

Energy management focused on carbon dioxide mitigation: a bibliometric analysis

The present work presents a study on energy management with a focus on carbon dioxide mitigation, a bibliometric analysis. Energy efficiency is a topic of great relevance in the debate on reducing greenhouse gas (GHG) emissions and their environmental and economic benefits. The objective of this study is to present the scientific production on energy efficiency associated with the reduction of GHG in the period from 1992 to 2022, as well as to show the number of documents, the partnership between authors, institutions and countries that stood out in literary production on the subject. Then, the number of publications per year, citations of documents, citations in journals, co-occurrence of key words, citation of co-authorship, co-authorship of authors by geographic distribution and the bibliometric network of organizations were demonstrated. A total of 260 documents were obtained to carry out the investigation. The data indicated that the number of publications increased in the last 10 years and the oldest documents were the most cited. Most publications were from China and the United States, and high impact factor journals accounted for a greater number of publications. The most used keywords in the documents were "CO2 emissions", "mitigation", "consumption", "conservation" and "China". Furthermore, the most relevant authors are of Chinese origin. This study, therefore, presents trends on scientific production of energy efficiency for mitigation of carbon dioxide, aiming to support further research on the subject and assist in future decision-making in this area of study. To obtain this information, the VosViewer program was used, a software tool for building and viewing bibliometric networks.

Keywords: Mitigation; Energy conservation; Energetic efficiency.

Gestão energética com foco na mitigação do dióxido de carbono: uma análise bibliométrica

O presente trabalho apresenta um estudo sobre gestão energética com foco na mitigação do dióxido de carbono, uma análise bibliométrica. A eficiência energética é um tema de grande relevância no debate sobre a redução das emissões de gases com efeito de estufa (GEE) e dos seus benefícios ambientais e económicos. O objetivo deste estudo é apresentar a produção científica sobre eficiência energética associada à redução de GEE no período de 1992 a 2022, bem como mostrar a quantidade de documentos, a parceria entre autores, instituições e países que se destacaram em produção literária sobre o tema. Em seguida, foram demonstrados o número de publicações por ano, citações de documentos, citações em periódicos, coocorrência de palavras-chave, citação de coautoria, coautoria de autores por distribuição geográfica e a rede bibliométrica de organizações. Foram obtidos 260 documentos para a realização da investigação. Os dados indicaram que o número de publicações aumentou nos últimos 10 anos e os documentos mais antigos foram os mais citados. A maioria das publicações veio da China e dos Estados Unidos, e os periódicos de alto fator de impacto foram responsáveis por um maior número de publicações. As palavras-chave mais utilizadas nos documentos foram "emissões de CO2", "mitigação", "consumo", "conservação" e "China". Além disso, os autores mais relevantes são de origem chinesa. Este estudo, portanto, apresenta tendências na produção científica de eficiência energética para mitigação de dióxido de carbono, visando subsidiar futuras pesquisas sobre o tema e auxiliar em futuras tomadas de decisões nesta área de estudo. Para obter essas informações foi utilizado o programa VosViewer, uma ferramenta de software para construção e visualização de redes bibliométricas.

Palavras-chave: Mitigação; Conservação de energia; Eficiência energética.


Topic: **Desenvolvimento, Sustentabilidade e Meio Ambiente**

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INTRODUCTION

Activities involving environmental impact have been gaining prominence on the world stage in recent years. Several are the events promoted by institutions in order to minimize the damage caused by human activity in the environment. Considering the magnitude of the issue, the Public Administration cannot avoid giving its share of contribution in the defense and protection of a balanced and sustainable environment, which constitutes the right of every Brazilian citizen consigned in Article 225, caput, of the Constitution of the Republic (BRASIL, 1988).

It is undeniable that the Public Power has a fundamental role, both with its direct participation and in setting an example for other entities and institutions in the adoption of sustainable practices. The State must be a vector of environmental protection and preservation, stimulating the various segments of society in the pursuit of the desired energy efficiency, thus contributing to the rational use of natural resources (ARAÚJO, 2018).

Electricity is one of the pillars of the Sustainable Logistics Plan - PLS, belonging to Theme 5, which sets the goal of maximizing energy efficiency in the jurisdictional and administrative units of the State Judiciary Branch - PJPE (PERNAMBUCO, 2020).

The use of energy is essential in economic activities and in society, constituting one of the main factors responsible for boosting the generation of products and services, in addition to offering the desirable thermal comfort (CERETTA et al., 2018). On the other hand, these facilities offered by electric energy charge a high price from a far-reaching environmental point of view, which justifies the adoption of measures aimed at rationalizing consumption since, combined with financial savings, there is the benefit of mitigating the emission of greenhouse gases - GHG, mainly carbon dioxide (CO₂).

Faced with the challenge of implementing sustainable policies, a bibliometric study on the subject is proposed, based on research carried out using the *VosViewer* software, to answer the question: how the subject has been and is being discussed worldwide in recent years? It is also intended to address a case study related to energy efficiency, carried out in a property belonging to the Judiciary Branch of Pernambuco, presenting the improvements and results found.

Thus, this work intends to contribute to the management of the State Judiciary in the implementation of public sustainability policies, especially in terms of energy efficiency, duly aligned with the guidelines established by the National Council of Justice, in particular Resolution No. 400, of 16/06/2021, which deals with the Sustainable Logistics Plan (PLS) applicable to bodies of the Judiciary throughout the national territory. Therefore, the general objective of the study will be to carry out a bibliometric analysis on energy management with a focus on environmental mitigation.

THEORETICAL REVIEW

Bibliometric Analysis

The permanent search for academic articles and consequently reading ease the action of researchers

as they allow them to identify and organize essential concepts in a given branch of knowledge, enabling the proposition of analytical models and research hypotheses, as well as raising the main points discussed by the academic community (SNYDER, 2019).

The advancement of information technology is an important ally of researchers in carrying out their actions. The technological resources available make it simpler to search and retrieve scientific papers stored and accessible on the internet. An infinite number of information and articles on the most varied topics can be obtained by searching the internet, facilitating the work of students and researchers (MORAES et al., 2020).

There are many ways to condense scientific work related to a given topic. Among them, bibliometrics stands out, due to its capacity to present an overview without losing, however, the representativeness of the scientific production of a certain area of knowledge. Bibliometrics, given its ability to define an overview, albeit representative of the scientific production in a given area of knowledge (MERIGÓ et al., 2018).

Bibliometric analysis proposes to provide a quantitative view and allows bringing the researcher closer to the object of study. It also enables the statistical analysis of the academic literature, from different perspectives, and can be defined as the characterization, evaluation and monitoring of a given science, discipline or knowledge field. This is done through data such as, for example, received citations, bibliographic references used, authorship and keywords (KÖHLER et al., 2021).

Another important feature of bibliometrics is the possibility of emphasizing the occurrence of gaps, serving as a source of information for filling them in, constituting a research tool that uses statistical methods to analyze academic production in the most varied types of documents (CABEZA et al., 2020). The constitution of the field and the identification of the main research and gaps in the area can only be verified through bibliometric and mapping research, as we also propose with this work (TAVARES, 2021).

Energetic efficiency

The use of energy is proportional to the development of human activities and vital to produce goods and services. A large part of the electricity generation used in the world comes from fuels, in which heat is generated by the combustion of fuels, converting it into electricity through mechanical rotation (DAMKE, 2019).

This growing demand for electricity requires public and private organizations to search for methods and practices to minimize energy consumption. According to studies by the International Energy Agency - IEA¹, the world demand for electricity in 2018 showed an increase of 4.1% compared to the previous year. In Brazil, the demand in 2021 was 4.1% higher than the 2020 record (CEEE) 2022. It is worth mentioning, however, the slowdown of the world economy, starting in 2020, due to the Coronavirus Pandemic.

Technological evolution has allowed the modern man to expand the sources of energy, some more, others less impactful in comparison to environmental effects. In Brazil, hydroelectric production

¹ <https://www-iaea-org.translate.goog/reports/world-energy-outlook-2019/electricity? x tr sl=em& x tr tl=pt& x tr hl=pt-BR& x tr pto=sc>

predominates, which, in the words of (CHICANO, 2019), despite the advantage observed in the very low emission rate of greenhouse gases, hydroelectric plants cause great social and environmental impact in the regions where they are built.

Neonergia, an electricity concessionaire that operates in some Brazilian states, including Pernambuco, defines energy efficiency as generating energy with fewer natural resources or obtaining services with the lowest expenditure on electricity. It means that this efficiency must be conceived in a systemic way, that is, the entire generation, distribution, and consumption process, avoiding losses along the energy chain (ERBER et al., 2019)

The search for the development of sustainable techniques and actions is an essential task. Furthermore, the activity of evaluating the result of these measures in improving energy efficiency is an obstacle to be overcome, since it is necessary to compare energy demand before and after the implementation of actions (BORTONI et al., 2020)

The encouragement of government institutions is a strong collaborator in expanding the use of energy efficiency measures. The Conserve Program, created by the Ministry of Industry and Commerce in 1981, although extinguished the following year due to the financial crisis, aimed to encourage the development of energy efficient products and processes in Brazilian industry.

In 1984, Inmetro, in partnership with the Ministry of Mines and Energy, launched a discussion on energy conservation with the intention of contributing to the rational use of electricity, informing consumers about the energy efficiency of each product, initiating, thus, the Brazilian Labeling Program (PBE).

These government encouragements in the promotion of energy-related policies advanced over time, culminating in the enactment of Law No. 9.478 of August 6, 1997, which provides for the national energy policy, activities related to the oil monopoly, in addition to establishing the National Energy Policy Council and the National Petroleum Agency (BRASIL, 1997).

With the energy management in mind and moved by the energy crisis that the country faced at the beginning of the 21st century, Law nº 10,295, popularly known as the Energy Efficiency Law, was published in October 2001, which established a rational use of energy in the whole country, including high penalties for manufacturers and importers of energy-consuming machines and appliances that do not meet the maximum levels of energy consumption and minimum levels of energy efficiency (BRASIL, 2001).

Carbon Dioxide Mitigation

Carbon dioxide (CO₂), also identified as carbon gas, is included in the group called greenhouse gases (GHGs), composed of fluids such as nitrous oxide (N₂O), methane (CH₄). These substances are released naturally into the environment, but human action has established an increase in the amount of GHGs, increasing their concentration and, consequently, generating dysfunctions and problems of a climatic nature.

The Greenhouse Gas Emissions and Removal System (SEEG), an initiative of the Climate Observatory (a network of civil society entities) based on the Governmental Panel on Climate Change (IPCC), showed, in its latest report on the issuance of greenhouse gases in Brazil, some sectors responsible for the emission of

GHGs. The emission of these substances and, consequently, of CO₂, occurs mainly through deforestation, where natural elements of carbon dioxide absorption are destroyed, in addition to the agriculture, energy, industrial processes and waste sectors².

There is a positive relationship between the use of non-renewable energy sources and environmental degradation, while there is a negative relationship between environmental degradation and consumption of renewable energy. For that matter, the need to reduce the emission of carbon dioxide, a substance that is associated with non-renewable energy sources, is highlighted (SOUZA, 2018).

Photovoltaic energy represents a type of renewable energy. Photovoltaic energy represents a great ally in reducing emission and polluting gases. In their study, the authors detect a reduction in the emission of carbon dioxide from the use of a photovoltaic plant next to the electrical network, with a decrease of around 32% when compared to the use and consumption linked solely to electrical energy, a fact that exposes greater energy efficiency of photovoltaic energy (DANTAS et al., 2019).

Renewable energy sources act as a way to overcome the economy heavily based on fossil fuels, popularly known as emitters of carbon dioxide. For the authors, electric cars represent an alternative to conventional cars (emitters of large volumes of CO₂), since they emit less amount of gases throughout their life cycle, thus being characterized as a more efficient alternative. However, it is necessary to improve its production process, increase the capacity of its batteries and reduce the cost (CHRISPIM et al., 2019). The need to develop battery technologies for electric vehicles and their use are important alternatives for mitigating pollutant emissions (PARENTE et al., 2020), as electric cars can replace vehicles powered by fossil fuels. However, to obtain energy efficiency from its use, it is necessary to develop technologies associated with the batteries of these cars, as well as to improve the recycling process (CHRISPIM et al., 2019; PARENTE et al., 2020).

Another alternative to the emission of carbon dioxide from fossil fuels is the application of railways. Historically, Brazil opted for the development of the modal road as the basis of transport, reaffirming the wide use of conventional cars, powered by fossil fuels. Silva et al. (2020) points out the possibility of using railroads, to the detriment of highways. In their study, for the same route and volume, a significant decrease in carbon dioxide emissions (in the order of 37%) can be seen with the use of trains compared to trucks, an element that reverberates greater efficiency of the modal rail compared to the highways (SILVA et al., 2020). The railways and diversification of the transport matrix, as highlighted, must be combined with the expansion of electric vehicles to reduce the emission of polluting gases such as CO₂ (CHRISPIM et al., 2019).

The reduction of carbon dioxide emissions is also associated with the State, as Nicolau (2018) points out. For the author, in order to achieve energy efficiency goals, government participation is necessary, acting from the implementation of differentiated taxes related to CO₂ emissions and consumption efficiency for automobiles, to the effective inspection of federation entities and companies that are not complying with the established legislation, in addition to the implementation of incentives for those who follow the defined

² <http://energiaeambiente.org.br/>
<http://seeg-br.s3.amazonaws.com/>

rules (NICOLAU, 2018). The State's action, in this regard, would cover several sectors associated with the emission of carbon dioxide.

For Alves and Diniz (2022), government actions must meet environmental governance. For the authors, environmental governance is understood as a necessary cost for mitigating deforestation or simply keeping the forest standing, ensuring the absorption of carbon dioxide through the preservation of the ecosystem (ALVES et al., 2022).

Regarding the agricultural sector, Silva et al. (2022) argue that, although the granting of credit (such as the Rural Credit Policy) can be used as a way of modernizing the sector, there is still no effective action to mitigate carbon dioxide and other greenhouse gases produced from agriculture. However, this policy has not contributed to the reduction of gas emissions. That way, it is important to align development policies, such as granting credit, and preservation policies, such as the National Policy on Climate Change (PMNC), reinforcing the State's need to mitigate CO₂ emissions (SILVA et al., 2022).

For that matter, considering the range of options available in the modern world to combat the emission of carbon dioxide in the atmosphere, the public power needs to act objectively, adopting policies focused on reducing the emission of greenhouse gases instead of limiting itself to legislation, inspecting and imposing penalties on entrepreneurs and society in general, despite the recognized importance of these actions.

METHODOLOGY

The bibliographic survey was carried out by approaching the focal theme. This method, which consists of reading published material (books, articles, and others), increasing initial knowledge about the subject, as well as determining indicators for the development of bibliometric studies. The bibliometric analysis allows bringing the researcher closer to the object of study, as well as enabling the statistical analysis of the academic literature, from different perspectives (LIU, 2019). This method employs a quantitative approach, which gives quality to the description, evaluation, and monitoring of scientific productions (ELLEGAARD et al., 2015; LÓPEZ et al., 2019).

The main laws that govern bibliometrics are focused on the scientific productivity of authors, journals and journal productivity, and word frequency. The bibliometric study is applicable to several fields of science, commonly used to obtain indicators of scientific production, demonstrating the behavior, development, and tendency of a certain area of knowledge.

The data collection was carried out between September 02 and 06, 2022, using the *Web of Science* database, searching for scientific documents published between 1992 and 2022, using the *Portal de Periódicos* of the *Capex* platform. Indicators correlated to the energy efficiency themes were used, aiming to find out how the scientific community has been treating the theme over the years. The query was applied to the title, abstract and keywords, using the indicators 'energy', 'conservation', 'mitigation' and 'CO₂'.

To deepen bibliometrics, 260 documents found on the *Web of Science* search site, a scientific database that gathers information on scientific studies, were used, using the Boolean operator 'AND'.

For the bibliometric analysis of the found documents, related to the researched indicators, the *VOSviewer* software, developed by Van et al. (2010) was used, being a free program used to build maps (clusters) based on networks, using data clustering mapping techniques. The *Vosviewer* software was used as a tool for building bibliometric networks for citation of documents, journals, co-authorship of authors, co-authorship of authors by geographic distribution, co-occurrence of keywords, the bibliometric network of organizations.

The analysis of the raised scientific productions content focused on the Court of Justice of Pernambuco, identifying aspects of research and current addressed issues, based on the history of publications. The overall illustration of the methodology can be seen in Figure 1.

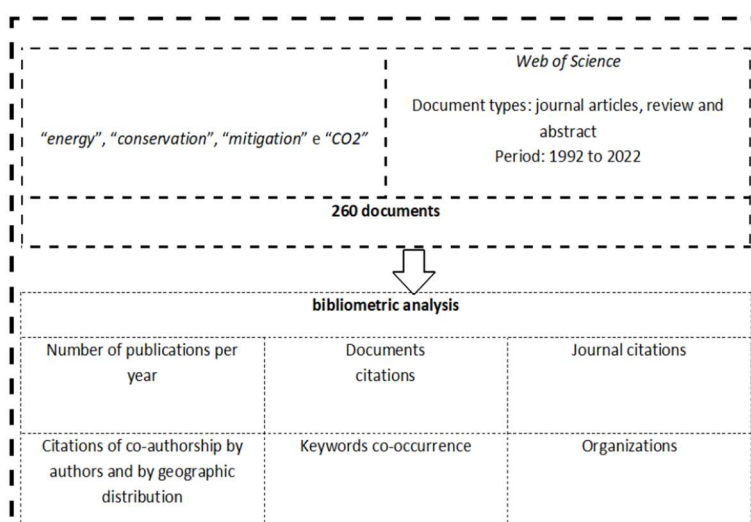


Figure 1: Synthesis of the bibliometric methodology.

RESULTS AND DISCUSSION

Analysis of Publications per year

Figure 2 shows the number of publications on the subject from 1992 onwards. According to the graph, it is possible to verify the relatively incipient start of publications, reaching five consecutive years without any work published (1998 to 2002).

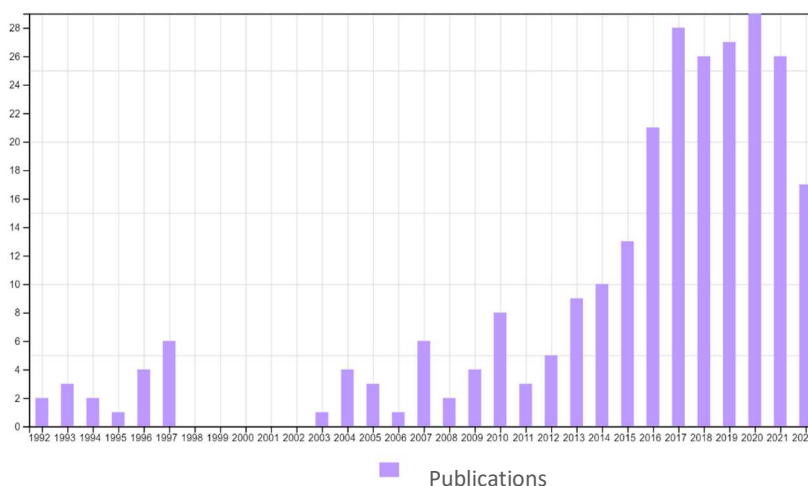


Figure 2: Publications on energy 2022.

Resuming the publications in 2003, a still shy behavior, although oscillating, of published articles can be seen. However, in the last ten years, an increase in academic interest is visible, maintaining between nine and 29 publications related to the theme. This increase can be justified by the importance given by governments, society, and organizations to environmental issues, especially those related to energy efficiency and mitigation of greenhouse gas emissions.

Bibliometric Network of Documents Citations

Figure 3 brings the number of scientific publications registered in the Web of Science through the thematic axis of the study, reaching a total of 260 documents, of which 216 were obtained using the filter of 3 citations per document.

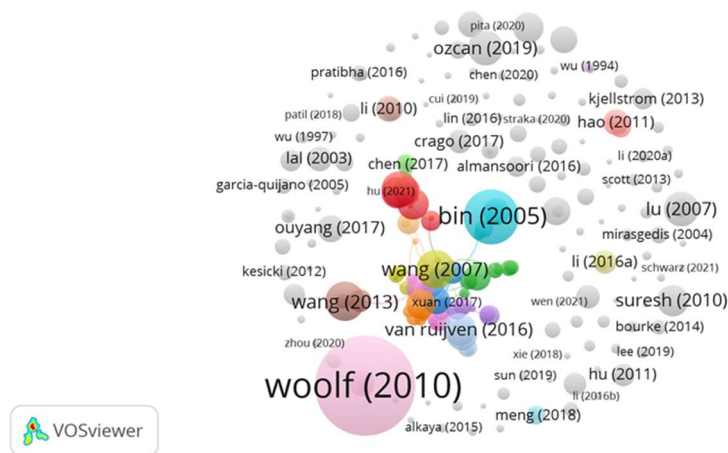


Figure 3: documents citation.

It is observed that the five most cited documents were Woolf et al. (2010), Bin (2005), Wang (2013), Wang (2007) and Zhao et al. (2016), as shown in Table 1.

Table 1: ranking of most cited documents.

Ranking	Title	Author (year)	Number citations	of	Journal
1 ^o	Sustainable biochar to mitigate global climate change	Woolf et al. (2010)	1294		Nat Commun
2 ^o	Consumer lifestyle approach to US energy use and the related CO ₂ emissions	Bin (2005)	398		Energy Policy
3 ^o	Energy and emissions efficiency patterns of Chinese regions: A multi-directional efficiency analysis	Wang (2013)	201		Applied Energy
4 ^o	Scenario analysis on CO ₂ emissions reduction potential in China's iron and industry	Wang (2007)	188		Energy Policy
5 ^o	Decoupling CO ₂ emissions and industrial growth in China over 1993–2013: The role of investment	Zhao et al. (2016)	167		Energy Economics

The most cited document was Woolf et al. (2010), entitled “Sustainable biochar to mitigate global climate change”, with 1294 citations, published in *Nat Commun* (Table 1). The authors study the maximum sustainable technical potential of biochar to mitigate climate change, as well as the possibility of reducing net emissions of carbon dioxide, nitrous methane and total net emissions over the period of a century, while maintaining unscathed food security, habitat or soil conservation.

The second most cited document was Bin (2005), with the title “Consumer lifestyle approach to US

energy use and the related CO₂ emissions", cited 398 times, published in the *Energy Policy* journal. In the work, the authors address the impacts caused by consumerist activities on energy use and their consequences on the environment, concluding that consumer activities and environmental impacts in the United States represent 4% of the country's GDP, but account for 28% and 41% of US energy use and CO₂ emissions, respectively.

In third place was the document by Wang (2013), called "*Energy and emissions efficiency patterns of Chinese regions: A multi-directional efficiency analysis*" with 201 citations and published in the *Applied Energy* journal. Wang, in co-authorship with two other authors, deals with the assessment of energy efficiency and emissions in regions of China. They study a comparison between data envelopment analysis (DEA) and multidirectional efficiency analysis (MEA), energy efficiency assessment techniques and conclude that, depending on the location, one technique is more effective than the other.

In fourth place among the most cited was Wang (2007), in partnership with four other authors, with the work "*Scenario analysis on CO₂ emissions reduction potential in China's iron and industry*", which had 188 citations and was published in the *Energy Policy* journal, where the potential for reducing CO₂ emissions in the Chinese steel industry is analyzed.

Closing the ranking is Zhao et al. (2016) with the title "*Decoupling CO₂ emissions and industrial growth in China over 1993–2013: The role of investment*", with 167 citations, published in the *Energy Economics* journal. In the study, the authors propose to present a specific investigation on the decoupling of CO₂ emissions and industrial growth in China from 1993 to 2013, as well as to provide policy recommendations considering conventional and investment factors for China's industrial sector to reach the emission reduction targets.

Bibliometric Network of Journal Citations

Of the 260 documents found in the research, 1 document per journal was established as a criterion to refine the classification, with 100 journals that meet this criterion being located, grouped into 74 clusters with 70 links. The bibliometric network presented in Figure 4 shows that of the 100 journals with a published document, only 33 journals have a cooperation network among them represented in 11 clusters and 66 links.

The journals with the highest number of published documents were *Journal of Cleaner Production*, *Applied Energy* and *Energy Policy* (Table 2). In addition, the three journals have a high impact factor (7.57 to 11.44) in the research area. These journals together published 82 documents, representing 31.5% of the total document sample.

For that matter, it is observed that the *Journal of Cleaner Production* was the most used, with 38 documents published and 1004 citations (Cluster 5). The *Journal of Cleaner Production* is a US-based, peer-reviewed scientific journal covering transdisciplinary research on cleaner production.

In second place, with 23 documents and 1096 citations, was *Applied Energy* (Cluster 2). *Applied Energy* stands out for being a journal specialized in publishing works on energy engineering focusing on energy conversion and conservation, optimal use of energy resources, analysis and optimization of energy

processes, mitigation of environmental pollutants and sustainable energy systems.

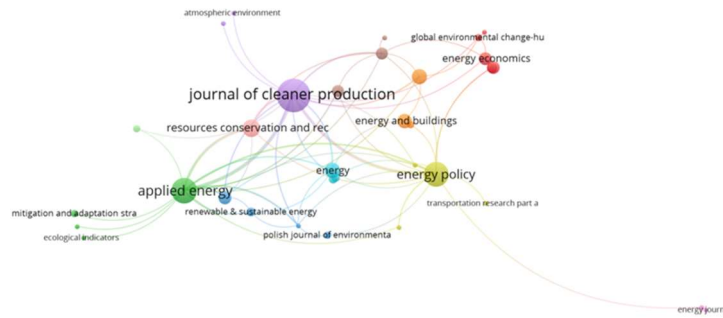


Figure 4: Journal citations.

Table 2: Ranking of journal citations.

Ranking	Journal	Number of Documents	Number of citations	%260 documents	Impact factor	Cluster
1º	Journal of Cleaner Production	38	1004	14.61	11.07	5
2º	Applied Energy	23	1096	8.84	11.44	2
3º	Energy Policy	21	1512	8.07	7.57	4

The *Energy Policy* journal ranked third with 21 documents and 1,512 citations (Cluster 4). It is an international peer-reviewed journal that addresses the policy implications of energy supply and use from its economic, social, planning and environmental aspects.

Bibliometric Network of Authors Co-authorship

The co-authorship bibliometric network was applied to analyze the authors' cooperation pattern, based on 260 documents, with the contribution of 969 different authors, with at least 1 document per author. The result has shown that, of the total, 81 authors had at least 2 documents published. Of the 81 authors, 59 authors had co-authorship cooperation in the studied research area, represented in 6 clusters and 426 links (Figure 5).

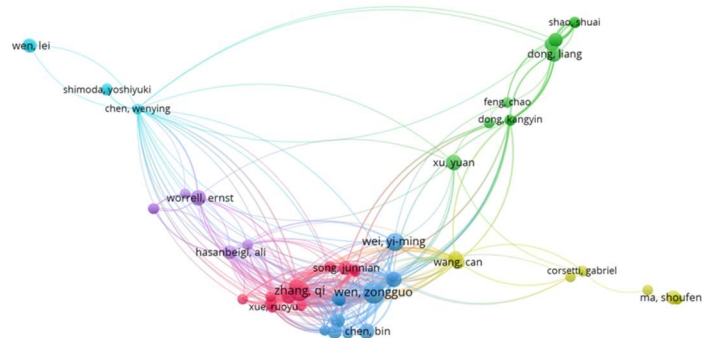


Figure 5: co-authorship citations.

Table 3 lists the 4 most outstanding co-authors, with the number of citations as a tiebreaker, in terms of number of documents and citations, based on Figure 5, through the thematic axis under study.

Chinese Professor Wen, Zongguo, Tsinghua University, Beijing, China has the most publications with 7 papers and 276 citations, followed by authors Zhang, qi, Professor, East China University of Science and Technology, Shanghai, China, with 6 published documents and 162 citations; Wei, yi-ming, professor at Guangxi University, Nanning, China, with 5 published papers and 189 publications and the author Meng

Table 6, lists the five institutions with the most documents published in the research area, being Tsinghua University, with 20 documents and 865 citations, the number one in the ranking. The ranking is completed by the Chinese Academy of Sciences, Beijing Normal University, Xiamen University and Beijing Institute of Technology.

A careful look at Table 6, shows that the most outstanding institutions in the number of publications are in China. The Asian giant emerges as a major hub and promoter of publications related to the subject under study in this work.

Table 6: ranking of organizations.

Ranking	Institution/ Country	Number of Documents	Number of citations	%260 documents	Cluster
1º	Tsigha University / China	20	865	7,69	1
2º	Chinese Academy of Sciences/China	16	365	6,15	1
3º	Beijing Normal University / China	13	269	5,00	3
4º	University of Xiamen/China	9	301	3,46	2
5º	Beijing Institute of Technology/China	8	591	3,07	2

CONCLUSIONS

It can be seen that there has been a significant growth in the number of published documents in the last 10 years (2015 to 2022) on the subject of energy efficiency with a focus on carbon dioxide mitigation.

Bibliometric analysis using the Vosviewer software was an essential method for obtaining a mapping of publications from the last 30 years on the studied thematic area. Of the 260 documents obtained from the Web of Science database, 83.07% (216 documents) had at least three citations; among these, the five most cited documents were Woolf et al. (2010), Bin (2005), Wang (2013), Wang (2007) and Zhao et al. (2016).

Scientific research on the subject is concentrated in five countries with a co-authorship relationship that together accounts for 81.11% of published documents. China was the country with the highest number of publications (128 documents).

The keywords with the highest frequency to represent the central theme of the study were "CO2 emissions", "mitigation", "consumption" "conservation" and "China".

The bibliometric study showed that the Chinese authors Wen Zongguo, Zhang Qi, Wei Yi-ming and Meng Fanxin were the authors with the most publications on the topic of energy efficiency and CO₂ mitigation.

The most relevant journals were Journal of Cleaner Production, Applied Energy and Energy Policy, accounting for 31.5% of the analyzed documents. In addition, these journals have a high impact factor in the study area.

Chinese organizations Tsinghua University, Chinese Academy of Sciences, Beijing Normal University, Xiamen University and Beijing Institute of Technology were the most productive in terms of number of publications.

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