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Mapping Climate Change Mitigation Strategies Adopted by Industries: An Overview from First Commitment of Kyoto Protocol (2009–2023)

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***Abstract* – This paper analyses the climate change mitigation strategies adopted by industries from the first commitment period of Kyoto Protocol (2008) till present day (2023). A systematic literature review was conducted using the AND operator to customise articles published in Scopus database of 15 years of first commitment period of Kyoto Protocol (2009–2023). Findings show that all the climate change mitigation strategies (CCMS) identified can broadly be classified into managerial and technological. These strategies span from carbon offsets to start-up (ex. renovation in construction industries) to hydrogen as an energy source. *VOSviewer* network analysis of research paper showed that large number of countries are working closely on CCMS with USA in the forefront. Keywords like climate change, sustainability, greenhouse gas (GHG) were found to be most common in the research articles. This study confirms the significance of adopting managerial and technological strategies in industries for sustainability management. In addition, finance for climate policy and mitigation in terms of cost effectiveness, trade-offs, pollution tax, investments seem to possess a considerable influence on the climate governance.**

***Keywords* – Climate change mitigation strategies; industries; managerial strategies; Scopus; technological strategies.**

1. INTRODUCTION

COP 27 at Sharm El-Sheikh marked the 30th anniversary of adoption of United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC's Kyoto Protocol is an established policy and framework for assessing the proper enactment of GHG concentration reductions in the atmosphere. Although the protocol was adopted in 1997, it came into action in 2005, thus marking its first commitment period from 2008–2012. In 2012, with the Doha Amendment to Kyoto Protocol, the second commitment period started for seven years (2013–2020). The ambition of saving the environment was raised by a 13 % by way of reducing the GHG emissions against the 1990 levels in the second phase [1]. It has been a long journey from effective agreements to combat climate change, framework development to adoption of Intergovernmental Panel on Climate Change (IPCC) to this year's decisions of extending focus on groundwork than rulebooks. The COVID-19 seemed to have brought short term reductions in GHG emissions but the evolution of global space system via technological advancements, rapid urban growth, economical transitions, and mechanization

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of physical labour has added to the plight of the current environmental scenario [2], [3]. Global warming might be the first string of problem caused by rapid industrialization, but high energy consumption and hazardous waste generation have piled upon the issue [4]. Industry, transportation, and buildings currently account for around half of the CO_2 emissions [5]. Levelling of GHGs is presented as the only feasible option to maintain current atmospheric conditions as an answer to ever increasing detrimental effects of climate change [6]. Latest work on hitting decarbonization goals via hydrogen pathways [7], financial aspects of up taking mitigation strategies in automobile industry [8] have attempted to shed light on the sustainable roadmap for industries. But it seems that sustained and substantial reductions in GHGs will limit climate change and its associated risks [9].

The Kyoto Protocol, the first conscious critical forward foot towards global emission reduction system marked its first commitment period from 2008–2012. Scopus database shows no published document in the year 1997, the year of its adoption. It was only post 2008 which marked a slow yet upward rise in publishing work carried out pertaining to the keywords considered for this study. In 2005, when Kyoto Protocol came into force; the said treaty fixed the goal of stabilisation of atmospheric GHG level to further prevent detrimental anthropogenic impact with the climate system, which led to a significant surge in reporting of research work from 2008 and onwards. The fact that first commitment period of Kyoto Protocol was from 2008–2012, same year COP11 Montreal Action Plan was adopted given Kyoto Protocol was effectively implemented with a robust review regime and great financial bolstering in its organizational structure [10]. A recent study covered thirty years of database on linkages between climate change and events following destabilising negative peace i.e. undermining violence and disputes through equitable resource allocation and acceptance of human rights [.3]. These studies covering hundreds of documents follow the path of systematic review or bibliometric analysis or both in some cases, if needed. Bibliometric analysis can be seen being standardised in reviews to present an overview of various constituents at one place which gives uniqueness [11]. The techniques when paired with network analysis by virtue of software like *VOSviewer* yields illustrations of bibliometric and intellectual framework [12]. Bibliometrics have spanned their applicability in agriculture [13] and food industry blockchain studies [14], quantum machine learning [15], bio-circular economy [16], supply chain management and carbon taxes [17], cloud computing [18], social media user behaviour [19] and solar physics [20].

Studies have also been carried out in the area of climate change mitigation for energy systems from energy supply sector [21], renewable energy resources [22] and freight sector [23]. However, these studies focus only on the general aspects of climate change mitigation strategies and certainly there is lack of focus on industrial sector and the strategies used by them. This is especially important in context to the Kyoto Protocol, which was signed in 1997, but came into force from 2008 as a part of its first commitment period (2008–2012). What seems to stand out is the work paving the roadmap from Stockholm Conference to Kyoto protocol [24] and from Kyoto protocol to Paris Agreement [25]. In backdrop of this, the present study covers the period from 2009 to 2023 (15 years) in relation to climate change mitigation adopted by the industries.

This study makes contribution to the existing literature in the following ways. First, it classifies all the climate change mitigation strategies into technological and managerial. Second, it has developed 15 themes depicting the year wise evolution of the mitigation strategies used to combat the negative impact of climate change. Third, the study aims to better equip researchers, policy makers and top management committee of industries to address problems and take the proper steps to improve the outcomes of the mitigation techniques that have been implemented.

TABLE 1. YEAR WISE MAPPING OF FOCAL RESEARCH AREAS IN CCMS (2009–2023)

Year of publication	**Focal areas/strategies deployed/studied in CCMS**	**References**
2009	– Developing carbon credit – Carbon storage and sequestration – Institutional support – Carbon offsets – Raw material substitution – Voluntary disclosures	[63,] 33], [79]
2010	– Renewable energy; low carbon economy – Bioenergy production – Sustainability assessment – Carbon sequestration – Legal stringency	[28], 80], [81]
2011	– White Certificate Trading schemes (WCT) – Intermittent energy options – Micro combined heat and power system – Budget constraints on GHG emission – Feed-in tariff for renewable sources – Recycling scrap metals	[55], 82], [83]
2012	– Carbon offsetting – Solar technology – Life cycle assessment – Risk assessment and management from financial lens	[84], 85], [86]
2013	– Nutritional management of ruminants – Retrofitting – Voluntary climate actions – Social awareness show – Government interventions – Timely operational checks – Industrial symbiosis checks via substance flow analysis – Supply chain improvements for end use efficiency	[86], 87], [88]
2014	– Aids for bioenergy production – Carbon capture and storage – GHG accounting – Integrating land use], land -use change and forestry in policy framework – Equipment recycling – Startups for renovations – Shale gas development	[59], 89], [90]
2015	– Carbon accounting – Carbon capture storage and use – Carbon neutral fuel choices – Rewards and equitable sharing – Bio-materials combinations – Engagements and government contracts – Renewable energy quota systems – Industrial green fostering	[38], 91], [92]

2016	–	Industrial integration (neighboring industries)	[56], [93], [94]
	–	Nuclear and renewable power development	
	–	Green computing	
	–	Market instruments for low emission	
	–	Sectoral approach in lieu of individual strategies	
	–	Renewable energy storage (wind and solar)	
	–	Climate justice	
2017	–	Organic practices	[64], 78], [95]
	–	Climate consciousness and awareness	
	–	Organizational structuring optimization	
	–	Pre-financing capital for mitigation strategies	
	–	Feed-in-tariff for energy consumption	
	–	Carbon tax and subsidies	
	–	Energy modelling	
	–	Collaborative initiatives	
	–	Carbon marketing and trading	
	–	Decoupling economic market and carbon emissions	
	–	Cleantech industrial options	
	–	Centralization of policy power to central governance	
	–	Forestry regimes under CSR projects	
2018	–	Leadership programs	[96], [97], [98]
	–	Industrial conjunction	
	–	Voluntary marketing and disclosures	
	–	Life cycle assessments	
	–	Input output analysis	
	–	Environmental and social reporting	
	–	Decision support system/Internal governance	
	–	Biodiversity offsets	
	–	Carbon marketing	
	–	Urban planning and green projects	
	–	Climate insurance	
2019	–	Climate litigation	[41], [99], [100]
	–	Biobased materials	
	–	Carbon capture, utilization, and sequestration	
	–	By-product utilization	
	–	Low carbon development projects	
	–	Biochar and carbon sequestration	
	–	Carbon accounting	
	–	Inventory and uncertainty analysis	
	–	Corporate climate risk management	
	–	Socio-ecological timeline adaptation	

	–	Sustainable architecture	[101], [102], [103]
	–	Media disclosure	
	–	Contesting and rewarding	
	–	Vertical institutional power flow	
	–	Negative emission technology	
2020	–	Reporting transparency	
	–	Energy revolution for carbon reduction	
	–	Two-pronged governance	
	–	Repair and maintenance survey	
	–	Bioenergy with carbon capture and storage	
	–	Latent economic vulnerability to emission reduction (LEVER) index	
	–	Carbon capture and transportation technologies	
2021	–	Carbon Border Adjustment Mechanism (CBAM)	[104], [105], [106]
	–	Nuclear power and communications	
	–	Long-range Energy Alternatives Planning Systems (LEAP)	
	–	Awareness campaigns	
	–	Electronic finance and environmental variables	
	–	Shared socio-economic track.	
	–	Carbon capture and use in methanol pathway.	
	–	Cooperative nexus of energy and policy	
	–	Circular bioeconomy	
	–	Water-land trade offs	
	–	Community approach	
	–	Meta-analysis	
	–	Climate Smart Mining and Recycling (CSM&R)	
2022	–	Global decomposition of CO_2 emissions	[107], [108], [109], [128]
	–	Decarbonization of fuel in transport sector	
	–	CO_2 mineralization	
	–	Commitment and disclosure projects coupling with legal framework.	
	–	Double carbon strategy of achieving carbon peak and carbon neutrality.	
	–	Carbon tax evaluation	
	–	Hydrogen as an energy carrier	
	–	Climate risk reporting and micromarketing	
	–	Environment disclosure and resource governance	
2023	–	Blue carbon stock	[36], [66], [110], [126] 127]
	–	Membrane distillation technology	
	–	Operational GHG management from top management committee	
	–	Agrivoltaics and Photovoltaics	
	–	Re-cultivation management strategies	
	–	Biomass alternatives to fossil use like microalgae, wood pulp and grasses.	

2. METHODOLOGY

2.1. Systematic literature mining through Scopus database

This study has selectively focused on peer reviewed articles listed in Scopus, and does not include documents from grey areas of publications or listings from database other than Scopus. Scopus is regarded as one of most renowned platforms for searching and analysing scientific citation data. In this study we have chosen the AND operator which customized our query results to 479 papers, the result found contained all the keywords 'climate change mitigation' AND 'industry'. To find and filter from the wide range of documents available on Scopus, stepwise map of Fig. 1 was followed. The search was narrowed down for years of publication to 15 years (2009–2023), source limited to journals and subject area as Environmental Science which was the top contributor at 42.6 %. The query results are a product of selection of articles published on the network matching the keywords. Initial outcomes included a total of 764 documents which is a variable number by the factor of date of assessment. These 764 documents included book chapter, articles, conference papers, erratum, letter, notes, etc. in press as well as final publications. The search was done in the first quarter of 2023, hence comparatively lower number of publications in 2023 against previous years. Therefore, limiting the document pool to 479. Final articles from standard journals were found with keywords like climate change, mitigation, CO_2, GHG, industrial emissions.

2.2. Network analysis using VOSviewer

In addition to Scopus database search, *VOSviewer* 1.6.15 was used for its analysis for efficient network based relationships like co-authorship and co-occurrence. *VOSviewer* is a research tool that analyses scientific networks using datasets from sources like Scopus, Web of Science, PubMed, etc.

Size of the frame represented by the weight of the term/citation as shown in Fig. 4 and Fig. 5. Size of the node is directly proportional to the frequency of the object. Hence, number of links between the keywords is directly proportional to the size of the frame [26]. The distance between the frames indicates the degree of relatedness between the keywords. The counting method was limited to full counting. In the graphic, the distance between two journals roughly reflects how closely the journals are associated in terms of co-citation relationships. In general, the closer two journals are near one another, the more closely they are related. Lines also show the strongest co-citation linkages between journals. The thicker the line used to indicate the link in the visualization of the presently active map, the stronger the link between two elements. The strength of this effect is controlled by the size variation slider.

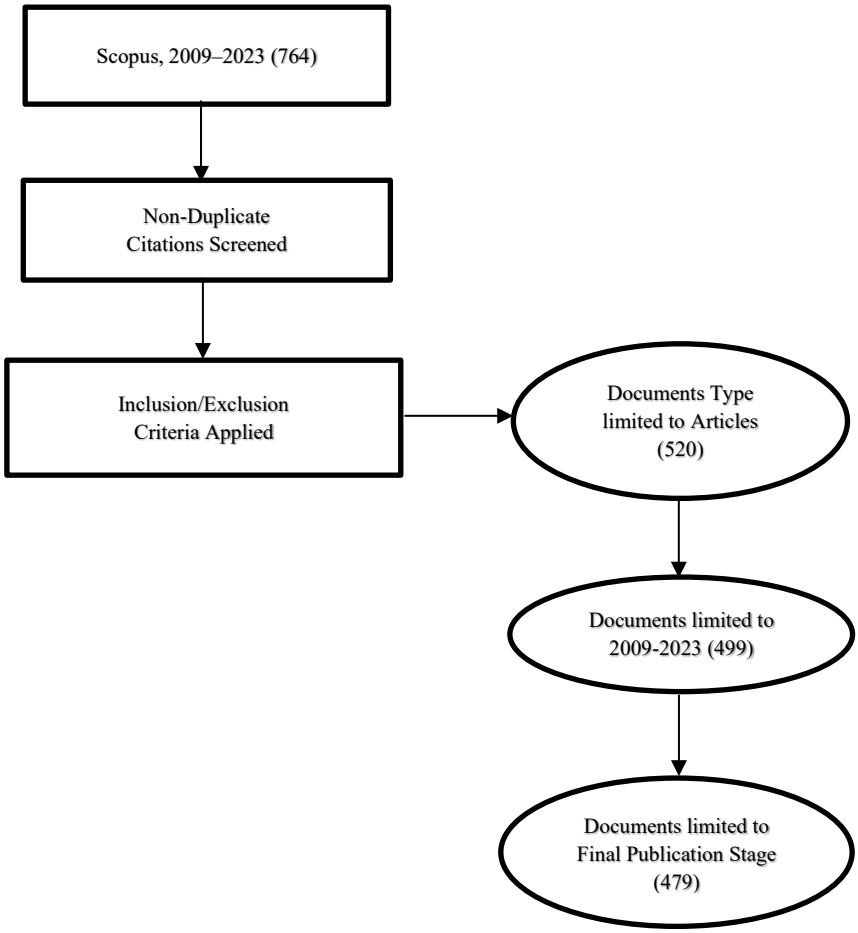


Fig. 1. Route map for mining relevant Scopus documents.

2.3. Mapping climate change mitigation strategies

In order to map the CCMS, all 479 research papers were critically evaluated for the strategies deployed by the industries worldwide during the period from 2009–2023. Further, the authors made an attempt to classify the CCMS into managerial and technological strategies from the industrial perspective.

3. RESULTS AND DISCUSSION

3.1. Analysing Scopus publications

The publications found on Scopus landed to 479 papers. English being the global language had a share of 426 papers followed by Chinese, German and Spanish. The majority source type for the database remained journals with 392 documents and 'climate change' as a keyword ranked highest with 304 occurrences. Table 1 depicts the list of diverse strategies used by the industries across the globe from 2009–2023 as mentioned in the retrieved documents from Scopus. The listed strategies were used in isolation or in combination

depending on the end solution requirement. Countries, institutions, authors, and the co-occurrence of authors' keywords were used in the analysis. These metrics were chosen to showcase countries and institutions at the forefront, as well as to identify top specialists in the area and to investigate networks of collaboration across these variables.

For the selected keywords 764 final documents were found from 1994 to 2023 wherein a surge in publication count was seen from in the year 2009, gradually increasing from 2006. Post Kyoto protocol the publication counts almost tripled in 2009 from 6 in 2008 to 16. In the last 14 years there has been a marginal increase in the number of publications in the year 2021 as compared to previous 3 years. Fig. 2 showcases the number of papers published per year from 2009–2023 on CCMS adopted by industries.

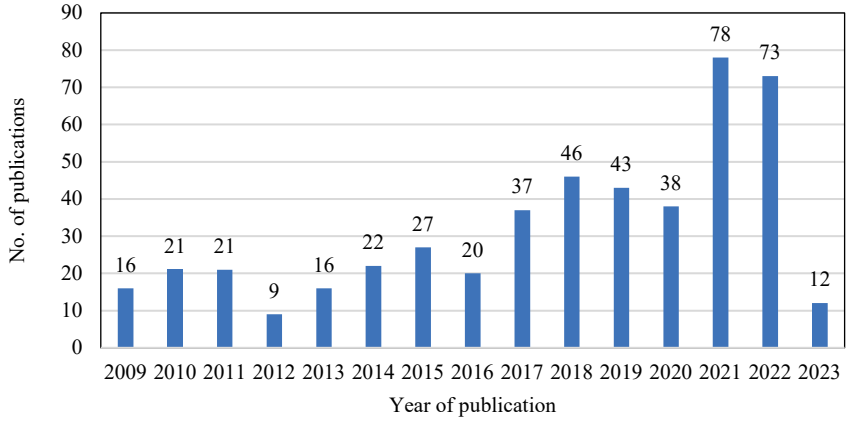


Fig. 2. Year wise analysis of Journal Papers (2009–2023).

When the question of source publishing the work in the area of CCMS came up, it was found 148 journals have contributed to the database. Table 1 is representative of the fact that *Journal of Cleaner Production* has the maximum number of papers followed by Science of The Total Environment. Papers with less than 5 publications are not listed in the table. It was found that 25 % of the total papers were published by top 10 journals as listed in Table 2.

TABLE 2. TOP 10 MOST INFLUENTIAL JOURNALS

Journal name	**No. of papers published**
Journal of Cleaner Production	27
Science of the Total Environment	14
Environmental Science and Technology	12
Energy Policy	12
Applied Energy	11
Climate Policy	10
Mitigation And Adaptation Strategies for Global Change	9
Sustainability Switzerland	8
Energy	7
Energy Research and Social Science	7

Tables 3 and 4 show the Scopus publication analysis based on top 10 authors and affiliation. It was found that International Institute for Applied Systems Analysis and Tsinghua University, China, rank the top 10 affiliations list with 13 documents in the last 15 years.

Fig. 3 is pictorial analysis of Scopus database showing that the USA (104) has the highest number of publications followed by China (70). Fig. 5 has graphically shown the top 10 countries across the globe. China is the only Asian country to publish second highest articles.

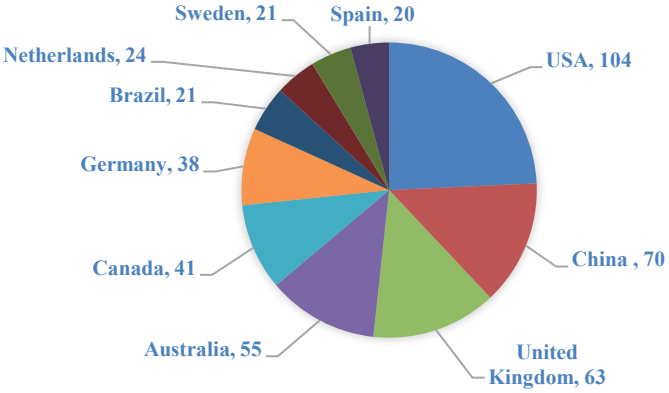


Fig. 3. Analysis of Journal Papers by Territory. Source: Scopus database.

In regard to publication analysis based on subject area and funding agencies, it was observed that several subject areas came under the area of climate change mitigation. Environmental Science had the highest number of 282 papers followed by Social Sciences with 98 papers.

It was found that 26 papers funded by National Natural Science Foundation of China, which was followed by 17 papers by National Science Foundation. Table 3 depicts all the sponsors with at least 6 publications in the Scopus database.

TABLE 3. PUBLICATION ANALYSIS BASED ON SUBJECT AREA

Subject area	**Publication count**
Environmental Science	282
Social Science	122
Energy	118
Engineering	100
Agricultural and Biological Sciences	78
Business, Management and Accounting	64
Earth and Planetary Sciences	53
Economics, Econometrics and Finance	32
Multidisciplinary	13

TABLE 4. TOP FUNDING AGENCIES

Funding agencies	Publication count
National Natural Science Foundation of China	27
National Science Foundation	17
European Commission	11
Natural Environment Research Council	10
Engineering and Physical Sciences Research Council	10
Horizon 2020 Framework Programme	9
Conselho Nacional de Desenvolvimento Cientifico e Technológico	9
Seventh Framework Programme	7
Economic and Social Research Council	7
National Institute for Food and Agriculture	6
UK Research and Innovation	6

3.2. Network analysis

Co-authorship analysis with countries showed that the minimum count of documents was kept at ten, showing 19 out of 72 countries to meet the threshold. Although China and the United Kingdom has 52 documents each, but the former has 1600 citations as compared to 1334 from China. The circle on the right-hand side of USA is United Kingdom. USA has the strongest link strength of 77 amongst the 19 countries as shown in Fig. 4.

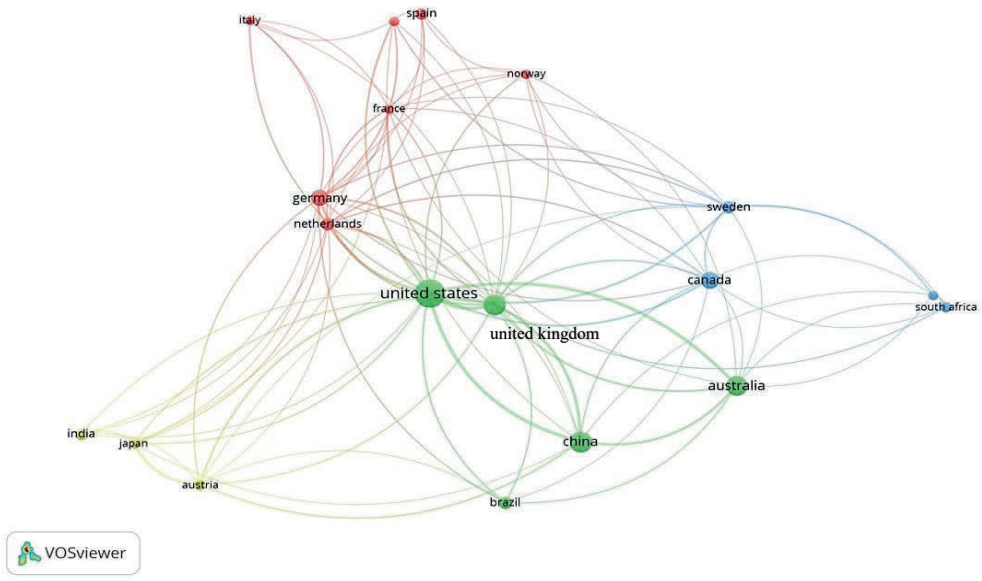


Fig. 4. Co-authorship Network Analysis with Countries.

The co-occurrence analysis with all keywords shows that out of the 3883 keywords, threshold was set to 5 out of which 253 met with the limit. In all 6 cluster were formed with 9748 links with maximum occurrence with climate change (304) followed by greenhouse gases (87), emission control (81) and climate change mitigation with 78. Keywords like climate policy and governance share a scant occurrence of 5 and 6. The co-occurrence analysis with author keywords shows that occurrence of 5 times per keywords was selected to find out only 27 keywords to meet the threshold out of 1373 in total. Authors found the co-occurrence between climate change and climate change mitigation to be the highest as shown in Fig. 5.

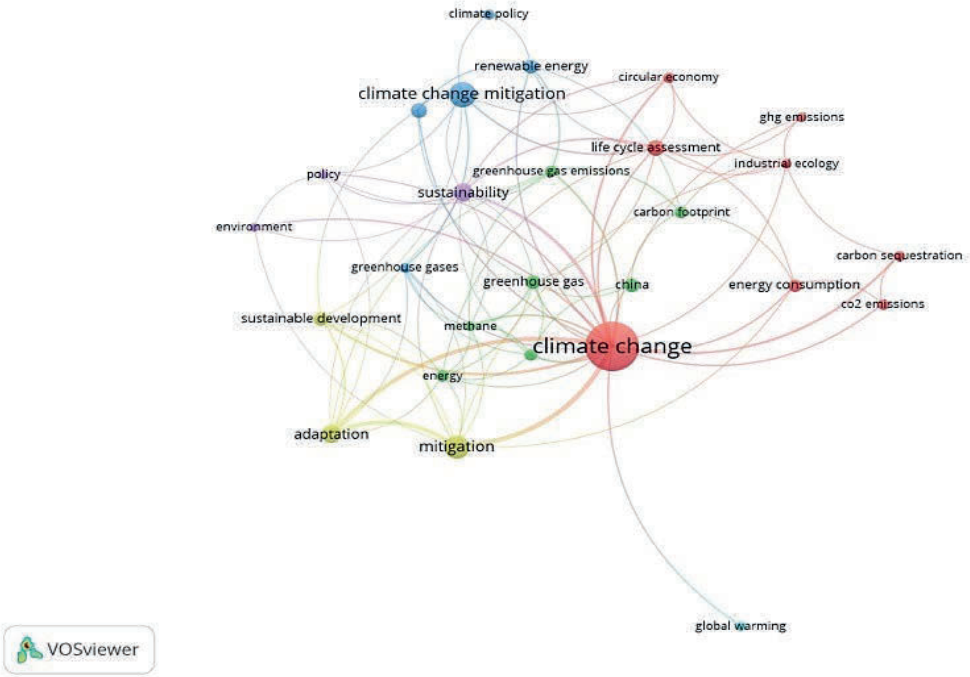


Fig. 5. Co-occurrence Network Analysis with Author Keywords.

3.3. Mapping and analysing CCMS

The authors have made an attempt to map and summarize the published list of strategies employed by the industries worldwide during the period 2009–2023. Table 5 depicts the year wise mapping of the deployed strategies. Literature review showed that there were 21 industries viz. cement [26]–[34], agriculture [13], [14], [35]–[39], energy [40], mining [41], [42], paper and pulp [44]–[45], iron and steel [7], [46]–[52], plastic [53], dairy [54], manufacturing [49], gas industry [45], [55]–[60], finance [61], [62], forest [63]–[67], water industry [68], wind power [69], pharmaceutical [70], chemical [71], [72], apparel [73], hospitability [74], construction [75], [76], cleantech [77] and real estate [78] were identified from the literature review. Amongst the listed strategies, many were repetitive which pointed to their high demand in the today's date, like fuel replacement wherein liquified natural gas will be used in place of coal, bioenergy in conjunction with carbon capture and storage [7], [27]–[28].

It is seen that the radical and rapid modernization process in steel industries has been indispensable in minimizing the anthropogenic GHG emissions to those levels needed in holding the global-warming temperature to within 2 °C. Although it is not enough for reaching out to climatic change mitigation destinations globally, it was possible with higher recycled steel productions. Carbon capture storage (CCS) can minimize the current emissions at a rate of seventy percent. It is estimated that it will save cost at a rate of one trillion by the year 2050, affording a continuous yearly benefit of fifty billion subsequently [46]. Carbon capture utilisation (CCU), CCS and electrolysis for the reduction process of iron ore to cut down CO_2 emissions has been lined up by energy intensive industries. CCS and CCU when combined with other innovative technologies like green innovation, can reduce GHG emission by 25–35 % in the steel industry [45]. The advanced efficient materials demand for minimizing the requirement of global steel [47]. Energy conservation and emission reduction which includes various practices like gas recovery from blast furnace, casting to continuous casting, electrification of industrial process, fuel switching etc. also helps in achieving emission reduction goals wherein energy conservation accounts to 12.5 % and emission reduction shares 6.9 % [48].

It has been reported that an integrated process involved in green cement production can help to minimize the environmental influence of the cement industry's activity without compromising reliability, quality, cost, performance [111]. In case of paper and pulp industry, speculated technologies to increase the efficiency of paper and pulp industry include black liquor gasification and efficient drying technology and operational commitment from top management [44].

Biomass is frequently viewed as the element of future energy systems as it could be utilized for the production of heat and electricity as a fuel for transport and as a chemical feedstock. Moreover, it could be used in fusion with storage and carbon capture to afford negative emissions. However, biomass production needs land, probably influencing the environmental services, food security and supplementary environmental services. Therefore, the approaches chosen in supplying, conversion as well as biomass usage have an important influence on its efficiency as an alleviation measure for climate change [27]. Soil carbon sequestration has proven to be an important tool for environmental health, ecosystem and food security in global times of climate change [112], [68]. Storage of atmospheric CO_2 as an organic carbon in the biosphere is gaining considerable interest as a potential alternative to slowing the rate of GHG accumulation and resulting climate change [113].

TABLE 5. MANAGEMENT STRATEGIES ADOPTED BY VARIOUS INDUSTRIES FOR CLIMATE CHANGE MITIGATION

Sr. No.	Management Strategies	Adoptive industries	Comments/Remarks	Reference
1.	Climate governance and intervention	Construction/ Energy	Local government ties with private consultancies for environment services have proven to reduce GHG emissions.	[114]
2.	Dietary management of the animals	Dairy	Replacement of crude heavy proteins and forage by granola, soybean and whey meals aid in reduced emission of methane from dairy animals.	[115]
3.	Robust policy and network	Oil and Gas	Institutional effectiveness in terms of laying clear yet distinctive policies across the organization aids in energy transitions for sustainable practices.	[60]
4.	Behavioural shifts	Apparel and fashion	Rooting awareness amongst society to choose sustainable fashion over fast, to go for long term needs than latest trends can help in climate change mitigation.	[116]

5.	Accounting strategies	Manufacturing, Automotives	Firms with weak environmental regulations have a lesser market value hence less capital. Less capital further prevents in engaging in mitigation measures of the polluting yet non-profitable firms. A robust policy with common but differential regulations across the supply chain and market can break the barrier.	[8]
6.	Community approach	Agriculture	Key community systems for driving sustainability from within the affected local area. Upscaling of the drivers and addressing the barriers leading to new pathways for climate resilience.	[35]
7.	Global discussion	Aquaculture/Mariculture	Climate smart approaches like linking food incentives, tax subsidies with reduced GHG emission targets. Discussions manoeuvring horizontally and vertically involving habitat will indirectly help in biodiversity restorations as well.	[117]
8.	Industrial grouping	Chemical	Clustering of industries together attracts local support and long-term investors. Combined mitigation strategy is promoted from the government and market. Standing together paves ways for energy recovery also. Although attaining deep carbon cuts is tricky given short term aims of each industry.	[109]
9.	Environment management policy	Cement	Stringent government laws and policies wins over industrial conflicts for same. Additionally pushes industries to find a workable way as per set norms.	[30]

TABLE 6. TECHNOLOGICAL STRATEGIES ADOPTED BY VARIOUS INDUSTRIES FOR CLIMATE CHANGE MITIGATION

Sr. No.	**Technological Strategies**	**Adoptive industries**	**Comments/Remarks**	**References**
1.	Carbon Capture Storage and Utilisation (CCUS) and Material efficiency	Cement and Construction	Downsizing of products, better quality raw materials, reuse, recycling appropriately to achieve lower carbon footprints in the cement and construction industry. Fuel switching to hydrogen or electricity or biomass without application of carbon capture and storage does not do anything for process emissions.	[32], [76]
2.	Biological agents like microalgae (*Chlorella* sp.)	Cement	Coupled industrial flue gas and microalgae cultivation system can mitigate up to 15 %(1268t/yr) of the CO_2 and generate 2317 litres of biodiesel annually.	[31], [126]
3.	Hydrogen based energy carriers	Iron and steel, Power, Transport, Energy Utilities, Construction and buildings	Hydrogen production from electrification exceeds the cost gap from its mitigation of CO_2. A holistic strategy can combat the issue of cost and mitigation potential if spearheaded strategically amongst industries.	[7]
4.	Double carbon strategy	Agro-based	Pairing carbon neutrality aims with building carbon sequestration spots in agriculture and rural areas. The coupling will indirectly help in dairy and livestock management.	[37]
5.	Material and energy efficiency	Iron and Steel	Use of Electric Arc Furnaces, quality coal with lesser impurities combats climate pollution. Although retrofitting is an expensive and time taking process but results aid in long term achievements.	[49]

6.	Material and energy efficiency	Mining	Exponential rise in metal demands for low carbon economy and replacement of energy source to renewable options like photovoltaic cells, wind power, nuclear power followed by carbon capture and storage.	[42]
7.	Material choice and efficiency	Fertiliser	Replacement of synthetic fertiliser by organic options lowers the N_2O emission and saves energy. Drip irrigation over sprinkler saves water, energy and capital.	[39]
8.	Carbon Capture Storage and Utilisation (CCUS)	Chemical	Coupling the captured CO_2 with clean hydrogen in methanol production releases lesser GHG emission compared to no capture at all.	[118]
9.	Biorefinery development	Paper and pulp	Biorefinery development and implementation boosts the business by using already available raw materials for better material efficiency and energy savings.	[43]
10.	Emission trade-offs	Power	Diffusing low carbon technologies (phasing out fossil fuel power) between mitigation strategies and local air pollution abatement will reduce terrestrial acidification.	[119]

The authors further analysed all the research papers and made an attempt to classify the strategies for climate change mitigation from industrial perspective into managerial and technological (Tables 5 and 6). It is known that a firm can uptake any strategic option while responding to environmental issues like climate change [120]. The usage of strategy based on financial resources and policies with recent technologies focusing on efficient carbon pricing mechanisms. Because the negative impact of industrial share into the GHG emissions not only impacts urban society but is causing disruption in the livelihood of rural population as well. Along with socioeconomic factors, the perception of climate change among farmers affects migration. Being dependent on climatic conditions for their livelihood, farmers migration is influenced by the adverse impacts of climate change [121]. It is reported that farmers in Tanzania showed great interest in adoption of better suited climate procedures in accordance with the local meteorological data, courtesy of the environmental awareness programs and rural workshops [122]. Green practices and indirect support to the local community via the policies and programmes of corporate social responsibility helps building a positive image of the industry and raises awareness [18]. Awareness and conscious call from industries and political power through the vertical and horizontal hierarchy might help in selecting the most sustainable choices for the goal of net zero emissions by 2050.

Technologies such as CCUS and CCS has proven to be a good fit for energy intensive industries such as cement, iron and steel wherein substitution options are limited for deep emission minimizations [50]. CCS can minimize the current emissions at a rate of seventy percent. It also saves cost at a rate of one trillion by the year 2050, affording a continuous yearly benefit of fifty billion subsequently [46]. Upcoming and yet to reach its full potential, i.e., hydrogen as an energy option was found to be the centre of discussion of many research articles and reports. Owing to its no direct emission of GHG, hydrogen holds indispensable importance in power, automobile and buildings sectors. Hydrogen is one of the main renewable energy storage options and seems to be the cheapest option for storing electricity for days, weeks or even months. It can ship energy from renewable energy sources over long distances as well as can be utilised for renewable energy options like photovoltaic cells and wind [69], [123]. Debates are going on how in reality, technology can become an integral part of the global effort to reach net zero, but there are real trade-offs in adopting technology as

we move from current behaviour to a more climate-friendly society [124]. Digitization and their service centres share almost an equivalent amount of GHG emission as the aviation industry [1].

4. CONCLUSION

Climate change being a cross-disciplinary field inculcates work from several subject areas. The year 2021 published maximum number of papers and the academic span from 2018–2020 marked a stagnant junction in terms of publication count despite COP23 and COP24 implementation of the Paris Agreement. This is indicative of focus being put on aspects of impact of climate change but lack of balance amongst the nations between pollution control and development goals. In terms of nationality, 19 countries actively worked on strategies in climate change mitigation in industries wherein USA tops the list but though China is transitioning from developing to developed nation ranks third in the list. Developing nations like India with 3rd highest CO_2 emissions lack behind in publishing the work done on combat climate change.

Immediate mitigation strategies and adaptable approaches are highly recommended for the climate change mitigation process. Most research reviewed has concentrated on energy intensive industries like iron and steel, fertilizers, paper and pulp, cement, power etc. 85 % of industrial energy use is powered by fossil fuels, which outflows the total CO_2 emissions [5]. Execution of carbon credit method is an additional strategy of Iron and Steel Companies (ISC) in China associated with the reduction in CO_2 [62]. Though it does not directly impact the CO_2 reduction of the producers, it can encourage producers to involve in various practices for CO_2 reduction [52]. Besides, the traditional solutions to mitigate climate change like changing the energy systems integrated with the usage of renewable energy or energy efficiency enhancement are not suffice for fulfilling the issues for 1.5 °C by the year 2050. However, for de-carbonization efforts negative emission technologies provides a strong solution. Thus, appropriate policies and frameworks should be made for negative emission projects. Some strategy options like fuel switching to renewable option also creates sectoral employment [125]. Behavioural shifts from the society can only push industries to go sustainable whilst aiding in climate change mitigation [73]. Thus, this study provides support to various researchers to build upon emerging technology to decarbonize industries. It attempts to enable sufficient policies structure for an industrial low carbon transition for the current and upcoming generation. Climate change cannot be escaped but can be stabilised for habitation. At present, there is no one ideal technology to promote emissions alignment with sustainability-targets for net zero emissions by 2050. Hence to bridge out this eco-innovation research gap, it is required to develop an efficient technology to generate steel production in very fewer footprints of carbon or in implementing CCS or CCU technology deployment. Voluntary disclosures have come out to be an indispensable mitigation strategy from energy intensive to agriculture industries, and the course has followed an upward trend, courtesy public awareness, customer interest and stakeholders' choice in sustainability. It is envisaged that new breakthrough technology would offer solutions which might establish new environmental management rules and approaches. With their unprecedented flexibility, adaptability, and contextualization, these new players can alter current operations. Circular economy shifts for economic and social outputs might get us in a position of better organizational values and innovation to achieve net-zero emissions by 2050.

5. LIMITATION AND FUTURE RESEARCH AGENDA

Journal databases such as Scopus and Web of Science are well recognized worldwide by Higher Education Institution (HEI) and ranking agencies. Since most of the Web of Science indexed journals are also indexed in Scopus, the authors in the present study have focused only on Scopus database. This may be considered as a limiting factor of this study. Future studies can aim at strengthening the work by incorporating feedback from multiple database sources. Researchers should work on the same to address the gap not only from the vision of mitigating climate change from energy intensive industry but as a function of consumerism, lifestyle, and sustainability.

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