

Research Development on Carbon Capture, Utilization and Storage as a Climate Change Mitigation Technology

by Dewan Riset dan Pengabdian kepada Masyarakat FALTL

Submission date: 01-Jul-2025 06:12PM (UTC+0700)

Submission ID: 2708819966

File name: CCUS.pdf (2.49M)

Word count: 8585

Character count: 45857

EREM 79/1

Journal of Environmental Research,
Engineering and Management
Vol. 79 / No. 1 / 2023
pp. 25-55
DOI: [10.5755/j01.erem.79.1.32424](https://doi.org/10.5755/j01.erem.79.1.32424)

Research Development on Carbon Capture, Utilization and Storage as a Climate Change Mitigation Technology

Received 2022/10

Accepted after revision 2023/02

<https://doi.org/10.5755/j01.erem.79.1.32424>

Research Development on Carbon Capture, Utilization and Storage as a Climate Change Mitigation Technology

Thalia Sunaryo¹, Maria R Nindita Radyati¹, Maria Ariesta Utha¹, Astri Rinanti^{2,*},
Astari Minarti²

¹Faculty of Economics and Business, Universitas Trisakti, Jakarta, Indonesia

²Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia

*Corresponding author: astirinanti@trisakti.ac.id

The continuous growth of energy consumption leads to the increase of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO₂). Carbon capture, utilization and storage (CCUS), which consists of carbon capture storage (CCS) as well as carbon capture and utilization (CCU), is a technology that aims to capture CO₂. Therefore, this study evaluates and provides an overview of CCUS in the period 2012–2022, by using a bibliometric analysis to obtain a complete perspective and reference on CCUS. The data search was carried out on January 20, 2022, by inputting the keyword "carbon capture utilization storage" into the Scopus database, and 296 documents were generated. Other software used included Open Refine, VOS viewer and Tableau to describe publication and citation trends, co-authorship, and co-occurrence. CCUS research trend increased by 2,766.6% from 2012 to 2022. The most productive country in investigating CCUS was China, and Zhang X. was the most prolific writer. The organization that published the highest number of research on the topic was the National Taiwan University. The publications and citations were dominated by the International Journal of Greenhouse Gas Control that was published by Elsevier Ltd., which also issues a number of significant publications and gives the highest number of citations.

Keywords: bibliometric analysis, carbon emission, carbon capture, carbon capture utilization, carbon capture storage.

Introduction

The increase of greenhouse gas (GHG) emissions has become a global climate issue that profoundly raises the world's attention due to the impact of climate change. The Intergovernmental Panel on Climate Change (IPCC) launched a Special Report on Global Warming of 1.50 °C, which contains various impacts created on human health, food security and ecosystems. The impact can be anticipated through the attempt of limiting the temperature rise by 1.50 °C above the average temperature prior to industrial era. Total GHG emissions in 2018 reached 55.3 gigatons of CO₂ equivalent. Consequently, hydro-meteorological disasters may occur due to extreme weather that changes the length of dry and rainy season and increases the frequency and duration of droughts. Another impact of climate change is a rise in temperature and sea level (Nerem et al., 2018; Zhao et al., 2020). According to Stene et al. (2009), carbon dioxide emissions have increased by 40% since the period of the Industrial Revolution, and human activities might have greatly contributed to CO₂ release since that time. Carbon dioxide is capable of absorbing long-wave IR radiation (heat) being emitted by the earth which can make the greenhouse effect stronger, hence any increase in CO₂ emissions ultimately causes a rise in the earth's temperature.

The largest CO₂ emissions are generated from agricultural activities, energy production and energy use. Furthermore, trade, transportation, and the growing manufacturing industry add to CO₂ emissions as stated by Adom (2012), which exacerbates the ecological aspects of environment such as climate and climate change. Moreover, the tourism industry elevates carbon dioxide emissions; thereby it is important to raise the awareness of global warming and climate change into the practice of business as usual (Balogh and Jambor, 2017). In order to abate the global warming, reducing the levels of carbon dioxide (CO₂) emissions from exhaust gases produced by industrial activities has to be promptly undertaken since the levels of carbon dioxide (CO₂) emissions have continued to increase from year to year (Rinanti et al., 2014). Global warming has an impact on all living things and nature such as

rising sea levels, climate anomalies and natural disasters (Fachrul et al., 2019; Rinanti et al., 2013).

By 2100, the level of atmospheric CO₂ emissions is estimated to reach around 800 ppm and the earth's surface temperature tends to rise by 4 °C (Wang and Oke, 2017). According to the Summary for Policy-makers of the IPCC Working Group III report, Climate Change 2022: Mitigation of Climate Change, 195 countries in the world have agreed to limit GHG emissions. A conference held in Paris from November to 12 December 2015 propagated the Paris Agreement to the United Nations Framework Convention on Climate Change. Furthermore, the Paris Agreement aims to mitigate the climate change towards a low-carbon, resilient and sustainable future and ensures that global temperature elevations keep well below 2 °C (Wang and Oke, 2017). Carbon capture, utilization and storage (CCUS) comprises carbon capture and storage (CCS) as well as carbon capture and utilization (CCU), both of which aim to capture CO₂ that is being released into the air. The difference between these two technologies lies mainly in the fact that, in CCS, CO₂ emissions are captured and injected into underground storage areas, while in CCU, the CO₂ is converted into commercial products. Based on Zaemi and Rchmana (2021), CCUS's goal is to capture 85% of CO₂ that is released from power plants and industries and the resulting emissions are to be transported into 700 meters depth below sea level through pipes.

Based on IPCC (2022), CCS is the most feasible/accessible technology to reduce emissions from carbon-intensive industries and power generation; however, the mitigation costs tend to reach 138% without CCS technology. This technology is applied for the downstream phase of CCS pathways, by capturing carbon emissions to be stored and utilized for other production processes (Prayitno et al., 2021). Meanwhile, Reiner (2016) has found that CCS technology is employed for climate mitigation and expected to decrease the GHG emissions by 32% until 2050. This target can be justified by the research done by Akbar et al. (2021) that CCS technology captures 85–95% of the CO₂ produced by an industry. Besides of that CCS technology is also

able to reduce carbon emissions with an accuracy level of 95% when applied in a waste-to-energy plant.

The Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) has summoned all countries in the world to commit to implementing actions to keep average global temperature below 2 °C and to continue with efforts for suppressing the increase to 1.5 °C. Afterward, targets for each country's commitment were created, where the Paris Agreement set a target to reduce GHG emissions, which is called the Nationally Determined Contribution (NDC). The achievement of GHG emission reductions is verified to ensure that the calculation process complies with the principles that have been recognized as transparent, accurate, consistent, comprehensive, and comparable (TACCQ) at the national and international level. This mechanism works through the improvement of scrutinizing and disclosure for lowering the GHG emissions level to encourage the countries for acquiring the climate incentive. The report of TACCQ will be beneficial for stakeholders to set a number of measureable goals for climate change mitigation that includes the efforts for reducing emission, resilience enhancement and for allocating financial resources (Weikmans et al., 2019).

However, the technology of CCUS has not been widely applied, although data and references collection on the technology is largely available. Moreover, the implementation cost of CCUS varies greatly in the fields of electricity and industry (Adisaputro and Saputra, 2017). According to Zaemi and Rohmana (2021), the challenges of developing CCUS are to determine the location of infrastructure and the environment to be used as CO₂ storage areas plus the high required costs. Owing to the significant topic of the IPCC Agenda 2030 on greenhouse gases, CCUS remains to be an interesting global issue to be investigated as a climate change mitigation technology although many studies of greenhouse gases have been extensively conducted. In addition, a number of research works have investigated the application of CCUS technology in some countries, such as the United States (Alphen et al., 2010), China (Jiang and Ashworth, 2020), ASEAN countries (Kimura et al., 2020) and the United Kingdom (Gough et al., 2020). This review, therefore, offers the trend of research development in the field

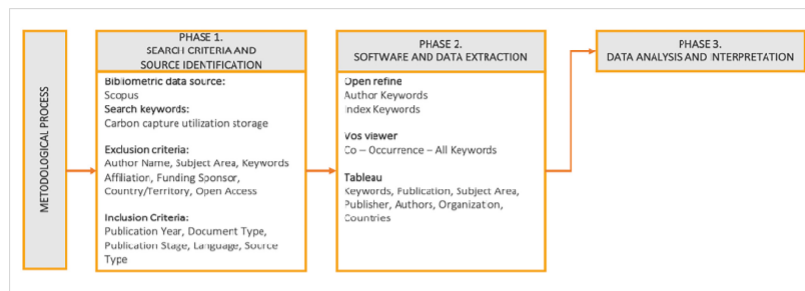
of CCUS to show the acceleration of technology used to apply the CCUS methods for industrialization in some countries within the year of 2012–2022.

The significant objective of this research is to evaluate the growing trend of investigation on CCUS from 2012–2022, as well as to determine the distribution and productivity of research by authors, organizations, and countries, plus the distribution of research work on subject areas and publishers through the following research questions namely: (1) How do the CCUS technologies provide a solution for reducing the carbon emission of industries around the world?; (2) What are the CCUS technologies that most frequently applied for the industry within 2012–2022?; (3) Who are the most prolific authors followed by the most productive countries and organizations?; (4) What are the potential areas of interest in the research development of CCUS technologies? Therefore, the bibliometric analysis which is to find the research gaps for further exploration on the topic of carbon capture, utilization and storage, was conducted by using the Scopus database. This article divides its systematics of writing into the following parts, namely the introduction, methods, results and discussion, conclusion and references list.

Methods

According to Chen et al. (2015), Singh and Borthakur (2018), a bibliometric analysis is an effective method of analyzing research progress and quantitative trends in publications on a particular topic, by providing an overview of literature contribution both nationally and internationally (Zhang et al., 2020; Zyoude et al., 2022). Sweileh (2022) explains that any bibliometric study uses a statistic approach to identify growth patterns and development of publications as well as collaborative patterns among authors, institutions, and countries. Moreover, bibliometrics identify the research gaps through analyzing the research niche offered by the publication database, which is useful to provide the basis for conducting further research (Singh and Borthakur, 2018; Zhang et al., 2020). The method is divided into three phases, namely data mining, extraction and analysis, as presented in Fig. 1.

Fig. 1. Study method diagram



Search criteria and source identification

In phase I, data search was carried out on January 20, 2022, by inputting the keyword "carbon capture utilization storage" into Scopus database. Owing to the nature of Scopus as the world's leading literature database published by Elsevier and known to have the highest number of citations (Herawati et al., 2022; Borthakur and Govind, 2017), the Scopus database fits into the expected outcomes of this study. Then, filtering was done with the year of publication, document type, publication stage, language, and source type to obtain more significant results. The data were mined from 2012 to 2022 by limiting the type of article document, final publication stage, journal source type and the English language used. After filtering, 296 available documents were generated and the search results were exported in the CSV format with citation information, bibliographical information, abstract, and keywords. Files exported from the Scopus database were fed into the Open Refine software to reduce inconsistent and repetitive keywords in the mined data.

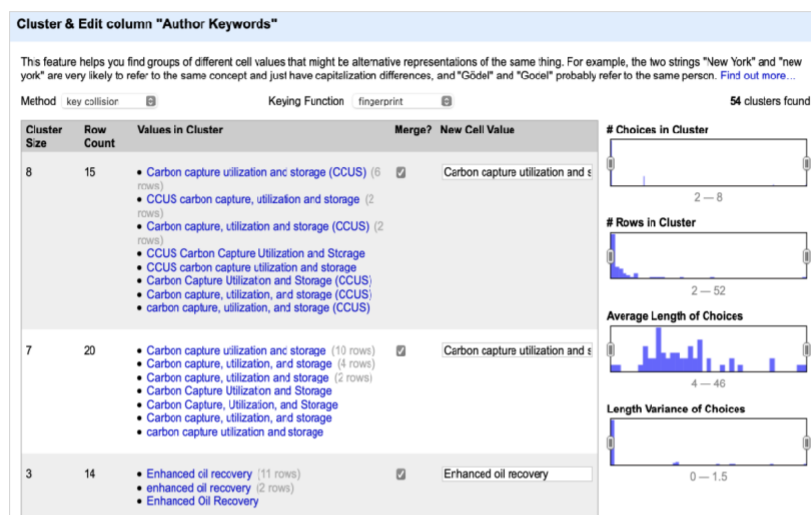
Software and data extraction

The data obtained from the Scopus database was further extracted and processed by using Open Refine, Vos Viewer and Tableau Public software. The data were fed into Open Refine to reduce several keywords with different spellings but same meaning and to establish the keywords in an exact writing format for avoidance of repetition. Open Refine is able to clean the data from

one format to another, overcomes inconsistencies in data sets and divides data into more detailed parts, in an automatic or manual attempt (NIH, 2022).

Fig. 2 shows repeated keywords, namely "Carbon Capture Utilization and Storage (CCUS)", "CCUS carbon capture, utilization and storage", "Carbon capture, utilization and storage (CCUS)", "CCUS Carbon Capture Utilization and Storage", "CCUS Carbon Capture Utilization and Storage", "Carbon Capture Utilization and Storage (CCUS)", "Carbon capture, utilization and Storage (CCUS)", "Carbon capture, utilization and storage (CCUS)" and "carbon capture, utilization, and storage (CCUS)". Some of these have the same meaning but different spellings, hence they are reduced to one format of the keyword, i.e., "Carbon Capture Utilization and Storage (CCUS)". The reduced keywords generated through Open Refine were then fed into the VOS Viewer software, which presents and visualizes specific information about bibliometric chart maps for easier analysis of the relationships or networks about a research topic (Althar et al., 2019). Open Refine enables the author to select the preferred data set, thus the results contained a list of useful data that removes redundant keywords. It means that carbon capture utilization and storage (CCUS) has been tested as the natural result of removing data with redundant keywords. In addition, CCUS is the representative value of other related values (Bergamini, 2019), to generate a more extensive subject field such as Carbon Capture and Carbon Storage, Carbon Capture Strategies and Carbon Storage Sustainable.

Fig. 2. Extract data using Open Refine



The software provides data visualization based on co-authorship, co-occurrence, citation, bibliometric coupling, and co-citation. In this study, co-occurrence of all keywords (author and index keywords) as well as co-authorship (authors) based on network and overlay visualization were used particularly. In co-occurrence analysis, all keywords were chosen as the selected unit with a full counting method. Based on the 296 documents from Scopus, 3,293 keywords were obtained. Once the minimum number of occurrences was set at eight, 78 thresholds were generated, indicating that 78 keywords were repeated eight times in the 3,298 keywords.

Even though the keywords were tidied up in Open Refine, some redundant keywords still appeared that had the same meaning as CO₂ and carbon dioxide. These were employed as a writing format using Thesaurus note, which were then imported into VOS Viewer. In co-authorship analysis, the applied unit analysis referred to authors with the full counting method. The total number of authors in the 296 Scopus-generated

documents was 1,011. After setting the minimum number of an author's documents at three, the threshold obtained was 76 authors. Tableau software was used to simplify complex data in the form of interactive graphic visualizations, for easy analysis and understanding (Akhtar et al., 2020). Akhtar et al. (2017) and Murray (2013) stated that Tableau is the most powerful and flexible analytical platform for providing data information and managing their rows into various visualization types.

Data analysis and interpretation

296 research publications were processed by using Open Refine, VOS Viewer and Tableau software regarding publication and citation trends; co-authorship and co-occurrence were analyzed and interpreted, then comparative analysis was conducted within the aforementioned research publications.

The method should consist of research design, subject characteristics, data collection process and data analysis. If necessary, it should raise ethical issues

particularly when dealing with human participants. Appropriate statistical methods should be used, although the biological mechanism should be emphasized. The statistical model, classes, blocks, and experimental units must be designated. Consultation with a statistician is recommended to prevent any incorrect or inadequate statistical methods.

Results and Discussion

Global distribution of publication and citation trend (2012–2022)

One of the objectives mentioned in this article is the determination of global research distribution in 2012–2022. The trends of publications and citations in those years are presented in Fig. 3. The total number of publications obtained from Scopus regarding "Carbon Capture Utilization and Storage" was 296. This figure increases significantly from 3 publications in 2012 to 83 publications in 2021. The number of publications and citations in 2021 are inversely related. In 2022, the total number of published documents and citations seemed to decrease because the data were collected in January, hence they did not represent 2022 as a whole. From 2012 to 2015, the increase of published documents and citations was directly proportional, but in 2016, the number of citations increased. The highest citations occurred in 2016; however, the number decreased by 72% after 2016.

Research on carbon capture, utilization and storage (CCUS) has been issued from several journals and

publishers including Elsevier Ltd., MDPI AG, Frontiers Media S.A., Italian Association of Chemical Engineering – AIDIC, and Blackwell Publisher Ltd, which are the top 5. Elsevier Ltd. has the highest number of publications and 1,322 citations of 97 documents as well as journals reaching 28. Furthermore, its top 5 journals with the number of publications and citations respectively are Journal of 1) Greenhouse Gas Control (36.76%; 24.93%), 2) Cleaner Production (17.65%; 7.01%), 3) Applied Energy (17.65%; 38.40%), 4) Energy (16.18%; 13.28%), and 5) CO₂ Utilization (1.76%; 16.38%). Based on the results, 138 journals published articles on carbon capture, utilization and storage with up to 3,947 received citations.

Co-authorship analysis

This co-authorship analysis indicates the relationship between authors, countries and organizations, represented in a network diagram containing nodes and lines classified in different clusters. The clusters of nodes and lines are being distinguished by colors, while the size of nodes shows the weight and repetition of keywords. In addition, the distance from one node to another illustrates the strength of their relationship, and farther link between nodes means both keywords have less research (Khosroabadi et al., 2021).

Authors

The authors who conducted research on CCUS were 62, while their productivity is depicted in Fig. 5 with the highest number of publications and 43 citations. Zhang X is the most prolific writer in terms of the number of

Fig. 3. Annual publication and citation spread (2012–2022)

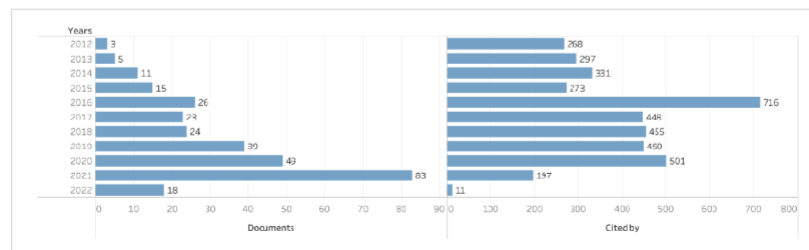


Fig. 4. Distribution of publications and citations by journal: (a) publication and (b) citation

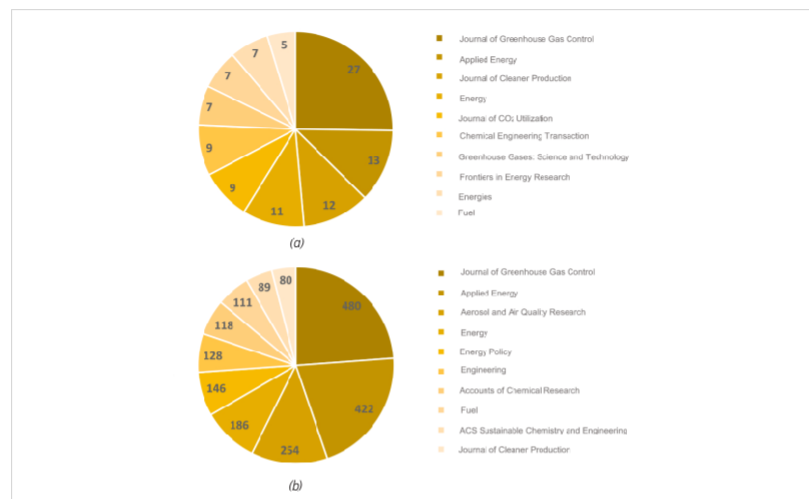
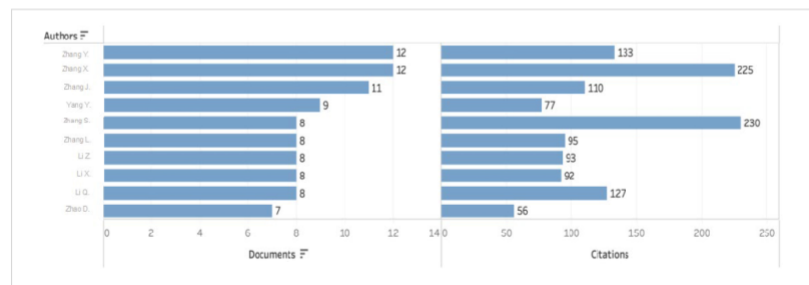


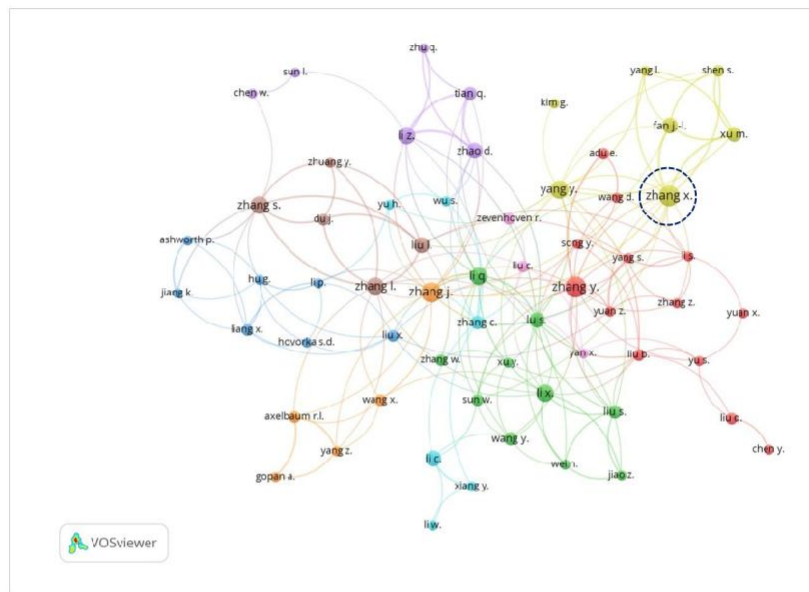
Fig. 5. Author productivity in terms of publications and citations



publications issued during 2012–2022, namely 12 documents that received 225 citations. These were lesser compared to Zhang S who reached 230 citations with a total of 8 documents published. The authors' relationship to one another is presented in Fig. 6, and in total, they are divided into 9 clusters distinguished by the

nodes' color. Zhang X has the highest total link strength of 33 and several relationships with 14 authors from other clusters through an average publication in 2019. The high citations obtained from authors are influenced by their number of links, meaning that there is a high chance of receiving citations with a high link.

Fig. 6. Co-authorship network of authors



During 2012–2015, Zhang X weighed the research development of CCUS technology in China including enhanced oil recovery and onshore saline aquifer as the most dominant options for the large-scale CO_2 utilization and storage techniques for the development of a roadmap of CCUS technology in China, followed by estimating the potential of methanol through hydrogenation (CTM) and steel slag mineral carbonation and utilization (S33) to optimize the efficiency of emission reduction, as well as the potential of CO_2 enhanced oil recovery (EOR) and CO_2 enhanced water recovery (EWR) for direct emission reduction.

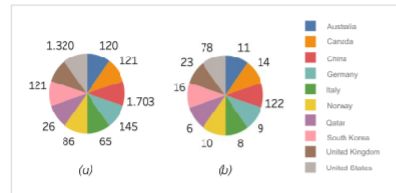
Throughout the period of 2016–2018, Zhang X highlighted the scope of his research among the topic of the benefit of a vertical integration model that fits for considering the revenue of CCUS technology applied for national projects in China, especially to determine

the economic benefits from enhance recovery oil (EOR) and the benefits of CO_2 EOR technology to ease the high investment cost by subsidizing the application of EOR to accelerate the CCUS development in China.

Countries

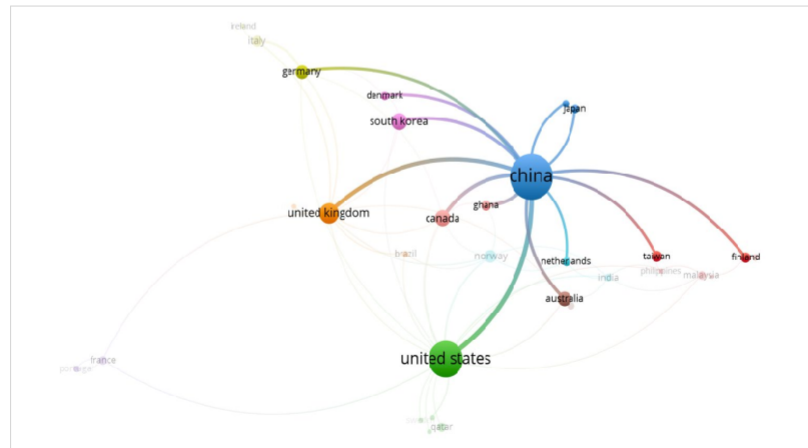
Fig. 7 shows the top 10 publications and citations based on their geographical location. The results of this study indicated China as the most productive country in conducting investigation on CCUS topics in 2012–2022, where the highest number of citations received was 43.39% and the publications reached 41.08% of the total citations amongst other 9 other countries. However, a similar study of CCUS by (Omogbe et al., 2018) showed a contrary result, that USA generated more publications (4,416) than China, which generated only 1,876 publications.

Fig. 7. Top 10 countries with the highest number of citations and publications: (a) citation and (b) publication



The second rank was occupied by the United States with publications and citations of 26.26% and 33.63%, respectively. As presented in Fig. 8, 32 countries were connected and divided into 10 clusters. The total link strength is the accumulated strength of the relationship between different items (Jiang and Ashworth, 2021). Based on countries analysis, the highest total link strength was achieved by China and the United States, namely 45 and 38. Meanwhile, the United Kingdom, Germany, South Korea, and Canada undertook a collaboration on research with China and the United States.

Fig. 8. Co-authorship network of countries



After the meeting of G8 in 2005, these above-mentioned countries were included into a pledge in Hokkaido for strengthening the climate change mitigation (Cosbey, 2009). Recently, Germany and United Kingdom reached the relative high rank for their international policy for climate change mitigation among other G20 countries, followed by the United States and China for their international level of climate negotiations performance. Meanwhile, the Republic of Korea (South Korea) and China received an appreciation amongst other G20 countries for their national climate policy. However, Canada showed the least willingness to improve their climate change mitigation performance due to political interest (Cosbey, 2009).

These remarkable achievements of respective countries were delineated from their Nationally Determined Contribution (NDC) for short-term that affects long-term goals, such as 55% of decarbonization goal belonging to Germany, 40% national reduction target of greenhouse gas emission in United Kingdom, and 25–28% reduction in greenhouse gas emission for the United States (Falduto and Rocha, 2020).

Organizations

In this study, the 296 publications were distributed across 687 organizations. This shows that this research was carried out from a diverse number of organizations including companies and mostly from universities. The top 10 organizations with the highest number of citations are shown in Table 1. The number of citations obtained from top 10 organizations with the highest citations was 1,553, belonging to the United States (47.39%), Taiwan (30.25%), and China (22.34%). However, the organizations with the highest citations were National Taiwan University and Taipei Medical University with citations of 235 each, while the lowest citations came from Amaren Corp United State (206).

Table 1. Top 10 organizations with the highest citations

Organization	Total Citation (%)
Graduate Institute of Environmental Engineering, National Taiwan University, Taipei, Taiwan	15.13%
Department of Biochemistry, Taipei Medical University, Taipei, Taiwan	15.13%
Indiana Geological Survey, Indiana University, Bloomington, United State	11.14%
Exxonmobil Upstream Company, Houston, United State	11.14%
Department of Geological Sciences, Indiana University, Bloomington, United State	11.14%
Laboratory of Low Carbon Energy, Tsinghua University, Beijing, China	7.60%
Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Department of thermal Engineering, Tsinghua University, Beijing, China	7.60%
Key Laboratory for Green Chemical Technology of Ministry of Education, Collaborative Innovation Center of Chemical Science and Engineering, School of Chemical Engineering and Technology, Tianjin University, China	7.15%
Department of Chemistry, University of North Carolina at Chapel Hill, United State	7.15%

National Taiwan University secured its most productive position in CCUS publication due to the efforts for weighing the importance of earth science, life science and social science which transformed into multi-disciplinary programs providing solutions particularly for climate change issues implemented in a number of climate change research and carbon capture practices as well as sustainable development related case studies and seminars (NTU, 2018). Meanwhile, Taipei Medical University put its remarkable efforts for CCUS related research topics such as carbonation, slags and steel making that plays a significant role into carbon capture, assigned under Department of Bio-chemistry.

Co-occurrence analysis

In this research, the keywords collected from 296 documents were 3,298. After setting the minimum number of occurrences at eight, 78 thresholds were generated. This shows that 78 keywords were repeated eight times in the 3,298 keywords. The co-occurrence visualization for all keywords is presented in Fig. 9, which is divided into four clusters marked with different colors: the first is red, second is green, third is blue, and fourth is yellow. Each cluster has one keyword with the highest total link strength. According to Table 2, cluster 1 is "carbon capture", 2 is "carbon sequestration", 3 is "CCUS" and 4 is "carbon dioxide".

The sphere shaped icons are called nodes and they have relationships with one another which indicate the relationships of different keywords. The node size shows the weight and repetition of a keyword, hence a larger size means that the keyword is more frequently used than the keyword of smaller node. The distance from one node to another illustrates the strength of their relationship, and the farther link between nodes means that both keywords have less research (Jiang and Ashworth, 2021). The keyword "carbon dioxide" contained in cluster 4 had the highest occurrence of 212, total link strength of 135 and up to 77 linkages compared to other keywords. Meanwhile, "slags" had the lowest occurrence which is 8, total strength of 46, and 19 linkages between keywords. The positions of the top 10 keywords with occurrences and citation scores are depicted in Fig. 10.

Fig. 9. Network of co-occurrence (all keywords)

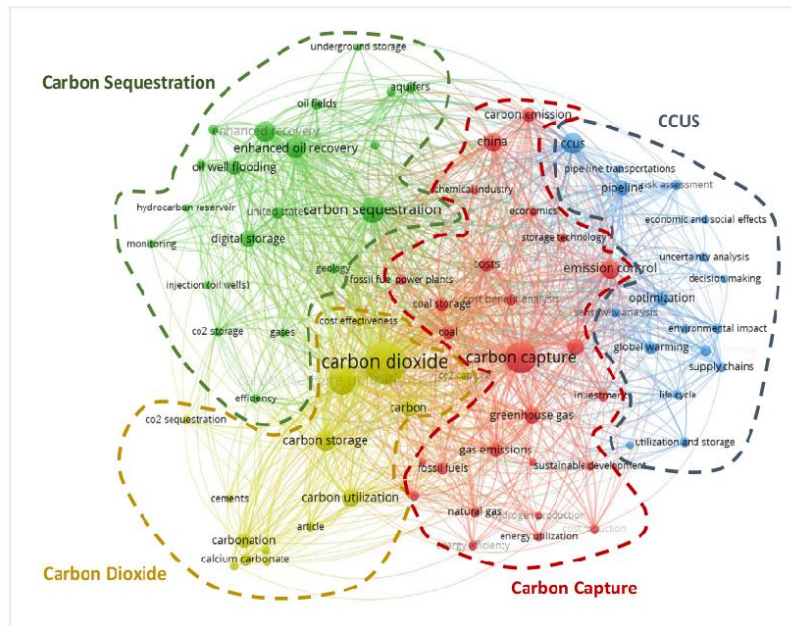


Fig. 10. Top 10 keywords based on the number of occurrences and citations

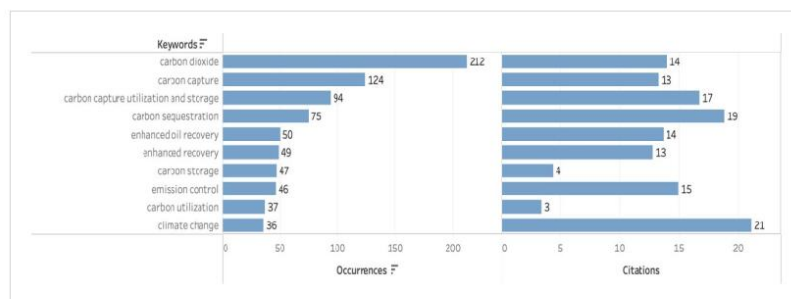
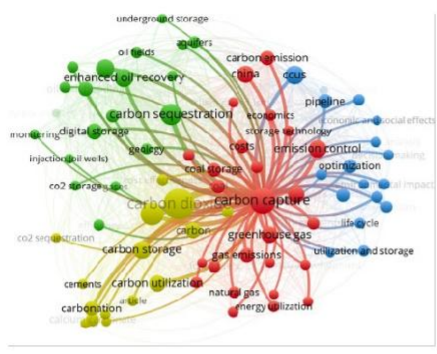
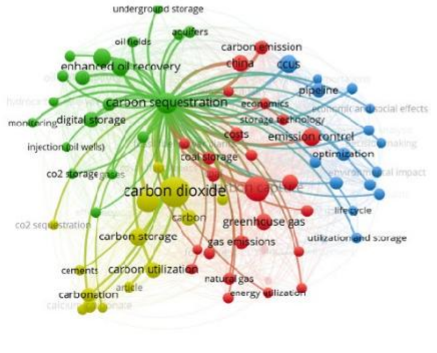


Table 2. Network visualization keywords in each cluster

Cluster	Visualization
1	 <p>In cluster 1, "carbon capture" is the keyword that has the largest node size of 76 links with other keywords, and the total link strength of 875. This technology aims to reduce carbon emissions produced from power plants and industries driven by fossil fuels, thereby promoting clean energy transition (Orlov et al., 2022). A report of clean energy transition through the application of CCJS has mentioned Norway as one of the European countries expanding the project of CO₂ capture facilities executed by Norcem (cement factory) and Fortum Oslo Varme (waste-to-energy plant) as well as a large facilities of CO₂ storage in the North Sea established by a group of oil and gas companies. This project, which is known as Longship CCS project, aims to accelerate the capacity of CO₂ transport and storage at the maximum of 5 Mt/year (IEA, 2020).</p>
2	 <p>In cluster 2, "carbon sequestration" has the largest node size, 74 links with other keywords and the total link strength of 560. This serves as an efficient and environmentally friendly approach by incorporating carbon dioxide emissions that have been captured into the soil in an organic matter form (Orlov et al., 2022). Even though soil carbon sequestration has been widely applied, analyzing a suitable management system and method to enhance its storage effect is still an important matter to be deepened (Hinge et al., 2020). Sanchez et al. (2018) weighed the potential of geologic sequestration for perpetual storage of CO₂ in saline aquifers, benefited by two corn-based ethanol companies in USA. The first company included the CCUS project established in Decatur, USA, to capture 1 MtCO₂/year which then sequestered in the Mt. Simon sandstone, USA. Another company named Red Trail Energy had a plan to sequester 180,000 t CO₂/year in the Broom Creek Formation, North Dakota.</p>

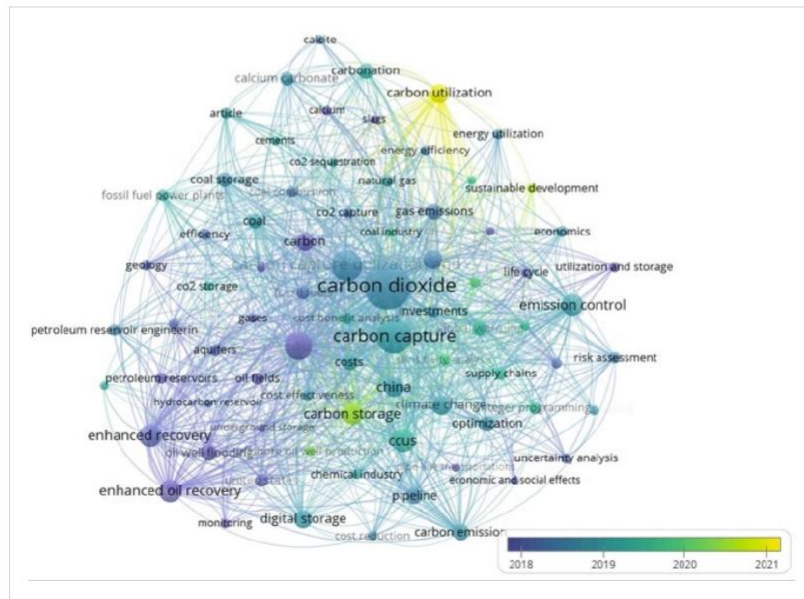
Carbon dioxide had the highest occurrence at 27.53% amongst the top 10 value of co-occurrence, although the number of citations for the publications with the keyword of "climate change" was higher than the number of citations for the publication with the keyword "carbon dioxide". This result was in line with the research conducted by Awosi et al. (2019), which generated 38 publications related to the keyword of "carbon dioxide".

According to Awosi et al. (2019), the highest publication appointed to the low carbon emission research occurred in 2012, within the 2011–2018 period. Meanwhile, Bergamschi (2019) mentioned that the publications of research on carbon capture technology increased gradually from 1998 to 2018 to reach 1,020 documents. Up to 3,800 citations were obtained in the research from 1998 to 2018, and they continued

to increase along with the publications even though there were fluctuations. This indicates that the research topics regarding carbon capture, utilization and storage are in annual demand. The International Journal of Greenhouse Gas Control has the highest number of publications, namely 27 documents and 480 citations (Khosroabadi et al., 2021). Fig. 4 is an overview of the top 10 journals based on the highest publications and citations.

The number of publications and citations on the topic of carbon capture technologies reached 4,532 and 166 with an average citation per publication of 553. This study showed the number of 17.78 as the average citation per publication. Fig. 11 shows the visualization of all keywords based on the publication year of 2018–2021. The difference of node color indicates the year of publication; hence, a lighter color implies the

Fig. 11. Overlay visualization co-occurrence (all keywords)



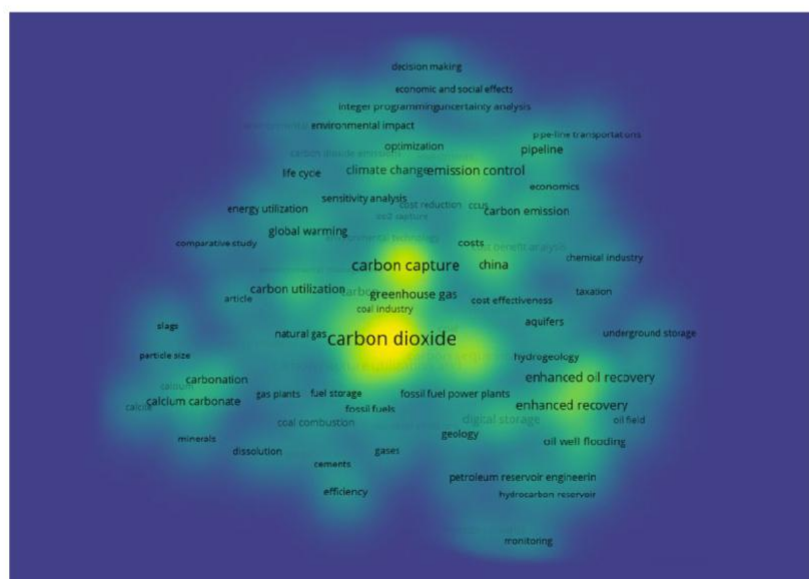
latest publication. The keyword "carbon dioxide" was widely investigated around 2018. "Carbon utilization" appeared around 2021 with 37 occurrences, total link strength of 259 and 62 linkages between keywords. This explains that the research related to carbon utilization was not largely conducted before 2021.

According to Ampah et al. (2021), the bibliometric research should be executed in a way that can strengthen the targeted discipline field through some approaches, namely (1) providing a comprehensive knowledge of the research area; (2) identifying research gaps; (3) highlighting the results of study for future studies. A number of journals identified through Vos Viewer have recognized the existence of CCUS incentive policies and regulations applied for some countries such as China (Zhang et al., 2013), United Kingdom (Leonzo et al., 2020), Hong Kong (Zhang et al., 2021) and United Arab Emirates (Al-Saleh et al.,

2012). However, there is a lack of studies addressing the policies and regulations released by ISO standards and international regulation boards to inform on the property rights of the selected sites and accountability for stored CO₂ with respect to the period of ownership and financial matters.

In addition, the density visualization of index keywords (Fig. 12) showed some keywords in the areas of hazy colors (e.g., green-blue color) that interpreted the research gaps in the literature that need to be identified, such as: "environmental impacts", which can be correlated to the analysis of environmental impacts for CO₂ leakage during transportation; "cost reduction", which relates to the knowledge of the reduced cost of capture, transport and storage capacity processes; and "carbonation" to be related to the need for optimizing the method of carbonation for CCUS technology in a more viable and feasible approach for the future,

Fig. 12. Density visualization co-occurrence (index keywords)



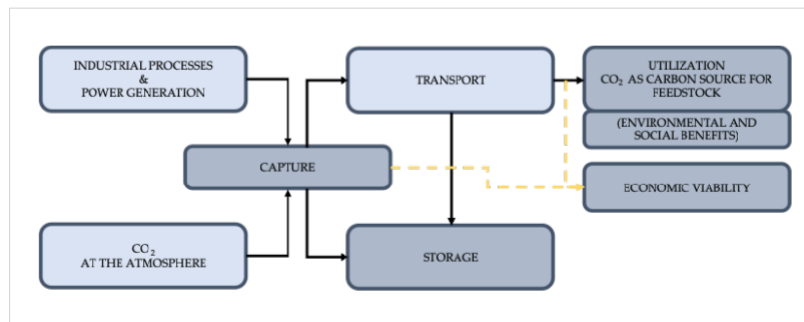
since the existing conventional method of carbonation still requires labor force and are cost-intensive (Simonson et al., 2020). Furthermore, the advanced carbonation method will contribute to the economic viability of carbon utilization, which can be achieved through the use of synthesized rare earth elements at the stage of the treatment process of mineral carbonation for accelerating the economic value of steel slags (Baciocchi and Costa, 2021).

CCUS technology is referred to as sustainable if the economic performance of the preferred method can be achieved without generating additional environmental negative impacts. Thus, CCUS, as one of the climate change mitigation technologies that may achieve the carbon emission reduction target, needs to provide economic, social, and environmental benefits as shown in Fig. 13 (Assche and Comprenolle, 2022). In addition, the technology of CCU offers the area of social and environmental benefits to be investigated beyond its current initial stage and limited scope of research (Cosbey, 2009). Mitigation and adaptation are important in reducing carbon emissions and are an integrated approach to climate action and development. The integrated approach includes assessment, goal setting, identification, financing and implementation as well as monitoring, evaluation and learning (Jeffrey and Anika, 2022).

Conclusions

CCUS is proven as one of the ultimate technologies for mitigating climate change by capturing carbon emissions produced by industries, which are then being stored at 700 m below the sea level. Bibliometric analysis was used to examine the research trends such as CCUS by identifying keyword network, authors, organizations, countries, growth trends in terms of the number of publications and citations by publishers and source titles in the period 2012–2022. The results of this study, derived from 296 documents of the Scopus database, showed the increase of publications concerning CCUS related keywords by 2,766.6% within the period of 2012–2022. Based on this study, the most productive country in conducting investigations on CCUS was China, empowered by Zhang X as the most prolific writer affiliated with China University of Petroleum. However, the organization that published the highest number of research on CCUS was National Taiwan University. On the basis of the publication and citation, this study found International Journal of Greenhouse Gas Control as the most productive journal that was published by Elsevier Ltd., that is widely known as a competent publisher of the highest number of publications and citations for research publications. Based on the co-occurrence analysis of index

Fig. 13. The inclusion of environmental, social and economic impacts into a simplification of the CCUS process to illustrate a sustainable CCUS pathway



keywords, the research gaps are identified in the literature, such as the analysis of environmental impacts for CO₂ leakage during transportation, the knowledge of the reduced cost of capture, transport and storage capacity processes as well as the need for optimizing the method of carbonation for CCUS technology in a more viable and feasible approach for the future since the existing conventional method of carbonation still

requires labor force and is cost-intensive. This study identified the potential further research for optimizing the method of carbonation for CCUS technology in a more viable and feasible approach. Hence, the importance of CCUS technology for CO₂ sequestration is clearly identified through this study, which is beneficial for the development of CCUS research, particularly to contribute to clean energy transition.

References

- Adisaputra C., and Saputra B. (2017) Carbon capture and storage and carbon capture and utilization: What do they offer to Indonesia? *Frontiers in Energy Research*. 5: 1-4. Available at: <https://doi.org/10.3389/fenrg.2017.00006>
- Adom P. K., Bekoe W., Amuakwa-Mensah F., Mensah J. T., and Botchway, E. (2012) Carbon dioxide emissions, economic growth, industrial structure, and technical efficiency: Empirical evidence from Ghana, Senegal, and Morocco on the causal dynamics. *Energy*. 47: 314-325. Available at: <https://doi.org/10.1016/j.energy.2012.09.025>
- Akbar F. M., Hafiz M. N., Ibrahim F., and Yudhistira, A. (2021) Effectiveness of Integrated Carbon Capture Technology in Waste to Energy Plants and Implementation Prospects. *Societate Politehnica*. 22: 33-47. Available at: <https://doi.org/10.33541/sp.v22i1.3304>
- Akhtar N., Parwez F., and Perwez Y. (2017) A Perusal of Big Data Classification and Hadoop Technology. *International Transaction of Electrical and Computer Engineers System*. 4: 26-38. Available at: <https://doi.org/10.12671/itecs-4-1-4>
- Akhtar N., Tabassum N., Perwez A., and Perwez Y. (2020) Data analytics and visualization using Tableau utilitarian for COVID-19 (Coronavirus). *Global Journal of Engineering and Technology Advances Cross*. 03: 28-50. Available at: <https://doi.org/10.30574/gjeta>
- Ali K. A., Alrhaid M. I. and Yusup Y. (2023) Issues, impacts, and mitigations of carbon dioxide emissions in the building sector. *Sustainability (Switzerland)*. 12. Available at: <https://doi.org/10.3390/su12187427>
- Alphen K.V., Noothout P.M., Hekkert M.P., and Turkenburg W.C. (2010) Evaluating the development of carbon capture storage technologies in the United States. *Renewable and Sustainable Energy Reviews*. 14: 971-985. <https://doi.org/10.1016/j.rser.2009.10.028>
- Al-Saleh Y.M., Vician G., Natarajan L., and Theeyattuparampil V.V. (2012) Carbon capture, utilisation and storage scenarios for the Gulf Cooperation Council region: A Delphi-based foresight study. *Futures*. 44(1): 105-115. <https://doi.org/10.1016/j.futures.2011.09.002>
- Assche F. L.-V.; Compemolle T. (2022) Economic feasibility studies for Carbon Capture and Utilization technologies: a tutorial review. *Clean Technologies and Environmental Policy*. 24: 467-491. <https://doi.org/10.1007/s10098-021-02128-5>
- Athar M., Shariff A. M., and Buang A. (2019) A review of inherent assessment for sustainable process design. *Journal of Cleaner Production*. 233: 242-263. Available at: <https://doi.org/10.1016/j.jclepro.2019.06.040>
- Ampah J.D., Yusuf A.A., Aframe S., and Jin C. (2021) Reviewing two decades of cleaner alternative marine fuels: Towards IMO's decarbonization of the maritime transport sector. *Journal of Cleaner Production*. 320 (128871): 1-25, <https://doi.org/10.1016/j.jclepro.2021.128871>
- Awolesi O., Osobamiro T. M., Alabi O. M., Oshinowo A. Y. and Jegede, S. L. (2019) Low Carbon Emission Studies A Bibliometric Approach. *International Journal of Innovative Science and Research Technology*. 4: 294-300. Available at: www.ijisrt.com
- Bacocchi R., Costa G. (2021) CO₂ Utilization and Long-Term Storage in Useful Mineral Products by Carbonation of Alkaline Feedstocks. *Front. Energy Res*. 9: 592600. <https://doi.org/10.3389/fenrg.2021.592600>
- Balogh J. M. and Jámor A. (2017) Determinants of CO₂ Emission: A Global Evidence. *International Journal of Energy Economics and Policy*. 7: 217-226. Available at: <http://www.econjournals.com>
- Bergamschi S. (2019) Analysis of the OpenRefine Data Preparation Tool, University of Modena and Reggio Emilia, Italy. 39-40
- Borthakur A., and Govind M. (2017) Emerging trends in consumers' E-waste disposal behaviour and awareness: A world-wide overview with special focus on India. *Resources Conservation and Recycling*. 117: 102-113. Available at: <https://doi.org/10.1016/j.resconrec.2016.11.011>

- Chen H., Jiang W., Yang Y., Yang Y., and Man, X. (2015) Global trends of municipal solid waste research from 1997 to 2014 using bibliometric analysis. *Journal of the Air and Waste Management Association* 65: 1161-1170. Available at: <https://doi.org/10.1080/10962247.2015.1083913>
- Cosbey A. (2009) United Nations; Developing country interests in climate change action and the implications for a post-2012 climate change regime.
- Fachrul M.F., Rinanti A., and Hendrawan, D.I. (2019) The carbon sequestration by phytoplankton in tropical lake and reservoir. *International Journal of Geomate* 16(55): 40 - 45. Available at: <https://doi.org/10.21660/2019.55.4513>
- Falduto C., Rocha M. (2020) Aligning short-term climate action with long-term climate goals. France. 19-21.
- Gough, C., Mander, S., and Haszeldine, S. (2020) A roadmap for carbon capture and storage in the UK. *International Journal of Greenhouse Gas Control*. 4: 1 - 12. <https://doi.org/10.1016/j.jggc.2009.10.014>
- Herawati P., Utami S. B., and Karlina N. (2022) Analisis Bibliometrik: Perkembangan Penelitian dan Publikasi mengenai Koordinator Program menggunakan Vosviewer. *Jurnal Pustaka Budaya*. 9: 1-8. <https://doi.org/10.31849/pb.v9i1.8599>
- Hinge G., Surampalli R.Y., and Goyal M.K. (2020) Sustainability of carbon storage and sequestration. In *Sustainability: Fundamentals and applications*, Istec; Rao, Y. Surampalli, T.C., Zhang, and Goyal, M.K., Satinder, K.B., and Tyagi, R.D., John Wiley and Sons Ltd. 46E. <https://doi.org/10.1002/9781119434016.ch22>
- Hill L.B., Li X.C., and Wei N. (2023) CO₂-EOR in China: A comparative review. *International Journal of Greenhouse Gas Control*. 103: 1 - 13. <https://doi.org/10.1016/j.jggc.2020.103173>
- IEA. (2020) *energy technology perspectives 2020. Special Report on Carbon Capture Utilisation and Storage CCUS in clean energy transition*.
- The Summary for Policymakers of the IPCC Working Group III report. (2022) *Climate Change 2022: Mitigation of climate change*.
- Jeffrey Q., and Anika T. (2022) Policy Brief: Addressing Climate Change Through Integrated Responses: Linking adaptation and mitigation. *International Institute for Sustainable Development (IISD)*.
- Jiang K., and Ashworth P. (2021) The development of Carbon Capture Utilization and Storage (CCUS) research in China: A bibliometric perspective. *Renewable and Sustainable Energy Reviews*. 138. Available at: <https://doi.org/10.1016/j.rser.2020.110521>
- Jiang K., and Ashworth P. (2020) The development of carbon capture utilization and storage (CCUS) research in China: A bibliometric perspective. *Renewable and Sustainable Energy Reviews*. 133: 1 - 16. <https://doi.org/10.1016/j.rser.2020.110521>
- Kimura S., Shinchi K., Kawagishi S., and Coulmas U. (2020) Study on the potential for the promotion of carbon dioxide capture, utilisation, and storage in ASEAN countries. ERIA Research Project Report. 21.
- Khosroabadi F., Aslani A., Bekhrad K., and Zolfaghari Z. (2021) Analysis of Carbon Dioxide Capturing Technologies and their technology developments. *Cleaner Engineering and Technology*. 5: 1 - 17. Available at: <https://doi.org/10.1016/j.clet.2021.100279>
- Leonzio G., Bogle D., Foscolo P.U., and Zordervan E. (2020) Optimization of CCUS supply chains in the UK: A strategic role for emissions reduction. *Chemical Engineering Research and Design*. 155: 211 - 228. <https://doi.org/10.1016/j.cherd.2020.01.002>
- Murray D. G. (2013) *Tableau Your Data! Fast and Easy Visual Analysis with Tableau Software*
- Nerem R. S., Beckley B. D., Fasullo J. T., Hamlington B. D., Masters D., and Mitchum, G. T. (2018) Climate-change-driven accelerated sea-level rise detected in the altimeter era. In *Proceedings of the National Academy of Sciences of the United States of America*. Available at <https://doi.org/10.1073/pnas.1717312115>
- Omoregbe O., Mustapha A. N., Steinberger-Wilckens R., El-Kharouf A., and Onyeaka H. (2020) Carbon capture technologies for climate change mitigation: A bibliometric analysis of the scientific discourse during 1998-2018. *Energy Reports*. 6: 1200 - 1212. <https://doi.org/10.1016/j.egyr.2020.05.003>
- Orlov A. A., Valtz A., Coquelet C., Rozanska X., Wimmer E., Marcou G., Horvath D., Pouain B., Varnek A., and de Meyer F. (2022) Computational screening methodology identifies effective solvents for CO₂ capture. *Communications Chemistry*. 5: 37. Available at: <https://doi.org/10.1038/s42004-022-00654-y>
- Prayitno J., Admiasari R., Sucinda T. W., and Winanti W. S. (2021) Teknologi Penangkatan Karbon dengan Mikroalga: Peluang dan Tantangan dalam Mitigasi Perubahan Iklim. *Jurnal Rekayasa Lingkungan*. 14: 91-100.
- Regufe M. J., Pereira A., Ferreira A. F. P., Ribeiro A. M., and Rodrigues A. E. (2021) Current developments of carbon capture storage and/or utilization-looking for net-zero emissions defined in the paris agreement. In *Energies*. 14. Available at: <https://doi.org/10.3390/en14092406>
- Rinanti A., Dewi K., Astuti D.I. and Halcmoan N. (2014) Preliminary Study on Biomitigation: Green House Gas Carbon Dioxide in Closed System Bubble Photobioreactor: Relationship Among the Mass Transfer Rate and CO₂ Removal Efficiency in

- High Level of CO₂. *Jurnal Teknologi*. 69: 93 - 99. <https://doi.org/10.11113/jt.v69.3248>
- Rinanti A., Kardena E., Astuti D.I. and Kania D. (2013) Screening of Potential Photosynthetic Microalgae from Wastewater Treatment Plant for Carbon dioxide Capture and Storage (CCS). *Asian Transactions on Science and Technology*. 3: 1 - 8.
- Ristiarini S., Cahyanto M. N., Wdada J., and Rahayu E. S. (2019) Pengaruh Penambahan Laurat dan Glisin terhadap Nilai Warna dan Kadar Sitirinin Angkak. *Agrotech*. 38: 320. Available at: <https://doi.org/10.22146/agritech.27042>
- Reiner C.M. (2016) Learning through a Portfolio of Carbon Capture and Storage Demonstration Projects. *Nature Energy*, 1. <https://doi.org/10.1038/nenergy.2015.11>
- Sanchez D.L., Johnson N., McCoy S.T., Turner P.A., and Mach K.J. (2018) Near-term deployment of carbon capture and sequestration from biorefineries in the United States. *PNAS*. 115(19): 4875 - 4880. <https://doi.org/10.1073/pnas.1719695115>
- Simonson K. (2020) Comparing Economics of Traditional Carbonation Method and a Novel Carbonation Invention for Craft Beer. Undergraduate, University of Arkansas, Fayetteville.
- Singh P. and Borthakur A. (2018) A review on biodegradation and photocatalytic degradation of organic pollutants: A bibliometric and comparative analysis. *Journal of Cleaner Production*. 196: 1669 - 1680. Available at: <https://doi.org/10.1016/j.jclepro.2018.05.289>
- Stone D. A., Allen M. R., Stott P. A., Pall P., Min S. K., Nozawa T., and Yukimoto S. (2009) The detection and attribution of human influence on climate. *Annual Review of Environment and Resources*. 36: 1 - 16. Available at: <https://doi.org/10.1146/annurev.viron.040308.101032>
- Sweilhe W. M. (2022) Health-related research publications on religious mass gatherings of Muslims: a bibliometric analysis (1980-2020). *Tropical Diseases, Travel Medicine and Vaccines*. 8. Available at: <https://doi.org/10.1186/s40794-021-00158-y>
- Weikmans R., Asselt H.V., Roberts J.T. (2019) Transparency requirements under the Paris Agreement and their (un)likely impact on strengthening the ambition of nationally determined contributions (NDCs). *Climate Policy*. <https://doi.org/10.1080/14693062.2019.1695571>
- Wang M., and Uko E. (2017) Special issue on carbon capture in the context of carbon capture, utilisation and storage (CCUS). *International Journal of Coal Science and Technology*. 4: 1 - 4. Available at: <https://doi.org/10.1007/s40789-017-0162-5>
- Zaeni F. F., and Rohmana R. C. (2021) Carbon Capture, Utilization, and Storage (CCUS) untuk Pembangunan Berkelanjutan: Potensi dan Tantangan di Industri Migas Indonesia, Prosiding Nasional Teknik Lingkungan Kebumihan Ke-III.
- Zhang H. (2021) Regulations for carbon capture, utilization and storage: Comparative analysis of development in Europe, China and the Middle East. SSRN. 173: 1 - 35. <https://doi.org/10.1016/j.resconrec.2021.105722>
- Zhang T., Yin X., Yang X., Man J., He Q., Wu Q. and Lu M. (2020) Research trends on the relationship between Microbiota and Gastric Cancer: A Bibliometric Analysis from 2000 to 2019. *Journal of Cancer*. 11: 4823 - 4831. <https://doi.org/10.7150/jca.44126>
- Zhang X., Fan J.L., and Wei Y.M. (2013) Technology roadmap study on carbon capture, utilization and storage in China. *Energy Policy*. 59: 536 - 550. <https://doi.org/10.1016/j.enpol.2013.04.005>
- Zhao Y., Weng Z., Chen H., and Yang J. (2020) Analysis of the evolution of drought, flood, and drought-flood abrupt alternation events under climate change using the daily SWAP index. *Water (Switzerland)*. 12(7): 1-23. Available at: <https://doi.org/10.3390/w12071969>
- Zyoud S. H., Al-Jabi S. W., Amer R., Shakhshir M., Shahwan M., Jarrar A. A., Akkawi M., and Abu Taha A. (2022) Global research trends on the links between the gut microbiome and cancer: a visualization analysis. *Journal of Translational Medicine*. 20(1). Available at: <https://doi.org/10.1186/s12967-022-03293-y>



Research Development on Carbon Capture, Utilization and Storage as a Climate Change Mitigation Technology

ORIGINALITY REPORT

14%	9%	11%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.trijurnal.lemlit.trisakti.ac.id Internet Source	1%
2	Vasyl V. Popovych. "Environmental Impact of Devastated Landscapes of Volhynian Upland and Male Polisia (Ukraine)", Environmental Research, Engineering and Management, 2019 Publication	1%
3	dev.journal.ugm.ac.id Internet Source	1%
4	www.rsc.org Internet Source	< 1%
5	Toyosi T. George, Anthony O. Obilana, Ayodeji B. Oyenihi, Fannie G. Rautenbach. "Moringa oleifera through the years: a bibliometric analysis of scientific research (2000–2020)", South African Journal of Botany, 2021 Publication	< 1%
6	bibliothek.fh-wien.ac.at Internet Source	< 1%
7	repository.karyailmiah.trisakti.ac.id Internet Source	< 1%
8	www.scirp.org Internet Source	< 1%
9	Vatalis, K.I.. "Intermediate technologies towards low-carbon economy. The Greek zeolite CCS outlook into the EU	< 1%

commitments", Renewable and Sustainable Energy Reviews, 201206

Publication

-
- 10 Sandylove Afrane, Jeffrey Dankwa Ampah, Emmanuel Aboagye Mensah. "Visualization and analysis of mapping knowledge domains for the global transition towards clean cooking: a bibliometric review of research output from 1990 to 2020", Environmental Science and Pollution Research, 2021

Publication

-
- 11 biopen.bi.no < 1 %

Internet Source

-
- 12 wwfhk.awsassets.panda.org < 1 %

Internet Source

-
- 13 www.crisis-response.com < 1 %

Internet Source

-
- 14 Elhadi M. Yahia. "Preventing food losses and waste to achieve food security and sustainability", Burleigh Dodds Science Publishing, 2020

Publication

-
- 15 research.birmingham.ac.uk < 1 %

Internet Source

-
- 16 Pavel Tcvetkov, Alexey Cherepovitsyn, Sergey Fedoseev. "The Changing Role of CO2 in the Transition to a Circular Economy: Review of Carbon Sequestration Projects", Sustainability, 2019

Publication

-
- 17 aaltodoc.aalto.fi < 1 %

Internet Source

-
- 18 www.cogitatiopress.com < 1 %

Internet Source

-
- 19 Donika Maloku, Péter Balogh, Attila Bai, Zoltán Gabnai, Péter Lengyel. "Trends in

scientific research on precision farming in agriculture using science mapping method", International Review of Applied Sciences and Engineering, 2020

Publication

- 20 Pardeep Singh, Anwesha Borthakur. "A review on biodegradation and photocatalytic degradation of organic pollutants: A bibliometric and comparative analysis", Journal of Cleaner Production, 2018 < 1 %

Publication

- 21 repozytorium.kul.pl < 1 %
Internet Source

- 22 Ahmed I. Osman, Mahmoud Hefny, M. I. A. Abdel Maksoud, Ahmed M. Elgarahy, David W. Rooney. "Recent advances in carbon capture storage and utilisation technologies: a review", Environmental Chemistry Letters, 2020 < 1 %

Publication

- 23 E. E. Chang, Chung-Huei Liang, Ya-Wen Ko, Pen-Chi Chiang. "Effect of Ozone Dosage for Removal of Model Compounds by Ozone/GAC Treatment", Ozone: Science & Engineering, 2002 < 1 %

Publication

- 24 academic.oup.com < 1 %
Internet Source

- 25 library.oapen.org < 1 %
Internet Source

- 26 ndl.ethernet.edu.et < 1 %
Internet Source

- 27 "Resource Recycling and Management of Food Waste", Springer Science and Business Media LLC, 2025 < 1 %

Publication

- | | | |
|-------|--|-------|
| 28 | desimone-group.chem.unc.edu
<small>Internet Source</small> | < 1 % |
| <hr/> | | |
| 29 | pub.norden.org
<small>Internet Source</small> | < 1 % |
| <hr/> | | |
| 30 | Dong Zhe, Nan Su, Xianglei Zhu, Haitham A. Mahmoud, Tazeem Akhtar. "Non-linear relationship between FinTech, natural resources, green innovation and environmental sustainability: Evidence from panel smooth transition regression model", <i>Resources Policy</i> , 2024
<small>Publication</small> | < 1 % |
| <hr/> | | |
| 31 | Eka Trisnawati. "Bibliometric Analysis: Trend of Digital Literacy and Scientific Literacy Research in Indonesia Biology Learning", <i>JURNAL BIOEDUKATIKA</i> , 2024
<small>Publication</small> | < 1 % |
| <hr/> | | |
| 32 | Ryan Janzen, Matthew Davis, Amit Kumar. "Evaluating long-term greenhouse gas mitigation opportunities through carbon capture, utilization, and storage in the oil sands", <i>Energy</i> , 2020
<small>Publication</small> | < 1 % |
| <hr/> | | |
| 33 | docslib.org
<small>Internet Source</small> | < 1 % |
| <hr/> | | |
| 34 | www.americaspig.com
<small>Internet Source</small> | < 1 % |
| <hr/> | | |
| 35 | Faezeh Khosroabadi, Alireza Aslani, Kaveh Bekhrad, Zahra Zolfaghari. "Analysis of Carbon Dioxide Capturing Technologies and their technology developments", <i>Cleaner Engineering and Technology</i> , 2021
<small>Publication</small> | < 1 % |
| <hr/> | | |
| 36 | Mohammad Mehedi Hasan, Kelvin Tsun Wai Ng, Tanvir Shahrier Mahmud, Jinkai Xue, Sagar Ray. "The role of collaborative research | < 1 % |

network on E-waste studies in North America
using a bibliometric approach", Ecological
Informatics, 2024

Publication

- 37 Ying Huang, Hongxu Guo, Cuiping Liao, Daiqing Zhao, Di Zhou, Qiang Liu, Xiaochun Li, Xi Liang, Jia Li. "Study of a roadmap for carbon capture and storage development in Guangdong Province, China", International Journal of Sustainable Energy, 2014

Publication

- 38 assets-eu.researchsquare.com < 1 %

Internet Source

- 39 cybersecurity.springeropen.com < 1 %

Internet Source

- 40 dalspace.library.dal.ca < 1 %

Internet Source

- 41 docplayer.net < 1 %

Internet Source

- 42 files.eric.ed.gov < 1 %

Internet Source

- 43 tdtmvjournal.biomedcentral.com < 1 %

Internet Source

- 44 www.iisd.org < 1 %

Internet Source

- 45 "International Law, Climate Change and Bangladesh", Springer Science and Business Media LLC, 2024

Publication

- 46 "Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology", Springer Science and Business Media LLC, 2022

Publication

47 Qingjia Cui, Na Chen, Cheng Wen, Jianing Xi, Lihui Huang. "Research trends and hotspot analysis of age-related hearing loss from a bibliographic perspective", *Frontiers in Psychology*, 2022

Publication

< 1 %

48 Sepehr Ghazinoory, Shohreh Nasri, Fatemeh Ameri, Gholam Ali Montazer, Ali Shayan. "Why do we need 'Problem-oriented Innovation System (PIS)' for solving macro-level societal problems?", *Technological Forecasting and Social Change*, 2020

Publication

< 1 %

49 Solomon O. Giwa, Kayode A. Adegoke, Mohsen Sharifpur, Josua P. Meyer. "Research trends in nanofluid and its applications: a bibliometric analysis", *Journal of Nanoparticle Research*, 2022

Publication

< 1 %

50 Xiao Lin, Xingyang Li, Hongwen Liu, Grzegorz Boczkaj, Yijun Cao, Chongqing Wang. "A review on carbon storage via mineral carbonation: Bibliometric analysis, research advances, challenges, and perspectives", *Separation and Purification Technology*, 2024

Publication

< 1 %

51 Ya Gao, Long Ge, Shuzhen Shi, Yue Sun, Ming Liu, Bo Wang, Yi Shang, Jiarui Wu, Jinhui Tian. "Global trends and future prospects of e-waste research: a bibliometric analysis", *Environmental Science and Pollution Research*, 2019

Publication

< 1 %

52 Zhang, Xian, Jing-Li Fan, and Yi-Ming Wei. "Technology roadmap study on carbon capture, utilization and storage in China", *Energy Policy*, 2013.

Publication

< 1 %

53	addi.ehu.es Internet Source	< 1 %
54	assets.researchsquare.com Internet Source	< 1 %
55	dokumen.pub Internet Source	< 1 %
56	econjournals.com Internet Source	< 1 %
57	ejournal.undip.ac.id Internet Source	< 1 %
58	journal.cbiores.id Internet Source	< 1 %
59	journal.hep.com.cn Internet Source	< 1 %
60	publications.jrc.ec.europa.eu Internet Source	< 1 %
61	publikace.k.utb.cz Internet Source	< 1 %
62	silo.tips Internet Source	< 1 %
63	www.ceocongress.org Internet Source	< 1 %
64	www.ipcc.ch Internet Source	< 1 %
65	Bamidele Victor Ayodele, Siti Indati Mustapa, May Ali Alsaffar, Dai-Viet N. Vo. "Sustainable utilization of CO2 toward a circular economy: prospects, challenges, and opportunities", Elsevier BV, 2022 Publication	< 1 %
66	Li, Q., Z.A. Chen, J.-T. Zhang, L.-C. Liu, X.C. Li, and L. Jia. "Positioning and revision of CCUS technology development in China",	< 1 %

International Journal of Greenhouse Gas Control, 2016.

Publication

- 67 Vikram Vishal, Yashvardhan Verma, Debanjan Chandra, Dhananjayan Ashok. "A systematic capacity assessment and classification of geologic CO₂ storage systems in India", International Journal of Greenhouse Gas Control, 2021 < 1 %

Publication

- 68 Carlo Villante, Sonia Dell'Aversano, Stefano Ranieri. "Transition to Sustainable Energy Technologies – Pathways, Sources, Mobility", Routledge, 2025 < 1 %

Publication

- 69 Gordana Zeba, Marina Dabić, Mirjana Čičak, Tugrul Daim, Haydar Yalcin. "Technology mining: Artificial intelligence in manufacturing", Technological Forecasting and Social Change, 2021 < 1 %

Publication

- 70 Grazia Leonzio, Edwin Zondervan. "Analysis and Optimization of Carbon Supply Chains Integrated to a Power to Gas Plant in Italy", Elsevier BV, 2020 < 1 %

Publication

- 71 Hetian Qin, Qiuhaohuang, Ziwei Zhang, Yu Lu, Manchun Li, Lang Xu, Zhenjie Chen. "Carbon dioxide emission driving factors analysis and policy implications of Chinese cities: Combining geographically weighted regression with two-step cluster", Science of The Total Environment, 2019 < 1 %

Publication

- 72 Sunday Goodness John. "Chapter 6 Using Social Media for Climate Change Mitigation and Adaptation Education in Nigeria", < 1 %

-
- 73 Sung-Hsi Huang, Chung-Hao Huang, Ning-Chi Wang, Tun-Chieh Chen et al. "Early Seroreversion After 2 Doses of Hepatitis A Vaccination in Human Immunodeficiency Virus-Positive Patients: Incidence and Associated Factors", Hepatology, 2019 < 1 %

Publication

-
- 74 Zhen Wu, Xianjin Huang, Ruishan Chen, Xiyan Mao, Xinxian Qi. "The United States and China on the paths and policies to carbon neutrality", Journal of Environmental Management, 2022 < 1 %

Publication

Exclude quotes On

Exclude matches Off

Exclude bibliography On

Research Development on Carbon Capture, Utilization and Storage as a Climate Change Mitigation Technology

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19