Review Article

Bibliometric analysis of global research on cities response to climate change through renewable energy

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ABSTRACT

The intricate connection between energy and urbanisation leads to climate change when inadequately addressed and regrettably, evidence of such has already arisen. As part of the progress towards a sustainable environment, researchers are focusing more on reducing greenhouse gas emissions in cities, which have become major contributors. Meanwhile, renewable energy sources have emerged as a key solution to addressing climate change. This study employed a bibliometric approach to analyze trends in publications and research on the link between climate change and renewable energies from 1992 to 2022, leveraging the Scopus database. The analysis revealed that China, the United States and the United Kingdom were the top contributors in this field. The findings highlighted that China, the U.S. and the U.K. emerged as dominant contributors to this field, with a sharp rise in publication output between 1992 and 2022. This growth was particularly noticeable following the publication of the fourth Intergovernmental Panel on Climate Change Assessment Report in 2007 and the ratification of the Paris Agreement. Furthermore, this study has identified critical areas of focus that relate to renewable energy sources, energy efficiency, energy policy and urban climate change mitigation. This underscores the urgent need to replace fossil fuels with cleaner energy alternatives in cities. Researchers and policy-makers at various levels need to prioritise these areas of research in order to develop effective policies and cut urban greenhouse gas emissions.

Keywords: Bibliometric analysis, Renewable energy, Urban Climate change.

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INTRODUCTION

Over the past few years, the most pressing concern has probably been how to provide hope for a sustainable world amidst various environmental challenges ranging from global warming, ozone layer depletion, pollution, loss of biodiversity and diseases. Climate change induced by human activities, appears to be the worst driver of these disruptions, affecting all countries in one way or another. In light of these circumstances, there are only two options available to humankind. Either to sit back and suffer from the consequences of climate change or to face its effects by relying on adaptation and mitigation measures. However, owing

to human nature, the second option would be more beneficial to people and their environment. Accordingly, in the 2015 Paris Agreement, countries are urged to implement measures through their Nationally Determined Contributions (NDCs) to prevent adverse impacts of climate change by maintaining global temperature rise below 2°C, with efforts to limit the increase to 1.5°C (UNFCCC, 2015). In compliance with the Paris Agreement, several efforts have been made worldwide to continue limiting GHG emissions. Therefore, it is essential to provide effective and progressive solutions and address the areas where action should be taken. In response to climate change concerns, international organizations and academic institutions have emphasized urban environmental governance (Wu *et al.*, 2018).

For the first time, urban areas represent roughly half of the global population and this proportion is projected to increase over time, reaching 60% by 2030 and 70% by 2050 (WHO, 2018). Cities consume approximately 60-80% of energy worldwide

and contribute approximately the same amount of global CO_2 emissions and thus to climate change (OECD, 2010). Consequently, cities are experiencing potential consequences of climate change, such as extreme heat, sea-level rise, floods, air and water pollution and diseases. Aside from contributing to anthropogenic global emissions, cities are also extremely sensitive to climate change and extreme weather (UN-HABITAT, 2019). Furthermore, climate change projections indicate that the average temperature will increase by between 2 and 8ºC in cities around the world over the next few decades, resulting in severe and more frequent droughts in Europe, South America and Africa (Huang *et al*., 2019). Over the last few decades, research has increasingly focused on how cities can respond to climate change, underscoring the city's potential significance in addressing this global issue. Local governments wield substantial influence over land use planning, waste management, transportation and energy consumption-all key contributors to greenhouse gas emissions (Agyeman *et al*., 1998; Bulkeley, 2000; Collier, 1997; Deangelo and Danny Harvey, 1998; Kates *et al*., 1998; Rayner and Malone, 1997). Despite the array of possible actions, it is crucial to prioritize those that are urgent and most beneficial. Therefore, efforts should focus on sustainable solutions that minimize long-term adaptation costs to ensure that responses to climate change are effective. Renewable energy sources are highlighted as among the most cost-effective and profitable options to achieve this objective (Dincer, 2000).

Renewable energy sources provide an adaptation option for countries that rely on natural resources to meet their energy demands (Sapkota *et al*., 2014). Moreover, renewable energy sources are being sought for carbon neutrality, placing them at the forefront of reducing emissions (Jin, 2022; Surendra *et al*., 2011; Q. Zhao, 2021). Furthermore, the Intergovernmental Panel on Climate Change the IPCC has underscored the importance of renewable energy in climate change mitigation by replacing fossil fuel-based emissions (IPCC, 2011). A significant body of research has explored the role of renewable energy technologies in cities' adaptation and mitigation efforts against climate change, utilizing diverse approaches and techniques. For instance, (Salvia *et al*., 2021) analysed the mitigation targets for 327 European cities that attempted to reduce greenhouse emissions at city level to keep global warming to less than 2ºC. Similarly, (Farzaneh, 2018) performed research on clean energy strategies for Asian cities aimed at cutting emissions through the use of renewable energy sources. Moreover, Žičkienė *et al*. (2022)reviewed the state of Action Plans of several Lithuanian municipalities aimed at reducing GHG emissions and promoting sustainable energy technologies. Going beyond, there are also considerable related review papers that have been published on this topic. For example, (Foley *et al*., 2017) reviewed 22 articles focused on energy sources and its applications, as well as policy and the environment. Furthermore, (Mauree *et al*., 2019) reviewed the city environment alongside its energy sustainability to ensure climate adaptation.

However, very few studies have been dedicated to bibliometric analysis methods to measure and analyse scientific publications on the topic in cities worldwide. Therefore, the goal of this study is to carry out a bibliometric analysis of global research on cities responding to climate change through renewable energy. The key questions addressed are: (1) What is the annual publication output on this topic? (2) Which journals, articles, authors and countries are the most impactful? (3) What are the trending research topics and how have they evolved over time?

With the aim of reaching this goal and responding to the prior interrogations. This work employed bibliometric analysis, which involves mapping books and any other communication media using mathematical and statistical methods (Pritchard, 1969). The application of bibliometric analysis is gradually extending to all disciplines (Basile *et al*., 2022). Indeed, with a large number of publications, it has become an effective tool for pinpointing research trends and strengths within specific topics (Fahimnia *et al*., 2015). This paper is divided into three main sections: the methodology section explains the data extraction and analysis techniques, the results and discussion provide insights into the findings and the concluding section summarizes the research.
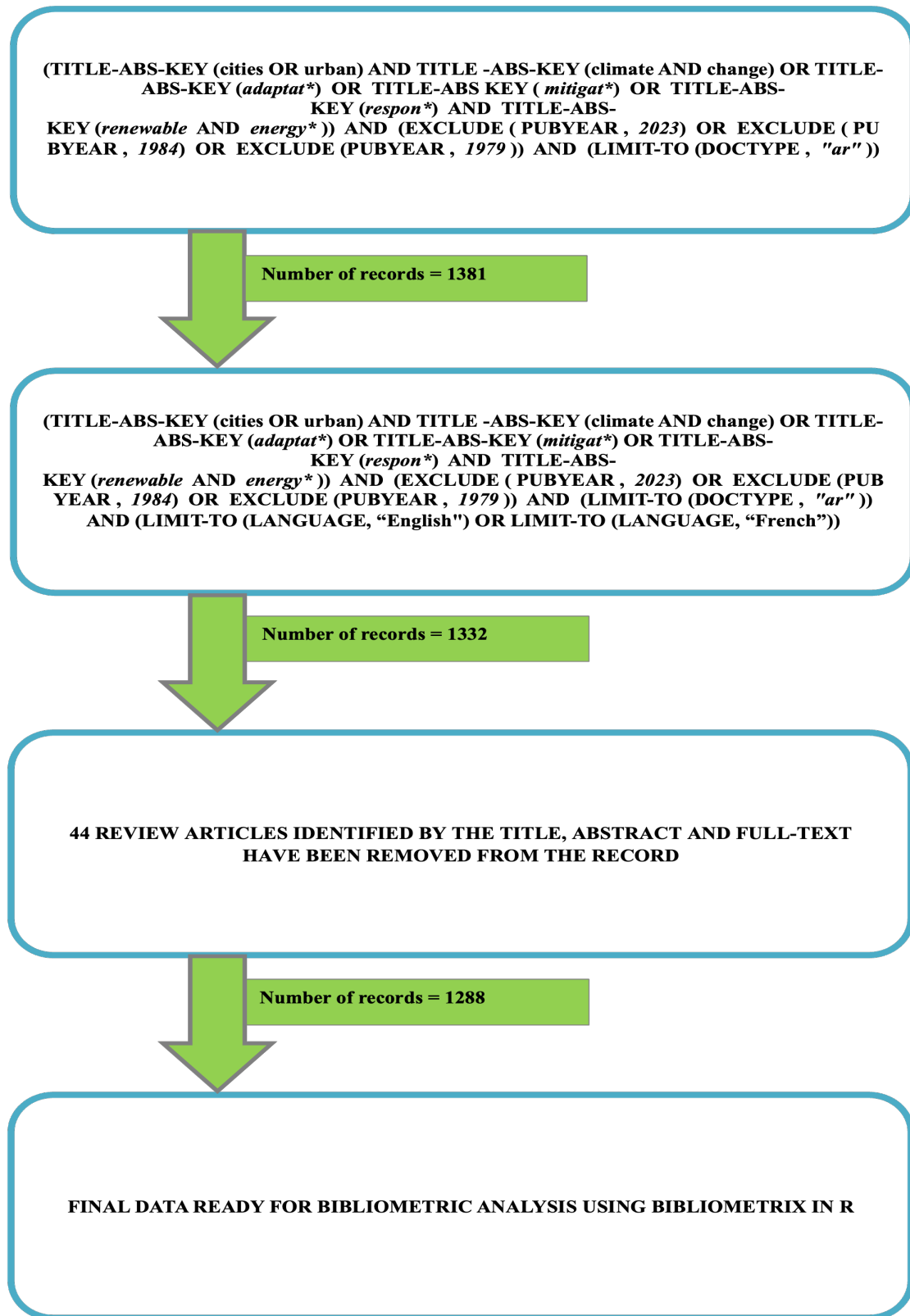
MATERIALS AND METHODS

Data retrieval procedure

Several online databases, such as WoS, Scopus, PubMed, ERIC, IEEE Xplore, ScienceDirect, DOAJ and JSTOR, can be used for bibliometric analysis. However, created by Elsevier Science in 2004, the Scopus database is considered the most extensive source of abstracts and citations, encompassing a wide array of subject areas (Alsharif and Baharun, 2020; Md Khudzari *et al*., 2018). Therefore, for its extensive coverage of top-notch, peer-reviewed literature on the subject, the data were retrieved from Scopus (http ://www.scopus.com) on May 2, 2024. The search criteria included the following terms "TITLE-ABS-KEY (cities OR urban) AND (climate change) OR (adaptat*) OR (mitigat*) OR (respon*) AND (renewable energy*))". The search was restricted to articles written in English and French and the retrieval time span was 1992-2022. A total of 1332 articles were identified. The records include the title, author, abstract, keywords and references. Furthermore, a critical screening of the 1,332 papers was performed by reviewing the titles, abstracts and full texts to eliminate out of database any review articles prior to analysis. Using this process, 44 review articles were identified and excluded. This final selection process resulted in 1288 articles, which were then exported in the CSV format to be further processed.

Bibliometric analysis

Bibliometrics are generally categorized into 2 primary fields "performance analysis and scientific mapping analysis" (Cobo *et al*., 2011; Noyons *et al*., 1999). Performance analysis focuses on evaluating various scientific entities (such as researchers,

(TITLE-ABS-KEY (cities OR urban) AND TITLE -ABS-KEY (climate AND change) OR TITLE-ABS-KEY (*adaptat**) OR TITLE-ABS KEY (*mitigat**) OR TITLE-ABS-KEY (*respon**) AND TITLE-ABS-KEY (*renewable* AND *energy**)) AND (EXCLUDE (PUBYEAR , *2023*) OR EXCLUDE (PUBYEAR , *1984*) OR EXCLUDE (PUBYEAR , *1979*)) AND (LIMIT-TO (DOCTYPE , *"ar"*))

Number of records = 1381

(TITLE-ABS-KEY (cities OR urban) AND TITLE -ABS-KEY (climate AND change) OR TITLE-ABS-KEY (*adaptat**) OR TITLE-ABS-KEY (*mitigat**) OR TITLE-ABS-KEY (*respon**) AND TITLE-ABS-KEY (*renewable* AND *energy**)) AND (EXCLUDE (PUBYEAR , *2023*) OR EXCLUDE (PUBYEAR , *1984*) OR EXCLUDE (PUBYEAR , *1979*)) AND (LIMIT-TO (DOCTYPE , *"ar"*)) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "French"))

Number of records = 1332

44 REVIEW ARTICLES IDENTIFIED BY THE TITLE, ABSTRACT AND FULL-TEXT HAVE BEEN REMOVED FROM THE RECORD

Number of records = 1288

FINAL DATA READY FOR BIBLIOMETRIC ANALYSIS USING BIBLIOMETRIX IN R

Figure 1: Workflow of the Methodological Approach.

institutions and countries) through bibliometric indices derived from publications and citations (Narin and Hamilton, 1996). In contrast, scientific mapping analysis examines the cognitive and social structure of a specific research field through topological and temporal mapping (Cobo *et al.*, 2011; Small, 1999). Both subjects were covered in this study by applying co-authorship, citation and co-occurrence analyses. The research methodology is illustrated in Figure 1. Furthermore, many popular software packages,

including CiteSpace, Gephi, Sci2, Publish or Perish, HistCite, BibExcel and VOS viewer, have been designed for bibliometric analysis, each offering distinct features and limitations. However, the choice of software can also depend on the compatibility of the operating system used, i.e., Mac OS, Windows or Linux. Although a large majority of science mapping tools are supported for all three operating systems, some are only available for Windows, such as BibExcel and CiteSpcace. "Bibliometrix" is a newly developed open-source software in the R environment by Aria and Cuccurullo (2017) that has recently become widely utilized for systematic mapping of scientific literature. Therefore, in this study, Bibliometrix was used to construct and visualise a network analysis of publications.

RESULTS AND DISCUSSION

Publication trend

A total number of 1,320 research articles have been published over the period 1992 to 2022. The trend of publications related to cities responding to climate change using renewable energy is illustrated in Figure 2. The results revealed an overall increase in annual publications between 1992 and 2022. Such a trend might elucidate the increasing global interest in climate change adaptation and mitigation measures using renewable energy sources. Indeed, growth in publications has been observed over two time periods, notably a period of relatively sluggish publication growth from 1992 to 2006 characterised by an annual

growth rate of 36.8%. Subsequently, a fast-growing trend between 2007 to 2022, marked with an annual growth rate of 47.2%, suggesting the greater attention paid to this subject over the last 16 years. Furthermore, the rise in publications between 2007 and 2022 reflects the growing global awareness and concern about climate change, particularly through the publication of the IPCC's Fourth Assessment Report (IPCC, 2007) and the facilitation of access to funding for researchers with the establishment of the International Renewable Energy Agency (IRENA) in 2009. In 2015, the Paris Agreement was established as a comprehensive framework, urging countries to take proactive steps for climate actions that will reduce emissions and build climate resilience. Likewise, Sustainable Development Goals 7 and 13 call for clean and affordable energy for all and climate change mitigation, respectively (UNSDG, 2015). Furthermore, with cities becoming a hotbed of climate action (Tadashi Matsumoto *et al.*, 2019), due to their growing population and energy consumption, the volume of publications focusing on climate change and renewable energy has grown over time.

Preferred journals

The findings of this study revealed that the ten most prolific journals belong to two different publishers (Elsevier and Multidisciplinary Digital Publishing). The two leading journals were published by Multidisciplinary Digital Publishing and the remaining eight were published by Elsevier (see Table 1). The most productive journal was Energies, with 73 publications and
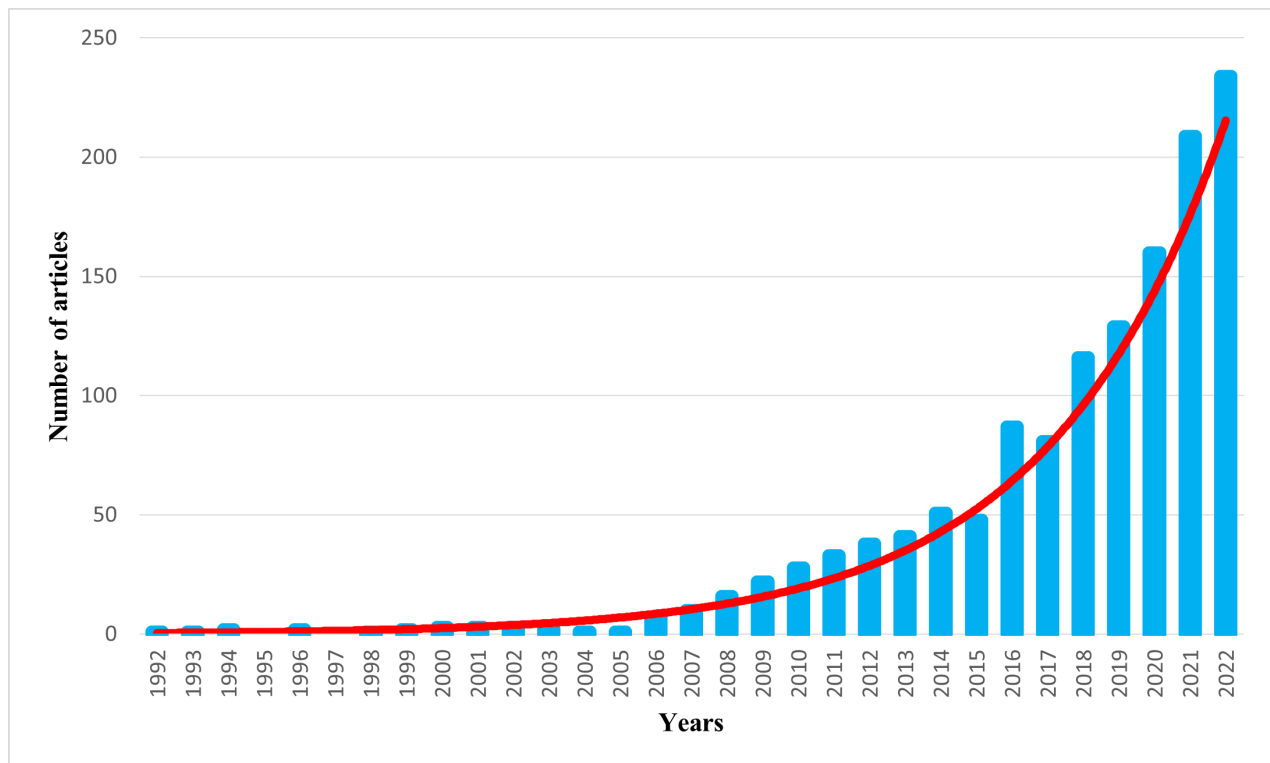

Figure 2: Trend chart of annual publications between 1992-2022 (Scopus database).

718 citations, then Sustainability, with 64 publications and 790 citations and Journal of Cleaner Production, with 52 publications and 1794 citations. Applied Energy was the fourth most productive journal, with 47 publications and 2017 citations. Although Energy Policy occupied the fifth position with 39 publications, it had the highest total citations (2759). Other important journals include Renewable Energy, Energy, Renewable and Sustainable Energy Reviews, Science of the Total Environment and Energy Conversion and Management.

Leading countries

From a global perspective, 78 countries have contributed papers on this topic. Figure 3 lists the leading 19 countries contributing actively to the growth of the given topic, where authors collaborated from Single-Country Publications (SCP) to Multiple-Country Publications (MCP) with the sum of SCP and MCP being of the total articles published. China, the world's largest emitter of greenhouse gases (CAIT, 2015; Ge *et al.*, 2014), contributed to the largest number of publications with 415 articles, accounting

Table 1: The 10 most productive journals, 1992-2022.

Journal	NP	TC	PY_start	Publisher
Energies	73	718	2012	MDPI
Sustainability (Switzerland)	64	790	2013	MDPI
Journal of Cleaner Production	52	1794	2013	Elsevier
Applied Energy	47	2017	2012	Elsevier
Energy Policy	39	2759	2003	Elsevier
Renewable Energy	38	1503	1993	Elsevier
Energy	23	861	2013	Elsevier
Renewable and Sustainable Energy Reviews	19	487	2019	Elsevier
Science of the Total Environment	18	771	2016	Elsevier
Energy Conversion and Management	15	687	2007	Elsevier

TC: total number of citations; NP: count of publications; PY_start: year of initial publication.
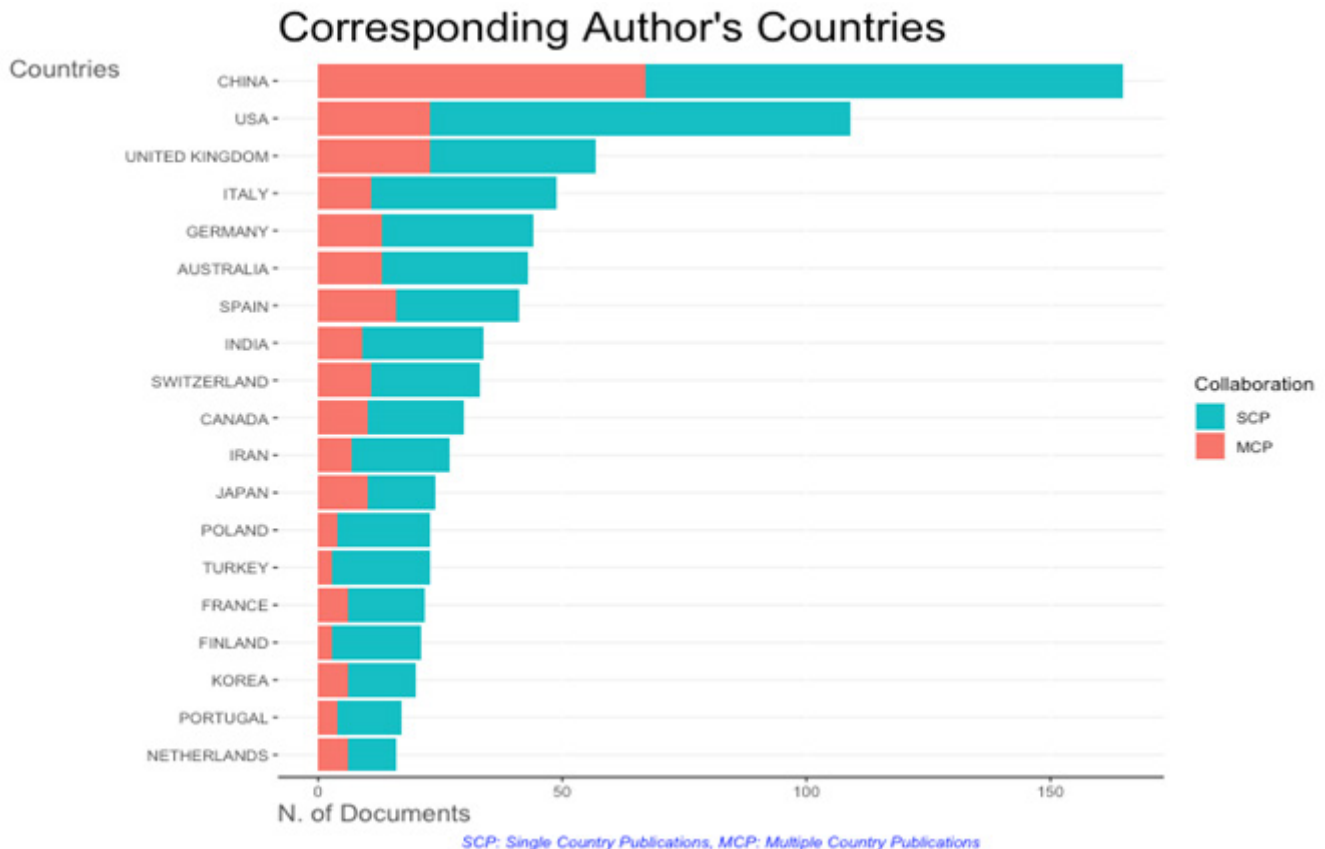
Figure 3: The top 19 most productive countries.

for 40% of global publications, followed by the United States, accounting for 21% of the total global publications. The United Kingdom is ranked the third most productive country. Although China and the United States were the most active countries in promoting the transition to renewable energy to tackle climate change, other countries, such as Italy, Germany, Australia, Spain and India, are also productive in such field. Furthermore, it is worth pointing out that none of African countries is among the top 19 contributing countries, while most African countries in Africa are bursting with potential in renewable energy (IRENA and AfDB, 2022). The reason behind China's interest comes from the fact that the largest GHG emitter today needs to take major responsibilities in responding to climate change by providing additional research funding to support relevant studies, leading to a growing volume of research papers. In addition, Figure 4 shows country's scientific production. On the world map, each country is coloured according to the number of articles published, while countries in grey have no published articles in the field. More articles were published in Asia, America, Europe and Oceania than in any other region. Among the 86 countries that produce papers worldwide, only 14 are located in Africa. Egypt, South Africa, Nigeria and Algeria are leading African countries conducting research on this topic. This reflects their commitment to accelerate renewable energy adoption and their energy transition efforts to mitigate climate change, while 40 other African countries have yet to intensify research on renewable energy for reducing greenhouse gas emissions.

Main authors

According to the results, 4138 authors produced 1,288 publications. Table 2 shows the 10 main authors who contributed to the publication of more articles on the subject, including various bibliometric indicators, such as publication count, total citations, h-index and the year of their first publication. The most productive author is Liu J with 14 records, followed by Wang S and Wang X with 10 publications each. Parallelly, Li M receives more total citations (294), followed Wang X and Wang S with 294 and 285 total citations, respectively. The most relevant authors are from China. This demonstrates China's serious participation in mitigating greenhouse gas emissions through rigorous policies to foster low-carbon solutions. Indeed, several commentators have argued that China remains the world's leading mitigation country (Biesecker and Watt, 2017; H. Zhao, 2017).

Most cited papers

The ten most cited papers from 1992 to 2022 are summarised in Table 3. Consistent with the results, the most cited paper was published by Dunn Seth and has 1140 citations (Dunn, 2002). The author discusses hydrogen futures for a sustainable energy system and how to strengthen governmental regulations and educational initiatives. The paper with the second highest citation count, totalling 625 citations, was authored by Shafiei Sahar. This paper examined the use of both renewable and non-renewable energy sources and their associated carbon dioxide emissions in OECD countries. The author revealed that using non-renewable energy increases the amount of CO_2 emitted, while a shift to renewable energy decreases it (Shafiei and Salim, 2014). The third most cited paper was from Sureshkumar K and addressed comparative measures of performance and emissions between *Pongamia pinnata* Methyl Ester (PPME), a renewable and sustainable source of biofuel and its blends with diesel. The research revealed that diesel blends containing up to 40% PPME
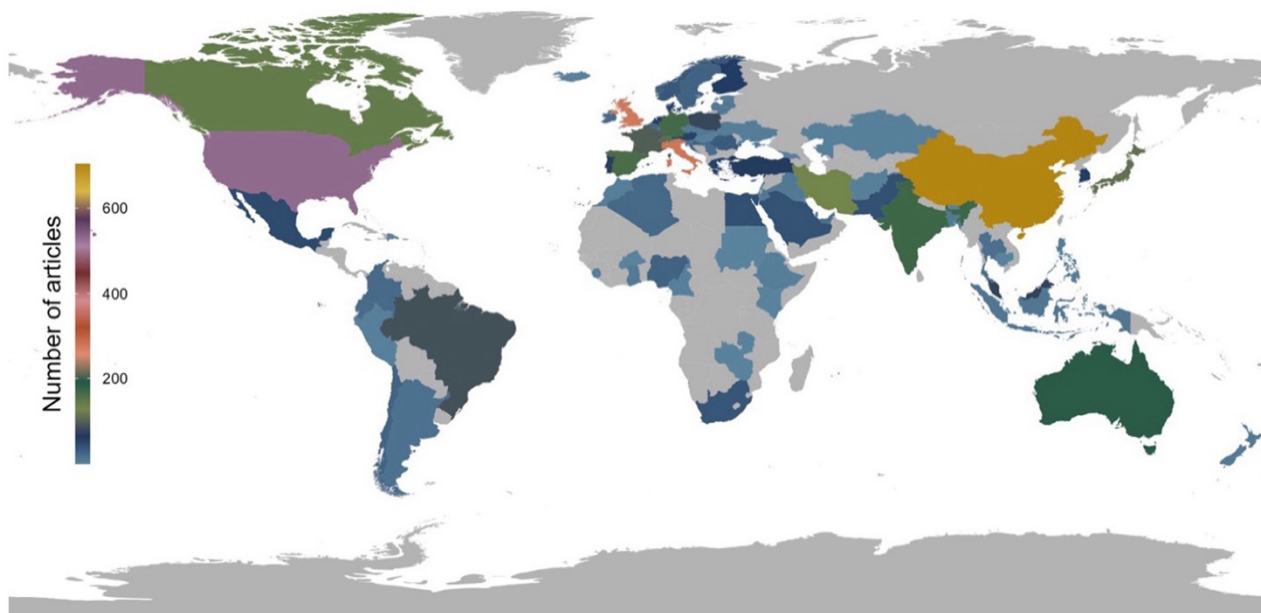

Figure 4: Country scientific production.

deliver superior engine performance and emission reductions (Sureshkumar *et al.*, 2008). Likewise, the fourth most highly cited paper was published by Akbari Hashem, who applied the degree days method to evaluate heat-island mitigation strategies in five U.S. cities. The results showed that under certain conditions, the implementation of heat-island reduction strategies can lead to significant energy savings in cities (Akbari and Konopacki, 2005). Similar considerations can also be drawn when looking at the last six most-cited papers, all targeting sustainable solutions for addressing energy issues in urban settings to lower greenhouse gas emissions. Furthermore, it is also noteworthy that the ten most cited papers were published in peer-reviewed journals, showing the visibility that the journals offer to published papers. Another interesting fact is that the top six most cited papers were published in Elsevier journals. These results indicate the relevance of targeting Elsevier journals when publishing papers related to urban climate change and renewable energy. Although comforting, there is ample evidence that a large proportion of highly cited papers may not always come from prestigious journals, as evidenced by various databases. A majority of researchers do not have the privilege of accessing papers that are not open access and equally not every author can publish in an open access journal. As a result, there's a limit, since it's only when an article is read that it is quoted. For instance, based on Google Scholar data, (Acharya *et al.*, 2014) found a considerable growth in highly cited papers published in non-elite journals from the period 1995 to 2013 driven by the convenience of retrieving articles in non-elite journals compared to tracking articles in elite journals.

Keyword co-occurrence analysis

The term "keyword analysis" is considered to be an approach that identifies specific subfields within a research area and examines their features and trends (Lee *et al.*, 2018). It also outlines global research trends (Liu *et al.*, 2016; Xu, Goswami, *et al.*, 2016; Xu, Wang, *et al.*, 2016), highlights emerging themes (W. Zhao *et al.*, 2018), disruptive topics (Dotsika and Watkins, 2017) and searches for patterns of collaboration between authors (Newman, 2001b, 2001a). Furthermore, (Wei *et al.*, 2015) have also highlighted the necessity of studying keywords to better grasp a topic within a particular region or timeframe. Consequently, keyword co-occurrence analysis was used in this paper to further

Table 2: The 10 most prominent authors.

ID	Author	h_index	TC	NP	PY_start
1	Liu J	6	231	14	2013
2	Wang S	7	281	10	2011
3	Wang X	6	285	10	2015
4	Wang Y	6	201	9	2007
5	Zhou Y	6	226	9	2014
6	Huang GH	8	273	8	2016
7	Li X	6	93	8	2011
8	Li YP	7	260	7	2016
9	Li M	5	294	5	2012
10	Yu L	5	217	5	2016

TC: Total citations.

Table 3: The top 10 highly cited documents.

| ID	Paper	Journal	Year	TC
1	Dunn S	International Journal of Hydrogen Energy	2002	1140
2	Shafiei S	Energy Policy	2014	625
3	Sureshkumar K	Renewable Energy	2008	289
4	Akbari H	Energy Policy	2005	274
5	Huisingh D	Journal of Cleaner Production	2015	250
6	Balduzzi F	Applied Energy	2012	223
7	Strunz K	IEEE Journal of Emerging and Selected Topics in Power Electronics	2014	214
8	Khan I	Science of the Total Environment	2021	212
9	Santamouris M	Solar Energy	2016	205
10	Perera ATD	Nature Energy	2020	191

TC: Total citations.
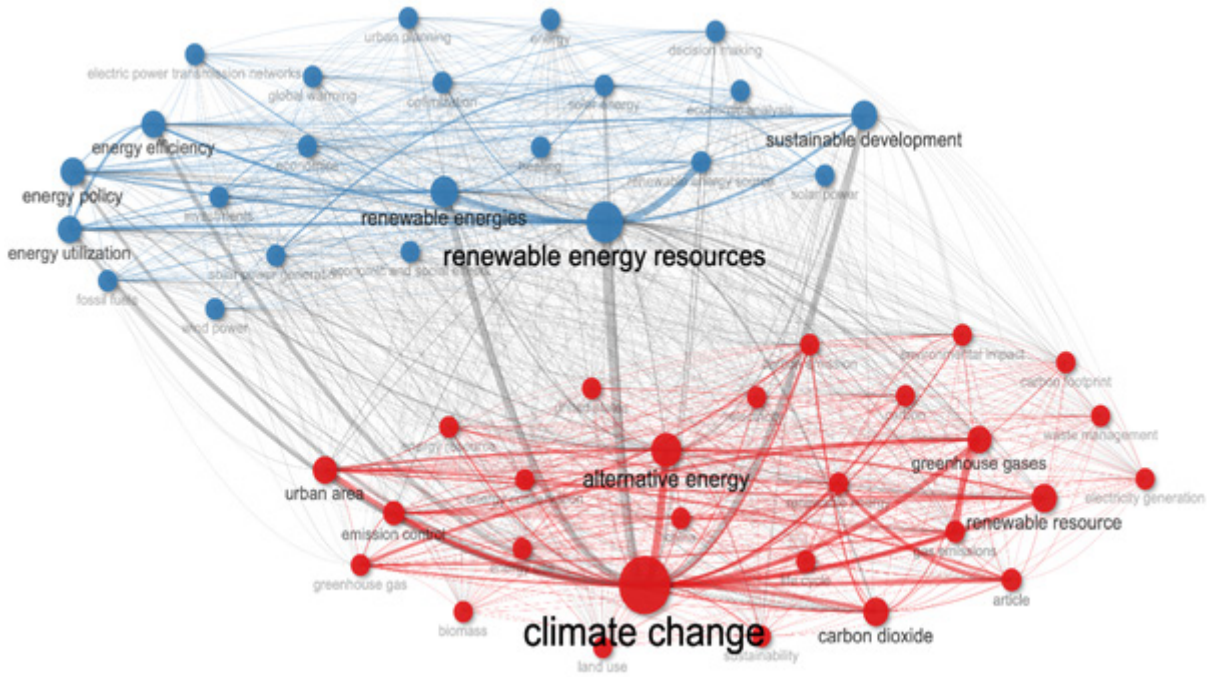
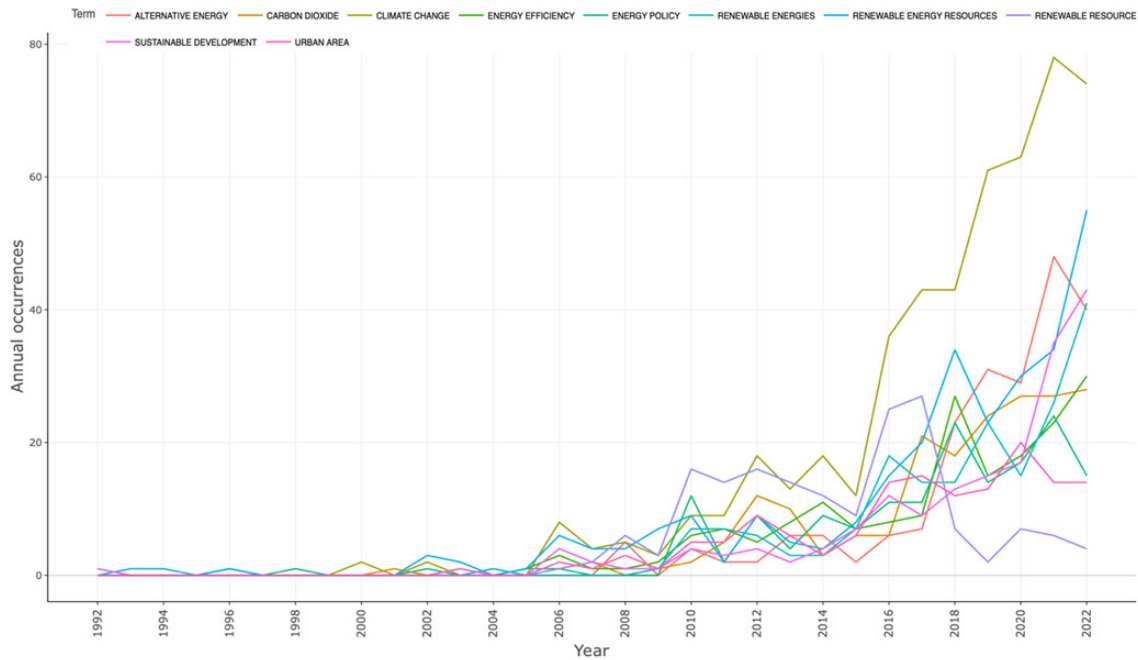**Figure 5:** Author keyword co-occurrence analysis.

Figure 6: Evolution of author keywords over time.

understand urban climate change and renewable energy trends. Figure 5 shows the most relevant research themes over the study period (1992-2022). The search themes are marked with various colors, making it easier to link relevant keywords and distinguish between different clusters. The line thickness between nodes reflects the strength of the connections, with thicker lines showing stronger relationships. Additionally, the size of the nodes represents term frequency, where larger nodes indicate terms that

frequently appear in titles and abstracts concerning urban climate change and renewable energy.

The analysis revealed two clusters representing the relationships between the keywords. The two main keywords connecting the network are "climate change" and "renewable energy resources". The first cluster (red) focuses on climate change, including drivers and the solutions that could be considered to address its consequences. Unsurprisingly, climate change remains a

Figure 7: Authors keywords.

Table 4: The 10 keywords of the authors that have been used most frequently during the last three decades.

ID	1992 - 2001		2002-2011		2012-2022	
1	Renewable energy resources	23	Renewable energy resources	198	Climate change	2447
2	Energy efficiency	16	Climate change	174	Renewable energy resources	1400
3	Climate change	14	Renewable resource	104	Renewable resource	1386
4	Sustainable development	10	Energy efficiency	79	Energy efficiency	978
5	Energy policy	10	Energy policy	69	Carbon dioxide	967
6	Carbon dioxide	1	Sustainable development	62	Energy policy	913
7	Alternative energy	0	Urban area	56	Renewable energies	865
8	Renewable energies	0	Carbon dioxide	46	Urban area	834
9	Renewable resource	0	Renewable energies	32	Alternative energy	819
10	Urban area	0	Alternative energy	30	Sustainable development	759

dominant topic, as numerous studies have recently focused on this issue. (Smith *et al.*, 2009) have reported that since the IPCC's Third Assessment Report (TAR), stronger evidence has emerged regarding the observed impacts of climate change on vulnerable systems, with increasingly severe consequences as temperatures continue to rise. Climate change is an emerging global reality that impacts most domains of social life (Henderson *et al.*, 2017). What is continuously needed is a clear, sober-minded adherence to cross-governmental efforts and policies to leverage them into sustainable resolutions. The second cluster (blue) illustrates that switching into renewable energy sources could lead to sustainable development by reducing the level of greenhouse gas emissions.

Following the Kyoto Protocol, many countries embarked on energy research to address climate change, with a focus on renewable energy as a low-carbon alternative (Mao *et al.*, 2018).

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regarding the observed impacts of climate change on vulnerable systems, with increasingly severe consequences as temperatures continue to rise. Climate change is an emerging global reality that impacts most domains of social life (Henderson *et al.*, 2017). What is continuously needed is a clear, sober-minded adherence to cross-governmental efforts and policies to leverage them into sustainable resolutions. The second cluster (blue) illustrates that switching into renewable energy sources could lead to sustainable development by reducing the level of greenhouse gas emissions. Following the Kyoto Protocol, many countries embarked on energy research to address climate change, with a focus on renewable energy as a low-carbon alternative (Mao *et al.*, 2018).

Future research directions

Figure 6 shows the author's keyword growth over time. Referring to the Figure, it is noticeable that the authors' keywords addressing urban climate change and energy solutions have increased over time. Although keyword occurrence may span two time periods, between 1992 and 2006, where the evolution of keywords was very low and between 2007 and 2022, where a high evolution of keywords was observed.

Evidently, terms such as "climate change" and "renewable energy resources" have been extensively employed for over a decade since 2007, with a remarkable exponential growth between 2015 and 2022. After the IPCC's Fourth Assessment Report was published, confirming that the increase in global temperatures was largely due to fossil fuel combustion and emphasizing the significance of energy efficiency, renewable energy, nuclear power, carbon capture, storage and land management (IPCC, 2007), several authors many researchers began focusing on climate change mitigation. This led to a notable rise in the use of the keywords "climate change" and "renewable energy resources". Additionally, research advancements in these areas were further stimulated by the release of the IPCC's Special Report on renewable energy, encouraging the implementation of policies by governments to hasten renewable energy adoption and reduce global greenhouse gas emissions (IPCC, 2011) and subsequently with IPCC's Fifth Assessment Report on climate change (Agrawal *et al.*, 2014). This sequence of events likely explains the rapid increase in the use of these keywords since 2015. It also stands out that despite a growth of keywords over the years; the frequency of the term "climate change" is far higher than "renewable energy resources". This is likely due to the lower rate of growth in interdisciplinary renewable energy research than in climate change research (Xu, Goswami, *et al.*, 2016), possibly because knowledge from climate change science has driven the subsequent growth of renewable energy.

As discussed in the previous Figure, Figure 7 further confirms that climate change and renewable energy resources have been consistently at the core of the literature over the last three decades. Additional words such as "alternative energy", "renewable resource", "renewable energies", "energy efficiency", "carbon dioxide", "energy policy", "sustainable development" and "urban area", have also been frequently discussed in the literature, broadly providing evidence that embracing renewable energy can certainly mitigate greenhouse gas emissions in urban areas. However, such an adoption is often supported by effective government policies. More recently, the connection between "climate change" and "renewable energy" has become difficult to break down and it could be that both words are linked forever. This connection has been facilitated over the years by a few pioneers, including the Intergovernmental Panel on Climate Change (IPCC, 2011; IRENA, 2021), in promoting the use of renewable energy to tackle climate change. Moreover, the 10 most commonly used author keywords over the past three decades have been analyzed and are listed in Table 4. Between 1992 and 2001, the frequency of occurrence of the following keywords was as follows: renewable energy resources (23), energy efficiency (16), climate change (14), sustainable development (10), energy policy (10) and carbon dioxide (1). After the IPCC's 1990 report, which underscored the scientific consensus on human-induced climate change (Houghton *et al.*, 1992), the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992, establishing a global framework to combat climate change (UNFCCC, 2022).

Meanwhile, all nations have acknowledged the importance of renewable energy in their sustainable development strategies (Mak *et al.*, 1996), representing the first step toward building bridges between climate change and renewable energy. The second decade refers to both climate change and renewable energy resources, with a growth rate of almost 10 times that of the previous decade and the emergence of keywords such as urban areas and carbon dioxide. Hence, there is a clear trend in the association between cities and greenhouse gas emissions. Going beyond, the occurrence of carbon dioxide and the absence of methane and nitrous oxide in the keywords are due to the sobering fact that the amount has been increasing steadily. Similar arguments were also made by (Gunter *et al.*, 1998). Furthermore, (Maheshwari *et al.*, 2020) also found significant global climate changes between 1986 and 2011 compared to 1960 to 1985, exacerbated by urbanization. In the last decade, climate change discussions have increasingly focused on urban areas as the main contributors to it and how to address the problem by relying on the advantages of renewable energy sources and energy efficiency. Further evidence emerged in the special IPCC report on global warming of 1.5ºC, which unequivocally calls for an immediate and large-scale switch to renewable energies and energy efficiency (IPCC SR 1.5º, 2018). Comparable findings have been presented by authors (Sun *et al.*, 2022; Zhang *et al.*, 2022).

CONCLUSION

In this paper, a comprehensive bibliometric analysis was conducted on global research addressing urban climate change responses through renewable energy adoption, using R-based Bibliometrix software. A total of 1,288 peer-reviewed publications from the Scopus database, spanning from 1992 to 2022, were analyzed. The results revealed that the scope of research on the implementation of renewable energy sources to mitigate urban greenhouse gas emissions has become broader and more extensive over the past three decades. China emerges as the leading contributor with 415 papers, representing 40% of the total output, followed by the U.S. and the U.K. However, no African country was listed among the top 19 contributors, suggesting that much effort remains to be made in Africa to implement renewable energy sources.

Furthermore, the study revealed that among the ten leading journals that publish in the field, the first two belong to the Multidisciplinary Digital Publishing Institute (MDPI) and the rest to Elsevier. Liu J emerged as the leading contributor, with 14 publications, followed by Wang S and Wang X. At the same time, Li M receives the most citations (294), followed by Wang X and Wang S with 294 and 285 citations respectively. The analysis also shows that the most cited article with 1140 citations is titled "hydrogen futures: toward a sustainable energy system," authored by Dunn Seth and published in the International Journal of Hydrogen Energy in 2002. So far, the most important research topics have been renewable energy sources, along with energy efficiency and energy policy and urban climate change mitigation. This reflects an ongoing transition towards greater reliance on renewable energy to replace fossil fuels, especially in major cities, to address climate challenges The results of this study offer valuable insights and guidance for researchers and policymakers to join global efforts to combat climate change in cities by strengthening their energy policies to ensure a swift adoption of renewable energy.

Despite the advantages of using bibliometric analysis methods, this research has some limitations. First, the search for articles was limited to the publications listed in Scopus, which, although a large database, does not encompass all relevant works available in other databases such as Web of Science, PubMed, or Google Scholar. Second, bibliometric analysis is mainly based on quantitative data and provide useful information on publications, however, the quality of those research publications may not be adequately captured. Lastly, while this paper explored global trends in renewable energy research within urban areas to combat climate change, future research should delve deeper into identifying which types of renewable energy are most effective for this purpose.

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AUTHOR CONTRIBUTIONS

K.D. carried out data collection and data analysis, and wrote the draft manuscript; E.T.U. contributed to the supervision, conceptualization and methodology; S.S. contributed to the supervision, conceptualization and visualization; R.L. contributed to the supervision, visualization and review; A.A.O contributed to the review. All authors have read and approved the manuscript individually.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

TC: total citations; **NP:** count of publications; **PY_start:** year of initial publication.

SUMMARY

This research analyzed 1,288 scientific articles from Scopus (1992-2022) on global cities' efforts to address climate change through renewable energy. The majority of research was conducted in leading countries such as China, the US, and the UK. The findings show significant growth in publications after 2007, reflecting increasing attention to climate action. Policies and strategies related to renewable energy, urban climate, and energy efficiency were among the key themes. As a result of the analysis, underexplored regions, particularly Africa, have not contributed substantially to climate research, which highlights the need to expand research efforts.

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