese by between 1.4 and 2.5 percentage points, while the amount of sleep, health status and level of psychological distress also influence the probability of being obese originating from EP [21]. However, EP also has a negative impact on household health expenditures [6].

The aim of the study is to identify the most productive researchers, institutions and countries in this field and to reveal research trends and key topics in this field by conducting a bibliometric analysis of scientific studies on EP and health conducted until 2023. According to these studies, it will also be revealed whether the countries that address this problem are energy poor countries.

2. METHOD

Bibliometric analysis was conducted on the relationship between EP and health. Bibliometric analysis is used in the qualitative and quantitative evaluation of publications in a particular research field and to obtain findings such as the impact factor of the publications, the frequency of citations, the number of pages, and references. These data obtained from publications guide field experts and researchers. A database search was completed to evaluate publications on the relationship between EP and health. The Web of Science (WoS) database was chosen as the main source of publication search. The reasons such as having the opportunity to access through institutions, providing rich data, allowing downloading data in a format suitable for relevant research, and having a rich publisher, document and network were effective in choosing the WOS database [22]. In order to obtain the data, data collection criteria were determined. Summary information on these criteria is present in Table 1.

Table 1. Criteria for data collection

Database	Web of Science Core Collection
Keywords	EP and health Fuel poverty and health
Search Section	Topic
Publication Date	Until the end of 2023
Language	All (618 English, 4 Spanish, 1 Ukrainian)
Document Type*	All Type
Access Type	Open Access, Early Access, Review Articles

The data of the study were obtained according to the research data criteria specified in Table 1. Data was collected in both Microsoft Excel and VOSviewer format. Variables such as publication number, author, journal, document type, keywords, funding organizations, number of references cited, number of citations, number of pages, and research area related to the data obtained were analyzed in the Excel program before the analysis. Differences in the data reviewed by both authors independently were discussed by the authors and a consensus was reached. VOSviewer, a java-based program used to create, visualize, and explore maps based on bibliographic data, was used in this study to analyze and visualize bibliographic matching of publications, co-authorship between countries, co-citation, and association of keywords [23]. Regarding EP, data of access to the electricity of countries and life expectancy at birth are used. These data was obtained from the World Bank website.

3. RESULTS AND DISCUSSION

A total of 623 studies matching the research criteria were obtained. These studies, including 1806 authors from 87 countries, have been published in 194 different journals and cited 23800 times (Table 2).

Table 2. Descriptive statistics of the database

Criteria	Frequency (n)
Publications	623
Authors	1806
Journals	194
Institutions/Organizations	881
Countries	87
Research Areas	47
Cited References	23800

The first study on the subject in the analyzed database was published in 1993. It has been observed that there has been an increase in the number of studies on the subject in recent years, and the highest number of studies was in 2022 (Figure 1).

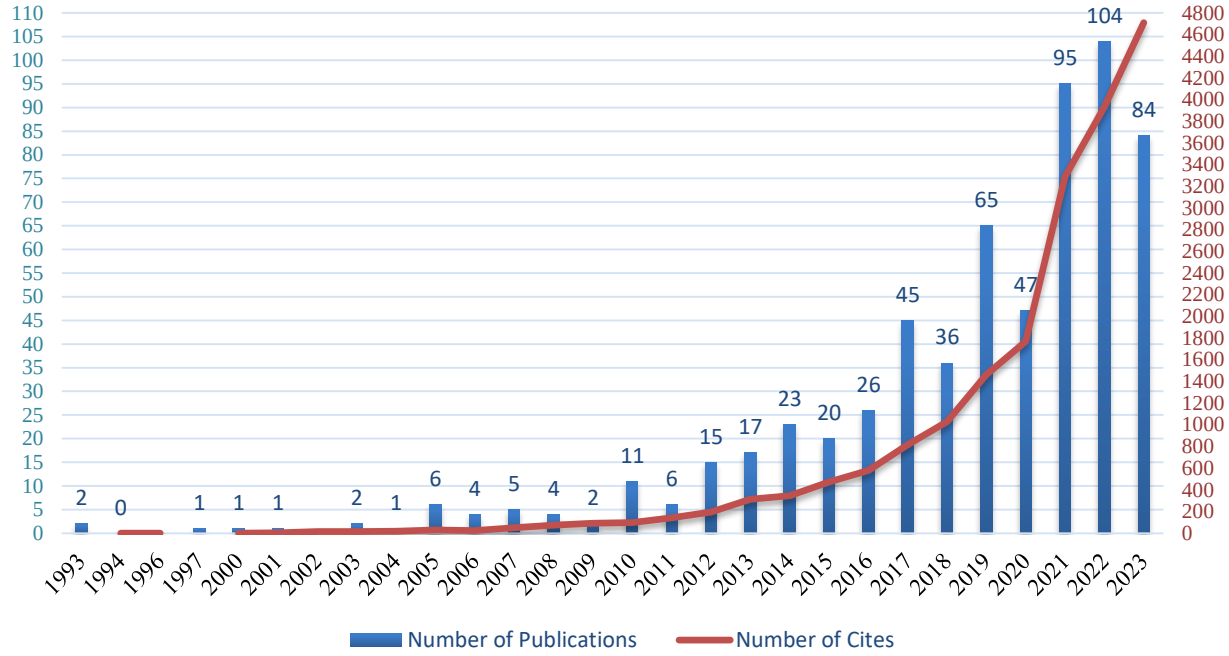

Figure 1. Number of publications by year

Among the 1,806 authors with at least one publication on EP and health, there is a large and geographically diverse group of researchers spread across 87 countries. Figure 2 presents the number of publications from each country. The UK leads with 134 publications, followed by the USA with 104, China with 90, Australia with 53, and Spain with 50 publications, making them the top five contributing countries.

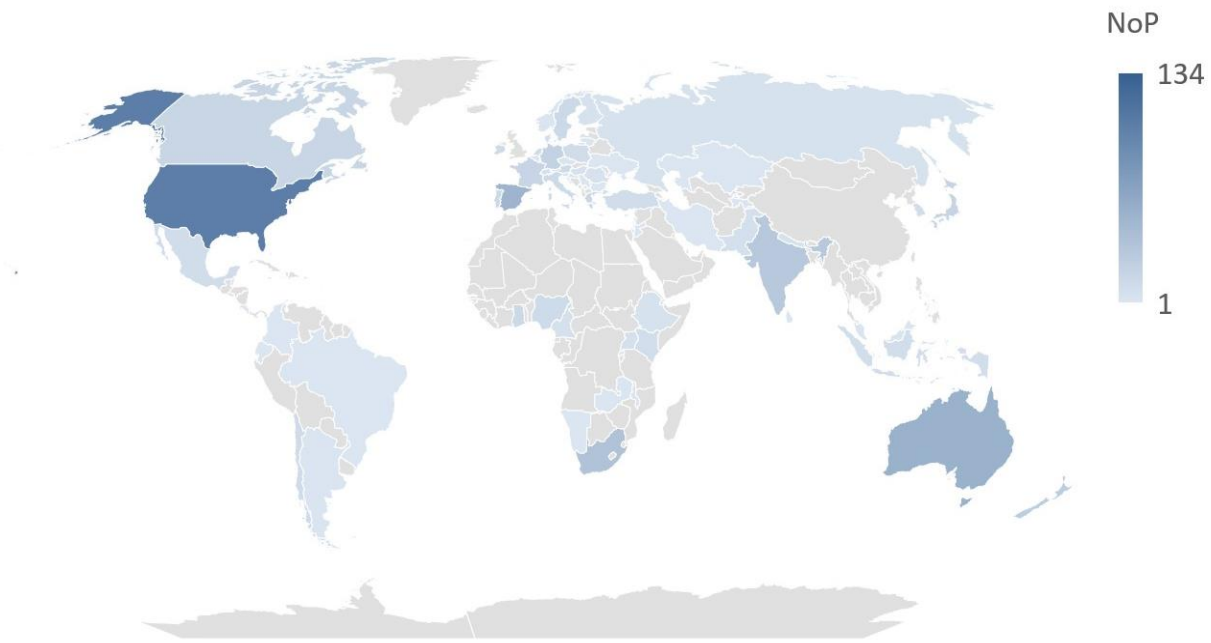

Figure 2. Spatial distribution of EP and health publications (*NoP: Number of publications)

The 15 countries with the highest number of articles, the average number of citations for countries (per publication), total Link Strength, and finally the percentage of access to electricity are given in Table 3. Total Link Strength is a standard that expresses the bond and strength between studies. links show the number of links with other works, and the total number of links shows the total link strength with other items [23]. The UK with the highest number of publications also ranks first in the link strength. In the average number of citations, India is the first, Canada ranks second, the Scotland third, and Germany fourth. In total link strength, USA ranks second, China third and Australia fourth. It is seen that almost all of the 15 countries with the highest number of articles have full access to energy [24]. In parallel, it is observed that life expectancy at birth in these countries is below the world average (world average is 72 years) [25]. However, we find it useful to point out that a single indicator is not sufficient to reach a general judgment and that in order to make a definitive comment, health status indicators that are outside the scope of this study should be examined in detail.

Table 3. The number of publications and access to energy by country

No	Country	Documents (n)	Average Citation per Publication ($\bar{x}$)	Total Link Strength	Access to electricity (% of the population)*	Life Expectancy at Birth (total, years)**
1	UK	134	61,43	77.00	100	82
2	USA	104	59,83	58.00	100	72
3	China	90	40,75	35.00	100	79
4	Australia	53	35,92	28.00	100	83
5	Spain	50	32,30	24.00	100	83
6	South Africa	36	13,83	13.00	85	61
7	India	30	66,56	17.00	99	68
8	New Zealand	25	27,88	9.00	100	83
9	Germany	20	61,65	18.00	100	81
10	Scotland	20	63,25	11.00	100	82
11	Japan	19	24,73	10.00	100	84
12	France	18	36,44	9.00	100	82
13	Canada	17	63,64	12.00	100	81
14	Greece	17	46,00	7.00	100	81
15	Sweden	14	38,42	12.00	100	83

*The World Bank, 2019, ** The World Bank, 2024.

Table 4 lists the results for the most productive authors, each with more than five publications on EP and health. Our bibliometric analysis identified a total of 1,806 authors with at least one publication on this topic. Among the top eighteen authors by publication count, the most prolific are Hua Liao from China and Marc Mari-Dell'olmo from Spain, both with eleven articles. Lucie Middlemiss from the UK ranks second, while Andres Peralta and Carme Borrel from Spain, along with Philippa Howden-Chapman from New Zealand, are tied for third.

Table 4. The most productive authors

No	Authors	Country	Publication (n)	Average Citation per Publication ($\bar{x}$)	Research Area
1	Liao, Hua	China	11	44,45	Institute of Technology
2	Mari-Dell'olmo, Marc	Spain	11	32,81	Epidemiology and Public Health
3	Middlemiss, Lucie	UK	9	56,00	Environment and Society
4	Peralta, Andres	Spain	8	36,87	Political and Social Sciences
5	Borrel, Carme	Spain	8	38,87	Dept Ciencies Expt&Salut
6	Howden-Chapman, Philippa	New Zealand	8	31,12	Public Health
7	Castano-Rosa, Raul	Spain	7	45,71	Appropriate Technology Sustainable Dev Grp

8	Marrero, Madelyn	Spain	7	45,71	Sustainable construction
9	Palencia, Laia	Spain	7	41,57	Public Health
10	Willand, Nicola	Australia	7	24,42	Construction and Project Management
11	Oliveras, Laura	Spain	6	40,83	Biomedical
12	Wei, Yi-Ming	China	6	58,83	Energy and Environmental Policy
13	O'Sullivan, Kimberley C.	New Zealand	6	15,66	Housing and Health Research Programme
14	Bouzarovski, Stefan	UK	6	131,66	Energy and Social Science
15	Lin, Boqiang	China	6	25,16	Institute for Energy Policy Studies
16	Pachauri, Shonali	Switzerland	6	88,00	Energy and Development
17	Sharpe, Richard A.	UK	6	27,66	Public Health
18	Sovacool, Benjamin K	USA	6	90,5	Energy Policy at the Science Policy

Table 5 presents the results for the most productive institutions, each with more than five publications on EP and health. Our bibliometric analysis identified a total of 847 institutions or organizations with at least one publication on this subject. Among the top twenty-eight institutions/organizations ranked by the number of publications, the most productive is the University of Otago from New Zealand, with twenty publications. The University of Leeds from the UK ranks second, while the Barcelona Public Health Agency from Spain, Pompeu Fabra University from Spain, and the Beijing Institute of Technology from China all share third place, each with twelve publications.

Table 5. The most productive institutions/organizations

Rank	**Institution**	**Country**	**Publication (n)**	**Average Citation per Publication ($\bar{x}$)**
1	University of Otago	New Zealand	20	30,00
2	University of Leeds	UK	13	49,30
3	Barcelona Public Health Agency	Spain	12	32,75
4	Pompeu Fabra University	Spain	12	32,75
5	Beijing Institute of Technology	China	12	54,75
6	Royal Melbourne Institute of Technology University	Australia	11	44,18
7	University of Johannesburg	South Africa	11	12,90
8	University of Seville	Spain	11	37,81
9	The University of Manchester	UK	10	90,10
10	University of Exeter	UK	9	29,77
11	University of Birmingham	UK	9	147,00
12	London's Global University	UK	9	29,22
13	CIBER of Epidemiology and Public Health	Spain	8	24,12
14	University of Melbourne	Australia	8	26,75

15	Columbia University	USA	8	136,87
16	University of British Columbia	Canada	7	125,00
17	International Institute for Applied Systems Analysıs	Austria	7	86,85
18	Monash University	Australia	6	57,00
19	Sheffield Hallam university	UK	6	56,16
20	University of Liverpool	UK	6	329,00
21	University of Sussex	UK	6	37,00
22	University of York	UK	6	86,83
23	Duke University	USA	6	11,50
24	Kyushu University	Japan	6	18,00
25	University of Cambridge	UK	6	19,83
26	New South Wales University	Australia	6	31,50
27	Ulster University	China	6	116,33
28	Xiamen University	UK	6	25,16

Table 6 presents the results for the top 10 research areas in EP and health. our bibliometric analysis identified 47 research areas with at least one publication on this topic. among the top ten research areas ranked by the number of publications, environmental sciences leads with the most publications, followed by energy fuels in second place. when considering the average number of citations in each research field, public environmental occupational health ranks first, with energy fuels in second place.

Table 6. Top 10 research areas in EP and health

No	Research Area	Publication (n)	Average Citation per Publication ($\bar{x}$)	*h*-index
1	Environmental Sciences	259	41,00	56
2	Energy Fuels	225	47,09	55
3	Science Technology Other Topics	113	39,73	72
4	Business Economics	104	34,61	67
5	Engineering	98	33,26	35
6	Public Environmental Occupational Health	76	56,55	28
7	Construction Building Technology	71	35,37	29
8	Public Administration	19	14,00	10
9	Urban Studies	18	15,5	11
10	Development Studies	15	5,07	5

Our bibliometric analysis discovered 1565 keywords with at least one time used on EP and health. The most frequently used keywords were Energy Poverty, Fuel Poverty, and Health. Keywords help to identify the subject of studies in any discipline [26]. In this study, a co-occurrence analysis of keywords was made. Co-occurrence analysis of keywords is used to indicate important topics [27]. Keywords that were repeated at least 5 times were included in the analysis. As a result of the analysis, 68 items, 7 clusters, 415 links, and 875 total link strengths were obtained (Figure 3). Different colors of the circles shown in Figure 3 indicate different clusters. The size of the circle

reflects the frequency of keyword usage. The line between the two circles indicates that both articles were cited in one publication. The length of the line represents the closeness of the two articles, the shorter the line, the closer the connection [28]. Accordingly, EP, fuel poverty, health, and energy efficiency emerged as the most prominent clusters.

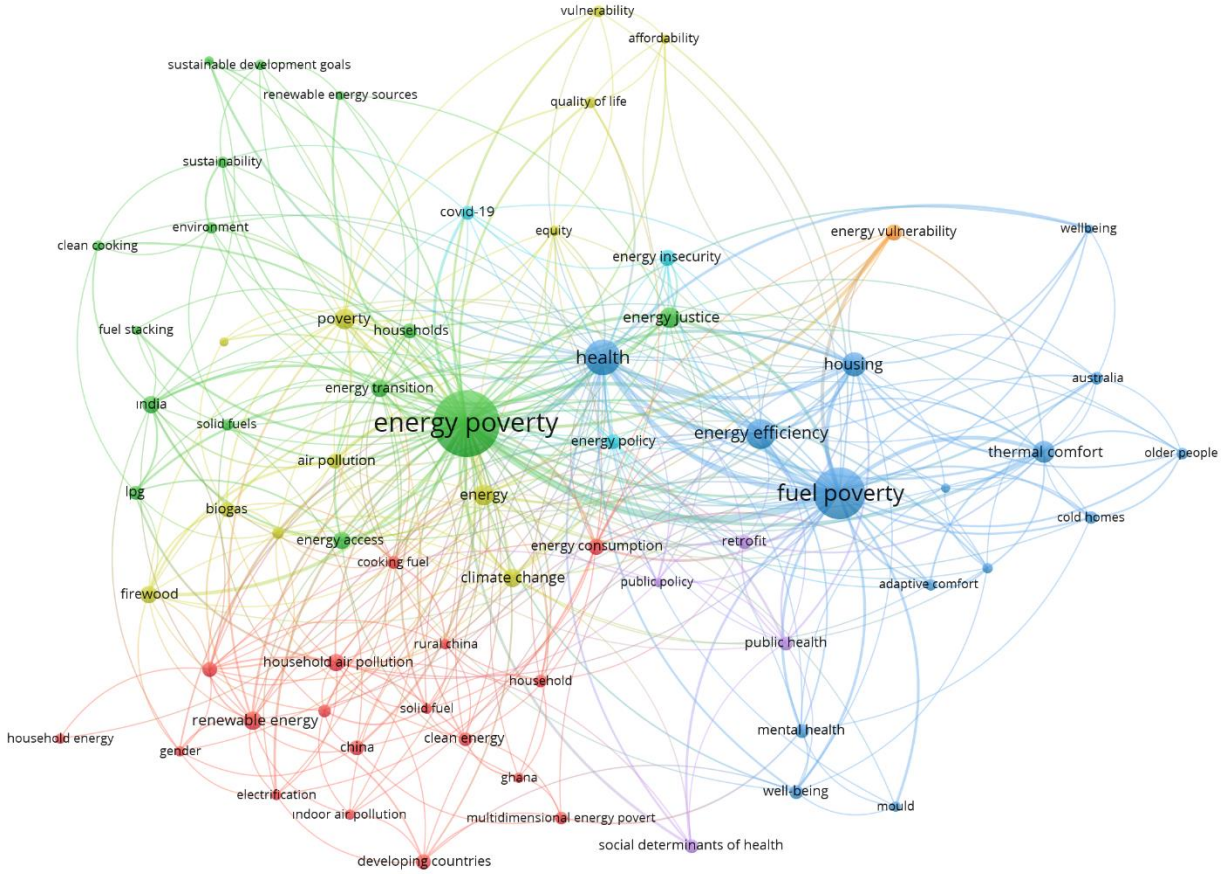

Figure 3. Co-occurrence analysis of keywords

The relationship between EP and health has gained significant attention in recent years, particularly in light of global events such as the COVID-19 pandemic and the ongoing energy crisis exacerbated by geopolitical tensions. EP, defined as the inability to access essential energy services, has profound implications for public health, social equity, and economic stability. Recent data from the European Union highlights the increasing prevalence of EP, with 10.6% of Europeans unable to keep their homes adequately warm in 2023, up from 6.9% in 2021. This rise is attributed to several factors, including high energy prices, low-income levels, and poor energy efficiency of buildings. The multidimensional nature of EP means that it disproportionately affects

vulnerable populations, including low-income households, the elderly, and those with pre-existing health conditions [29].

In developing countries with insufficient levels of economic development and limited energy demand, tackling EP often focuses on eliminating shortfalls in energy supply and optimizing the energy structures of underdeveloped regions. In addition to the health problems that arise due to air pollution, there are studies that are examined from wider perspectives such as the problems that pose a public health hazard [16, 30, 31]. It shows that the lack of access to electricity in developing economies is a critical barrier to economic development and that poverty plays a crucial role in shaping the health outcomes [20]. The consensus is that EP has a significant negative impact on health outcomes [5, 6, 32-35].

Local and regional factors need to be included in the assessment in order to develop a uniform methodology for assessing EP, which is seen as an emerging field of study [19]. Using a new composite index, how EP affects health outcomes has been examined and a multidimensional energy-poverty-health relationship has been demonstrated for developing countries [6].

A study investigating the relationship between EP, health, and well-being in 32 European countries, based on the 2012 European Quality of Life Survey, found that the distribution of these variables was not uniform. Eastern and Central European countries were most adversely affected by the intersection of EP and health. Additionally, energy-poor populations in most countries experienced higher rates of both physical and mental ill-health compared to non-energy-poor households. Notably, the greatest disparities in health and well-being between energy-poor and non-energy-poor households were observed in relatively egalitarian societies like Sweden and Slovenia [3]. Other studies have also highlighted that EP is a significant public health issue across the European Union [15, 36]. Furthermore, a study examining the impact of EP on health and education outcomes in 50 developing countries across Asia, Africa, Latin America, and Europe between 1990 and 2017 found that increased energy development was linked to improved health and education outcomes. It also revealed that access to electricity had a more substantial positive impact on development outcomes than energy use alone [20].

Unlike European countries, EP due to Australia's country-specific climate is associated with health problems, both due to the difficulty of maintaining adequate temperature in winter and providing

adequate cooling in summer [37]. Despite advances made globally, population growth in Sub-Saharan Africa is unable to keep up with electrification efforts. It is estimated that 600 million of the 674 million people without access to electricity by 2030 will be individuals, mostly in rural areas of sub-Saharan Africa [7]. The rate of access to electricity worldwide has been determined as 90.1% [24]. Among the developing Asian countries, the number of populations without access to energy is decreasing in India, Indonesia and Bangladesh. In countries such as South Asia, the Middle East and South Africa, and Latin America, the access rate tends to increase [7]. Despite these advances, there is an unequal distribution in general, which does not provide any improvement in terms of the vulnerable population.

Consistent with previous findings, a study investigating the relationship between EP and health outcomes in Turkey reveals that EP is negatively associated with health outcomes. In addition, individuals' health status is associated with demographic and household-level factors such as physical deficiencies and insulation problems, whereas regional-level variables are not significant variables for Turkish residents [13]. On the other hand, according to 2019 data, the access of the Turkish population to electricity has been reported as 100% [24]. Another matter of discussion is that the data published by the institutions that collect and share international data sometimes do not reflect the truth. Despite significant economic developments and growth in China, which is called the largest developing country in the world, a large part of the population is limited in accessing and using modern forms of energy. It is one of the countries that has achieved 100% electrification, but households, especially in rural areas, use solid fuel for cooking [5].

4. CONCLUSION

This study highlights the significant relationship between EP and health outcomes, emphasizing the need for comprehensive strategies to address this issue. The bibliometric analysis reveals that while there is a growing body of literature on the subject, the majority of research is conducted by countries that are not themselves energy-poor. This indicates a potential gap in the research focus, suggesting that more attention should be given to studies originating from or focusing on energy-poor regions.

It is seen that the number of studies examining both EP and its relationship with health is increasing in the literature. In this study, however, the literature also shows a relationship between EP and health outcomes. It is seen in studies based on certain years for a single country or a group of

countries that the increase in EP in developing countries adversely affects health outcomes. Therefore, countries that are energy poor/with limited access to energy should pay more attention to this issue. However, in this study, which shows the bibliometric structure of the relevant field from a wide window, it has been seen that the countries, authors and institutions that focus on studies on the subject are not energy-poor countries. The references are in this direction. It has been observed that only two of the 15 countries with the most publications on this subject do not have access to 100 percent energy. Only 15% of the population in South Africa and 1% in India do not have access to energy. This result also supports our thesis. Among the health status indicators given in Table 3, only 2 countries (India and South Africa) are below the world average in life expectancy at birth. It needs to be interpreted with more detailed data to make a clear inference.. In addition, it has been observed that there are generally many branches of environmental science and engineering and business/management areas among the research areas that study the subject.

In this period, where the importance of the issue and the developments towards its solution are increasing, it is necessary to increase academic activities that will support the implementation studies on the subject, especially in energy-deficient countries. Researchers working in health-specific research areas will also turn to this subject, it will provide the opportunity to look at the problem from the perspective of health. It is thought that increasing the number of these studies will reduce poor health outcomes and reduce health expenditures, which are a problem for many countries, especially health insurance expenditures.

In conclusion, addressing EP is crucial for achieving global health and development goals. Ensuring access to clean and affordable energy can significantly improve health outcomes and quality of life, particularly in vulnerable populations. Therefore, it is imperative to continue and expand research efforts in this field to inform and guide effective policy-making.

DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Mustafa Kaya: Analysis, Investigation, Writing, Methodology, Visualization.

Aysun Kandemir Türe: Writing, Review & Editing, Supervision.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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