Explore action to enhance net zero emission 2050: Research trends and the way forward 13th SDGs?

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Abstract. Net zero emissions are an important step that must be strived to achieve the 13th SDGs goal. This research aims to explore progress in achieving net zero emissions. The systematic review method (PRISMA) is integrated with a bibliometric analysis model with Scopus data sources. The analysis results show that four steps such as decarbonization, renewable energy transition, transportation electrification, and reforestation have proven effective in achieving net zero emissions by 2050. These findings highlight the big challenges in achieving net zero emissions through these four steps, especially in the technology sector. It is recommended that further research be more exploratory in studying technology in achieving net zero emissions, especially in exploring the potential for vehicle electrification and technology in the use of renewable energy sources. The implications of this research can provide support in efforts to achieve environmental balance and can be used as a basis for thinking for further research.

1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) and the United Nations or UN on Climate Change (UNFCCC) pay great attention to the importance of achieving a balance that occurs between greenhouse gas emissions (output) and absorption by the atmosphere, as well as the importance of countries achieving net zero emissions by the end of the century [1]. In addition, political leaders, especially within the framework of the UN (United Nations) Climate Change Conference of the Parties (COP), have played an essential role in spreading this idea as a global target for addressing climate change [2]. This idea is disseminated to achieve the Sustainable Development Goals (SDGs), especially point 13, which focuses on "Action Against Climate Change," which has been set as the 2030 agenda by the UN [3]. Specifically, point 13 of sustainable development emphasizes various efforts to achieve net zero emissions.

Net zero emissions is one of the programs the government is intensifying to improve the quality of the environment [4]. This program refers to efforts to reduce greenhouse gas

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emissions until the number of emissions produced is equal to the amount absorbed from the atmosphere or released from other sources [5]. This is a critical strategy to mitigate climate change and achieve the SDGs [6]. Based on previous research, research has yet to be identified that simultaneously integrates four steps (decarbonization, renewable energy transition, electrification transportation, and reforestation afforestation).

Currently, the earth is facing numerous environmental challenges, such as global warming, air and water pollution, deforestation, and biodiversity decline [7]. Rogue industries worsen these conditions by producing greenhouse gas emissions, hazardous waste, and uncontrolled deforestation [8]. Therefore, bibliometric research plays a crucial role in comprehending the impact of rogue industries on the environment and in identifying trends and patterns of their activities.

Bibliometric analysis is a type of analysis that processes metadata [9]. This analysis uses quantitative tools to examine scientific publications, analyze the number of publications, citation patterns, authors, and research topics to uncover trends and impact [10]. This research identifies influential authors, key journals, and emerging research areas, helping researchers and policymakers understand developments in knowledge and guiding future research and policy decisions [11].

To the best of our knowledge, no bibliometric studies have been conducted to examine all net zero emissions actions that focused on SDGs13. In addition, investigating net zero emissions action is very important for future research and expanding boundaries. For this reason, bibliometric studies are needed, to investigate and reveal trend, current conditions, and gaps in net zero emissions (i.e., decarbonization, renewable energy transition, transport electrification, and reforestation). By analyzing scientific publications, bibliometric methods can help identify the following things to focus on:

a. How do the year of publication, author, affiliation, type of source, and field of study influence action research aimed at achieving net zero emissions?
b. What are the dominant keywords, topics, and actions in efforts to achieve net zero emissions?

2 Methods

This research employs a systematic review approach to identify causal relationships, feedback, and impacts [12]. It integrates this approach with bibliometric analysis models to collect data on existing research trends [13], [14]. The data was obtained from the Scopus database in February 2024, saved in.csv and.ris formats, and visualized using VOSviewer, MS Excel, and Datawrapper. The research also follows the PRISMA stage guidelines for finding literature sources.

Based on Figure 1, the PRISMA method involves identifying keywords, filtering data using additional keywords like "SDGs," and setting a year limit of 2019-2022. The screening stage involves screening documents with the highest number of citations, followed by selecting those with high relevance to the research topic. The final stage includes selecting documents with high relevance.

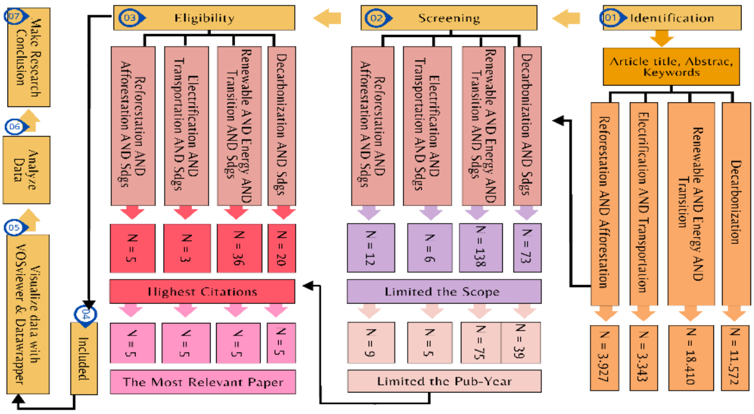


Fig. 1. Research stages by integrating the PRISMA method [15], [16].

3 Results and Discussions

3.1 Trends in publications on achieving net zero emissions

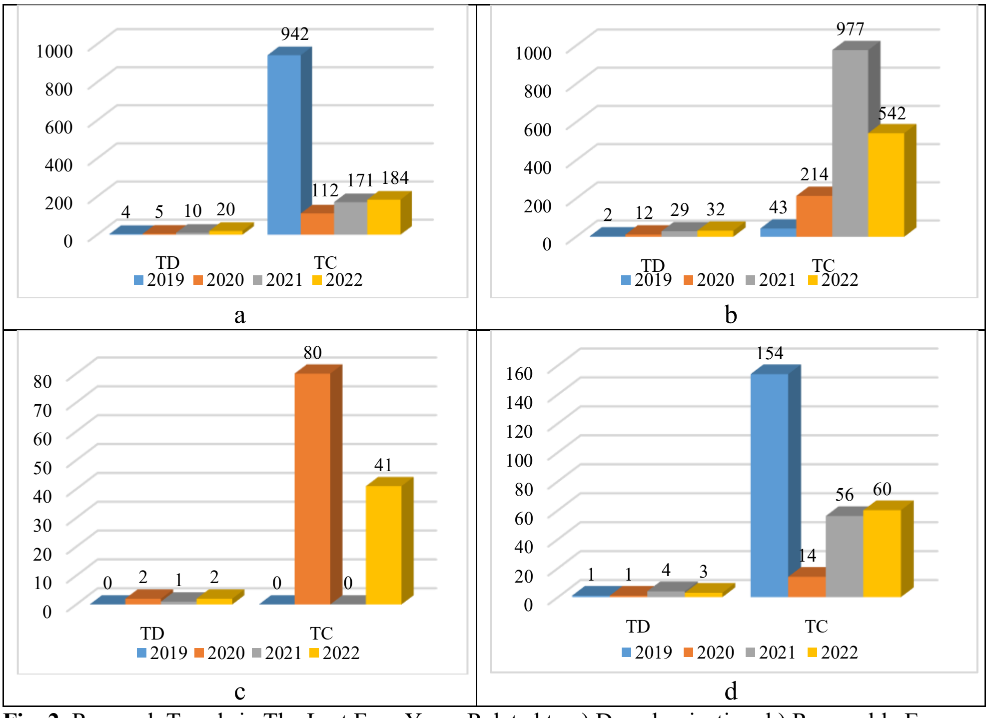


Fig. 2. Research Trends in The Last Four Years Related to a) Decarbonization, b) Renewable Energy Transition, c) Electrification Transportation, and d) Reforestation and Afforestation.

Figure 2a shows a consistent increase in research on decarbonization to achieve net zero emissions each year, with the highest average growth of 25% and publications peaking in 2022 [17]. Nevertheless, the most citations on this subject were in 2019 (66.86%) because of a special report by the IPCC stressing the need for action to limit global temperature increase to 1.5 degrees Celsius above pre-industrial levels, alongside stronger government policies promoting renewable energy, reducing subsidies for fossil fuels, and facilitating the shift to a low-carbon economy [18]. However, citations dropped by 58.86% in 2020. Moreover, citation rates stayed fairly steady, with an average annual increase of 11%. This data mirrors ongoing endeavors to reduce CO_2 and greenhouse gas emissions from human activities.

Figure 2b shows a steady increase in renewable energy transition research, with an average annual growth rate of 25%. Total document citations also increased by 23.16%, reaching a peak in 2021 of 977 citations, and decreasing by 24.5% in 2022. This shows persistent efforts in the transition to renewable energy to restore natural balance [19].

Meanwhile, research on electric transportation and reforestation, as shown in Figure 2 (c-d), exhibits fluctuating trends with minimal differences in growth. This is because, in 2019, interest in electric transportation research surged due to initiatives aimed at emission reduction and limiting global temperature rise to 1.5˚C, as stipulated by the IPCC [18]. However, interest in reforestation and afforestation research may decline due to insufficient focus on deforestation and land rehabilitation.

3.2 Top 3 authors with high productivity

Table 1 shows the top three authors on each research topic with a high level of H-index which indicates their level of productivity.

Table 1. Top 3 Authors on Each Topic.

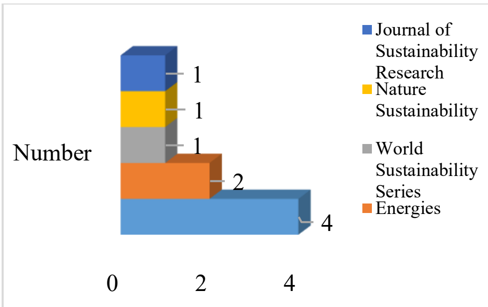
Name	Affiliation	Country	HI	TC	Citation
Sachs, J. D.	Columbia University	Columbia	149	872	[20]
Erdogan, S.	Selcuk University	Turki	19	46	[21]
Ruggieri, R.	University of Rome	Italia	12	46	[22]
Magazzino, C.	Roma Tre University	Italia	46	59	[23]
Madurai, E. R.	University of Queensland	Australia	43	117	[24]
Falcone, P.M.	The University of Naples	Italia	33	168	[25]
Johnsson, F.	Chalmers University of Technology	Sweden	74	80	[26]
Ahmad, F.	Hamad Medical Corporation (HMC)	Qatar	18	22	[27]
Shams, E. Z.	Eindhoven University of Technology	Belanda	18	19	[28]
Smith, P.	University of Aberdeen	Scotland	170	154	[29]
Wu, Z.	Southern University of Science and Technology	Tiongkok	40	54	[30]
Galleguillos, M.	Universidad Adolfo Ibanez	South America	21	29	[31]

Note: HI: H-index; Blue: Decarbonization; Green: Renewable Energy Transitions; Grey: Electrification Transportation; and Yellow: Reforestation and Afforestation.

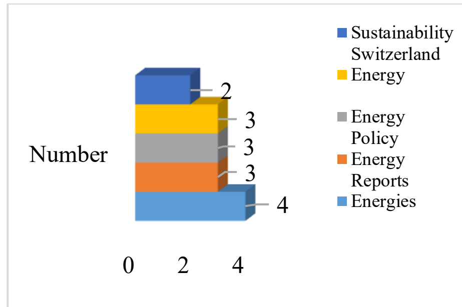
Sachs from Columbia University leads research on decarbonization and SDGs, utilizing the Earth Institute and Lamont-Doherty Earth Observatory to address global challenges like climate change and sustainability, as well as earth science aspects like atmospheric circulation.[32]. Magazzino, C., from Roma Tre University, leads research on renewable energy transition, equipped with a sophisticated laboratory, that focused on technology. Johnsson F., from Chalmers University of Technology, Sweden, leads research on electrification transportation and SDGs, equipped with advanced facilities.[33]. The University of Aberdeen has access to the Royal Botanic Garden Edinburgh, the modern laboratory. Smith leads research on reforestation, afforestation, and SDGs that involves conducting experimental forests and plants on campus [34].

3.3 Top 5 publication sources with high relevance

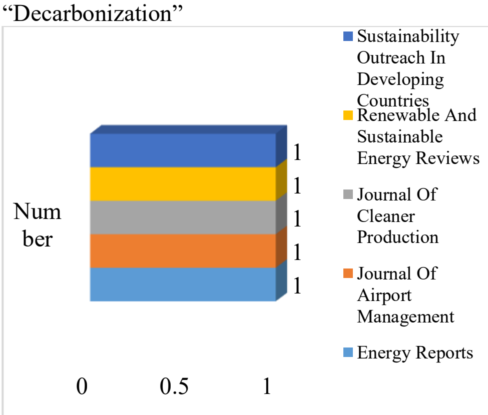
Based on Figure 3, it shows the sources that have published documents with a high level of relevance for each of the keywords used in this research.



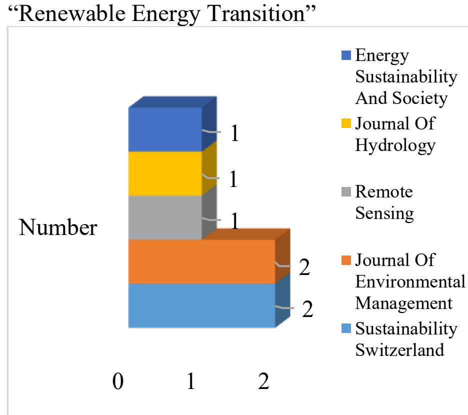
“Decarbonization”



“Renewable Energy Transition”



“Electrification Transportation”



“Reforestation and Afforestation”

Fig. 3. Top 5 document sources with high productivity.

Figure 3 shows sources that have high relevance to the keywords used in this research, with “Sustainability Switzerland” as a productive source. This report covers four main topics related to the Sustainable Development Goals (SDGs): decarbonization, renewable energy transition, transport electrification, and reforestation and greening. Sustainability Switzerland is recognized as a publishing institution specializing in sustainability-related publications.

3.4 Countries participating in research

Based on Figure 4, the United States leads in research productivity towards net zero emissions, with extensive studies on decarbonization, renewable energy transition, electrification transportation, reforestation, and afforestation.

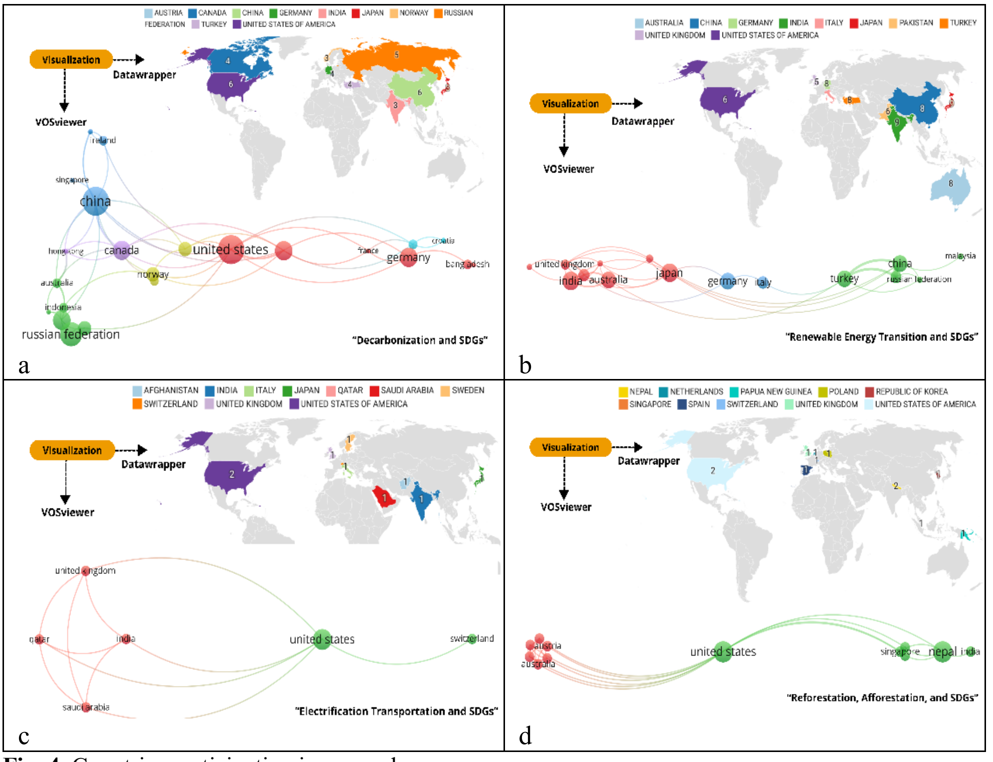


Fig. 4. Countries participating in research

Based on Figure 4 (a-d), the United States leads as the most productive country due to its extensive research across all topics in this study (decarbonization, renewable energy transition, electrification transportation, reforestation, and afforestation), resulting in significant publications on each topic. The country benefits from highly skilled and diverse human resources in science, technology, and engineering fields. Its top universities and research institutions attract global talent, making substantial contributions to related research. Additionally, the US has a robust research infrastructure, including government laboratories, private research institutions, and innovation centers. [35]. Initiatives like the Green New Deal and the Clean Energy for America Act further drive investment in sustainable technology and innovation, promoting collaboration between public sectors [36].

3.5 Subject area that participated in net zero emissions research

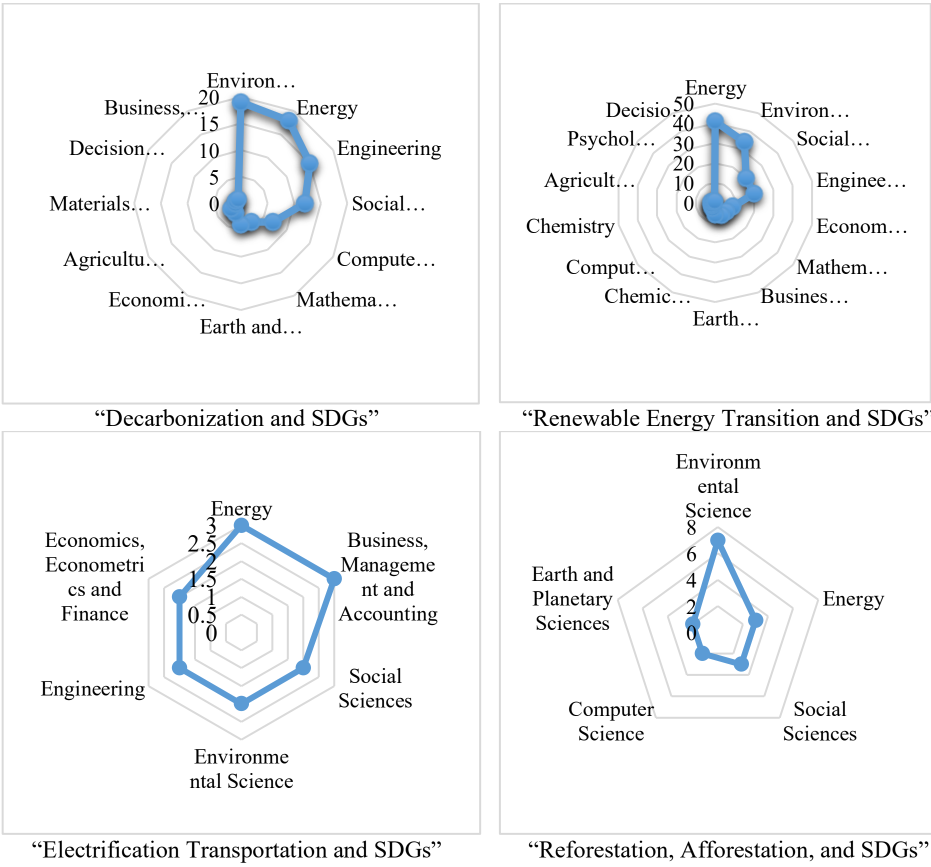


Fig. 5. Subject Area with High Relevance to The Research Topics.

The data in Figure 5 above shows a correlation between environmental science, energy, and social science. Energy as a subject ranked highest in relevance, with 40% of documents published (65 documents from four keywords). Environmental sciences were next at 38% (62 docs), and social sciences ranked lowest in terms of relevance, at 22% (37 docs). Apart from that, in this research several subjects such as engineering and computer science support efforts to achieve zero emissions by developing environmentally friendly technology and carrying out modeling and simulations to optimize new designs.

3.6 Keywords

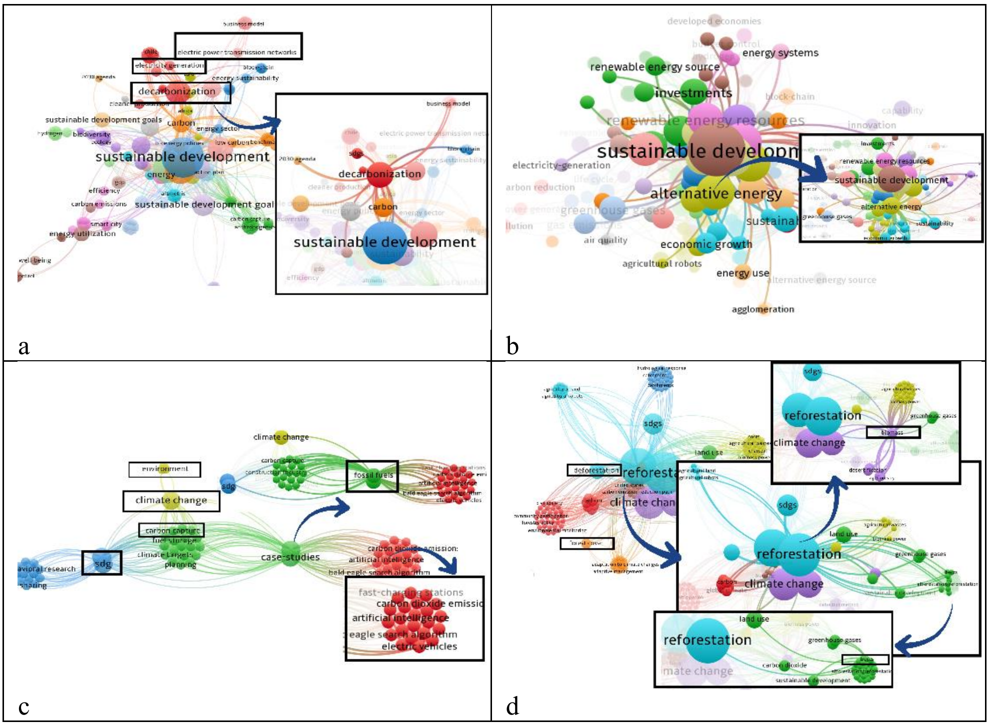


Fig. 6. Four keywords in achieving zero emissions a) Decarbonization and SDGs, b) Renewable energy transition and SDGs, c) Electrification transportation and SDGs, and d) Reforestation, afforestation, and SDGs.

Figure 6a shows steps towards decarbonization involving increased use of electric power transmission starting in 2022. The relationship between electric power transmission in decarbonization efforts to achieve net zero emissions relates to how energy transmission infrastructure affects ecosystems [37]. Decarbonization efforts are closely related to efforts to achieve sustainable development as evidenced by the thickness of the links and the size of the decarbonization nodes which are larger compared to others.

Figure 6b depicts progress in achieving net zero emissions by switching to renewable energy. The size of the node owned by "alternative energy sources" is larger than other nodes, thus indicating that alternative energy sources play an important role in efforts to achieve sustainable development when applied in everyday life. Figure 6d depicts reforestation and afforestation through land use for "BECCS" (Bioenergy with Carbon Capture and Storage). BECCS aims to reduce carbon emissions by utilizing biomass as energy fuel and capturing and storing the resulting carbon dioxide [38]. The promotion of BECCS initiatives began in 2019 and requires further development.

This research significantly impacts global efforts to achieve net zero emissions by 2050, a key goal of SDG 13. It provides insights into decarbonization, renewable energy transition, transport electrification, and afforestation, emphasizing the IPCC and UNFCCC's focus on greenhouse gas balance and the COP's political leadership. Using a bibliometric approach, it identifies trends in scientific publications and offers strategic guidance for government and industry to enhance environmental quality, encourage collaboration, and make effective climate policies.

4 Conclusion

Based on a systematic review integrating bibliometric analysis, it's shown that achieving net zero emissions by 2050 involves four effective steps: decarbonization, renewable energy transition, transportation electrification, and reforestation. The top authors in each topic are Sachs, J.D. from Columbia University for decarbonization and SDGs, Magazzino, C. from Roma Tre University for renewable energy transition and SDGs, Johnsson, F. from Chalmers University of Technology, Sweden for transportation electrification, and Smith, P. from the University of Aberdeen for reforestation, afforestation, and SDGs. Sustainability Switzerland is the most productive publisher, and the USA is the most productive country. Subjects highly relevant to achieving net zero emissions and SDGs are energy, environmental science, and social sciences. This research has significant implications, particularly in exploring steps toward net zero emissions, providing updates on the topic, and aiding climate change mitigation (goal 13 of the SDGs). Identifying relevant articles in the Scopus database offers clear directions for future research. However, utilizing databases other than Scopus and different data visualization software is recommended for more comprehensive coverage and visualization in further research on actions to achieve net zero emissions.

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