Bibliometric Review of Renewable Energy and Environmental Degradation
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Bibliometric Review of Renewable Energy and Environmental Degradation: Current Status, Development and Future Research

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ABSTRACT

Renewable energy is gaining prominence in today's world as the consumption of renewable energy can reduce carbon dioxide emission and environmental degradation. Global warming and climate change in recent years have further accelerated the use of renewable energy to replace fossil fuel energy that emit carbon dioxide, the source of greenhouse gases that pollutes the environment. This study conducts a bibliometric analysis for the 14 years (2010–2023) that contributes to the intellectual structure and knowledge progress of renewable energy and environmental degradation using descriptive analysis. The descriptive analysis comprises publication trends, publishers, category and research areas and citation analysis using Scopus database. The findings of the descriptive analysis reveal that the number of publications in the renewable energy and environmental degradation has gradually increased over the years. The most productive publishers are American Accounting Association, Elsevier and Springer. Researchers from United Kingdom, China and United States tend to be the most prolific authors. Based on our findings of top five categories of publications, we have proposed several new directions for future research.

Keywords: *renewable energy, environmental degradation, carbon dioxide, greenhouse gas, bibliometric review.*

INTRODUCTION

The war between Russia and Ukraine in the year 2022 which led to energy poverty and the increase in energy price in Europe prompted the use of renewable energy sources in the long run (Zhang & Wang, 2024). Many countries have developed various measures to ensure that energy source use is sustainable for the environment and economic growth in the long run. These countries met in conventions at the Climate Change Paris Agreement in 2015, the 2021 Glasgow Climate Pact and 2022 Climate Change Conference in Egypt in order to discuss and share ideas on reducing the use of fossil fuels and moving to clean and sustainable energy use (United Nations, 2023).

In the last two decades, clean and renewable energy use has become an integral part of environmentalist and government decisions, because of the adverse impacts of fossil fuel use that pollutes the environment with the release of carbon dioxide and carbon monoxide. The carbon dioxide released from industrial factories can lead to greenhouse gas and pollute the environment. Policymakers in most countries compromise with the burning of fossil fuels and the release of carbon dioxide in order to achieve economic growth and employment opportunities for their people. This led to pollution, an increase in sea level, rising water temperature and unprecedented adverse impacts such as global warming and climate change.

Climate change has led to devastating effects to the environment and ecosystem. Climate change leads to the spreading of yellow-band disease that kills corals over vast stretches of the sea floor in the calm turquoise waters off eastern Thailand and the Great Barrier Reefs in Australia. The loss of corals could have a devastating impact on the ecosystem, fish and other marine life. It eventually impacts humans as fishermen catch less fish to sustain their livelihood. Thus, pollution must be mitigated by identifying sustainable energy use.

Various studies have analysed various aspects of renewable energy use. A group of study focused on green hydrogen as a potential source of renewable energy (Li et al., 2023; Reda et al., 2024), renewable energy sources and economic growth (Yu et al., 2023) and solar energy use (Kumar et al., 2023). Some studies have discussed the drivers of sustainable

development (Wang et al., 2023) and green finance and green technology as a tool to promote sustainable development.

In recent years, bibliometric analysis has seen a significant growth in interest due to the increase in the number of software programs and multidisciplinary methods. This analytical method can help researchers identify trends in different research fields as well as journal performance. To the best of our knowledge, there is limited study on the bibliometric analysis of renewable energy-environment nexus published in the present literature. In contrast to most previous literature reviews that focused on systematic review and meta-analysis on the renewable energy and environmental degradation, this paper contributes to a bigger scope, more systematic and updated analysis by employing bibliometric analysis to better understand the landscape of renewable energy and environmental degradation.

Through a bibliometric analysis, this study identifies the most frequent renewable energy use topics covered in the literature, identified various gaps in the literature and identified paths for future research in this genre. This is essential as identifying sustainable energy use can assist policymakers to design suitable energy use methods that ensure sustainable development and economic growth. Sustainable development also means environmental sustainability, economically and socially acceptable development. Therefore, this study sheds light on this topic. This paper contributes to the literature by evaluating the most relevant topics by presenting a comprehensive summary on the existing studies on the said topic. There are a total of five sections. After the introduction, Section 2 reviews the relevant literature by presenting a summary. Section 3 explains the methodology that is followed for empirical examination in the study. Section 4 presents the empirical results and discussions. Finally, Section 5 presents the conclusion including limitations and suggestions for future studies.

LITERATURE REVIEW

The trend of literature renewable energy and environmental degradation commenced in 2010 and starts to gain prominence since 2021 (from 18 articles to 69 articles in Scopus database as shown in Figure 2). The main

studies on renewable energy and environmental degradation revolve around aggregate level examples (Wang et al., 2023; Voumik et al., 2023; Adebayo et al., 2023). However, the results between renewable energy and environmental degradation are mixed. On one side, Wang et al. (2023), Voumik et al. (2023) and Adebayo et al. (2023) show that renewable energy consumption and environmental degradation have negative relationship. On the other side, Ali et al. (2022) and Kartal et al. (2022) show that there is a positive relationship between renewable energy consumption and environmental degradation. Most of these studies also employ the Environmental Kuznet Curves (EKC) hypothesis to explain the relationship between economic growth and environmental degradation. Environmental degradation is often proxy by carbon dioxide (CO2) emissions. Even though there are mixed results between renewable energy consumption and environmental degradation, majority of the studies inclined towards explaining the positive relationship between renewable energy consumption and environmental degradation. Studies on renewable energy and environmental degradation in our literature review section are divided into aggregate study and disaggregated study.

Aggregated studies of renewable energy and environmental degradation

Aggregated studies of renewable energy only focus on the main renewable energy variable without dividing renewable energy into subsectors such as hydro, solar, geothermal, biomass and biofuel. The advantage is we can observe the direct relationship between the main renewable energy and environmental degradation. The drawback of using the main renewable energy is that we will not understand the impact of each subsector on environmental degradation. Renewable energy studies can be divided into consumption and production of renewable energy. The results are mixed for renewable energy consumption and environmental degradation. For example, Wang et al. (2023), Voumik et al. (2023) and Adebayo et al. (2023) showed a negative relationship between renewable energy consumption and environmental degradation. This implies that adoption of renewable energy consumption can reduce environmental degradation. However, there are some studies (Ali et al., 2022; Kartal et al., 2022) show that the relationship between renewable energy consumption and environmental degradation is positive.

There are very limited studies on production of renewable energy and environmental degradation. Production of renewable energy also shows positive relationship with environmental degradation. Kartal et al. (2022) use ARDL model to examine the relationship between renewable energy production and environmental degradation in the United States. Their results show that renewable energy production positively impacted environmental degradation in the short run and negatively impacted environmental degradation in the long run.

Studies on disaggregated renewable energy and environmental degradation

Disaggregated renewable energy means separating renewable energy into subsectors such as hydro, solar, geothermal, biomass and biofuel. The impacts of each subsector of renewable energy was examined on environmental degradation. The advantage is that we can have an understanding about the holistic relationships between the subsectors of renewable energy and environmental degradation.

The impacts of each subsector of renewable energy consumptions on environmental degradation are different. Sahoo and Sahoo (2020) show that nuclear energy consumption has negative impact on environmental degradation in India while Udeagha and Ngepah (2022) also found out the same relationship in South Africa. For hydroelectric, Destek and Aslan (2020) found out negative relationship between hydro and environmental degradation in G-7 countries. The result of Destek and Aslan (2020) is also similar to Udeagha and Ngepah (2022) result in South Africa.

There is also limited studies on renewable energy production and environmental degradation. Zhang et al. (2022) employed the Generalized Methods of Moments (GMM) and Fully Modified Ordinary Least Squared (FMOLS) to examine the impacts of disaggregated renewable energy source on environmental degradation in E5 countries. Their results showed that hydropower and geothermal energy production increase environmental degradation whereas the nuclear and wind energy production reduces environmental degradation.

METHODOLOGY

In this section, we provided the database, time period and methodology to analyse a comprehensive assessment of renewable energy and environmental degradation. The, VOS viewer software, version 1.6.17 was used for analysis. Moreover, the required information and raw data for assessment were sourced from the Scopus Collection database. Although it is acknowledged that there are other databases, such as ScienceDirect and WoS database, the Scopus database was used because it is the most inclusive and comprehensive database of scientific documents. In contrast to Scopus database, Web of Science and ScienceDirect has a smaller scope.

In this study, the six-step approach was followed for a bibliometric analysis and the proposed research framework is presented in Figure 1. The first step was to determine the scope of the study. The second and third steps of the study were to download the publication raw data from the Scopus database by using pre-determined keywords that were highly related to the topics examined. The fourth step was to perform a bibliometric analysis. The fifth step was to present the comparison of the results. Finally, the sixth step was to provide the conclusion and implications as well as the limitations of the study and some suggestions for future studies.

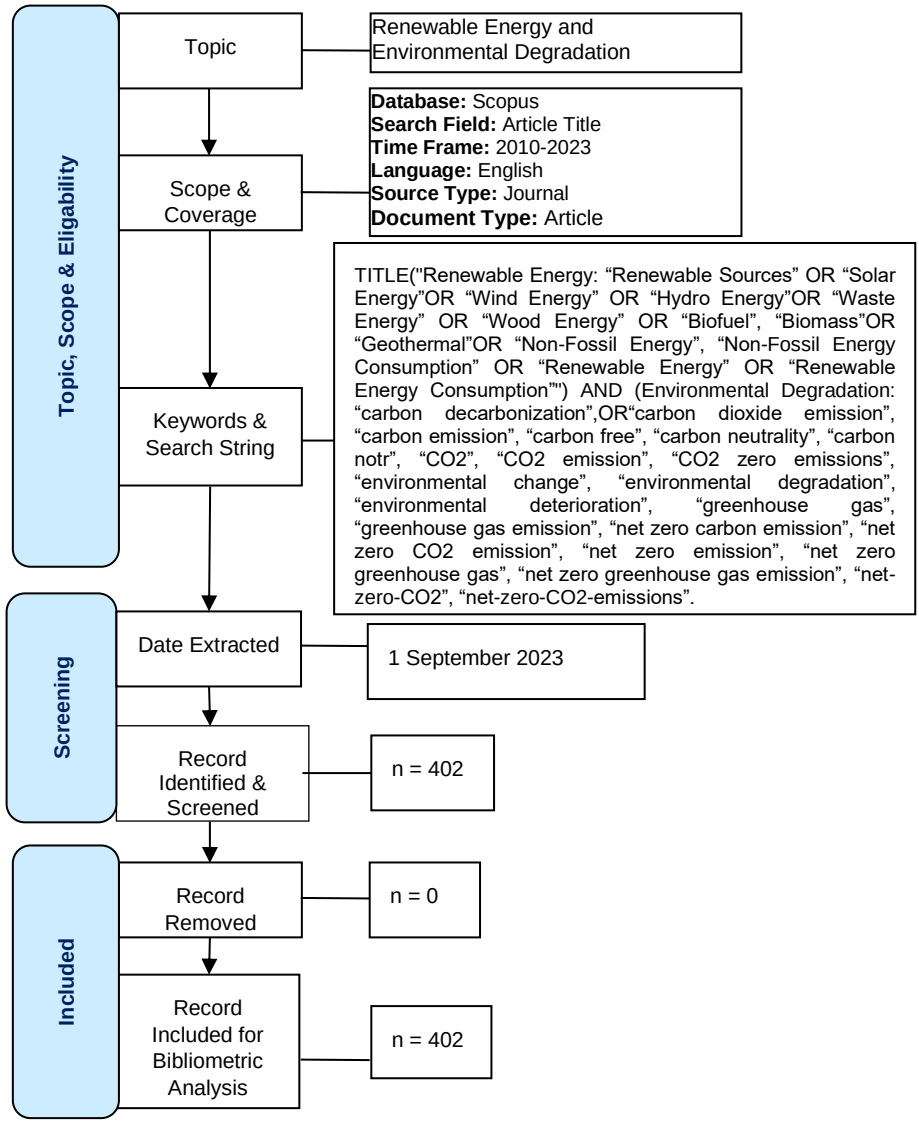
Scopus database was used to search for the keywords, titles and abstracts related to renewable energy & environmental degradation for the period of 2010-2023. Two different datasets were obtained from the database by using the following keywords:

• Renewable Energy: “Renewable Sources”, “Solar Energy”, “Wind Energy”, “Hydro Energy”, “Waste Energy”, “Wood Energy”, “Biofuel”, “Biomass”, “Geothermal”, “Non-Fossil Energy”, “Non-Fossil Energy Consumption”, “Renewable Energy”, “Renewable Energy Consumption”,

• Environmental Degradation: “carbon decarbonization”, “carbon dioxide emission”, “carbon emission”, “carbon free”, “carbon neutrality”, “carbon notr”, “CO2”, “CO2 emission”, “CO2 zero emissions”, “environmental change”, “environmental degradation”, “environmental deterioration”, “greenhouse gas”, “greenhouse gas emission”, “net zero carbon emission”, “net zero CO2 emission”, “net zero emission”, “net zero greenhouse gas”, “net zero greenhouse gas emission”, “net-zero-CO2”, “net-zero-CO2-emissions”.

Figure 1

Flow diagram of the search strategy



Source: Zakaria, R., Ahmi, A., Ahmad, A. H., & Othman, Z. (2020) Worldwide Melatonin Research: A Bibliometric Analysis of the Published Literature between 2015 and 2019, Chronobiology International. https://doi.org/10.1080/07420528.2020.1838534
Modified from PRISMA (Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097)

Every keyword in each topic was combined with the "OR" statement. Renewable energy keywords were combined with the keywords of environmental degradation. There are 402 publications in the first query on renewable energy and environmental degradation.

FINDINGS AND DISCUSSIONS

In order to understand the current publication trend in renewable energy and environmental degradation, we analysed the publication trend in renewable energy using total publications by year, country, journal, contributing author and organization. We calculated the data for this analysis using the bibliographic data collected from the ISI Scopus database. Before starting the bibliometric examination of the dataset, the descriptive statistics of the two queries are given in this section. The number of publications is given in Figure 2.

The "Renewable Energy & Environment Degradation" label represents the first query. The gap between the number of publications about renewable energy and environmental degradation has increased since 2010. In the year 2010, the number of publications on the renewable energy and environmental degradation is only 1 article. However, the number of publications on the renewable and environmental degradation nexus has reached 158 in 2023. This statistic in Figure 2 shows that renewable energy consumption reported an increasing trend year by year.

The publications were categorized based on the topics of the studies on the Scopus database and one publication can go under more than one category. Based on this categorization, the top-five Scopus categories of the query of "Renewable Energy and Environmental Degradation" is shown in Figure 3.

The major Scopus categories of publications are Carbon Dioxide and Greenhouse Gases. The top publication articles are in the area of carbon dioxide, which has a score of 34.33 percent whereas percentage of publications on greenhouse gases has a total score of 33.58 percent. Publications in the area of zero emission has the lowest score at 21.14 percent.

Figure 2
The Number of Publications by Years

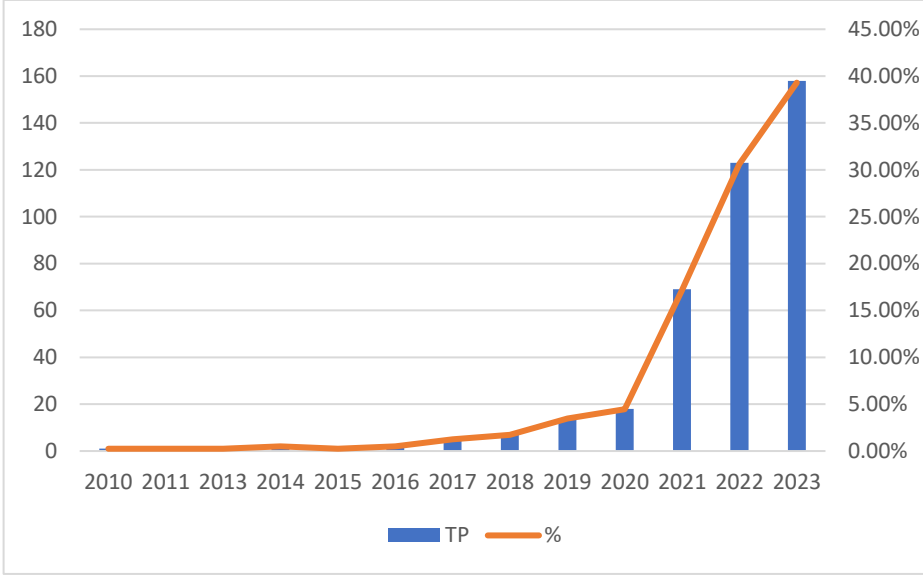
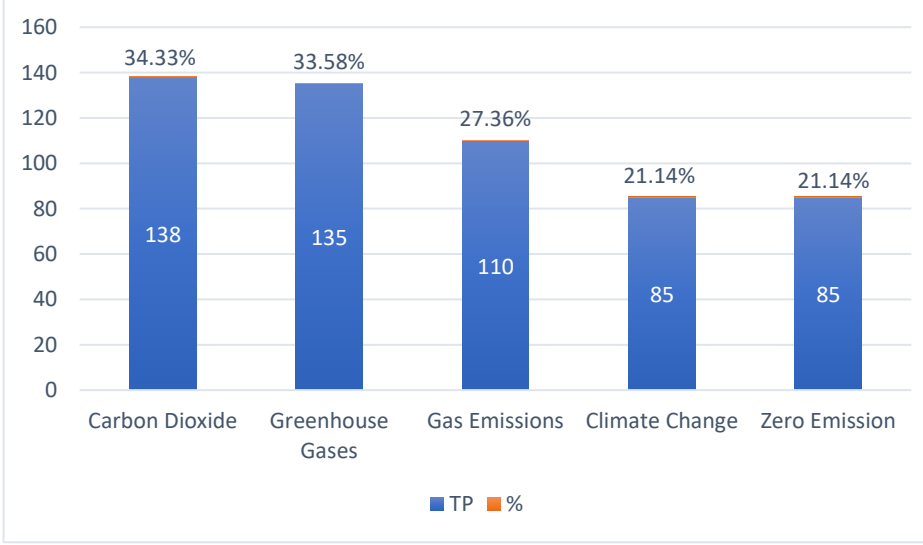
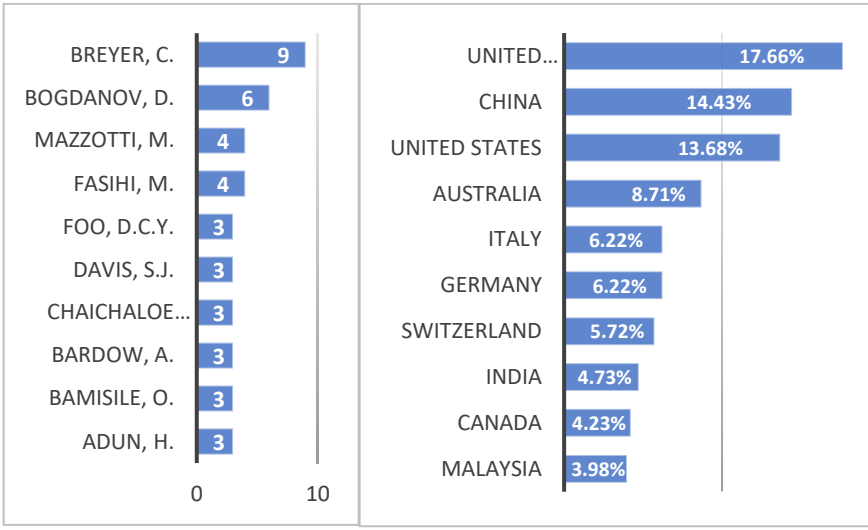


Figure 3
The Top Five Scopus Categories of Publications



We also performed an analysis on the number of publications by authors, the distribution of publishers and the percentage of publications by the authors' countries. The results are shown in Figure 4 and Figure 5, respectively. Breyer, C. and Bogdanov, D. are the authors who have the highest number of publications on renewable energy & environmental degradation. Breyer published nine articles related to renewable energy whereas Bogdanov published six articles related to renewable energy. In terms of countries, United Kingdom has the most studies in query results, recording at 17.66 percent whereas China comes second at 14.43 percent. This is followed by the United States at 13.68 percent.

Figure 4
Top Authors and countries by publication



We also performed an analysis on top publishing journals on renewable energy and environmental degradation. The results on the top publishing journal titles, the publishers, total publications (TP) and total citations (TC) are shown in Table 1.

Table 1

Top Publishing Journals on Renewable Energy and Environmental Degradation

Source Title	TP	TC	Publisher	Cite Score	SJR 2018	SNIP 2018
Energies	23	203	American Accounting Association	N/A	N/A	N/A
Applied Energy	14	340	Elsevier B. V.	N/A	N/A	N/A
Renewable and Sustainable Energy Reviews	12	198	Springer	2.44	0.9	1.252
International Journal of Hydrogen Energy	11	50	University of Huelva	1.78	0.464	1.099
Energy Conversion and Management	10	67	Sun SITE Central Europe	N/A	N/A	N/A
Journal of Cleaner Production	8	140	Palgrave Macmillan	1.06	0.283	0.713
Sustainability Switzerland	8	104	American Accounting Association	3.53	1.085	1.995
Energy	5	55	Springer Nature	4.07	1.419	2.354
Energy Policy	5	52	Emerald Publishing Limited	7.72	2.323	3.797
Environmental Science and Pollution Research	5	2	Springer Nature	0.97	0.219	0.819
Fuel	5	58	American Accounting Association	0.51	0.221	0.454
Science of the Total Environment	5	120	American Accounting Association	0.43	0.155	0.503
ACS Sustainable Chemistry and Engineering	4	9	Elsevier B. V.	N/A	N/A	N/A
Energy Reports	4	11	IGI Global	0.00	0.102	0.101

From Table 1, Energies journal has the highest number of publications with 23 articles. This is followed by Applied Energy journal at 14 articles. Renewable and Sustainable Energy journals record 12 articles. In terms of citations, the top cited journal is Applied Energy with 304 citations in renewable energy, Energies journal comes second at 203 citations, Journal of Cleaner Production is third at 140 citations, Science of the Total Environment is fourth at 120 citations and Sustainability Switzerland journal is fifth at 104 citations. Researchers that intend to publish in high citation journals can submit their manuscripts in Applied

Energy Journal, Energies Journal and Journal of Cleaner Production. This can increase the citations of the author.

Table 2
Most influential institutions with minimum of five publications

Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*G*
ETH Zurich	Switzerland	11		229	9.54	14.31	7	15
Imperial College London	UK	10	17	318	13.83	18.71	6	17
LUT university	Finland	9	13	246	15.38	19.92	7	15
Chinese Academy of Sciences	China	7	12	691	49.36	57.58	7	14
Chalmers University of Technology	Sweden	6	8	21	1.62	2.63	3	4
Universiteit Ultrecht	Netherlands	6	9	49	3.77	4.22	5	6
University of Aberdeen	UK	6	5	13	1.18	2.60	2	3
University College London	UK	6	6	199	19.9	33.17	5	10
University of Melbourne	Australia	6	7	441	44.10	63.00	5	10
The University of Manchester	UK	5	16	229	9.54	14.31	7	15
National University of Singapore	Singapore	5	17	318	13.83	18.71	6	17
Copernicus Institute of Sustainable Development	Netherlands	5	13	246	15.38	19.92	7	15
University of Surrey	UK	5	12	691	49.36	57.58	7	14
Politecnico di Milano	Italy	5	8	21	1.62	2.63	3	4
University of Chinese Academy of Sciences	China	5	9	49	3.77	4.22	5	6

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

From Table 2, it shows that the most influential institutions published works on renewable energy and environmental degradation. ETH Zurich from Switzerland comes first with 11 publications. This is followed

by Imperial College of London from United Kingdom at 10 publications, LUT University from Switzerland at nine publications, Chinese Academy of Sciences from China at seven publications and Chalmers University of Technology from Sweden at six publications. Europeans, China and United States are developed countries that have the resources and manpower talents to undertake work on renewable energy and therefore the publication works are many.

The Chinese Academy of Sciences from China and University of Surrey from theUnited Kingdom both have the most citations at 691. The University of Melbourne, Australia comes second at 441 citations. This is followed by Imperial College of London from United Kingdom and the National University of Singapore each at 318 citations respectively. These institutions are the highest cited institutions. Researchers that intend to undertake research on renewable energy and affiliated themselves with these institutions as these prominent institutions have high citations and renowned researchers that they can work with.

CONCLUSION

In general, this paper considers the historical development of renewable energy research in different areas: top publishing countries, top publishing journals, top authors, most influential institutions. This approach has identified a few patterns that can justify further research. The chosen time lag of 14 years showed the relevance of this topic in the last 10 years and allowed us to divide the time period into 2 stages. There is a positive increase in the number of publications in the renewable energy and environmental degradation over the years. Thus, we can conclude about the relevance of this topic.

In this study, we were able to confirm the direction of publications in renewable energy. 2/3 of all the work focuses on carbon dioxide reduction and greenhouse gases. This shows the urgent need to reduce carbon dioxide and greenhouse gases. An interesting result of the study concerns publications by countries. Analysis revealed that most of the work published by researches concentrated in United Kingdom, China and the United States. There are also several prominent institutions that focus on the work on renewable energy and environment degradation. Therefore, it is necessary

to pay attention to the work of the following research centers: ETH Zurich from Switzerland, Imperial College of London, LUT University from Finland, Chinese Academy of Sciences from China and Chalmers University of Technology from Sweden.

Lastly, there are some specific recommendations for future research on Carbon Capture Storage technologies for renewable energy plants which include: Developing new and more cost-effective CCS technologies, addressing public concerns about CCS technologies through public education and outreach, demonstrating the feasibility and safety of CCS technologies for renewable energy plants at scale, developing policies and incentives to support the deployment of CCS technologies for renewable energy plants.

CONTRIBUTION OF AUTHORS

The authors contributed equally for this paper.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest with any party.

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