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Review

30 years of energy and fuel poverty research: A retrospective analysis and future trends☆

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A R T I C L E I N F O

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A B S T R A C T

While the terms "energy poverty" and "fuel poverty" are developing rapidly, their relationship, evolution and trends remain unclear. Efforts to apply the concepts are constrained by the lack of a comprehensive review and the conceptual clarity of the energy–fuel poverty relationship. The article therefore aims to address this gap by synthesising the similarities and differences both within/between the terms as found in scientific literature of the past 30 years. The results draw on a bibliometric and network analysis of 670 articles in the Scopus database. Our analysis shows we are dealing with evolving concepts whose definition, boundaries and principles are still not consolidated. By providing a complete review of the area and comparing the two concepts, we help with the clarification and reciprocal integration of this emerging field for the purpose of informing research and policymakers, while also identifying the current knowledge gaps and discussing several research areas likely to be hotspots for future research, including the social aspects of energy transition, engineering and architectural advancement and the public policy landscape.

Contents

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1. Introduction

The rising challenge of energy deprivation has seen the concepts of energy and fuel poverty occupy an important place on the research and political agenda. The term “energy poverty” is generally used in developing countries to capture problems related to the lack of physical access to energy services (Castaño-Rosa et al., 2019). Parajuli (2011) describes the concept as the absence of choice in accessing adequate, affordable, reliable, quality, safe and environmentally acceptable energy services. Since energy poverty addresses the basic issues of access to energy, we believe it is one of the most important sustainable development challenges. On the other hand, the term “fuel poverty” is mainly used in industrialised countries to describe the situation where households lack disposable income to pay for their basic energy needs (Castaño-Rosa et al., 2019). The concept mostly builds on the interaction of energy prices, low incomes and domestic energy inefficiency. In this sense, fuel poverty may be seen as a distinct form of deprivation and disadvantage (Robinson et al., 2018). In certain cases, an overlap exists between people who are both energy-poor and fuel-poor (Li et al., 2014). Yet, many researchers use the two terms synonymously (Thomson et al., 2016). Despite their importance for academia and policymakers, the conceptual relationship between energy poverty and fuel poverty remains unclear, possibly to the detriment of future progress in the field and ultimately sustainable lifestyles of the population. Lack of access to local grids and affordable technologies, high prices and environmental pollution from conventional fossil energy sources have led to chronic energy problems and impeded sustainable economic development (Agyekum, 2020). Access to clean, affordable and reliable energy is identified as a pre-requisite for alleviating poverty. The effect of energy on achieving sustainable development has seen its inclusion in the Sustainable Development Goals (SDGs). It is the seventh goal, i.e. SDG 7, and aims to provide universal access to affordable, sustainable, reliable and modern energy to all by 2030 (United Nations, 2020). An accurate energy/fuel poverty assessment and stringent policy actions can assist in reaching the target by 2030. However, the complex nature of energy/fuel poverty requires a thorough understanding of the interdependencies and relationships of socio-economic, demographic, geographical and technological factors (Qurat-ul-Ann and Mirza, 2021), currently largely missing from the scientific debate.

The concepts of energy and fuel poverty initially attracted attention in the early 1970s when the fuel poverty problem was first recognised during the oil crisis. In 1979, Isherwood and Hancock introduced the concept of energy poverty. Two decades later, Boardman (1991) defined fuel poverty as the situation when a household’s fuel expenditure on all energy services exceeds 10% of its income to achieve a satisfactory indoor temperature. Fuel poverty, in its original meaning, was officially adopted by the United Kingdom government in 1997. This emerging field has been developing rapidly over the past 5 years with quick growth seen in the number of academic publications, including several recent literature reviews on energy and fuel poverty. However, those reviews have a common limitation – their scope. Scholars have intentionally limited the review scope to accommodate feasibility and focus considerations. Therefore, the majority focus on a specific aspect like definitions and methodological approaches to measurement (e.g. Fizaine and Kahouli, 2019; Romero et al., 2018; Scarpellini et al., 2019; Tirado Herrero, 2017), household energy consumption (e.g. Han and Wei, 2021), emergency measures to protect households during a pandemic (Mastropietro et al., 2020) or policy perspectives (e.g. Gregory and Sovacool, 2019; Kerr et al., 2019). Existing review studies essentially give summary statistics and qualitative analyses of topical areas and identify several critical issues in the emerging literature. Among others, the most important concern the lack of agreement on definitions, the shortcomings of the current indicators, and the multi-dimensionality and complexity of these two terms (Gouveia et al., 2018).

Overall, the prior reviews provide fragmented insights and lack a holistic understanding of the energy/fuel poverty field in its entirety. This limitation is pointed to by critics who stress the field’s theoretical and methodological fragmentation and argue that this limits the theoretical and methodological depth, inclusiveness and progress of the field, and therefore risks its utility in practice (Che et al., 2021). In response, we aim to address the limitations of existing reviews and provide a comprehensive and objective picture of a 30-year span of research into the topic of energy/fuel poverty by using bibliometric methodologies.

On these grounds, the paper makes two main contributions. First, to the best of our knowledge, this systematic study of 670 articles from the past 30 years is the first to provide insights into similarities and diversities within/between the two concepts in a quantitative and objective manner. Second, the study identifies and discusses overall patterns and emerging topics in the literature on energy/fuel poverty based on usage count. The bibliometric tools used in the current study are valuable for mapping out the structure of the subject of interest, identifying established and emerging areas (clusters) of research and helping to describe the most influential researchers and papers. Further, comprehensive network analysis allows the opportunity to illustrate the field’s evolution over time and objectively describes the clusters of research streams found within the energy and fuel poverty literature. The algorithmically identified clusters of topical areas set the stage for classification of the current research interests, while usage count, in contrast, is suitable while further investigating the directions for future research. Usage count, largely neglected in review studies, permits us to address the limitation of citations as the primary measure of an article’s impact, as they require time to accumulate due to the prolonged publishing process and thus often do not accurately reflect the present situation.

The paper is structured as follows. Section 2 introduces the methodological approach employed to provide insights not fully grasped by other reviews, while also presenting the dataset used for our analysis. Section 3 provides a systematic overview of the research field, focusing on research hotspots, papers, authors and journals. Section 4 identifies research gaps in the existing literature and predicts future trends in energy/fuel poverty research. The paper concludes by commenting on possible policy implications, the research limitations, and opportunities for future research.

2. Methodology and data

2.1. Methodology

Bibliometric methods have become an integral part of research evaluation in both scientific and applied fields. Moreover, they are being increasingly used by scholars due to the greater availability of online databases that provide article and citation data, as well as the development of new and improved analysis software (Dominko and Verbič, 2019; Ellegaard and Wallin, 2015). Bibliometric methods offer several advantages over traditional review techniques. First, they provide a quantitative and thus an objective and transparent way of measuring research impact. Second, they allow for the examination of large datasets. Finally, they are scalable, meaning the studied field can be analysed from both the micro (researcher, institution) and macro (country, world) perspectives.

Our bibliometric network analysis relies on citations, which are not only a sign of the physical document itself, but provide the most objective measure of a paper's importance in a field of knowledge (Garfield, 1979; Small, 1978). In order to cluster authors, papers and journals, we employ bibliographic coupling, a technique that uses the number of references shared by two papers as a measure of the similarity between them, thereby connecting papers that have a greater overlap in their bibliographies (Župić and Čater, 2015). Although bibliographic coupling (Kessler, 1963) is an older technique and not as widespread as co-citation analysis (Small, 1973), which connects papers that are cited together, it addresses several of the latter's limitations. Most importantly, bibliographic coupling does not require publications to accumulate and thus allows for the easier detection of research gaps and trends. Moreover, it is more suitable for mapping smaller research fields, such as the one we are analysing (Boyack and Klavans 2010; Small, 1999; Zhao and Strotmann, 2008). To form and visualise clusters, we use the VOSviewer software package developed by van Eck and Waltman (2010), which constructs a map based on a similarity matrix and then applies three transformations to obtain consistent results (see van Eck and Waltman, 2010 for a more detailed discussion). The presented quantitative methodological approach allows a transparent, systematic and reproducible review process without introducing subjective bias. In addition, it allows us to both evaluate the publication performance and reveal the structure and dynamics of the research field under study.

2.2. Data

We gathered all relevant paper and citation data from the Scopus database, which started in 2004 and is owned by Elsevier. Compared to the Web of Science database, Scopus has a wider coverage and is thus more appropriate for mapping smaller and emerging research areas like ours. To retrieve the data, we used the following search terms combined with the Boolean operator OR: "energy poverty"; "fuel poverty"; "energy poverties"; and "fuel poverties". The search was applied to both abstracts and research papers in the English language. Our inquiry yielded 670 papers, 304 of which included the search terms in their titles (the database was obtained in October 2019). Since the database is relatively small, we qualitatively analysed the titles and abstracts of the acquired papers in order to check whether we had included all relevant papers, as well as to refrain from broadening the database to the extent it would distort the results. To check the relative weights of both search terms, namely "energy poverty" and "fuel poverty", as well as their respective plural forms, we ran additional search queries. These showed that "energy poverty" appeared in 413 papers and "fuel poverty" in 294 papers. The two terms appear together in only 18 papers.

A descriptive overview of the dataset reveals that the oldest article in our database is from 1970, although there is only a handful of articles on energy and fuel poverty in the period prior to the last 15 years. Fig. 1 shows that the field expanded from just 11 articles published in 2004 to 135 (and counting) articles published in 2019. Further, the number of citations grew even faster from only 10 citations in 2004 to 2851 in 2019 (and counting). A deeper look at the database shows that the exponential growth of energy and fuel poverty research in the last 5 years is mostly due to the greater number of articles concerning energy poverty. While in 2015 articles on energy poverty and fuel poverty each held a share of some 50%, in 2019 the share of articles touching on energy poverty had risen to around 80% while the share of articles on fuel poverty had dropped to around 20% (see Fig. 1).

The review also shows that the top 10 publishing journals contributing to the area of energy and fuel poverty issued 301 articles, representing 43.8% of all papers published. Table 1 lists the journals in which these articles appeared. Another interesting aspect is that only two journals in the table are clearly targeting one of the terms. While *British Indoor and Built Environment* publishes papers in the domain of fuel poverty, *Energy for Sustainable Development* almost exclusively publishes studies on energy-related topics in developing countries, including energy poverty. In total, the top 10 journals published 58% of the articles containing the term energy poverty and 42% with the term fuel poverty (Table 2).

Finally, a historical overview of the field reveals the substantial globalisation of research on energy and fuel poverty. Fig. 2 shows that, by 2019, 73 countries have published scientific articles on energy and fuel poverty. The UK is the clear leader with 243 published articles, followed by the USA with 68 articles, and Spain with 58. Scholars in the UK mostly use the term fuel poverty, whereas the term energy poverty is more widespread in the USA, Spain and other EU countries.

3. A systematic overview of the field

3.1. Research hotspots

The development of the two concepts of energy and fuel poverty can be explored using the most relevant keywords (Fig. 3). The keyword analysis reveals the field's multidisciplinary and interdisciplinary nature. The most important topics are found in five clusters. The green cluster associated with keywords like vulnerability, energy justice, and equity denotes the research area of energy affordability. Part of this cluster also appears to be methodologically oriented. The topic developing in the red cluster is the research area dedicated to energy policy, especially in developing countries. As expected, the cluster revolves around the term energy poverty. On the other hand, the blue cluster, in close proximity to fuel poverty, is clearly concentrated on health and demographics in the context of developed countries. Next, the yellow cluster is associated with keywords that hint at energy efficiency and building stock. Finally, the topic shown in purple relates to emissions, including keywords such as greenhouse gases and emission control.

A synthesis of the similarities and differences within/between energy poverty and fuel poverty reveals the bipolar nature of these two terms: the research related to energy poverty at one pole is dominated in the developing world by issues of energy accessibility and a clear focus on institutional and infrastructural development, whereas studies on fuel poverty at the other pole deal with energy affordability in the developed world with humans at the centre of

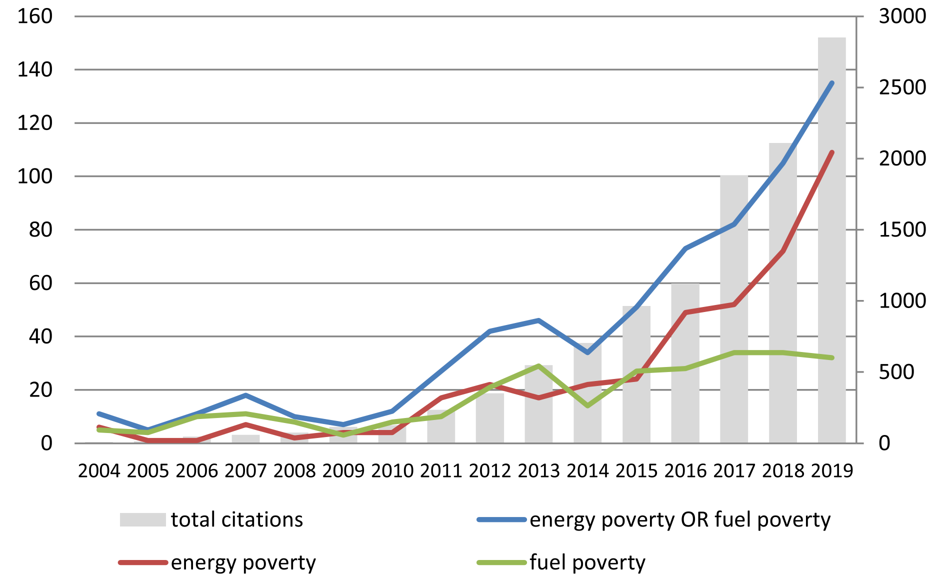

Fig. 1. Number of articles and number of citations on energy and fuel poverty.

Table 1
Top 10 journals contributing to the area of energy-related aspects of poverty.

Source	Search keywords		Total
	Energy poverty	Fuel poverty	
Energy Policy	66	58	124
Energy Research and Social Science	25	22	47
Energy and Buildings	28	18	46
Energies	13	3	16
Energy for Sustainable Development	13	0	13
Energy	9	3	12
Sustainability Switzerland	8	4	12
Indoor and Built Environment	1	10	11
Applied Energy	5	5	10
Journal of Cleaner Production	8	2	10
Total	176	125	301

interest. This is accompanied by diffuse research in the domains of renewable energy (solar power, wind power, hydroelectric power, biomass), rural electrification, electricity and power generation in developing countries with untapped (clean) energy potential and abundant engineering opportunities (Fig. 4).

Based on the keywords obtained through the bibliometric analysis, each topic seems to highlight the issue of energy (fuel) poverty from a distinct perspective. The observed internal diversity of the energy and fuel poverty literature causes the concepts to be split into different disciplines; namely, sociology, psychology, political science, public health, earth and environmental science, engineering and technology. Accordingly, we can justifiably expect new areas of research to emerge soon.

A historical overview of the most important keywords reveals that the identified clusters are becoming more pronounced. Another important discovery relates to the distance between the keywords energy poverty and fuel poverty, where the terms are more closely connected in recent years. One reason is that the two keywords are frequently used as synonyms, like in the UK. Lately, stronger interest has been shown in specific countries (e.g. France, Greece, Japan, Spain, Nigeria, Chile), while the terms poverty, energy efficiency, energy policy and energy utilisation remain highly relevant throughout the whole period. Moreover, it can also be observed that in recent years literature on energy poverty has outpaced the literature on fuel poverty in terms of the number of articles published, as can be seen in Fig. 5 where the keywords most occurring before and after 2015 are presented. This is in line with the increase in studies in developing countries where the term is generally used to describe problems relating to a lack of physical access to energy services, and with the increase in studies in developed countries where authors use the terms interchangeably.

3.2. Articles

Fig. 6 points to six clusters of articles that are fairly intertwined, which may be expected because the field has still not reached the stage of maturity. The most-cited articles (see Table 2 for a thorough overview of the most-cited articles) are located in the green and red clusters that deal with issues of affordability and health-related problems, and issues of energy access and domestic energy deprivation, respectively. The article on high winter mortality and related risk factors in Europe by Healy (2003) argues that the thermal standards for housing in southern and Western Europe have a strong role to play in winter mortality. Another popular paper on the same subject, namely the health impacts of tacking fuel poverty, was written by Liddell and Morris in 2010. A paper by Moore (2012) from the same cluster also focuses on questions like whether the UK fuel poverty policy is targeted at households least able to afford their fuel costs or primarily those at risk for winter mortality and morbidity. In contrast, the article by Goldthau (2014) in the red cluster provides a new insight into the energy infrastructure–governance nexus. Highly-cited papers from the red cluster also include those written by Bouzarovski and Petrova (2015) who identify the main components and implications of energy service and vulnerability approaches relating to domestic energy deprivation, and Pachauri and Spreng (2004) who present a new measure of energy poverty and energy distribution that combines elements of access to different energy types and quantity of energy consumed. As seen in Fig. 6, the yellow, turquoise and purple clusters are mainly dominated by more recent literature on the development of new measures of energy and fuel poverty, comparative analysis across countries, the links between the concepts of energy or fuel poverty, and different forms of inequality and injustice.

Table 2
Most-cited papers, including authors, number of citations, year, journal and keywords.

R	Authors	Article	Journal	Year	Cit.	FW cit.[a]	SciVal[b]	Author Keywords	Topic
1	Healy, J.D.	Excess winter mortality in Europe: A cross country analysis identifying key risk factors	*Journal of Epidemiology and Community Health*	2003	345	3.97	Temperature; Hot temperature; Heat-related mortality	–	Fuel poverty
2	Liddell, C., Morris, C.	Fuel poverty and human health: A review of recent evidence	*Energy Policy*	2010	204	2.92	Housing; Energy; Fuel poverty	Fuel poverty; Health; Mental health	Fuel poverty
3	Bouzarovski, S., Petrova, S.	A global perspective on domestic energy deprivation: Overcoming the energy poverty-fuel poverty binary	*Energy Research and Social Science*	2015	185	10.44	Housing; Energy; Fuel poverty	Energy poverty; Energy services; Fuel poverty; Vulnerability	Both
4	Power, A.	Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?	*Energy Policy*	2008	183	3.11	Buildings; Energy efficiency; Energy retrofit	Embodied energy; Sustainable communities; Urban regeneration	Fuel poverty
5	Hang, L., Tu, M.	The impacts of energy prices on energy intensity: Evidence from China	*Energy Policy*	2007	183	3.85	Carbon emission; Energy utilisation; Carbon intensity	China; Energy intensity; Energy prices	Fuel poverty
6	Walker, G., Day, R.	Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth	*Energy Policy*	2012	182	4.21	Housing; Energy; Fuel poverty	Fuel poverty; Justice; Policy	Fuel poverty
7	Goldthau, A.	Rethinking the governance of energy infrastructure: Scale, decentralisation and polycentrism	*Energy Research and Social Science*	2014	174	9.55	Investments; Electricity; Economic growth	Energy governance; Infrastructure; Polycentrism	Energy poverty
8	Wilkinson, P., Pattenden, S., Armstrong, B., Fletcher, A.,Kovats, R.S., Mangtani, P., McMichael, A.J.	Vulnerability to winter mortality in elderly people in Britain: Population based study	*British Medical Journal*	2004	167	9.31	Temperature; Hot Temperature; Heat-related mortality	–	Fuel poverty
9	Moore, R.	Definitions of fuel poverty: Implications for policy	*Energy Policy*	2012	133	3.74	Housing; Energy; Fuel poverty	Definitions; Fuel poverty; Policy implications	Fuel poverty
10	Santamouris, M., Kapsis, K., Korres, D., Livada, I., Pavlou, C., Assimakopoulos, M.N.	On the relation between the energy and social characteristics of the residential sector	*Energy and Buildings*	2007	143	4.24	Housing; Energy; Fuel poverty	Buildings; Energy consumption; Energy poverty; Income	Fuel poverty
11	Thomson, H., Snell, C.	Quantifying the prevalence of fuel poverty across the European Union	*Energy Policy*	2013	133	3.65	Housing; Energy; Fuel poverty	EU-SILC; European Union; Fuel poverty	Fuel poverty
12	Newell, P., Mulvaney, D.	The political economy of the 'just transition'	*Geographical Journal*	2013	125	4.12	Biofuel; Sustainability; South Africa	Climate justice; Energy justice; Energy poverty; Just transition; Low carbon economy; Political economy	Energy poverty
13	Ormandy, D., Ezratty, V.	Health and thermal comfort: From WHO guidance to housing strategies	*Energy Policy*	2012	121	3.74	Housing; Energy; Fuel poverty	Health; Housing; Thermal comfort	Fuel poverty
14	Pachauri, S., Mueller, A., Kemmler, A., Spreng, D.	On measuring energy poverty in Indian households	*World Development*	2004	121	1.30	Rural areas; Electricity; Solar home	Asia; Energy access: Energy consumption; Household poverty; India	Energy poverty
15	Day, R., Walker, G., Simcock, N.	Conceptualising energy use and energy poverty using a capabilities framework	*Energy Policy*	2016	116	9.19	Housing; Energy; Fuel poverty	Capabilities; Energy demand; Energy poverty; Energy services; Fuel poverty; Functionings	Energy poverty
16	Kemmler, A., Spreng, D.	Energy indicators for tracking sustainability in developing countries	*Energy Policy*	2007	114	2.66	Rural areas; Electricity; Solar home	Energy indicators; Poverty measurement; Tracking sustainability	Energy poverty
17	Bouzarovski, S., Petrova, S., Sarlamanov, R.	Energy poverty policies in the EU: A critical perspective	*Energy Policy*	2012	113	3.04	Housing; Energy; Fuel poverty	Bulgaria; Energy poverty; EU	Energy poverty
18	Ekholm, T., Krey, V., Pachauri, S., Riahi, K.	Determinants of household energy consumption in India	*Energy Policy*	2010	113	3.37	Rural areas; Electricity; Solar home	Energy access; Household energy consumption; India	Energy poverty
19	Middlemiss, L., Gillard, R.	Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor	*Energy Research and Social Science*	2015	110	7.24	Housing; Energy; Fuel poverty	Energy consumption; Energy vulnerability; Fuel poverty; Lived experience	Fuel poverty
20				2013	105	5.96	Housing; Energy; Fuel poverty		

(*continued on next page*)

Table 2 (*continued*)

R	Authors	Article	Journal	Year	Cit.	FW cit.[a]	SciVal[b]	Author Keywords	Topic
	McLeod, R.S., Hopfe, C.J., Kwan, A.	An investigation into future performance and overheating risks in Passivhaus dwellings	*Building and Environment*					Building simulation; Enhanced Morris method; Global sensitivity analysis; Overheating; Thermal comfort; Thermal mass	Fuel poverty
21	Healy, J.D., Clinch, J.P.	Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland	*Energy Policy*	2004	102	1.29	Housing; Energy; Fuel poverty	Fuel poverty; Market failure; Severity	Fuel poverty
22	Howden-Chapman, P., Viggers, H., Chapman, R., O'Sullivan, K., Telfar Barnard, L., Lloyd, B.	Tackling cold housing and fuel poverty in New Zealand: A review of policies, research, and health impacts	*Energy Policy*	2012	96	3.15	Housing; Energy; Fuel poverty	Energy policy; Fuel poverty; Housing and health	Fuel poverty
23	Nzila, C., Dewulf, J., Spanjers, H., Tuigong, D., Kiriamiti, H., van Langenhove, H.	Multi criteria sustainability assessment of biogas production in Kenya	*Applied Energy*	2012	94	4.48	Biogas; Anaerobic digestion; Biogas digesters	Biogas; Energy poverty; Exergy; Kenya; Multi-criteria; Sustainability assessment	Energy poverty
24	Santamouris, M.	Innovating to zero the building sector in Europe: Minimising the energy consumption, eradication of the energy poverty and mitigating the local climate change	*Solar Energy*	2016	93	5.21	Housing; Energy; Fuel poverty	Climate change; Energy poverty; Local climate change and urban heat island; Low income households; Mitigation and adaptation; Near zero energy buildings	Energy poverty
25	Sagar, A.D.	Alleviating energy poverty for the world's poor	*Energy Policy*	2005	93	2.03	Rural areas; Electricity; Solar home	Biomass; Climate change; Equity; Sustainable development	Energy poverty

[a] Field-Weighted Citation Impact - shows how well this document is cited compared to similar documents. A value greater than 1.00 means the document is more cited than expected.
[b] SciVal Topic Prominence - topics are based on clustering the citation network of 95% of Scopus content (all documents published from 1996).

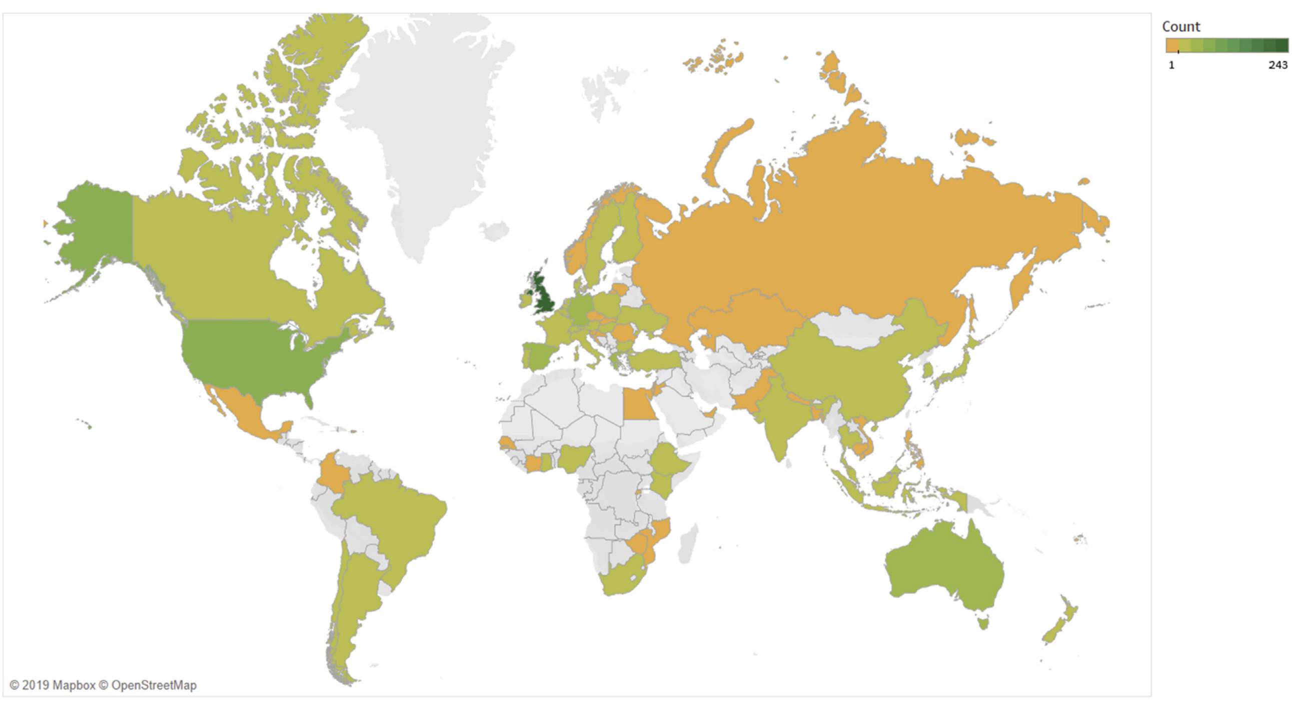

Fig. 2. Countries publishing research on energy and fuel poverty.

3.3. Authors

The author field, which records the frequency of appearance, shows that the author with the most articles is Stefan Bouzarovski (16 articles), followed by Saska Petrova and Hariett Thomson, who have each authored or co-authored 8 articles . All three authors employ the terms energy and fuel poverty. As the data reveal, the leading scholars tend to publish studies relating to energy (fuel)

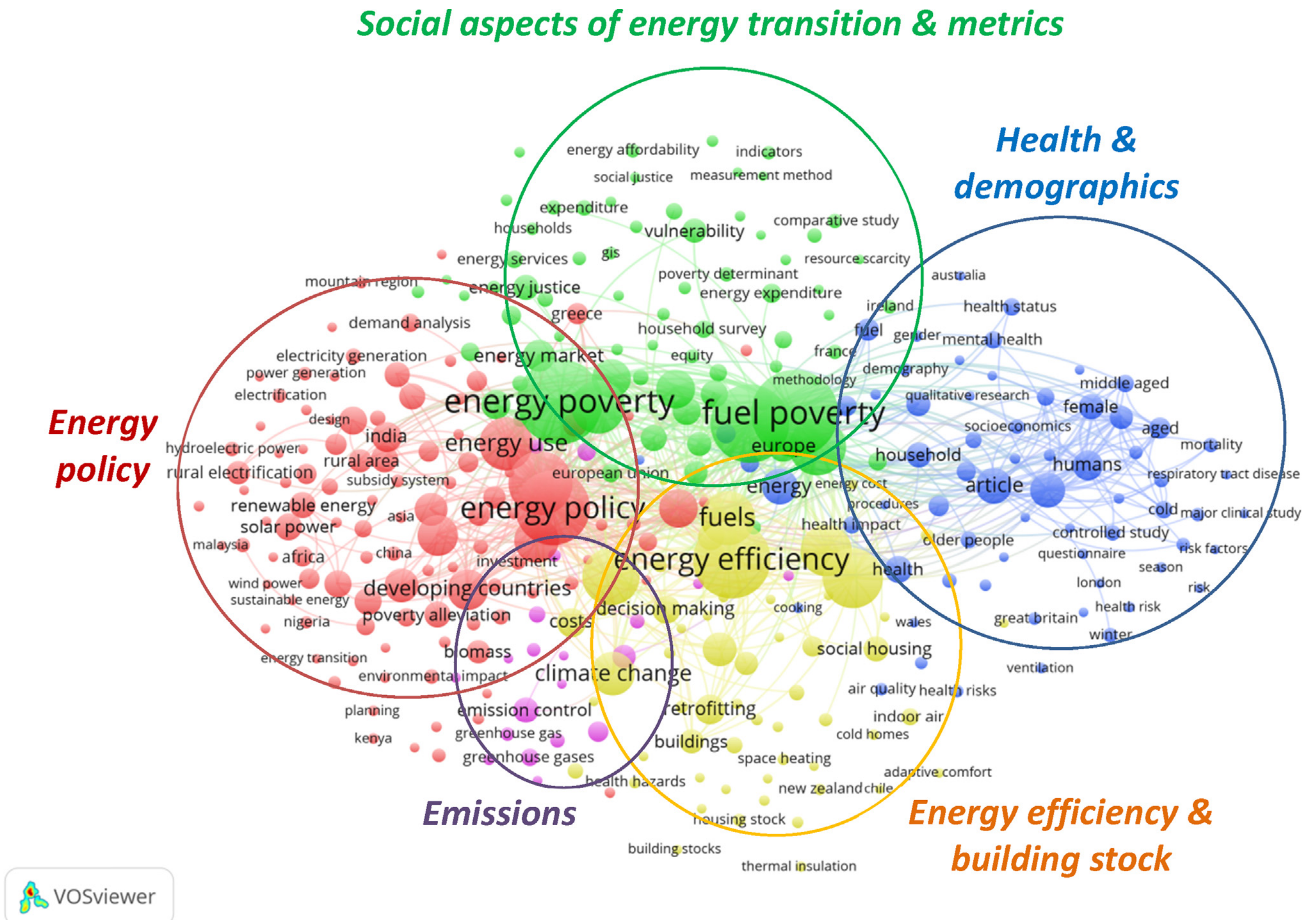

Fig. 3. Most important keywords in energy poverty and fuel poverty research.

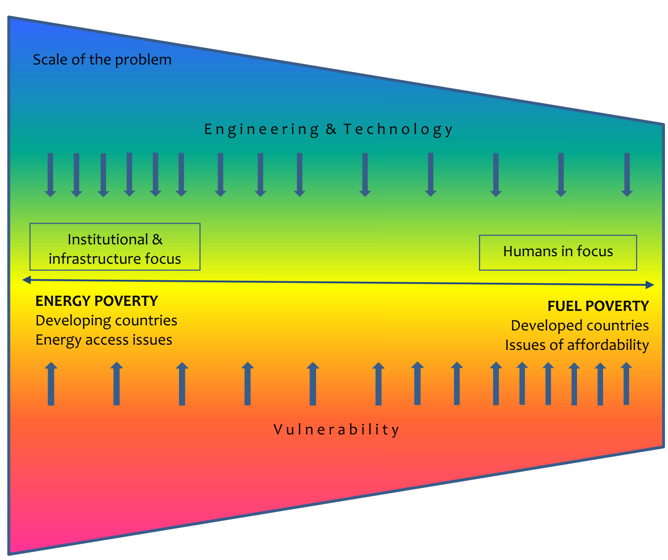

Fig. 4. Bipolarity of the terms "energy poverty" and "fuel poverty".

poverty measurement and its socio-spatial aspects/distribution (see the purple cluster), the energy-efficiency performance of buildings and vulnerable groups (red cluster), health-related issues (yellow cluster), energy access and measurement of energy poverty in developing countries (blue cluster) and the determinants of energy (fuel) poverty, including climate (green cluster) (Fig. 7). The links between the clusters reveal the blue cluster (energy poverty as a developmental issue) has the weakest connection with the other clusters. Strong relationships indicate study directions, while weak relationships imply potential research perspectives. Overall, the breadth of the work undertaken, even just among the leading authors, shows the field's interdisciplinary nature.

3.4. Journals

Fig. 8 displays a map of journals that have published at least two articles concerning energy or fuel poverty research. The map distinguishes three main journal topics. A more detailed qualitative analysis reveals that the red cluster of journals chiefly deals with areas related to the policy implications of energy demand/supply. The leading journal in this cluster, as well as the overall leader, is *Energy Policy*. This journal has a close connection to *Energy Research and Social Science*, which dominates the green cluster that is more oriented towards society and its relations to energy systems. The third important journal in terms of number of published articles is *Energy and Buildings*, concerned with topics that revolve around energy use in buildings.

Finally, the overlay analysis of the journals (Fig. 9) shows that the most influential journals by the number of normalised citations are *Building and Environment*, *Solar Energy*, *European Urban and Regional Studies* and *Journal of Epidemiology and Community Health* that only published a small number of articles on energy poverty and fuel poverty. These journals primarily publish articles with

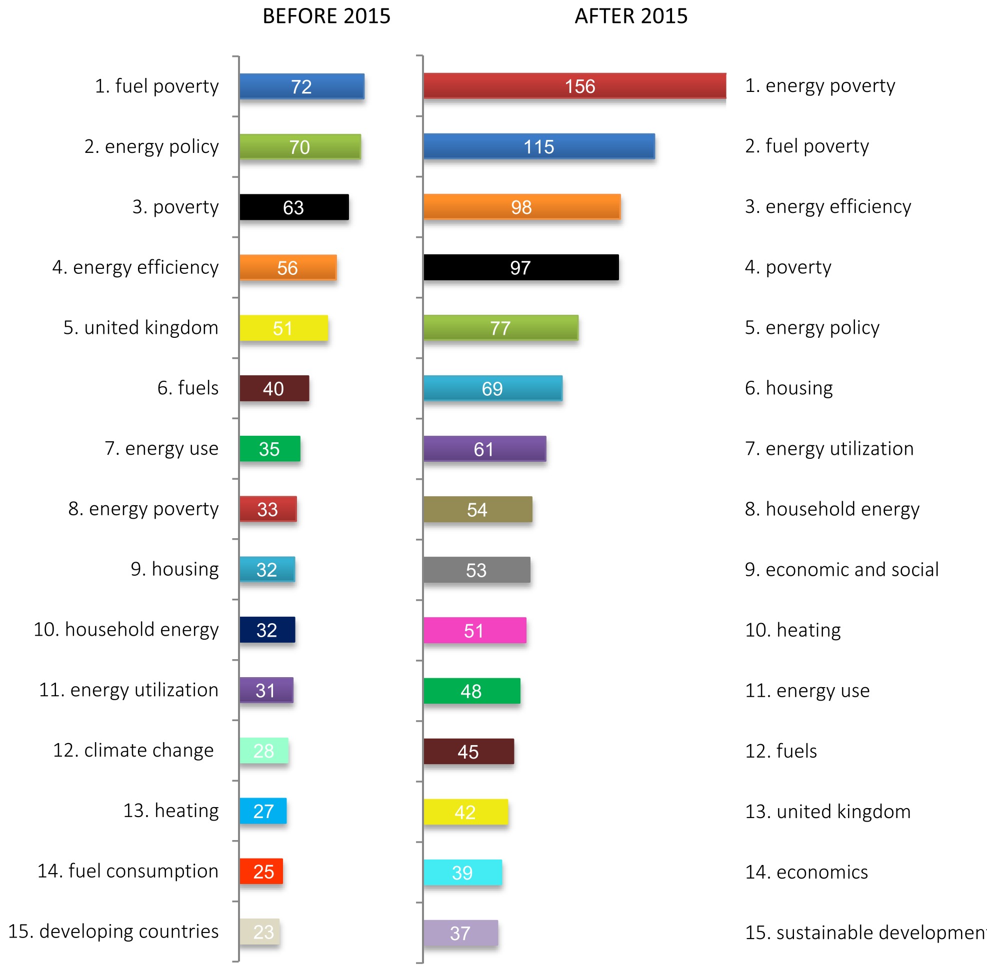

Fig. 5. The keywords most occurring before and after 2015.

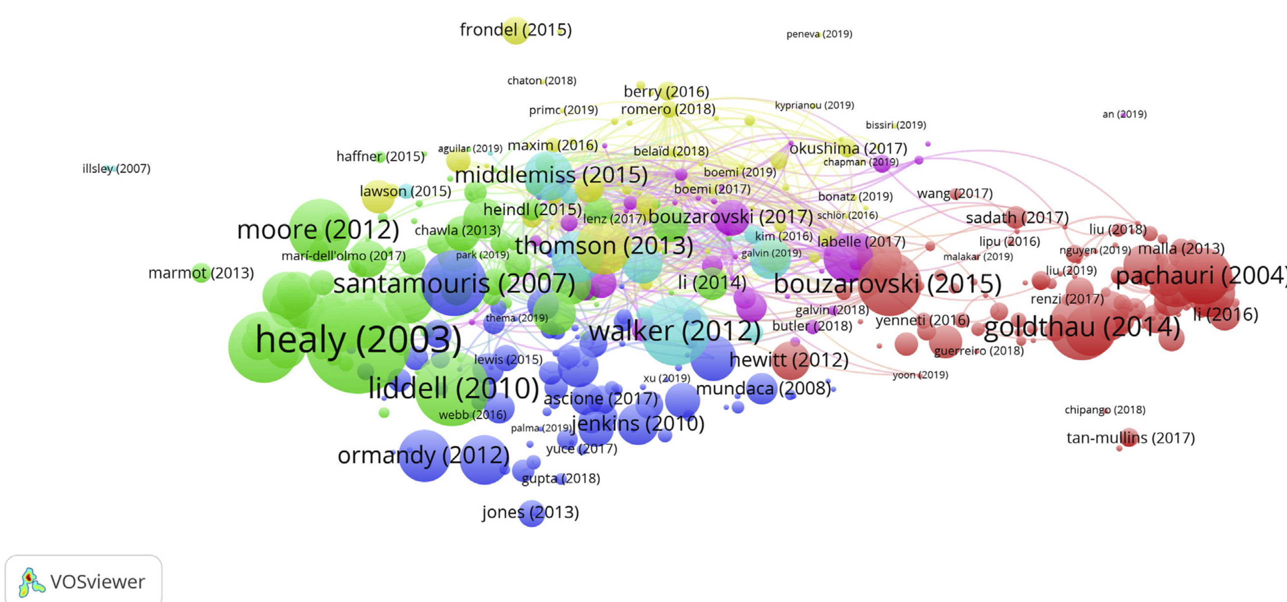

Fig. 6. Clusters of articles in the energy poverty and fuel poverty research.

topics other than energy (fuel) poverty, such as the science and technology of solar energy applications, building science, urban physics, urban and regional development, and epidemiology and public health.

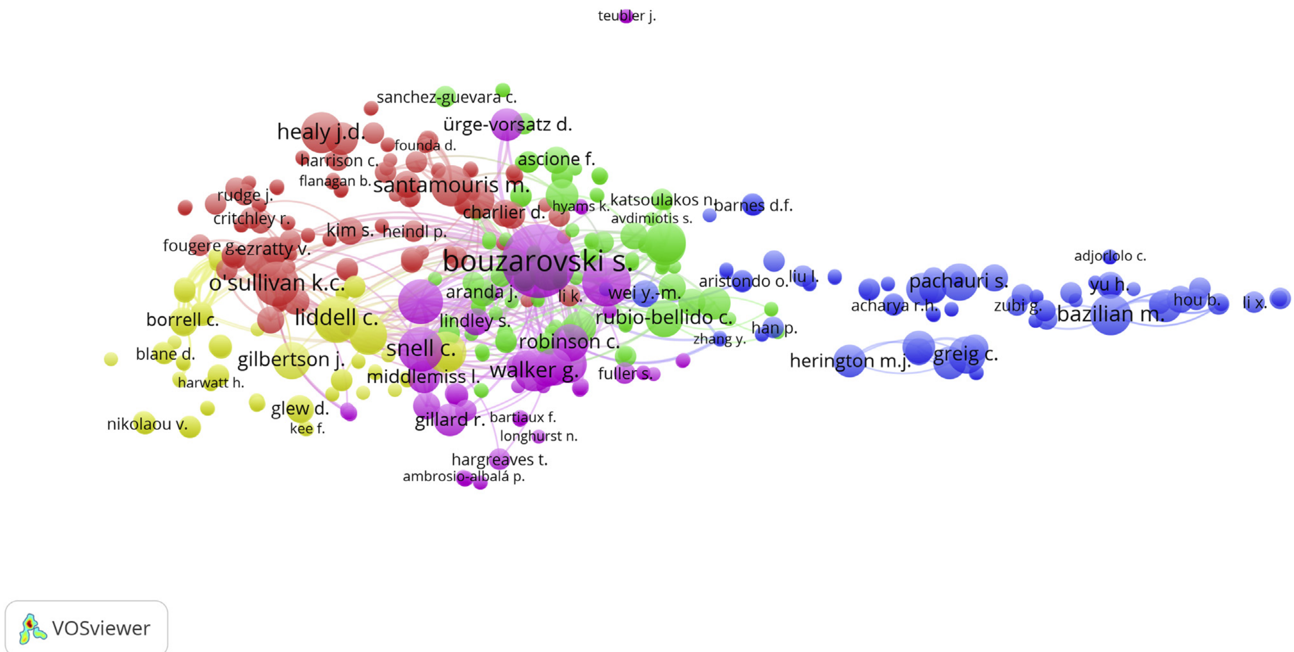

Fig. 7. Clusters of authors engaged in energy poverty and fuel poverty research.

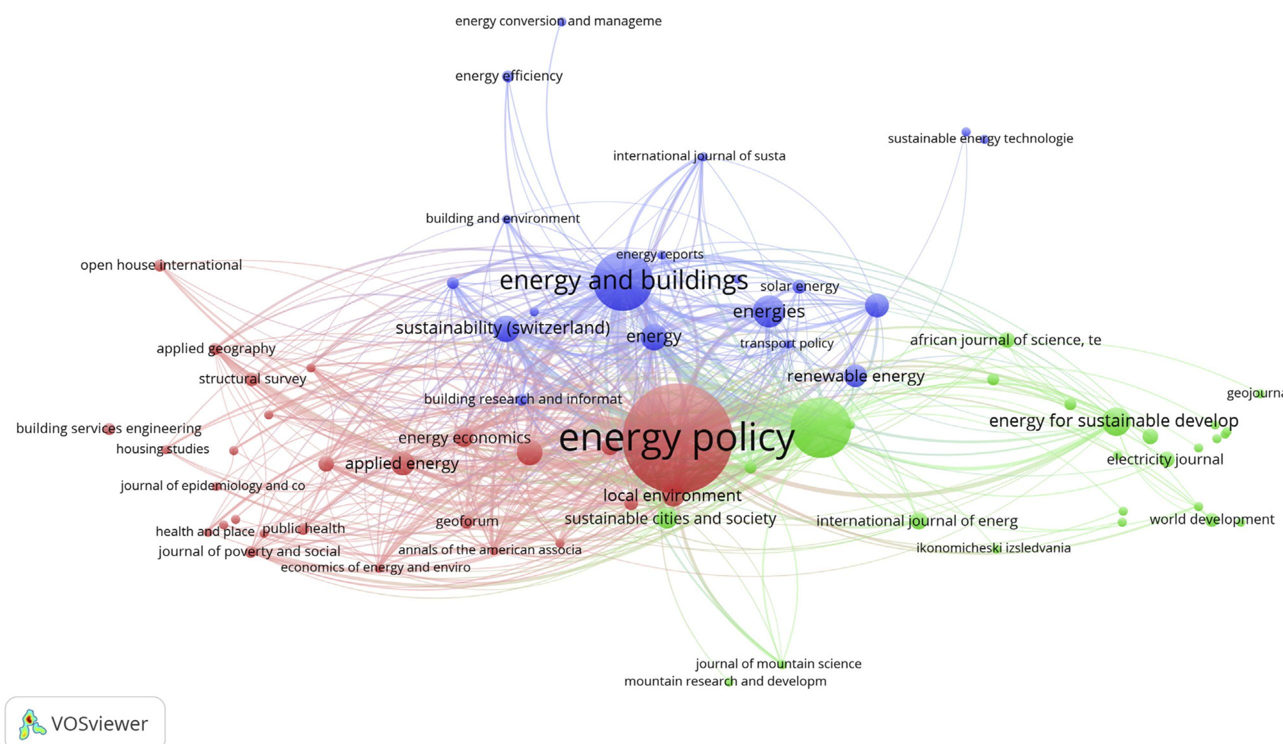

Fig. 8. Clusters of journals publishing energy poverty and fuel poverty research.

4. Knowledge gaps and future trends

Analysing, predicting and directing future trends is extremely important for ensuring the field's effective development. To identify them, we qualitatively reviewed our database and identified articles with the highest 180-day usage count. Usage count is the number of times an article has been accessed or saved in the last 180 days (in our case, the observed period extends from July 14, 2020 to January 10, 2021. Because scholars prefer to use newer articles, usage data usually peaks within the first years of an article's existence and offers considerable real-time accuracy. Therefore, it addresses one of the limitations of only using citations as the measure of a paper's impact, namely the fact that citations require time to accumulate and do not always accurately reflect the present situation (Wang et al., 2016). We used the Web of Science database to obtain the 180-day usage count since Scopus does not provide

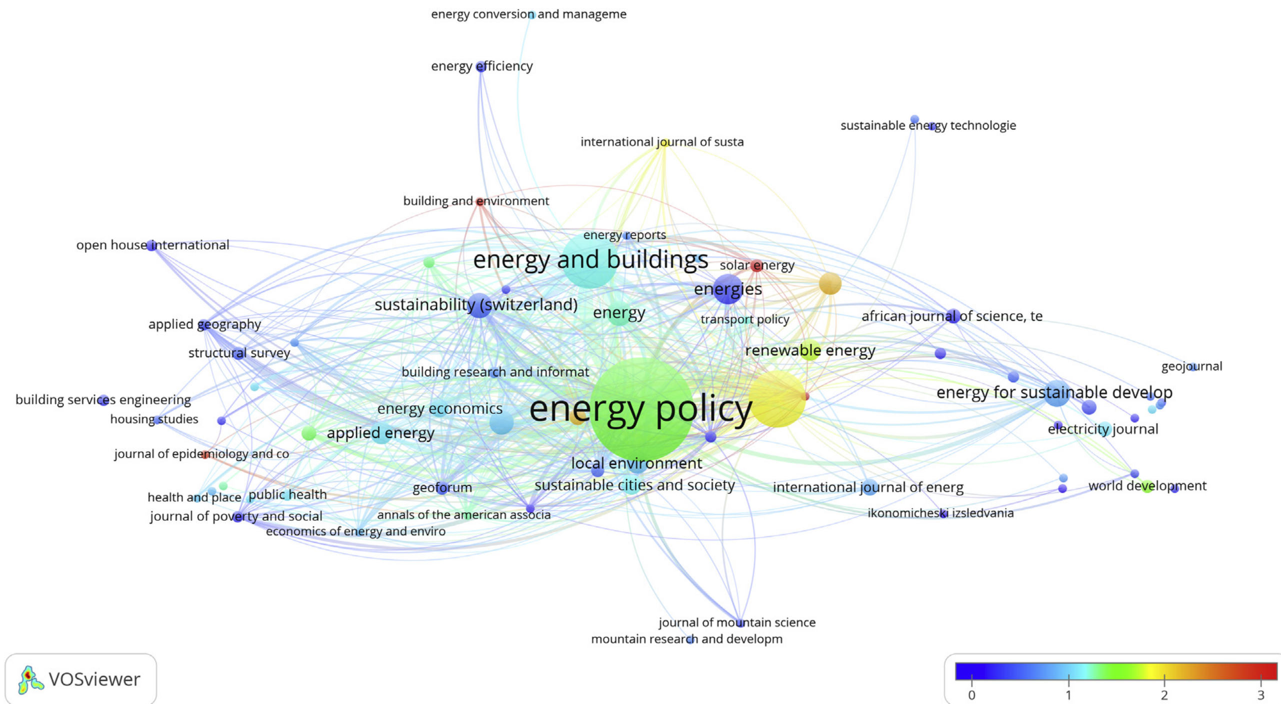

Fig. 9. Overlay analysis of journals based on normalised citations.

Table 3
Papers with the highest 180-day usage count.

R	Authors	Article	Journal	Year	Usage (180)
1	Boruah, B.D., Wen, B., Nagane, S. et al.	Photo-rechargeable zinc-ion capacitors using V2O5-activated carbon electrodes	*ACS Energy Letters*	2020	54
2	Chen, Z., Liu, X., Zhao, J. et al.	Strain effect on the catalytic activities of B- and B/N-doped black phosphorene for electrochemical conversion of CO to valuable chemicals	*Journal of Materials Chemistry A*	2020	31
3	McCauley, D., Heffron, R.	Just transition: Integrating climate, energy and environmental justice	*Energy Policy*	2018	28
4	Lin, B., Wang, Y.	Does energy poverty really exist in China? From the perspective of residential electricity consumption	*Energy Policy*	2020	26
5	Bao, H.X.H., Li, S.H.	Housing wealth and residential energy consumption	*Energy Policy*	2020	25
6	Newell, P., Mulvaney, D.	The political economy of the “just transition’	*Geographical Journal*	2013	21
7	Bienvenido-Huertas, D., Sanchez-Garcia, D., Rubio-Bellido, C.	Analysing natural ventilation to reduce the cooling energy consumption and the fuel poverty of social dwellings in coastal zones	*Applied Energy*	2020	20
8	Abbas, K., Li, S., Xu, D. et al.	Do socioeconomic factors determine household multidimensional energy poverty? Empirical evidence from South Asia	*Energy Policy*	2020	20
9	Jin, S.H.	Fuel poverty and rebound effect in South Korea: An estimation for home appliances using the modified regression model	*Energy & Environment*	2020	19
10	Sovacool, B.K., Del Rio, D.F., Griffiths, S.	Contextualising the Covid-19 pandemic for a carbon-constrained world: Insights for sustainability transitions, energy justice, and research methodology	*Energy Research & Social Science*	2020	18
11	Zhang, D., Li, J., Han, P.	A multidimensional measure of energy poverty in China and its impacts on health: An empirical study based on the China family panel studies	*Energy Policy*	2019	18
12	Sovacool, B.K., Heffron, R.J., McCauley, D. et al.	Energy decisions reframed as justice and ethical concerns	*Nature Energy*	2016	18
13	Mao, S., Qiu, S., Li, T. et al.	Using characteristic energy to study rural ethnic minorities’ household energy consumption and its impact factors in Chongqing, China	*Sustainability*	2020	16
14	DellaValle, N., Sareen, S.	Nudging and boosting for equity? Towards a behavioural economics of energy justice	*Energy Research & Social Science*	2020	14
15	Shane, A., Gheewala, S.H.	Missed environmental benefits of biogas production in Zambia	*Journal of Cleaner Production*	2017	14

this option. A closer look at the list of articles with the highest usage count in Table 3, along with the most often used keywords in 2019 in Fig. 10, reveals several new and potential areas of research, such as the social aspects of energy transition, engineering and architectural advancements and the political landscape. Novel methodological approaches are also penetrating the field.

4.1. The public policy landscape

Despite the literature growing, the current studies are largely oriented to the micro level, leaving the macroeconomic aspect relatively poorly discussed. The ambitious national and international climate and social policy goals dictate that future energy/fuel

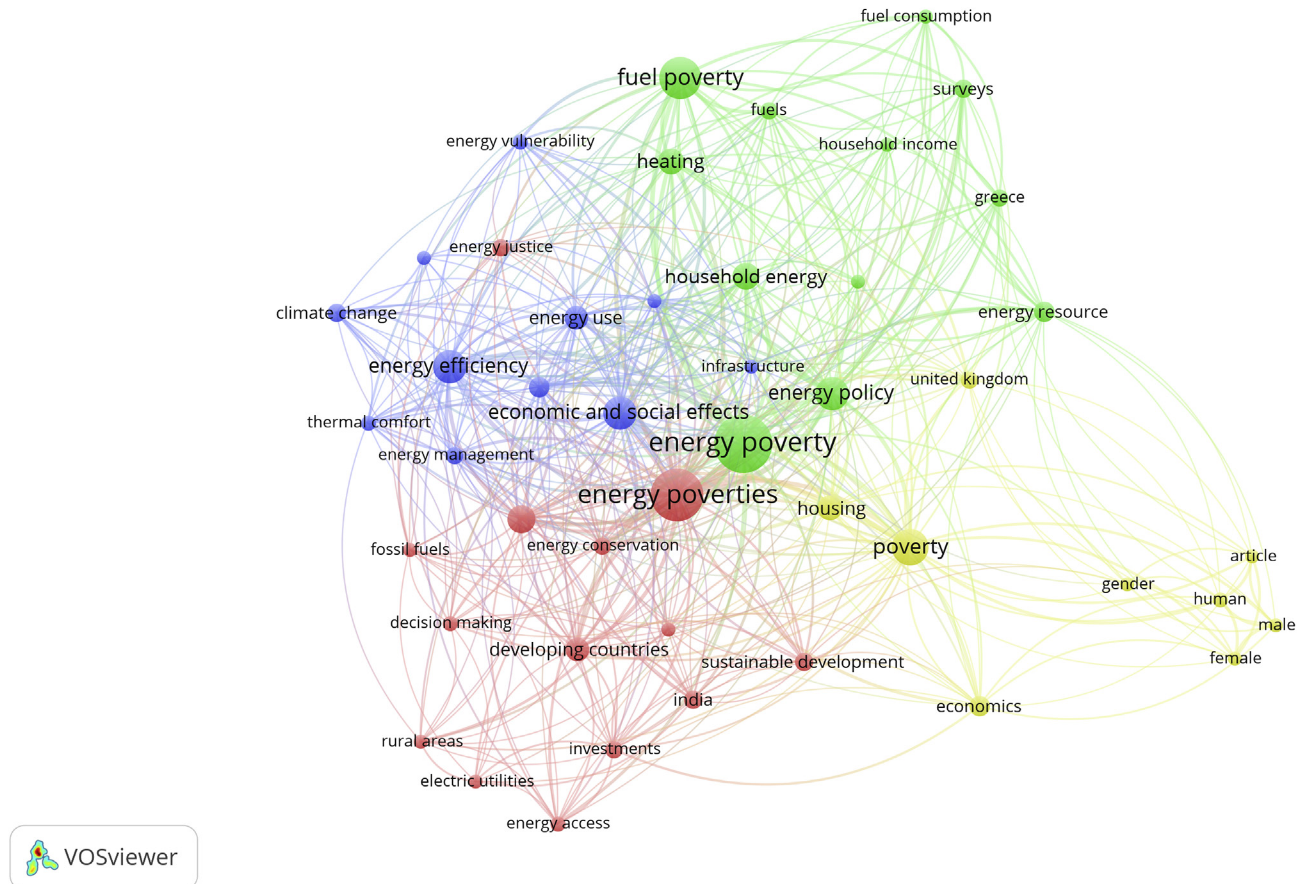

Fig. 10. Most important keywords in energy poverty and fuel poverty research in 2019.

poverty studies also address issues relating to income inequality, unemployment and economic growth. Nowadays, the assessment of the potential economic and political decisions on energy and climate change policy interventions is the priority of accountable governments across the world. Governments must play a key enabling and steering role in improving levels of support and access to clean and affordable energy and mediating the competing powerful interests at stake. This raises a whole series of issues about how decisions are taken, options assessed and trade-offs made between different energy features (Newell and Mulvaney, 2013). The political economy of a 'Just Transition', which intends to ensure that efforts to steer society towards a lower carbon future do not leave anyone behind, has recently been gaining a lot of attention from academics (McCauley and Heffron, 2018). However, the fact that there is no universal definition of the term limits the concept's application in practice (Henry et al., 2020). Similar is the concept of "The Global Energy Trilemma", which might serve as a good approach while looking for simultaneous solutions in terms of energy/fuel poverty, inequality, economic growth and climate change mitigation. Sadly, it remains unclear how the current COVID-19 pandemic will alter these transitions. The pandemic is reconfiguring populations in rapid and unforeseen ways and altering behaviours and daily routines (Sovacool et al., 2020). Original studies and article reviews on policies implemented and emergency measures taken during the COVID-19 pandemic are greatly needed to identify potential inefficiencies, but also best practices (Bienvenido-Huertas, 2021; Mastropietro et al., 2020). Our pre-COVID-19 study points to the separation and breakthrough of the health-related cluster of research by developing in-depth epidemiological studies, health risk assessment, and assessment of the costs of the healthcare system related to respiratory diseases and the worsening of other diseases in the conditions of extremely cold or hot homes. This cluster is expected to strengthen markedly in the near future, revealing relationships between exposures, such as high or low temperatures in homes, high humidity within a dwelling or suffering because of financial distress, which is further exacerbated by working from home and the related increased electricity consumption (Nagaj and Korpysa, 2020). The identification of causal relationships between these exposures and health outcomes should contribute to an evidence-based policy for preventing energy/fuel poverty.

4.2. Social aspects of energy transition

Energy deprivation is associated with many social features of poverty, such as homelessness, gender issues, crime, minority groups, social housing tenants, elderly, the very young and people with disabilities. Effective policy planning requires that individuals be recognised as having different abilities, motivations, preferences and economic conditions. Social justice concerns are rarely incorporated into scientific and political debates, yet are vital for an equitable energy future. Therefore, such concepts from justice and ethics provide an important structure to think about (Sovacool et al., 2016). Current energy and fuel poverty policies around the world still largely ignore the identified social features of poverty, although providing everyone with affordable, clean and reliable energy sources should be a priority in alleviating energy and fuel poverty. It is therefore in the hands of academia to start more actively discussing these topics and keep policymakers alert to their present invisibility. It is equally important to understand people's cognitive processes when living in an energy shortage, where theories from behavioural sciences could play an important role. The policy interventions should sufficiently and accurately factor in human behaviour. For example, a deeper understanding of the behavioural dimension related to energy scarcity could unveil critical roots of homelessness and crime. The dynamics in patterns of human decision-making could be studied using behavioural economics (DellaValle and Sareen, 2020). Behavioural economics shows that individuals exhibit systematic and predictable patterns of decision-making that depart from the simplistic assumption embedded in rational choice theory, thus giving policymakers a richer model of human behaviour (DellaValle and Sareen, 2020).

4.3. Engineering and architectural advancement

Rural residents, especially those in developing countries, are clearly in need of rural electrification, which can be addressed using different solutions, from traditional diesel generators to modern renewable energy systems (e.g. solar photovoltaic systems, wind turbines, hydrokinetic energy, electrochemical energy storage devices) (Boruah et al., 2020). The living standard of many people can be significantly improved by ensuring energy security for their basic needs. At the moment, policymakers are stuck with expensive and unappealing alternatives. This means that affordable yet efficient technological solutions able to power basic electronic equipment in homes are in great need.

Important avenues for future research include existing and emerging technologies, for example sustainable carbon-based chemicals for cost-effective fuel production Chen et al. (2020), strategies for minimising the energy consumption of buildings (Zhang et al., 2020), such as possibilities for natural ventilation (Bienvenido-Huertas et al., 2020), and reducing building cooling. In particular, urban overheating in recent years shows we need to start controlling the interplay between buildings and the environment also in the warmer months of the year. Central to energy efficiency is a design that maximises the performance of the building envelope, efficient HVAC systems, and household renewable energy technologies. Further efficient and cost-effective systems, as well as technology advancements and their commercialisation, offer significant potential in monitoring energy needs. The identified hot research topics involve efficient retrofitting options, sustainable and energy efficient building materials, green roofs and façades, dynamic insulations, breathing walls, nocturnal and evaporative cooling, smart homes to control energy consumption, the urban landscape and green architecture.

4.4. Novel methods

Future trends regarding novel methods in energy and fuel poverty research concern both data collection and empirical analyses. First, reliable data are needed to provide relevant policy implications of energy deprivation. This has led to the introduction of data loggers, which are electronic devices that track data over time and can monitor temperature, relative humidity, power usage, CO2, voltage etc., and thus provide relevant and precise information for assessing the impact of fuel and energy poverty (Boemi and Papadopoulos, 2019; Porras-Salazar et al., 2020). Second, despite the expansion of energy poverty research in the last decade, the lack of a general and effective way of measuring energy poverty remains an important weakness of the field (Thomson et al., 2017). An important cause of this problem is the complexity of modelling the discrepancies between the actual energy consumption of households and the targeted one. These issues can be appropriately addressed with novel mathematical models, such as the "Stochastic Model of Energy Poverty" (SMEP) by Papada and Kaliampakos (2018), which includes both modelling of energy poverty at the household level and its transition to the country level through a stochastic analysis. Finally, single-indicator approaches for official energy poverty statistics only narrowly define which household is worthy of support, thus preventing the possibility of alternative understandings of the factors behind energy and fuel poverty. This may lead to vulnerable groups of people being left out of support schemes. Therefore, what is needed is a multiple indicator approach that is able to capture the diversity of experiences and intensities of energy poverty (Castaño-Rosa et al., 2019; Herrero, 2017; Zhang et al., 2019).

5. Discussion

The otherwise missing critical structured review of the concepts we have presented provides the grounds for the field's future development. Although the origins of energy poverty and fuel poverty date back to the 1970s, the concepts became globally more popular after the 2010s. The geographical distribution of the two terms shows that fuel poverty is particularly popular in the UK, while in other countries the term energy poverty clearly dominates. Our analysis also reveals that in the past decade the popularity of the term fuel poverty has started to fade. Publishing on energy-related aspects of poverty has seen a major expansion in the last 5 years, primarily in the domain of "energy poverty". This is because after 2015 researchers started to pay greater attention to the problem in developing countries and authors in the UK and in other developed countries have begun to use the terms interchangeably.

A holistic analysis of the energy and fuel poverty concepts using rigorous bibliometric methods complements what is currently known and provides further insights neither previously evaluated nor discussed. For example, the present analysis of salient keywords and topics reveals that the literature is quite homogenous with a certain internal diversity regarding the research content. While the energy poverty concept relates more to concepts like energy market and energy justice (e.g. Bouzarovski and Simcock, 2017; Goldthau, A., 2014; Munro, van der Horst and Healy, 2017; Reames, 2016), social inequality (e.g. Bridge et al., 2016; Filčák and Živčič, 2017), energy use and energy policy (e.g. Bazilian et al., 2014; Khandker et al., 2012), the fuel poverty concept is more strongly associated with concepts like energy efficiency (e.g. Gilbertson et al., 2012; Rudge, 2012), health (e.g. Healy, 2003; Liddell and Morris, 2010; Ormandy and Ezratty, 2012) and household socio-economic characteristics (e.g. Barnicoat and Danson, 2015; Cotter et al., 2012; Santamouris et al., 2007).

Literature on both terms revolves around five clusters: Energy affordability and metrics, energy policy, health and demographics, energy efficiency and building stock, and emissions (i.e. natural environment).

5.1. Energy affordability and metrics

The development outlined above reveals that energy affordability has become a serious political issue in recent years. However, as Castaño-Rosa et al. (2019) report, only a few European Union (EU) countries (besides the UK and Ireland) have an official fuel (energy) poverty definition, while there is no official standard across the EU. This is somewhat surprising as the field is no longer in its infancy and, at the same time, it indicates its complexity. A valuable step forward was taken in 2017 when the EU Observatory on Energy Poverty (EPOV) started its activity. The EPOV called for the definition of a set of criteria to measure energy poverty and continuously monitor households with respect to energy poverty (Tirado Herrero, 2017).

One can find a variety of ways to assess energy affordability and fuel/energy poverty. Debates and proposals are continuing today in the direction of comparing energy-poor households' profiles obtained via different approaches, accompanied by sensitivity analyses and the development of new composite indices (e.g. Bollino and Botti, 2017; Castaño-Rosa et al., 2019; Legendre and Ricci, 2015; Robinson et al., 2018). As Tirado Herrero (2017) argue, it is difficult to identify a single best metric, with various indicators providing different pieces of evidence. In connection to these indices, another emerging issue concerns determining the weights to be assigned to individual indicators that make up the combined index (e.g. Maxim et al., 2016; Nussbaumer et al., 2012; Tirado Herrero, 2017). The complexity of both the phenomenon and its measurement means that it is becoming increasingly important to study the profiles of energy-vulnerable households using different variables and methods (e.g. Belaïd, 2018; Fizaine and Kahouli, 2019; Primc, Slabe-Erker and Majcen, 2019a; Primc, Slabe-Erker and Majcen, 2019b). Several energy poverty drivers have been examined, including the socio-demographic characteristics of households, dwelling characteristics, macroeconomic performance and climate (e.g. Bollino and Botti, 2017; Bouzarovski and Tirado Herrero, 2017; Primc, Slabe-Erker and Majcen, 2019b). Namely, more research is needed to consider new variables, for example country- and spatial-specific variables, social differences (e.g. urban—rural, cultural preferences, marital status) that appeared to be important determinants of energy poverty in past studies (e.g. Primc, Slabe-Erker and Majcen, 2019a; Simcock et al., 2017).

5.2. Energy policy

By the same token, studying the consequences of and concepts related to energy/fuel poverty is equally important. The first and most fundamental is, of course, energy policy given that all of the research in the field is targeted at bringing an end to detecting energy-poor households and searching for effective policy measures to overcome what causes energy poverty (e.g. Dubois and Meier, 2016; Gregory and Sovacool, 2019; Kerr et al., 2019; Romero et al., 2018).

The uncertainties in energy resources, demand dynamics, energy inequality, climate change, and emission costs call for robust models able to support investment and decisions in planning and projecting supply capacity expansion (Diawuo et al., 2020). A smart power system planning ensures that an energy policy and investment decision recognises that supply- and demand-side management options are critical to improved power generation (Ouedraogo, 2017). A key element of future electricity supply planning is fuel diversification. Since the electric power system is moving away from the traditional forms, the development of indigenous renewable and clean energy sources, such as solar and wind, is critical for ensuring energy interdependence. A shift from the current situation is only possible with properly educated engineers and policymakers, who should be capable of dealing with a rapidly changing sector (Ruiz-Rivas et al., 2020). Therefore, appropriate educational contents are needed as the first step in bringing about the required changes.

Energy poverty carries serious micro- and macroeconomic implications for developing countries, ranging from difficulties in performing essential daily life functions and poor well-being, to sluggish economic growth and environmental unsustainability (Qurat-ul-Ann and Mirza, 2020; Samarakoon, 2019). With the expansion of research studies and literature reviews, we are moving ever closer to understanding of the true effect size of energy poverty in this part of the world. However, in recognition of the energy inequality around the world, further study of socio-technical systems and energy justice framed in local circumstances is essential for promoting and achieving sustainable energy for all.

5.3. Health and demographics

Paraphrasing the original sources leads us to conclude that energy poverty is a serious threat to public health around the world. Many studies prove that energy poverty is strongly associated with poorer mental and physical health (Oliveras et al., 2020a). Economic crises are also exacerbating energy poverty and its impact on health (Oliveras et al., 2020b). Therefore, studying the links between energy poverty and health, by emphasising demographic differences, has become a new direction in public health research. While the area is still relatively understudied, existing studies show that health sensitivity and mortality rates due to energy poverty are influenced by demographic differences (Jessel et al., 2019). In a few recent studies, a negative relationship was found between energy poverty and women's health (Abbas et al., 2020), the health of resident children (Mohan, 2021), and the health of the elderly (López-Bueno et al., 2020). Yet, identifying the effects of energy poverty on health continues to be challenging because the adverse effects of energy poverty on health might only be fully captured with the simultaneous use of objective and subjective measures of energy poverty (Llorca et al., 2018). As energy poverty and its impact on individuals is a growing health, social and policy issue, we expect this research area to be further strengthened in the future.

5.4. Energy efficiency and building stock

Attempts to reduce energy demand by physical re-design, utilising technical standards for thermal comfort as well as financial incentives are often less successful than theoretically expected, with the realised energy savings being 30%—40% less than anticipated (Galvin and Sunikka-Blank, 2017). This substantial lower energy saving in the building improvement is largely attributable to different understandings of thermal comfort between building energy stakeholders, including building designers, operators, managers, engineers, homeowners, occupants, industry, vendors and policymakers (Xu et al., 2020). Due to the variety of existing and emerging indoor comfort levels within and between households, energy use in identical homes can vary by a factor of 3—4 (Gram-Hanssen, 2010). This seems to reveal a poor understanding of the multidimensionality of retrofitting (de Feijter and van Vliet, 2021). While building envelope characteristics have a direct effect on the thermal performance, understanding of energy demand as being accommodated in wider socio-material systems would lead to a broader range of retrofit strategies. For instance, with an alternative and broader view, energy retrofitting would take account of social conventions, differentiated meanings of thermal comfort, location of the activity, moving around the house, food, bedding and clothing, instead of only building insulation or energy-saving appliances (Maller and Strengers, 2014). While building energy retrofitting gives substantial opportunities to reduce the level of building energy consumption and saves costs, prolonged exposure to poor hydrothermal conditions in buildings negatively impact people's health. Despite the significant contributions of previous studies, one issue that is still to be addressed is why and how stakeholders should collaborate to close this gap from a system perspective.

5.5. Emissions

In the past few decades, many attempts have been made globally to curb the increasing greenhouse gas (GHG) emissions, leading to several multilateral climate agreements, including the recent 2015 Paris Agreement on climate change. While considerable success has been achieved in developed countries, China and other emerging economies have put pressure on emissions growth. This means there is a need to pay attention to every single country or region across the globe and its efforts to ameliorate energy poverty using low carbon technologies (Lin and Agyeman, 2020). For example, a recent study by Setyowati (2020) examines Indonesia's efforts to realise its vision of energy justice by focusing on private sector participation and investment in renewable rural electrification. On a similar note, a study by Shane and Gheewala (2017) quantifies the environmental benefits that have been missed in Zambia by not fully adopting biogas production. Biogas production from biomass can help immensely in solving ecological problems and in bringing about environmental sustainability (Hamid and Blanchard, 2018). On this basis, a framework for identifying and assessing emissions from different sources, such as livestock waste, crop residues and forest residues, should be developed and systematic methodologies for assessing the emissions created (Briones-Hidrovo et al., 2021; Shane and Gheewala, 2017). Once this is achieved, interested parties should have access to the database and use it to help formulate policies.

6. Conclusion and limitations

As the field continues to mature, we expect the dominant clusters to become bigger and more closely connected while at the same time new clusters will emerge. Some of these newcomers identified in Section 4 will begin to grow and new fields will start to develop, such as those related to sociology (e.g. social justice, behavioural economics, homelessness, minority groups, gender differences), various public policies (e.g. climate policy, health policy, social policy, energy policy, economic policy), architecture (e.g. retrofitting, greenspace for mitigating urban heat, smart homes), engineering (e.g. rural electrification, insulation, carbon-based chemicals for fuel production), and novel methods in research like stochastic modelling and the introduction of data loggers for data collection. Therefore, at the research level, there is a need to promote a holistic interpretation and the merging of concepts in light of their harmony and conflicts. In other words, the energy (fuel) poverty phenomenon cannot be studied independently from other closely related identified disciplines. Increased international collaboration entailing the exchange of knowledge among scholars from various disciplines is thus strongly needed. In addition, opportunities also exist in econometric modelling and other advanced statistical techniques that better mimic the complex reality and offer effective solutions.

A comparison of the concepts and their evolution gives an important basis to further inform scholars and policymakers. Despite often being used as synonyms, the differences between energy and fuel poverty have been made explicit by numerous authors in the literature (e.g. Li et al., 2014; Castaño-Rosa et al., 2019). Yet, inconsistent use of the terms further constrains the efficacy of their use in practice. By analysing both terms, the current study sheds light on the areas and motivations of their use. Based on the investigated literature, the paper argues that the area's current development seems to be reasonable and that it is hence appropriate to maintain the diversity seen in the definition of these terms. This provides the leeway needed to design a wide range of strategies to suit the specific needs and settings which policymakers across different countries, both developed and less developed, can adopt.

Like with most studies, ours is not immune to certain limitations. These largely concern the fact that our database is drawn exclusively from the Scopus database, meaning we were unable to systematically analyse the selection bias and therefore ran the risk of possibly omitting relevant articles from the analysis. Another limit concerns the selection of the keywords. Namely, we focussed solely on energy and fuel poverty. Recently, new terminology has started to appear in the literature, such as electricity poverty, lighting poverty and transport poverty, which might be included in future analyses. In addition, the analysis could be extended to other databases, quantitative or qualitative tools and types of documents. Still, despite the above limitations, we were able to provide a robust and data-driven map of the scientific landscape of energy and fuel poverty research and thereby add relevant information with respect to the further development of the respective fields.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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