



## Research Article

# Bibliometric study of the combustion of cane cutting waste (RAC) in the capture of carbon dioxide

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## Abstract

The bibliometric observational study in this research describes the search carried out by the authors, the statistical and regular behavior for a period of five years, focusing on the different elements related to the combustion process of the RAC of sugar cane with CO<sub>2</sub> capture by manganese-based oxygen carriers during the 2015–2020 period. Main measurements: In each record, journal, year of publication, first/last author, work center and autonomous community were obtained, related to the investigation of combustion of cutting waste in the capture of CO<sub>2</sub> by means of manganese-based oxygen carriers. The information was classified and later the articles were classified according to their content or research area. The impact factor was obtained from Scopus and Vosviewer bibliometric analyses. Using the search criteria used, 475 documents were retrieved in the 2015–2020 five-year period, excluding 2637 because they did not correspond to affiliation with centers or institutions directly related to documents related to Chemical combustion and CO<sub>2</sub> capture. In total, 73 documents were selected, in which an increase and interest in the study of these processes was verified both in the research areas and in the journals in which they are published. Most of the studies have been published in universities or research centers and differences were observed in terms of the volume of international and national scientific production, being necessary to increase these investigations in the country of Colombia.

**Keywords** Chemical looping combustion · Capture · Carbon dioxide · Biomass · Energy

## Abbreviations

CLC	Chemical looping combustion
CO <sub>2</sub>	Carbon dioxide
G20	The European Union and four countries
GHG	Greenhouse gases
IPPC	Intergovernmental panel on climate
UNFCCC	United Nations framework convention on climate change
RAC	Cutting residues of sugar cane
Scopus	A bibliographic database containing abstracts and citations for academic journal articles

TSO	Oxygen transporter
Vosviewer	Is a software tool to build and visualize bibliometric

## 1 Introduction

The study of bibliometrics as a scientific discipline is essential for research and statistical behavior for periods of time as scientific production has been developed. The global explanations to the observed phenomena are achieved through the formulation of the bibliometric laws. De Solla Price (1956) found that the growth of scientific information

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was exponential and occurred at such a rapid rate that every 10–15 years the existing global information doubled (Price's law). However, each discipline undergoes its own evolution, passing through various stages [1].

The fields used in the searches are presented with their respective formulas: ((chemical AND looping AND combustion)) AND ((carbon AND dioxide AND capture)) AND (manganese-based AND oxygen AND carriers).

Lignocellulosic biomass is a major source of renewable energy with potential in the production of biofuels with neutral CO<sub>2</sub> emissions, cogeneration of electrical energy and generation of compounds [1]. It is so named because of its chemical composition, which structurally possesses cellulose, hemicellulose and lignin and, in smaller quantities, starch polysaccharides, proteins, and other water-soluble organic substances [2, 3]. There are agricultural residues in the biomass that are obtained from sugarcane harvest and derived from straw, stem pods and dried leaves; these residues are called RAC (cutting residues) [1].

RACs are used as a source of animal feed or raw material for several processes. The present work focuses on the fact that they have high potential as fuel in the generation of electrical energy based on being a renewable resource with high availability and good properties as a source of fuel and the availability of effective technology for its use. According to León-Martínez (2013), it is estimated that the RACs correspond to 15 to 20% of the weight of cane at a humidity of 15%, which explains its high volume and the large amount of energy that can be used [1].

All scientific publications and research on biomass are shared by the scientific community, so publication is an essential phase of the advancement of knowledge. It is also known that combustion by oxygen transporters stands out as one of the most promising CO<sub>2</sub> capture technologies due to its low energy penalty, separation of CO<sub>2</sub>, and low cost [4]. These disseminations of new knowledge make a decisive contribution to scientific progress.

The analysis of the publications in the CLC area has made it possible to value scientific productivity since the bibliometric analyses have the advantage of being objective and serving to influence the judgment of experts [3]. However, despite their use and unquestionable value, it is necessary to analyze bibliographic citations that have limitations when used as the only mechanism for evaluating scientific activity. For the IPCC (2019), the use of biomass for bioenergy may have benefits, adverse side effects and risks to land degradation, food insecurity, GHG emissions and other environmental and sustainable development objectives; in journals with high-factor bibliographic impacts, relevant information is obtained about the advances of biotechnology and the agricultural industry [5]. To clarify, gases in the atmosphere that absorb infrared radiation from Earth or outgoing radiation are known as

greenhouse gases (GHGs), which include carbon dioxide, water vapor, nitrous oxide, methane, and ozone. These gases have molecules whose vibrational frequency is located in the infrared part of the light spectrum [6].

The Intergovernmental Panel on Climate Change has three working groups and a task force that provides scientific, technical and socioeconomic advice to countries that are members of the United Nations Framework Convention on Climate Change (UNFCCC) [7].

There are mutually supportive climate and land policies that can save resources, increase social resilience, support ecological restoration, and foster multistakeholder engagement and collaboration [5].

The Energy Plan for 2050 in Colombia mentions these objectives and promotes the efficient management of energy demand while incorporating clean transport technologies. With this objective, it seeks to reduce the country's energy intensity and pursue low-carbon development by decreasing demand and improving consumption efficiency [8].

It is already possible to improve bibliometric culture and its evolution; there are several studies on the CLC, CO<sub>2</sub> capture, and a complete energy plan for 2050 at the country level. Some studies already show the specific concept of thermochemical friction, in which a carbonaceous substrate (organic matter) is transformed into a combustible gas of low or medium calorific value by a gasifying agent under certain operating conditions [9]. Other studies describe international scientific production and specify positive aspects of the use of organic industrial waste, whether solid or liquid, thus stimulating further research [9].

On the other hand, although scientific publications on technological advances in CLC and CO<sub>2</sub> capture in Colombia focus on the use of organic waste to reduce environmental impacts, there are also scientific journals in numerous specialties indicating that low-cost materials based on iron and manganese have potential as TSOs in CLC technology [10, 11].

Although progress has been made in several studies, there is still a lack of bibliometric studies on combustion processes using residue from the cuttings and bagasse of sugar cane [12].

We seek to analyze other factors, such as the volume of research activity, its evolution over time, the type of research, the topics addressed, the groups and centers most active in the different areas and the collaborations between them. The objective of this research is to determine the scientific production of CLC and CO<sub>2</sub> capture with residues from the cuttings and bagasse of sugar cane, analyzing its geographical distribution, the impact factor of the journals involved, the main areas of research and the participation of the different institutional sectors [10].

## 2 Methods

The present study is an observational study of bibliographical character and international scope using the period from 2015 to 2020. The study units were scientific articles directly related to the processes of CLC in the capture of CO<sub>2</sub> from the cuttings and bagasse of sugar cane, published in any scientific journal of a period indexed in the Scopus database and carrying out a generic search strategy to recover the largest possible number of references published in each autonomous community during the study period.

The following search criteria were used for this purpose: 'chemical looping combustion', 'carbon dioxide capture', 'manganese-based' and 'oxygen carrier'.

Then, each of the documents recovered was manually reviewed, excluding those that did not correspond to CLC and CO<sub>2</sub> capture based on the information contained in the title, abstract and affiliation data.

In each of the records obtained, the following variable quantities were collected: title of the journal, year of publication, surnames and initials of the first and last author, institution or place of work of the signatory primer and autonomous community.

Subsequently, the articles were categorized according to the following topics: energy and fuels, applied energy, biofuel, International Yearbook of Green Energy and Gas, Yearbook of Chemical Engineering, Biotechnology for Biofuels, Energy and Energy Technology, Research in Industrial and Engineering Chemistry.

In cases where more than one institution was mentioned, the item was assigned to the original institution, and documents that had few research matches were rejected, as illustrated in Fig. 1.

Using these criteria, 475 papers were recovered in the five-year period from 2015 to 2020, excluding 2162 papers because their affiliation did not correspond to center institutions directly related to CLC and CO<sub>2</sub> capture. In total, 212 documents were selected, and 10 different authors were identified, as shown in Fig. 2.

In Fig. 3, the various percentages of the analysis of the documents by area of study are indicated. In Energy 125 journals were found (25.5%), in Chemical Engineering 107 journals were found (21.8%), in Environmental Science 81 (16.5%), 74 in Chemistry (15.1%), 71 in Engineering (14.5%), 12 in Physics and Astronomy (2.4%), 10 in Materials Science (2.0%), 5 in Biochemistry, Genetics and Molecular Biology (1.0%), 2 in Agricultural and Biological Sciences (0.4%), and 4 in other topics (0.6%).

When analyzing the documents by year between 2015 and 2021, there were more publications in the first five years, with the highest totals of 40 and 44 articles in 2015

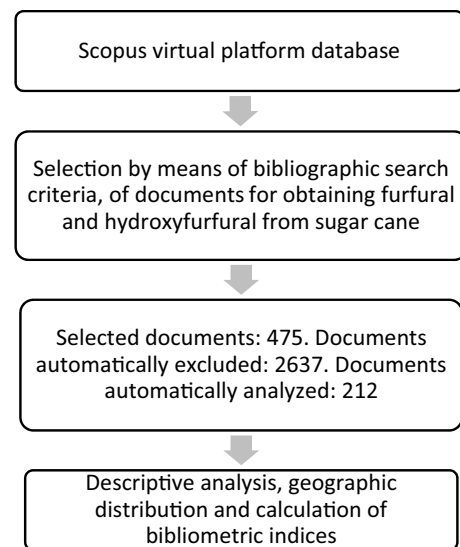


Fig. 1 Outline of the study results (Source: the author)

and 2020, respectively. In 2019, there was a decrease in the number of publications to 26, but by 2021, there were already 9 articles related to the processes of CLC and CO<sub>2</sub> capture (Fig. 4).

We identified 23 studies related to energy and fuels between 2015 and 2020, which was the most common topic, while in the area of chemical, industrial and engineering research, only 6 sources were found, as shown in Fig. 5.

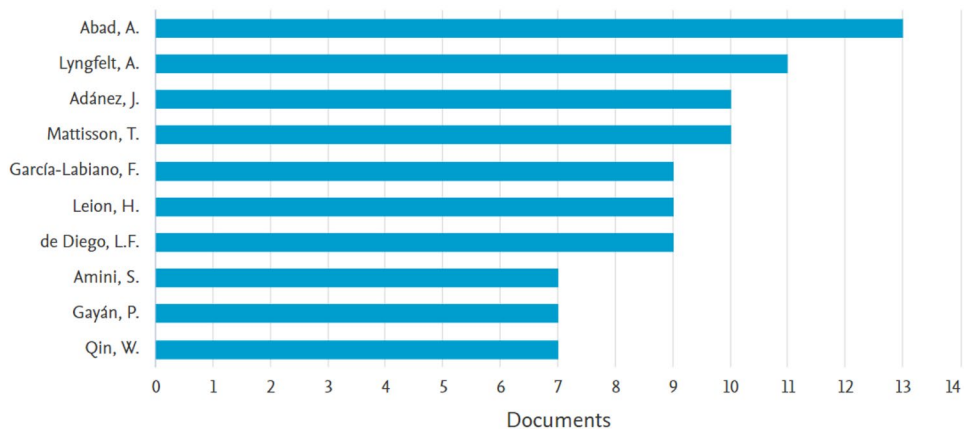
When searching the documents by affiliation, it was determined that most publications were published in China, as 71 investigations were carried out by the Chalmers University of Technology of China. In the case of South America, 3 scientific journals disseminated in Brazil were identified from the Institute of Energy and Fuels, where they determined that the process of manganese transporters is insufficiently investigated (Fig. 6). Considering that China has the largest number of studies, the most relevant authors are Abad, Lynfelt and Adanez; the authors with the most citations are Lynfelt with 17,913 citations; Mattisson with 978 citations as shown in Fig. 7.; and the most relevant authors are Abad; with 11 articles of his authorship; Mattisson, with 13 articles of his authorship; Lynfelt, with 15 articles of his authorship while García and Adanez, with eight articles of his authorship; Gayán presents 7 articles of his authorship; while De Diego, Ryden and Hossain five articles each; as indicated in Figure To complement this analysis, it was determined that China, the United States and Spain are the countries where this study has the greatest relevance, while in Iran, there are only 7 publications during the period from 2015 to 2020 (Fig. 8).

Finally, we investigated the types of research carried out during the period of this bibliometric study and found

**Fig. 2** Documents by author (Source: [www.scopus.com](http://www.scopus.com))

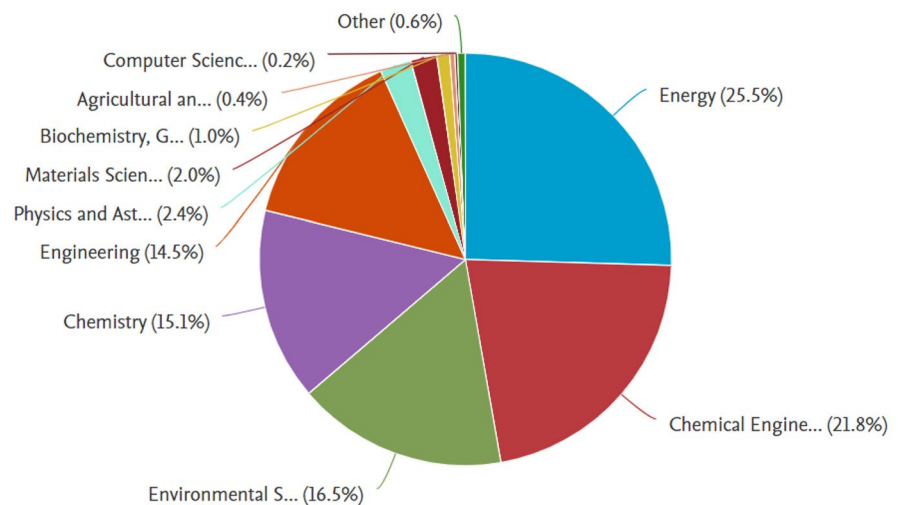
Documents by author

Compare the document counts for up to 15 authors.



**Fig. 3** Documents by Area of Study (Source: [www.scopus.com](http://www.scopus.com))

Documents by subject area



170 articles (80.2%), 24 reviews (11.3%), 10 book chapters (4.7%), 7 conference articles (3.3%) and 1 retracted article (0.5%), as shown in Fig. 9.

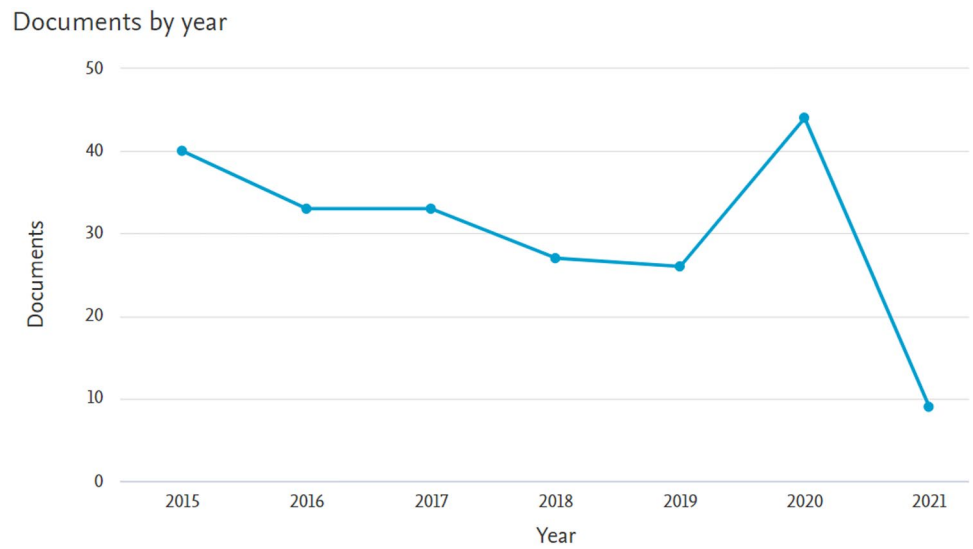
Maps were obtained using the software VOSviewer software version 1.6.7 is a software tool for building and viewing bibliometric networks. With the ability to reach journals, researchers or publications, they can be built based on citations, bibliographic coupling, co-citations or author relationships. As shown in the active map of the CLC process, CO<sub>2</sub> captures RAC biomass from sugarcane. At the national and international levels, this correlation was detected when using the carbon dioxide phrase in most cases. The largest green dot (carbon dioxide) represents each author who has published a large number of articles. Twenty-four articles were considered in this study

that were not finalized and marked on the active map with a different color (Fig. 10). For a greater understanding of the identification of networks, academics have proceeded to establish the results through Vos's viewer to identify the groupings or clusters.

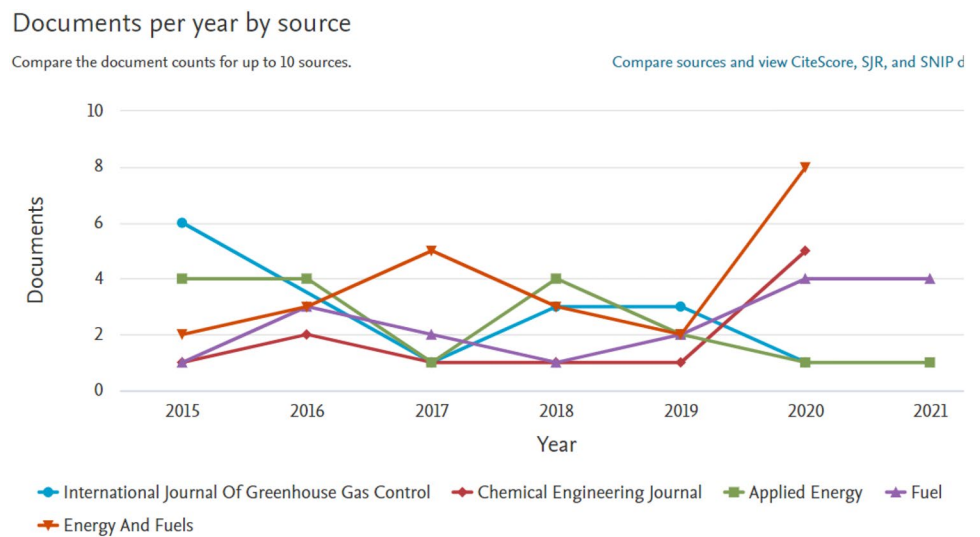
CLC, one of the most widely used methods for CO<sub>2</sub> capture with sugarcane, uses chemical reactors (Fig. 11). [10] For indirect combustion with solid oxygen transporters (chemical looping combustion—CLC), it is an energy efficient alternative for capturing CO<sub>2</sub>, as it is a technology with inherent separation of CO<sub>2</sub> through the use of solid oxygen conveyors, or TOs (metal oxides) [13].

CLC technology uses oxygen transporters, which are basically metal oxides of copper, nickel, manganese, iron or cobalt, based on an inert species acting as a porous

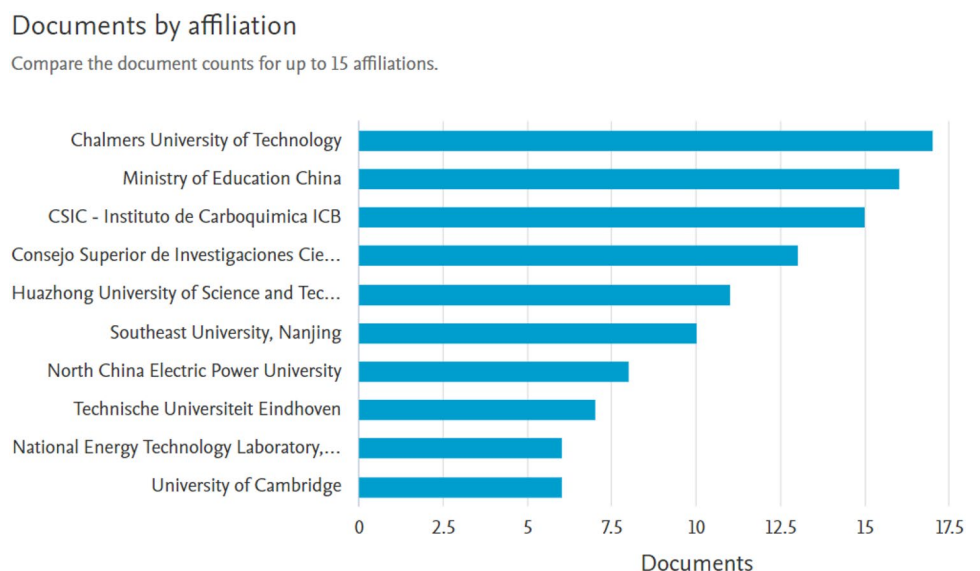
**Fig. 4** Documents by Year of Publication (Source: [www.scopus.com](http://www.scopus.com))



**Fig. 5** Documents by Year and Source (Source: [www.scopus.com](http://www.scopus.com))



**Fig. 6** Documents by Affiliation (Source: [www.scopus.com](http://www.scopus.com))









15 members have not yet made this commitment at the international level [15]. In general, the process of capturing CO<sub>2</sub> by CLC in Colombia is still an emerging discipline when compared to other countries such as China, the United States or Spain, where research is more advanced.

The gasification process is a method used to obtain a gaseous fuel, carbon monoxide mostly and, to a lesser extent, hydrogen from another fuel source, such as any type of biomass with carbon content [15]. Once this process is started, another series of components that proportionally accompany carbon monoxide, such as carbon dioxide, solid waste and other components resulting from the reactions that occur parallel to the gasification, is obtained. These include pyrolysis, oxidation, and even hydrogenation [16].

The development of gasification technology makes it possible to recover the energy present in waste materials, such as biomass. Within the energy use of biomass, gasification is performed by converting a carbonaceous fuel into a gas at a high temperature by partial oxidation, resulting in useful energy [17].

Currently, Colombia recognizes the need to promote development or research into these operations, and the lack of viability of scientific production has been highlighted [17].

The increase in research in recent years and the higher impact factor from specific study structures observed in the results indicate that more resources and the consolidation of such structures (research units, networks and CLC study institutes) are needed. The results also indicate that the research is highly transitory, which suggests that strategies for consolidating lines and research sets should be implemented. It is possible that the creation of university departments of Biotechnology, which has happened in almost all Western countries, can also serve as a strategy to improve the volume and quality of research. To monitor if this development occurred in the coming years and to be able to quantify the magnitude of the changes, bibliometric studies will continue to be of the utmost use.

## 5 Conclusions

In conclusion, in the published documents related to the methods of CLC with solid oxygen transporters, in recent years at the international level, there was an increase or spiked interest in the study of these methods and reactions both in the research areas and cutting-edge journals in which they are published. Most studies have been published in universities or research centers, and differences were observed in terms of the volume of international and national scientific production. It is necessary to increase these investigations in Colombia.

- Scientific publications allow the dissemination of new knowledge and make a decisive contribution to scientific progress.
- Bibliometric studies related to the methods of CLC in the capture of CO<sub>2</sub> provide useful information on professional activity and the research developed, analyzing, among others, aspects such as the volume of scientific production and its temporal evolution.
- The publications arising from the subject studied are distributed in journals of numerous specialties, which, together with the lack of updating of bibliometric studies, makes it difficult to evaluate scientific production.
- The increase in the scientific production of the chemical looping combustion process in the capture of CO<sub>2</sub> has been progressive over the last few years. The publications were dominated by biotechnological studies in the area of energy and fuels from organic waste.
- Some autonomous communities stand out for a greater number of documents in relation to the number of inhabitants, in which there is also a higher proportion of articles published in journals in other countries.

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**Availability of data and material** E-mails: Sandra Peña Murillo: sandra.penam@ug.edu.ec; Carmen Forero: carmen.forero@correounivalle.edu.co; Francisco Velasco francisco.velasco@correounivalle.edu.co all references are available at mendeley.

## Declarations

**Conflict of interest** The authors declare that they have no conflicts of interest.

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