



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(1): 171-182
Received: 02-11-2025
Accepted: 05-12-2025

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The carbon footprint challenge: A holistic review of causes, impacts and global solutions

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i1Sc.4680>

Abstract

This study provides a comprehensive review of the concept, causes, effects, and solutions to the carbon footprint, with a focus on its significance in the global climate change narrative. Originating from the concept of the ecological footprint, the carbon footprint quantifies the total greenhouse gas emissions, primarily CO₂, attributed to human activities. The study highlights that major contributors to global emissions include energy production, agriculture, industry, and transportation, with the United States, China, the European Union, and India being the top emitters. The escalating carbon emissions have led to severe environmental impacts, including global warming, habitat destruction, and depletion of natural resources. To mitigate these effects, the study discusses various strategies, such as carbon sequestration through agroforestry and sustainable land use practices. The methodology involved a systematic review of 123 scholarly articles following PRISMA guidelines, providing insights into current research trends and future directions in carbon footprint studies. This paper aims to serve as a valuable resource for researchers, policymakers, and practitioners by synthesizing dispersed information and offering a cohesive understanding of the carbon footprint and its global implications.

Keywords: Carbon footprint, climate change, carbon sequestration, renewable energy, and sustainable agriculture

1. Introduction

The concept of "footprint" was originally developed by William Rees and Mathis Wackernagel at the University of British Columbia in 1992, with its roots in the idea of the ecological footprint, a metric designed to assess human demands on Earth's ecosystems. Over time, this idea has evolved into the widely recognized term "carbon footprint," which refers to the total volume of carbon dioxide (CO₂) and other greenhouse gases emitted due to the activities of individuals, organizations, events, or products (Carbon Trust, 2007)^[17].

In the United States, the average personal carbon footprint is currently estimated at approximately 16 tons, one of the highest globally, while the global average hovers around 4 tons per capita (Bhalawe *et al.*, 2023)^[13]. The largest contributors to global CO₂ emissions China, the United States, the European Union, and India together account for roughly 60% of the global total (Crippa *et al.*, 2022)^[23]. To prevent a rise in global temperatures by 2°C, a critical threshold beyond which catastrophic climate impacts become more likely, the global average carbon footprint must be reduced to below 2 tons per person by 2050 (Bhalawe *et al.*, 2023)^[13]. This goal aligns with the objectives of the Paris Agreement, which aims to limit the global temperature increase to well below 2 °C above pre-industrial levels, with additional efforts to keep the increase to 1.5 °C (Gera, 2018)^[33].

The consensus on the severe threat posed by climate change has grown, with significant evidence pointing to human-generated greenhouse gas emissions as the primary driver of environmental degradation. Among greenhouse gases, carbon dioxide accounts for around 70% of total emissions (IPCC, 2007). Major sources of CO₂ emissions include the burning of fossil fuels for heating, electricity production, and transportation (Government of India [GOI], 2015). Furthermore, the indirect emissions associated with the production, transportation, and disposal of goods and services highlight the broad environmental impacts of human activity.

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Effectively addressing the diverse challenges posed by climate change requires precise quantification of carbon emissions across all sectors. The principle that "only what is measurable is controllable" underscores the importance of carbon footprint assessments in developing and implementing mitigation strategies. These measurements are essential for reducing emissions and achieving sustainability targets.

Although research on carbon footprints has expanded, there remains a lack of comprehensive review studies in the field. Many existing reviews tend to focus on specific methods or applications, often neglecting broader theoretical advancements or research trends. Bibliometric analysis offers a quantitative method for evaluating the literature, identifying key areas of focus, and illuminating the underlying theoretical and knowledge structures within carbon footprint research.

This study seeks to fill this gap by conducting a thorough review of the carbon footprint literature using bibliometric techniques. The study has four key objectives: (1) to clarify the concept of the carbon footprint; (2) to identify and analyze the main drivers of carbon footprints; (3) to investigate the environmental and societal effects of carbon footprints; and (4) to explore potential solutions and strategies for effectively mitigating carbon footprints. By synthesizing scattered information and offering a comprehensive understanding of carbon footprint dynamics, this study aims to provide valuable insights for researchers, policymakers, and practitioners working to promote sustainability and address climate change on a global scale.

2. Methodology

2.1 Study Design

This study employed a systematic literature review combined with bibliometric analysis to synthesize and evaluate existing research on the causes, impacts, and mitigation strategies of the carbon footprint. The methodology was structured in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a comprehensive and transparent review process.

2.2 Data Sources and Search Strategy

A comprehensive search was conducted across multiple academic databases to identify relevant literature published between January 2000 and December 2023. The databases searched included:

- Web of Science
- Scopus
- PubMed
- ScienceDirect
- SpringerLink
- Google Scholar

The search strategy was developed using a combination of keywords and Boolean operators to capture a broad spectrum of studies related to the carbon footprint. The primary search terms included:

- "carbon footprint"
- "greenhouse gas emissions"
- "climate change"
- "carbon footprint measurement methods"
- "causes of carbon footprint"
- "effects of carbon footprint"
- "carbon sequestration"
- "renewable energy"
- "sustainable agriculture"

- "carbon emission reduction strategies"
- "mitigation of carbon footprint"

These keywords were applied both individually and in combination using Boolean operators (AND, OR) to refine the search results. For example:

- ("carbon footprint" OR "greenhouse gas emissions") AND ("climate change" OR "global warming") AND ("mitigation strategies" OR "reduction methods")

Reference lists of relevant articles were also examined to identify additional studies not captured in the initial database searches.

2.3 Inclusion and Exclusion Criteria

To ensure the relevance and quality of the included studies, the following inclusion and exclusion criteria were applied:

Inclusion Criteria

- Publications in English language.
- Studies published between January 2000 and December 2023.
- Peer-reviewed journal articles, conference proceedings, and authoritative reports.
- Studies directly addressing the causes, impacts, measurement methods, or mitigation strategies of the carbon footprint.
- Articles providing empirical data, theoretical insights, or comprehensive reviews relevant to the research objectives.

Exclusion Criteria

- Non-English publications.
- Studies not available in full text.
- Articles not directly related to carbon footprint analysis (e.g., focusing solely on ecological footprints without specific emphasis on carbon emissions).
- Editorials, commentaries, opinion pieces, book reviews, and non-peer-reviewed sources.

2.4 Study Selection Process

The initial search yielded a total of 1,256 records. After removing duplicates, 1,034 records remained for screening. Titles and abstracts were screened independently by two reviewers to assess their relevance based on the inclusion and exclusion criteria. Discrepancies were resolved through discussion or consultation with a third reviewer.

Full-text articles were retrieved for 212 studies that met the initial screening criteria. These articles were further assessed for eligibility, resulting in 123 studies included in the final review.

2.5 Data Extraction and Management

Data from the included studies were extracted using a standardized data extraction form developed in Microsoft Excel. The extracted information included:

- Author(s) and year of publication.
- Title and source of the study.
- Objectives and research questions.
- Study design and methodology.

Key findings related to:

- Definitions and concepts of the carbon footprint.
- Main drivers and causes of carbon footprints.
- Environmental and societal impacts.

- Mitigation strategies and solutions.
- Conclusions and recommendations.
- Identified gaps and limitations.

To ensure accuracy, data extraction was performed independently by two reviewers, with cross-verification of the extracted data.

2.6 Quality Assessment

The methodological quality of the included studies was appraised using the Critical Appraisal Skills Programme (CASP) checklists appropriate for each study design (e.g., systematic reviews, cohort studies, cross-sectional studies). The quality assessment focused on:

- Validity of the research methodology.
- Clarity of objectives and research questions.
- Appropriateness of data collection and analysis methods.
- Transparency of results and conclusions.
- Relevance to the research objectives of this review.

Studies were not excluded based on quality assessment scores; however, the appraisal informed the synthesis and interpretation of findings.

2.7 Bibliometric Analysis

A bibliometric analysis was conducted to identify research trends, influential authors, key journals, and collaboration networks within the field of carbon footprint research. Data for the bibliometric analysis were obtained from the Web of Science and Scopus databases.

The analysis utilized software tools such as VOSviewer and CiteSpace to visualize:

- Publication trends over time.
- Co-authorship networks.
- Citation analysis to identify highly cited works.
- Keyword co-occurrence to reveal emerging themes and research hotspots.

2.8 Data Synthesis and Analysis

A thematic synthesis approach was employed to analyze and integrate the findings from the included studies. The synthesis was structured around the four key objectives of this review:

- **Clarification of the Carbon Footprint Concept:** Definitions, measurement methods, and theoretical frameworks were compared and contrasted.
- **Identification of Main Drivers:** Analysis of the primary anthropogenic activities contributing to carbon footprints.
- **Investigation of Environmental and Societal Effects:** Examination of the impacts of carbon footprints on climate change, ecosystems, and human societies.
- **Exploration of Mitigation Strategies:** Evaluation of proposed solutions, their effectiveness, and implementation challenges.

Quantitative data were presented using descriptive statistics, while qualitative findings were synthesized narratively. Visual aids such as tables, charts, and graphs were used to enhance the presentation of results.

2.9 PRISMA Flow Diagram

The study selection process is illustrated in Figure 1, the PRISMA flow diagram, which details the number of records identified, screened, assessed for eligibility, and included in the

review. Reasons for exclusion at each stage are provided to ensure transparency in the selection process.

3. Results and Discussion

3.1 Types of Emissions

Carbon footprint emissions can be broadly categorized into three main types: direct, indirect, and embodied emissions (Fig. 2). These classifications offer a detailed understanding of the different sources and pathways through which greenhouse gases (GHGs) are released, contributing to global climate change (WRI, 2015; IPCC, 2014).

- **Direct Emissions:** Also known as Scope 1 emissions, direct emissions refer to GHGs released directly from sources owned or controlled by an individual or organization. These emissions arise from the combustion of fossil fuels on-site, such as in vehicles, industrial activities, or heating systems (EPA, 2023). Examples include carbon dioxide (CO₂) emissions from company-operated vehicles or methane (CH₄) emissions from livestock farming (IPCC, 2014). Since these emissions stem from sources under direct control, they are generally easier to monitor and manage.
- **Indirect Emissions:** Indirect emissions include Scope 2 and Scope 3 emissions. Scope 2 emissions are GHGs emitted during the generation of electricity, heat, or steam consumed by an organization but generated off-site (WRI, 2015). Scope 3 emissions, on the other hand, involve all other indirect emissions along the value chain, such as those from raw material extraction, transportation, waste management, and employee commuting (CDP, 2022). Unlike Scope 1 emissions, indirect emissions involve complex measurement methodologies due to their broader and less controllable nature (GHG Protocol, 2021).
- **Embodied Emissions:** Embodied emissions refer to the GHGs emitted throughout the lifecycle of products and materials, from extraction and manufacturing to transportation and disposal (Hammond & Jones, 2011)^[41]. These emissions, part of Scope 3, are particularly impactful in industries like construction and manufacturing (Malmqvist *et al.*, 2011)^[76]. For instance, embodied carbon in building materials like concrete and steel includes emissions from their production and transport to construction sites (Pomponi & Moncaster, 2016)^[95]. Reducing embodied emissions is essential to minimize the overall carbon footprint across product lifecycles.

3.2 Causes of the Carbon Footprint

Literature reviews identify several key factors that contribute significantly to carbon footprint emissions (Figs. 3 & 4). These include industrial activities, agricultural practices, energy consumption in domestic and commercial sectors, transportation, and land-use changes (Table 1).

1. **Industrial Activities:** Industrial sectors are major contributors to carbon footprints due to high energy consumption and the reliance on fossil fuels for processes such as cement production, steel manufacturing, and chemical synthesis (Jones *et al.*, 2015; Lee *et al.*, 2017)^[57, 69]. These processes, particularly energy-inefficient machinery, release significant amounts of carbon dioxide and other GHGs.
2. **Agricultural Practices:** Agriculture contributes notably to GHG emissions, primarily through livestock farming and crop cultivation. Livestock, especially ruminants such as cattle, produce methane (CH₄) through enteric fermentation, while the application of synthetic fertilizers leads to nitrous

oxide (N₂O) emissions (Gerber *et al.*, 2013; Smith *et al.*, 2008) [34, 109]. Deforestation and land-use changes for agriculture also release large amounts of carbon stored in forests and peatlands (FAO, 2020).

3. **Domestic and Commercial Energy Consumption:** The residential and commercial sectors contribute to the carbon footprint mainly through energy consumption for heating, cooling, and electricity, which are often generated using fossil fuels (IEA, 2019). Waste management practices like landfilling also release methane and carbon dioxide, adding to emissions (Barker *et al.*, 2019) [111].
4. **Transportation:** Transportation is a significant source of carbon emissions, particularly due to the burning of gasoline and diesel in vehicles, planes, and ships (Sperling & Gordon, 2009) [110]. Increasing global transportation demand and reliance on non-renewable energy sources have escalated emissions from this sector.
5. **Land-Use Changes:** Changes in land use, such as deforestation, urbanization, and agricultural expansion, substantially increase carbon emissions. Deforestation reduces carbon sequestration capacity, while urban development leads to higher energy consumption and infrastructure demands, driving up CO₂ emissions (Houghton, 2012; Seto *et al.*, 2014) [45, 105].

3.2.1 Approach to Calculating the Carbon Footprint

Calculating a carbon footprint involves a structured five-step process (Carbon Trust, 2007; Awanthi & Navaratne, 2018) [17, 9].

1. Define the methodology
2. Specify the boundary and scope of coverage
3. Collect emissions data and calculate the footprint
4. Verify the results
5. Report and describe the carbon footprint

This process is typically used to:

1. Publicly report GHG emissions
2. Set targets for reducing emissions
3. Identify activities contributing most to the footprint
4. Monitor changes in emissions over time
5. Offset emissions

Carbon footprints can be calculated for both products and organizations:

- **Product Carbon Footprint:** The carbon footprint of a product involves estimating the total GHG emissions generated throughout its lifecycle, including direct and indirect emissions (Gao *et al.*, 2014; Chukka *et al.*, 2022) [32, 22]. This "cradle-to-grave" approach assesses emissions at each stage, from raw material extraction to disposal, and is quantified through environmental lifecycle assessments (Pandey *et al.*, 2011; Shabir *et al.*, 2023) [91, 106].
- **Organizational Carbon Footprint:** Organizational carbon footprints are calculated using a systematic approach, which involves setting clear boundaries for the organization, determining operational emissions (including Scope 1 and Scope 2), and optionally including Scope 3 emissions (Hammerschlag & Barbour, 2003; Loyarte-Lopez *et al.*, 2020) [40, 72]. Accurate carbon footprint calculations rely on thorough data collection, and the results are often verified by third parties for credibility.

3.3 Effects of Carbon Footprints

Rising concentrations of GHGs in the atmosphere pose a significant threat to global ecosystems, with increasing CO₂ levels leading to drastic environmental changes (McMichael &

Lindgren, 2011) [78]. Since the industrial revolution, atmospheric CO₂ concentrations have risen from 280 ppm to over 412 ppm, contributing to climate change impacts such as altered temperature patterns, ocean acidification, and ecosystem disruption (Kabir *et al.*, 2023) [60].

The key impacts of elevated carbon footprints include:

1. **Water Scarcity:** Climate change is projected to exacerbate global water scarcity, increasing demand while reducing availability. By 2025, 1.8 billion people are expected to live in regions of absolute water scarcity (IPCC, 2022; Mahato *et al.*, 2022) [74].
2. **Severe Weather Events:** Increasing GHG emissions contribute to more frequent and severe extreme weather events, including droughts, floods, and wildfires (Bolan *et al.*, 2024; Abram *et al.*, 2021) [16, 1]. These changes threaten both ecosystems and human health.
3. **Food Security:** Rising temperatures and altered precipitation patterns affect global agricultural productivity, threatening food and nutritional security as population growth pressures agricultural systems (Zhang *et al.*, 2021) [123].
4. **Depletion of Natural Resources:** Human activities, including resource extraction and environmental degradation, contribute to the depletion of natural resources and worsen environmental quality (Joshua & Bekun, 2020; Magazzino *et al.*, 2020) [59, 73].
5. **Greenhouse Effect Intensification:** The greenhouse effect, primarily driven by GHGs such as CO₂, methane, and nitrous oxide, has been intensified by human activity, contributing to global warming and related environmental issues (Le Treut *et al.*, 2007) [69].
6. **Climate Change:** Increased carbon footprints have intensified the greenhouse effect, resulting in global temperature increases, sea level rise, and widespread ecological consequences (McMichael, 2013; Hsiang & Kopp, 2018; IPCC, 2022) [79, 46].
7. **Marine Ecosystem Damage:** Marine ecosystems are experiencing rising temperatures, increased CO₂ concentrations, and pollution, which have disrupted species distributions and coral reef ecosystems (Jan *et al.*, 2023) [56].
8. **Habitat Destruction:** Human activities, particularly deforestation and urbanization, have led to widespread habitat destruction, reducing biodiversity and contributing to species extinction (Laurance, 2010; Bodo *et al.*, 2021) [66, 15].

3.4 Solutions to Reduce Carbon Footprint

Carbon Sequestration: A Strategy to Mitigate Carbon Footprint

Carbon sequestration is one of the most prominent strategies for mitigating atmospheric CO₂ levels (Lal, 2008) [64]. This process involves capturing and storing carbon in natural reservoirs such as oceans, vegetation, or soils, either through biological or physical mechanisms (Jose, 2009) [58]. Terrestrial ecosystems play a significant role in carbon sequestration, where vegetation, particularly trees, act as carbon sinks during their lifespan, storing carbon in biomass. Upon death, this biomass either contributes to soil carbon or releases CO₂ if combusted (Ramaswamy *et al.*, 2001) [100]. This natural process offers an economically viable method of removing carbon from the atmosphere, storing it within ecosystems (Chavan & Rasal, 2010) [21]. Forests and agroforestry systems, in particular, have been identified as practical solutions for carbon sequestration due to their ability to store significant amounts of CO₂ in both vegetation and soils (Murthy *et al.*, 2013) [83].

Forests as Carbon Sequestration Agents

Forests store about 19% of the carbon in the Earth's biosphere, with 31% of this carbon in biomass and 69% in soils (IPCC, 2000). Tropical forests, in particular, are notable carbon reservoirs, with estimates suggesting they store approximately 428 billion tonnes of carbon (Lasco, 2001)^[65]. Globally, forests sequester about 1.1 billion tonnes of carbon annually.

The Potential of Agroforestry in Carbon Footprint Reduction

Agroforestry, the integration of trees and shrubs into agricultural landscapes, plays a crucial role in enhancing carbon sequestration and mitigating climate change (Bijawan *et al.*, 2016)^[14]. Compared to monoculture practices, agroforestry systems sequester more carbon, which can be traded in carbon markets, providing economic incentives to farmers. Timber from agroforestry can also lock in carbon for long periods when used in industries like construction and paper production (Rahangdale & Koshta, 2016)^[98]. Agroforestry systems contribute to both climate mitigation and secondary environmental benefits, such as biodiversity restoration, improved watershed hydrology, and enhanced food security (Murthy *et al.*, 2013)^[83]. These systems have been shown to store substantial amounts of carbon, particularly in tropical regions (Nair *et al.*, 2009)^[85]. The carbon sequestration potential of agroforestry globally has been estimated at 1.9 Pg C over the next 50 years, with substantial opportunities for enhancing carbon storage on degraded lands (Nair *et al.*, 2009)^[85].

Organic Farming as a Strategy to Reduce Carbon Footprint

Organic farming is increasingly seen as a sustainable alternative to conventional agriculture, offering both environmental and health benefits. Excessive use of inorganic fertilizers depletes soil health and contributes to environmental pollution (Albiach *et al.*, 2000)^[5]. Organic farming promotes the use of organic matter to enhance soil fertility, reduce dependence on synthetic inputs, and lower greenhouse gas emissions (Quandt, 2021)^[97]. The shift toward organic farming is driven by growing consumer awareness of the environmental impacts of conventional farming, which includes soil degradation and the negative effects of chemical fertilizers on human health and ecosystems (Meemken & Qaim, 2018)^[80]. Organic farming improves soil quality, enhances microbial activity, and reduces greenhouse gas emissions, thus contributing to a reduction in the agricultural carbon footprint.

Installation of Renewable Energy to Reduce Carbon Footprint

Transitioning to renewable energy sources, such as solar, wind, hydroelectric, and biomass, is a critical global strategy for reducing greenhouse gas emissions and achieving sustainable development (Kamau, 2024; Rahman *et al.*, 2024)^[61, 99]. Renewable energy technologies offer substantial reductions in CO₂ emissions compared to fossil fuel-based systems, with solar photovoltaic (PV) systems emitting as low as 20 gCO₂e/kWh compared to over 1,000 gCO₂e/kWh from coal-fired plants (International Energy Agency, 2020) (Fig 5). The global adoption of renewable energy has already had significant impacts; in 2019 alone, renewable energy prevented approximately 2.6 gigatons of CO₂ emissions (IRENA, 2021). Lifecycle assessments confirm that renewable technologies, even considering their production and maintenance, have much lower total emissions compared to fossil fuels (European Commission, 2016).

Countries worldwide are adopting renewable energy technologies as part of their climate action strategies. For instance, India has set ambitious targets under its Nationally Determined Contributions (NDCs), aiming for 50% of its installed power capacity to come from non-fossil fuel sources by 2030 (GOI, 2023) (Table 2). This transition not only reduces carbon emissions but also provides long-term economic and public health benefits by improving air quality and reducing reliance on fossil fuels.

Other Solutions

Several other strategies have been proposed to reduce carbon footprints across various sectors. For example, Accorsi *et al.* (2017)^[22] optimized warehouse design to reduce carbon emissions by 1%, while carbon mineralization techniques in power plants can capture up to 95% of CO₂ emissions (Alturki, 2022)^[6]. In the realm of smart cities, IoT-enabled buildings have reduced carbon footprints by over 22% (Asopa *et al.*, 2021)^[8], while sustainable supply chain practices have been adopted by nearly 75% of major international companies (Ghosh *et al.*, 2020)^[36]. Furthermore, advancements in product design, such as low-carbon approaches using Weighted Edge Coloured Graphs (He & Yu, 2021)^[42], and alternative construction materials, like geopolymers, have significantly reduced emissions (Mellado *et al.*, 2014)^[81].

In agriculture, renewable energy integration in dairy farms has cut carbon emissions by 3,920 t CO₂e (Minoofar *et al.*, 2023)^[82], and optimization of residential building heating systems has minimized both operational and embodied carbon footprints (Pal *et al.*, 2017)^[90]. Other innovative solutions, such as transitioning blockchain platforms from Proof of Work (PoW) to Proof of Stake (PoS), have the potential to reduce energy consumption by 99%, highlighting the diverse approaches available for reducing carbon footprints across industries.

These solutions underscore the broad range of possibilities for reducing carbon footprints, from energy transitions to sustainable practices in various sectors.

4. Recommendations for Reducing Carbon Footprint

- **Individual Level:** At the individual level, adopting several practical measures can significantly reduce carbon footprints. One effective strategy is turning off appliances when not in use, thereby decreasing unnecessary energy consumption. Modifying dietary habits, such as reducing meat consumption and minimizing food waste, also contributes to a lower environmental impact. In addition, choosing energy-efficient vehicles, utilizing public transportation, walking, or cycling instead of driving, further helps to reduce greenhouse gas emissions. Incorporating renewable energy sources into homes, participating in carpooling, and conserving water are other valuable approaches for individuals seeking to reduce their carbon footprints.
- **National Level:** Governments play a pivotal role in addressing carbon footprints through strategic interventions. Regulating industries that contribute heavily to environmental degradation is crucial. In addition, launching public awareness campaigns and providing educational resources can increase citizens' engagement with environmental issues. Diversifying resource use and promoting sustainable consumption and conservation practices are also important. Establishing recycling infrastructure and encouraging green building initiatives can further reduce national carbon emissions, fostering a more

sustainable and environmentally responsible society and infrastructure.

- **Global Level:** At the global level, several key strategies are essential for reducing carbon footprints. A priority is halting deforestation while simultaneously promoting reforestation to enhance global carbon sequestration. The widespread adoption of green and clean energy technologies is equally important. Additionally, implementing policies to manage population growth can mitigate its environmental impact. Incentivizing companies to adopt eco-friendly practices promotes sustainability in business operations. Expanding the use of electric vehicles and improving public transportation infrastructure are also critical steps toward reducing fossil fuel dependence.

Investing in research and development of carbon capture and storage (CCS) technologies is another important strategy, offering a direct method to remove CO₂ from the atmosphere. Introducing global carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, would create financial incentives for reducing emissions. International collaboration on climate technology transfer, particularly to developing countries, is vital for equitable and effective carbon reduction efforts.

Furthermore, international financial support from global institutions can help governments, especially in economically challenged regions, achieve carbon reduction goals. These collective efforts are critical in addressing climate change and mitigating its impacts.

5. Conclusion

Human activities are the main contributors to greenhouse gas emissions, which drive global climate change. The concept of the carbon footprint is central to understanding and addressing this challenge, as it quantifies the impact of individual and collective actions on the environment. The carbon footprint measures the total emissions of carbon dioxide and other greenhouse gases associated with various activities, which accelerate global warming and environmental degradation. Accurate calculation and understanding of carbon footprints are

essential for setting meaningful emissions reduction targets, prioritizing mitigation strategies, and implementing effective measures. By tracking emissions over time, it becomes possible to identify the most significant contributors to climate change and target specific activities for reduction.

This study consolidates diverse sources of information to provide a comprehensive understanding of carbon footprinting, serving as a valuable resource for researchers and policymakers. Key actions, such as publicly reporting emissions, establishing reduction targets, identifying major emissions sources, and monitoring mitigation efforts, are crucial components of climate action. Additionally, compensating for emissions through carbon offset initiatives supports broader environmental goals. This integrated approach enhances our understanding of carbon footprints and aids in the development and implementation of more effective climate policies and strategies.

Author's contributions

Mitali Mehta contributed to the contextualization of the theme, data collection, data analysis, study design, formal analysis, visualization, writing the overall review and editing. Mohd. Hussnain contributed to the data collection, writing review and language editing. Ankush Moran and Suraj R. Hosur contributed in writing. All the authors read and approved the final manuscript.

Declarations of Competing interests

The authors declare no competing interests.

Availability of Data and Materials

The datasets and materials used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding

This review did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Tables and Figures

Table 1. Global greenhouse gas emissions by different sectors (IPCC, 2014)

Sr. no.	Source	Emission %	Detail
1	Electricity and Heat Production	25%	Burning of coal, natural gas, and oil for electricity and heat
2	Agriculture, Forestry, and Other Land Use	24%	Cultivation of crops, livestock, deforestation, and forest fires
3	Industry	21%	Involve fossil fuels burnt on site and emissions from chemical, metallurgical, and mineral transformation processes
4	Transportation	14%	Fossil fuels burnt for road, rail, air, and marine transportation
5	Buildings	6%	Energy generation and burning fuels for heat in buildings or cooking in homes
6	Other Energy	10%	All emissions from the energy sector that are not directly associated with electricity or heat production, such as fuel extraction, refining, and processing.

Table 2: Total installed capacity of India as of March 2023 (Report on optimal generation capacity, 2023)

Resource	Capacity (MW)
Coal+ Lignite	211855
Solar PV	66780
Hydro	42104
Wind	42633
Gas	24824
Biomass	10802
Nuclear	6780
Small Hydro	4944
Total installed capacity	4,15,469

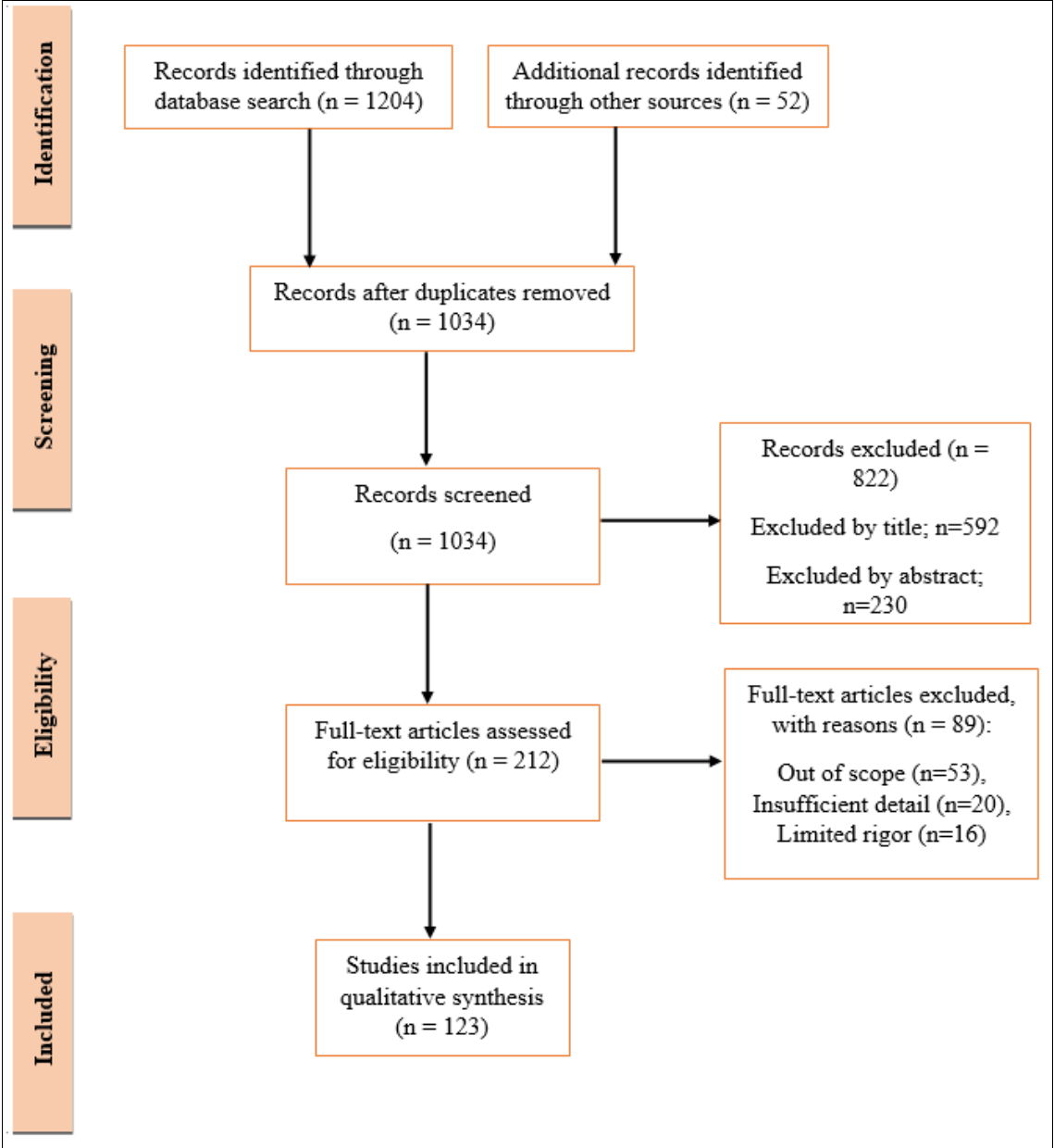


Fig 1: PRISMA flow diagram for literature identification and selection

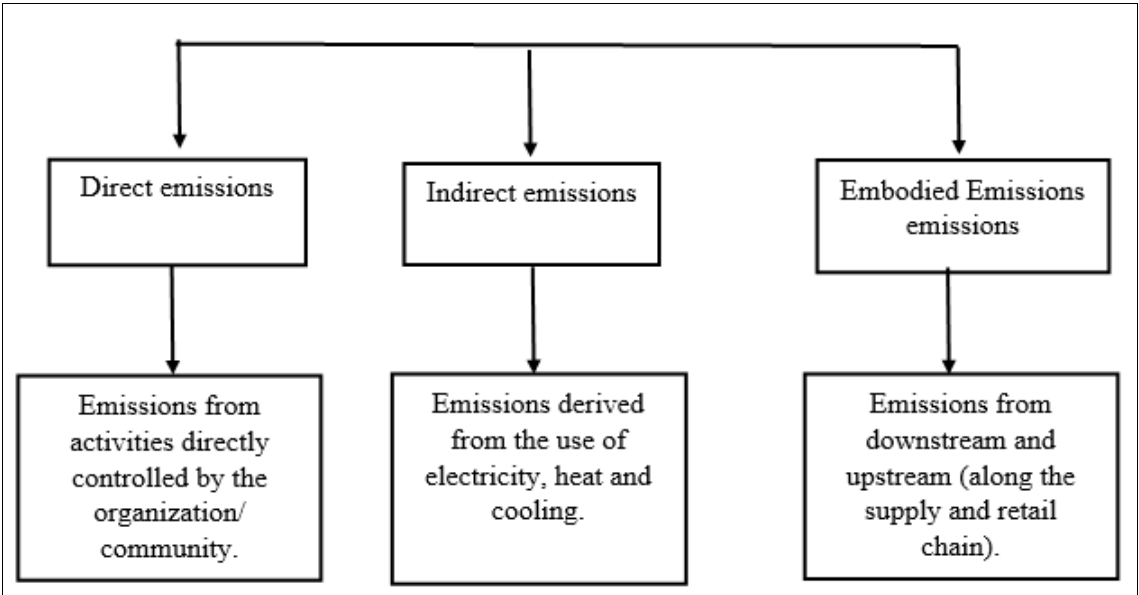


Fig 2: Different types of emission

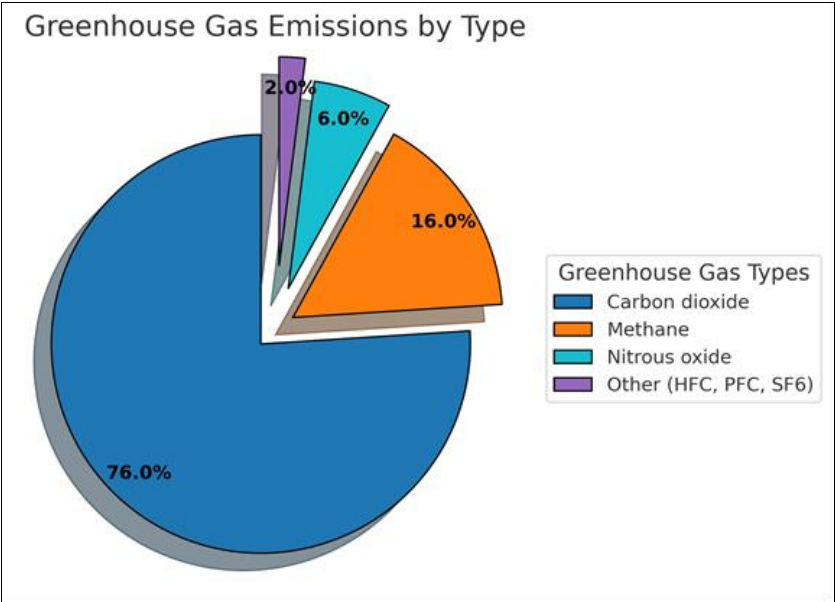
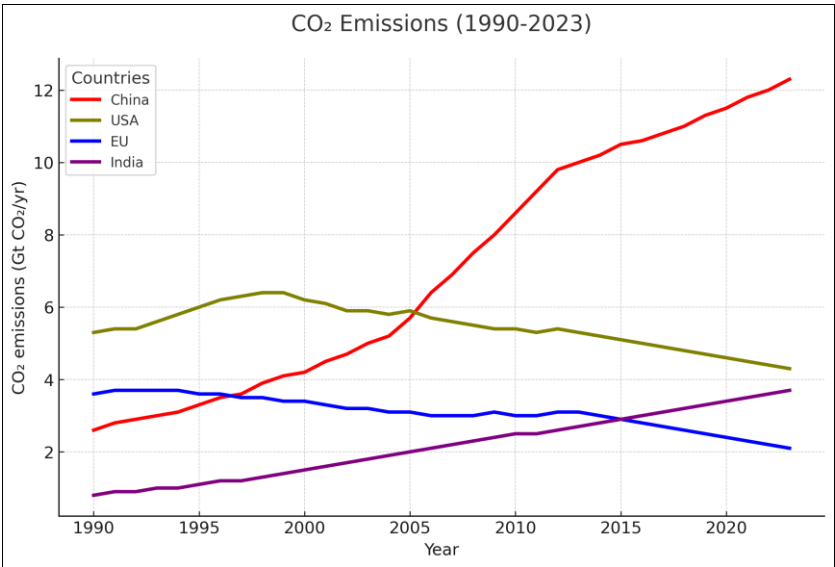


Fig 3: Trend of global manmade greenhouse gas emission (IPCC, 2021)



Sources: International Energy Agency (IEA) reports on CO₂ emissions trends up to 2023 World Bank and Global Carbon Project historical CO₂ emissions data.

Fig 4: Per capita CO₂ emission in the leading countries emitting GHGs

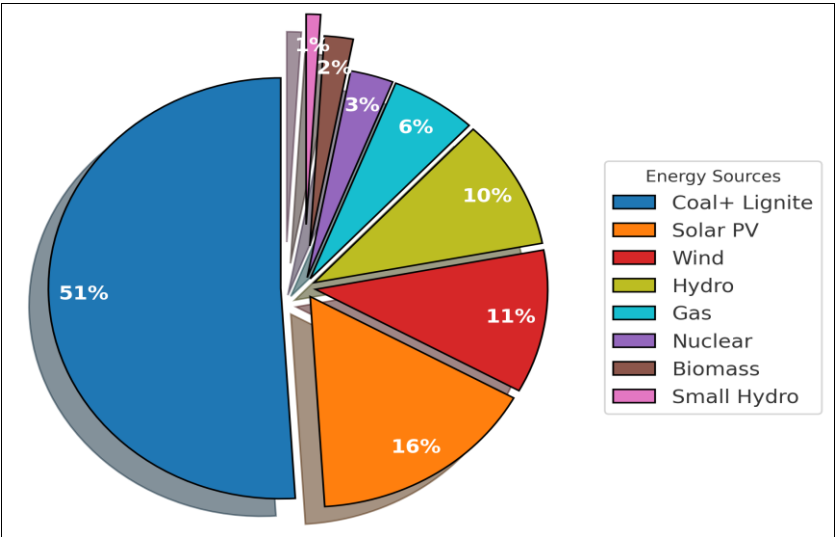


Fig 5: Percentage of contribution in energy by different source (GOI,2023)

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