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From carbon-neutral to climate-neutral supply chains: a multidisciplinary review and research agenda

Laharish Guntuka
Rochester Institute of Technology, Rochester, New York, USA
Prabhjot S. Mukandwal
Mike Ilitch School of Business, Wayne State University, Detroit, Michigan, USA
Emel Aktas
Department of Logistics, Procurement and Supply Chain Management, School of Management, Cranfield University, Cranfield, UK, and
Vamsi Sai Krishna Paluvadi
Deepak Fertilisers and Petrochemicals Corp. Ltd, Navi Mumbai, India

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Abstract

Purpose – We conduct a multidisciplinary systematic literature review on climate neutrality in the supply chain. While carbon neutrality has gained prominence, our study argues that achieving carbon neutrality alone is not enough to address climate change effectively, as non-CO_2 greenhouse gases (GHG) are potent contributors to global warming.

Design/methodology/approach – We used multiple databases, including EBSCO, ProQuest, Science Direct, Emerald and Google Scholar, to identify articles related to climate neutrality in the context of non-CO_2 gases. A total of 71 articles in environmental science, climate change, energy systems, agriculture and logistics are reviewed to provide insights into the climate neutrality of supply chains.

Findings – We find that, in addition to CO_2, other GHG such as methane, nitrous oxide, ozone and fluorinated gases also significantly contribute to climate change. Our literature review identified several key pillars for achieving net-zero GHG emissions, including end-use efficiency and electrification, clean electricity supply, clean fuel supply, "GHG capture, storage and utilization," enhanced land sinks, reduced non-CO_2 emissions and improved feed and manure management.

Originality/value – We contribute to the literature on climate neutrality of supply chains by emphasizing the significance of non-CO_2 GHG along with CO_2 and highlighting the need for a comprehensive approach to climate neutrality in addressing climate change. This study advances the understanding of climate neutrality of supply chains and contributes to the discourse on effective climate change mitigation strategies. It provides clear future research directions.

Keywords Climate neutrality, Carbon neutrality, Emissions, Climate change, Supply chain, Logistics

Paper type Literature review

1. Introduction

We recognize the urgent need to address pressing global challenges such as biodiversity loss, resource depletion, pollution, social inequality and climate change (Lim, 2022). Sustainability, with its focus on balancing environmental, social, economic and governance dimensions, provides a framework for navigating these challenges and ensuring a better future for generations to come (Lim *et al.*, 2022b; Guntuka *et al.*, 2024). One of the most critical challenges we are facing today is climate change (Boyson *et al.*, 2022). Climate change, driven primarily by human activities, poses profound risks to ecosystems, economies, and human well-being (Gammelgaard, 2023). It is a direct consequence of unsustainable practices, such as excessive greenhouse gas (GHG) emissions, deforestation and reliance on fossil fuels (Chen and Fei, 2022).

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As such, understanding and addressing climate change is integral to the broader sustainability agenda.

CEOs around the globe are increasingly recognizing that climate change and natural disasters present an existential threat to their supply chains if they are not prepared (Boyson *et al.*, 2022). Anthropogenic GHG emissions have led to climate change (Zhang *et al.*, 2022b), increasing the global average surface temperature by 1.2 °C since 1850, resulting in weather-related events that damage production networks around the globe (Chen, 2021). Given the severity and urgency of the climate issue, the United Nations Framework Convention on Climate Change identified that the world's most pressing need is to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Schneider and Mastrandrea, 2005). In the context of supply chain and logistics, stabilizing GHG concentrations in the atmosphere should be done within a timeframe that allows ecosystems to adapt to climate change naturally, prevents disruptions to logistics networks and enables sustainable economic development (Brazzola *et al.*, 2022; Scheibe *et al.*, 2022). This is critical to ensuring the long-term viability of supply chains and logistics operations while mitigating the impacts of climate change (Sovacool *et al.*, 2021).

In addition to CO_2, non-CO_2 gases, such as methane, nitrous oxide, tropospheric ozone and fluorinated gases, are also significant contributors to climate change (Sovacool *et al.*, 2021). From 1970 to 2010, the role of CO_2 in global warming is about three times the role of non-CO_2 gases (Ramaswamy and Solomon, 2001; Forster *et al.*, 2007, Forster *et al.*, 2021; Myhre *et al.*, 2013). Despite being a much smaller contributor to global warming, non-CO_2 gases can be much more potent than CO_2. Indeed, in terms of heat trapping potential, CO_2 and non-CO_2 GHG emissions contribute close to equal shares (52–57% for CO_2 and 43–48% for non-CO_2 GHG, Dreyfus *et al.*, 2022). For example, methane is over 20 times more effective at trapping heat in the atmosphere than CO_2, and nitrous oxide is over 300 times more effective (Malerba *et al.*, 2022). While energy generation and transportation are the largest sources of CO_2 emissions, key industries like agriculture, waste management and industrial processes are significant sources of non-CO_2 GHG (Ou *et al.*, 2021).

In response to the need to address climate change by reducing GHG emissions, the concept of carbon neutrality, i.e. the state where the net release of CO_2 emissions into the atmosphere is zero, has evolved (Mishra *et al.*, 2022). Carbon neutrality means that any CO_2 emissions produced are offset by equivalent reductions in emissions or removals of CO_2 from the atmosphere (Caro *et al.*, 2013). This can be achieved through measures such as reducing emissions in supply chains, implementing renewable energy sources or adopting alternative transportation modes (Wang and Zhao, 2022).

While carbon neutrality has gained recognition on a global level, the potency of non-CO_2 GHG means that achieving carbon neutrality alone may not be enough to address climate change (Brazzola *et al.*, 2022). Hence the concept of climate neutrality has emerged, which involves not only reducing emissions of CO_2 but also addressing emissions of other potent GHG (Krammer *et al.*, 2013). In this context, climate neutrality refers to the state where there is no net release of any GHG into the atmosphere, not just CO_2. In essence, carbon neutrality has now become a subset of climate neutrality. Despite the complexities and uncertainties surrounding the non-CO_2 impacts of certain industries on the environment, regulations have excluded them from international climate agreements, mitigation policies and carbon markets (Waugh *et al.*, 2011). Addressing non-CO_2 GHG is necessary for achieving climate goals, as reducing these emissions can have a significant impact on slowing the pace of global warming.

The literature addressing supply chain management and climate neutrality lacks a review of research on this stream. The connection between climate change and supply chain management highlights the significant impact of climate change-driven risks on food production, natural resources and transportation (Ghadge *et al.*, 2020); however, carbon emissions attract higher attention than other GHG. The scarce availability of climate neutrality research in supply chain calls for a distinct multi-disciplinary systematic literature review on the topic for multiple reasons. First, the concept of climate neutrality within the realm of supply chain and logistics is not widely comprehended, justifying a comprehensive literature review of various fields. Achieving climate neutrality in the supply chain involves grappling with intricate issues across different points, including sourcing, production, distribution and disposal, along with their interconnected dynamics. Second, a multidisciplinary literature review encompasses insights from diverse areas such as economics, engineering, environmental science and sociology (Kano *et al.*, 2020), thereby enabling a more insightful exploration that identifies any overlooked knowledge gaps or potential research queries resulting from narrower perspectives. Finally, due to the complex nature of climate neutrality and supply chain matters (Zhang *et al.*, 2022a), a holistic approach becomes imperative for fully grasping their interrelationships. Our multidisciplinary literature review provides a comprehensive picture of the challenges and opportunities related to achieving climate neutrality in the supply chain.

Past literature reviews on emissions mainly focus on circular economy and emissions in transportation and agriculture industry highlighting CO_2 emissions (Mishra *et al.*, 2022; Windsperger *et al.*, 2019; Krammer *et al.*, 2013). Little to none of the research has focused on the influence of non-CO_2 GHG impacts. As climate neutrality focuses beyond CO_2 impacts, a systematic literature review is needed to identify associated emerging themes for conducting rigorous research at the intersection of climate neutrality, supply chain and logistics. However, as non-CO_2 gases are a relatively underexplored topic in the logistics and supply chain management literature, this study draws on a multidisciplinary literature review to inform the field, incorporating insights and findings from disciplines that have advanced research in this area. This study synthesizes the broader climate neutrality literature related to supply chain management across disciplines and identifies research gaps. Specifically, we aim to address the following research questions.

RQ1. What factors drive climate neutrality in non-CO_2 emissions of the supply chain, and how have these factors changed over time?

RQ2. How do different industries and sectors differ in their strategies for achieving climate neutrality in non-CO_2 emissions of the supply chain, and what factors contribute to these differences?

RQ3. What are the major research gaps and future directions for studying non-CO_2 emissions in achieving climate neutrality in the supply chain, and how can organizations and researchers address these gaps?

By addressing the above research questions, our study makes a significant contribution to the literature on climate neutrality in the supply chain. While carbon neutrality has gained prominence in discussions on mitigating climate change, our research argues that achieving carbon neutrality alone is unlikely to address the full extent of climate change impacts. By conducting a multidisciplinary systematic literature review, we highlight the importance of non-CO_2 GHG as potent contributors to global warming, which should be explicitly considered when designing supply chain operations. Through our analysis, we identify key pillars for achieving net-zero GHG emissions, encompassing various aspects such as end-use efficiency, clean electricity and fuel supply, GHG capture and storage, land sinks, non-CO_2 emissions reduction and improved management practices. In addition, our synthesis of the literature demonstrates that climate neutrality provides a more comprehensive approach to addressing climate change in the supply chain and logistics context. By shedding light on this important distinction and the limited existing literature, our study advances the understanding of climate neutrality in the supply chain and contributes to the broader discourse on effective climate change mitigation strategies.

The rest of the paper is organized as follows. In Section 2, we document the methodology followed to conduct the literature review. Next, in Section 3, we present the themes in climate neutrality and on non-CO_2 gases in Section 4. Section 5 discusses the industries represented in the literature. Managerial and policy implications are elaborated on in Section 6 and future research directions in Section 7. Finally, we conclude the paper in Section 8.

2. Methodology

We employed a multidisciplinary systematic literature review approach to address our research questions. This approach is commonly employed by researchers when a topic is not extensively covered by the primary field, and borrowing knowledge from related fields becomes crucial (Kano *et al.*, 2020). For instance, Solarino and Aguinis (2021) utilized a multidisciplinary literature review to provide insights on designing and conducting interviews with elite informants, drawing from a variety of fields. Similarly, Gligor *et al.* (2019) utilized a comparable approach to study the multidisciplinary nature of concepts related to agility and resilience and argued such an approach was necessary to explore the literature outside the business domain and gain a comprehensive understanding of the constructs. As previously noted, the topic of climate neutrality necessitates a multidisciplinary systematic literature review due to its inherently interdisciplinary nature and because studies on non-CO_2 gases do not commonly address supply chain management.

Given the nature of this systematic literature review, it was essential to cover a wide range of sources. As a result, we used a variety of databases, including EBSCO, ProQuest, Science Direct, Emerald and Google Scholar, as is typical in multidisciplinary literature reviews (Gligor *et al.*, 2019). The research team developed a set of keywords based on an initial literature search and interactions with industry experts.

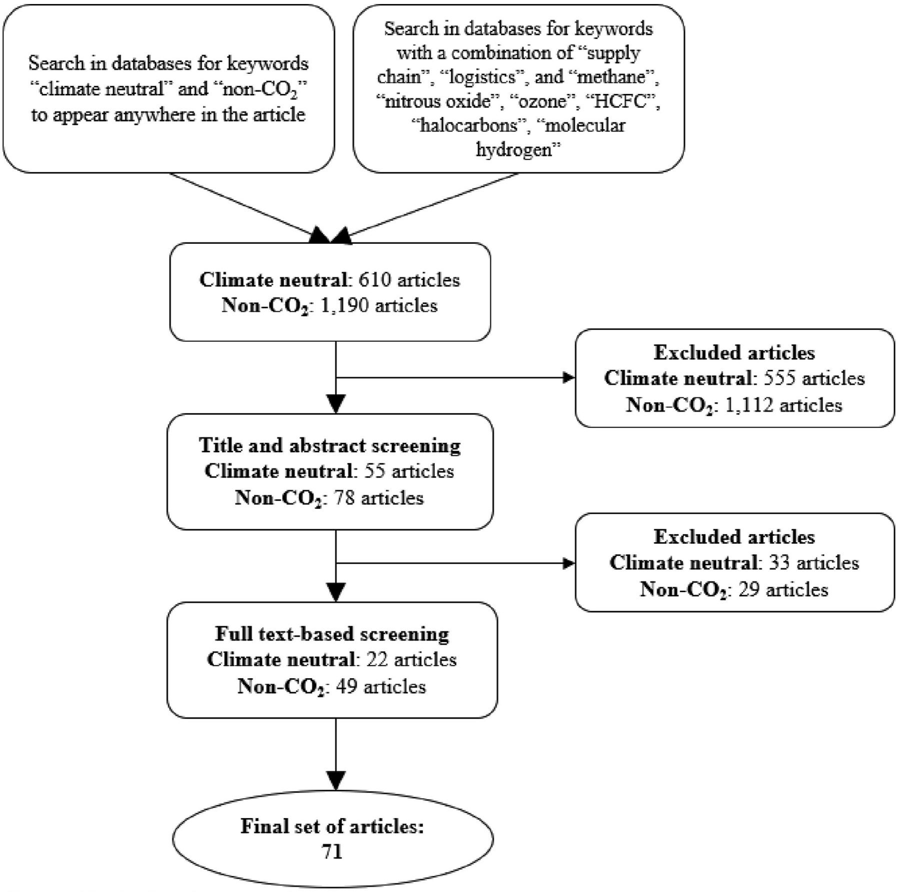
Our focus is on the larger narrative of climate neutrality and not just carbon neutrality. We therefore conducted two searches to explore the topics of climate neutrality and non-CO_2 gases comprehensively. These two searches were necessary due to the limited coverage by existing research of climate neutrality, which often fails to include non-CO_2 gases in its scope. Our search criteria in Table A1 of online appendix encompass language, journal areas, article types, search fields and timeframe. Table A2 shows the inclusion and exclusion criteria for scope, relevance and methodology of the papers returned from the two search strategies we employed.

The first search focused on the concept of climate neutrality using keywords such as "climate neutral" and "non-CO_2" to ensure the inclusion of studies that addressed the broader concept of climate neutrality, encompassing both CO_2 and non-CO_2 gases (See Table A3). This initial search yielded 610 articles from various disciplines, including transportation and logistics, sustainability and agriculture. However, given the interchangeability of the terms "carbon neutrality" and "climate neutrality" in most domains, we carefully reviewed these articles to identify those that explicitly discussed climate neutrality in the context of non-CO_2 gases. This critical evaluation resulted in a refined selection of 22 articles that specifically addressed the broader concept of climate neutrality and its association with non-CO_2 gases.

Recognizing the need to further explore the role of non-CO_2 gases in the context of supply chains, we conducted a second search. This search aimed to investigate the individual non-CO_2 gases and their connection to supply chain management. To accomplish this, we employed a combination of keywords such as "supply chain," "logistics" and specific non-CO_2 gases like "methane," "nitrous oxide," "ozone," "halocarbons," "HCFC" and "molecular hydrogen." This refined search strategy focused on the abstracts and titles of the articles, resulting in 1,190 relevant articles spanning multiple domains, including environmental science, climate change, energy systems, agriculture and logistics. From this extensive set of articles, we meticulously evaluated each one to select those that were most relevant to the study's focus on supply chain and logistics. This rigorous evaluation process allowed us to identify 49 articles that specifically addressed the connection between non-CO_2 gases and supply chain management (Figure 1).

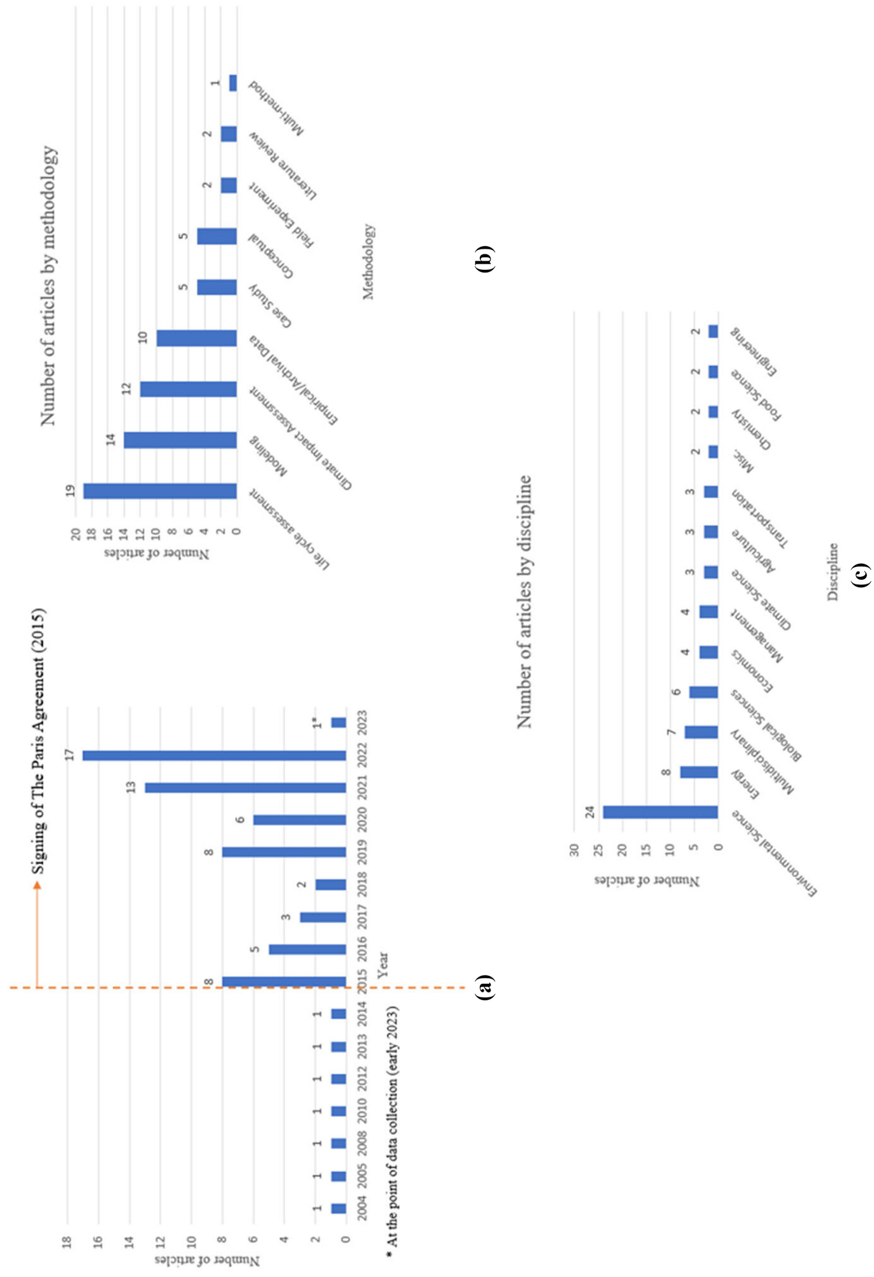
By conducting these two searches and employing a comprehensive approach, our study considered both the broader concept of climate neutrality and the specific role of non-CO_2 gases in the context of supply chains, contributing to a more comprehensive understanding of these important topics.

Descriptive statistics of the articles we identified are provided in Figure 2. The distribution of articles across the years revealed a relatively consistent presence of research, with a noticeable increase in publications in recent years. The highest number of articles were published in 2022 (17), followed closely by 2021 (13). A remarkable surge in the number of articles can be observed following the signing of the Paris Agreement in 2015 (Figure 2a). This significant increase in publication volume highlights the growing scholarly attention



Source(s): Authors' own work

Figure 1.
Selection of studies



Source(s): Authors' own work

Figure 2.
Distribution of articles over the analysis period by methodology and discipline

and research focus on climate neutrality in supply chains in the years that followed this global environmental milestone.

In terms of the methods used, life cycle assessment (LCA) was the most commonly utilized approach, with 19 articles (Figure 2b). These articles employed LCA to evaluate the environmental impact of supply chains. Modeling techniques were also prevalent, with modeling being utilized in 14 articles to simulate and analyze different scenarios related to achieving climate neutrality. Climate impact assessment studies represented a significant portion of the literature, as 12 articles focused on assessing how non-CO_2 gases affect supply chains. Additionally, empirical studies based on archival data were found in 10 articles, which provided valuable real-world insights into the relationship between supply chains and non-CO_2 gases. Furthermore, some articles included case studies, conceptual analyses and field experiments but in smaller numbers compared to other methodologies discussed above. While existing research has produced insightful findings, there is still limited empirical evidence available on climate neutrality within supply chains. This scarcity points to a need for further investigation to establish concrete empirical evidence in this area. Moreover, researchers have an opportunity to introduce innovative approaches and methodologies into the field of supply chain management so as to deepen our understanding of non-CO_2 gases' role within these systems. By adopting these new methodologies identified in our review, researchers can explore more intricate aspects of managing supply chains in relation to non-CO_2 gases.

Regarding disciplinary coverage, most articles originated from the field of environmental science (24 articles), reflecting the significance of understanding the environmental implications of non-CO_2 gases (Figure 2c). Other disciplines contributing to the body of literature included energy, multidisciplinary research, biological sciences, economics and management. These findings highlight the growing interest and multidisciplinary nature of research on climate neutrality and non-CO_2 gases in supply chains.

We identified several themes based on our analysis of articles related to "climate neutral" and "non-CO_2" gases. Within the category of "climate neutral," we identified three main themes: (1) Climate neutrality in relation to non-CO_2 gases, (2) Emissions reduction goals, and (3) Mitigation strategies for all GHG. In the category of "non-CO_2" gases, the majority of articles focused on three gases: methane, nitrous oxide, and ozone. Our detailed findings are presented in Sections 3 and 4.

3. Key themes in the literature on climate neutrality

3.1 Theme 1: climate neutrality in relation to non-CO_2 gases

Climate neutrality refers to the state where GHG emissions are balanced by removing the same amount of GHG from the atmosphere (Brazzola *et al.*, 2022). To become climate neutral, CO_2 emissions along with non-CO_2 are offset by removal methods, renewable energy and energy efficiency measures (Ćetković *et al.*, 2021). The concept of climate neutrality is becoming increasingly important in global industrial and regulative initiatives (Zhang *et al.*, 2022b). While CO_2 emissions are the main contributor to global warming, other GHG such as methane, nitrous oxide, ozone and fluorinated gases also play a significant role (Wang *et al.*, 2022). However, there is no consensus of the exact extent of these effects, the operational aspects they depend on, and metrics used for their evaluation (Pouzolz *et al.*, 2021). While these non-CO_2 gases have shorter atmospheric lifetimes than CO_2, they have much higher global warming potential (GWP), meaning they can trap more heat in the atmosphere per unit of gas emitted (Klophaus and Lauth, 2022). Reducing emissions of non-CO_2 gases can be challenging because they come from a variety of sources, including agriculture, waste management and industrial processes (Ou *et al.*, 2021).

We note that reduction and offset are two strategies used to achieve climate neutrality (Grewe *et al.*, 2021). Reduction involves decreasing GHG emissions through energy efficiency, renewable energy and process improvements (Ćetković *et al.*, 2021). In contrast, offsetting compensates for the remaining emissions that couldn't be reduced (Zhang *et al.*, 2022a). Table 1 presents a comparison of various reduction and offset mechanisms that can be employed by organizations to achieve climate neutrality.

3.2 Theme 2: emissions reduction goals

Emissions goals encompass the objectives set by countries, industries, or other entities to reduce their GHG emissions during a specific timeframe (Wang *et al.*, 2022). These targets are important in addressing climate change as decreasing GHG emissions is imperative to curbing global warming and its associated consequences (Klophaus and Lauth, 2022; Pouzolz *et al.*, 2021). Various emissions goals and initiatives have been explored. For instance, the European Union's "Clean Aviation" framework seeks to establish a carbon-neutral aviation system in Europe by 2050 (Pouzolz *et al.*, 2021; Paleari, 2022).

The Paris Agreement (December 12, 2015) has set ambitious goals to combat climate change, and countries are taking various measures to reduce their GHG footprint (Wang *et al.*, 2022; Grewe *et al.*, 2021). The Western Balkan countries are urged to start implementing the Paris Agreement by creating suitable procedures and policies (Ćetković *et al.*, 2021). Several analytical frameworks and models are being developed to guide the transition to net-zero emissions (Zhang *et al.*, 2022a). The reduction of non-CO_2 emissions such as methane and fluorocarbons is critical to mitigating climate change (Ćetković *et al.*, 2021; Sovacool *et al.*, 2021). The agriculture sector's competitiveness is likely to face greater challenges as efforts to mitigate non-CO_2 emissions become more stringent (Frank *et al.*, 2021; Antimiani *et al.*, 2023).

While the importance of pledging to combat climate change is highlighted in the literature, critics often argue that firms set vague targets (Rogelj *et al.*, 2021). Frequently, when firms pledge to reduce their emissions, they do not specify whether their policy includes all GHG or solely carbon dioxide, whether their pledge applies to their own operations or also to their supply chain parties, or why a particular base year was chosen for setting target levels (Timperley, 2021). For instance, Procter & Gamble signed "The Climate Pledge" and declared

	Reduction	Offset
Driving factor/focus	Addressing sources of emissions under an organization's control (Charabi, 2021)	Addressing sources of emissions beyond an organization's control (Fragkos and Fragkiadakis, 2022)
Boundary conditions	Typically involve internal projects that are implemented within an organization/supply chain (Sovacool *et al.*, 2021)	Generally involves external projects or initiatives that may involve local communities, or the global climate system (Brazzola *et al.*, 2022)
Time horizon	Immediate reductions of emissions	Long-term removal/offset of emissions
Examples	Switching to renewable energy sources (e.g. wind and solar), energy efficiency improvements, electric vehicles, reduced waste going into landfills, improved livestock management, reduced use of synthetic fertilizers (Antimiani *et al.*, 2023; Lovett *et al.*, 2008)	Reforestation, crop rotation, tillage reduction, methane capture, conservation and restoration of coastal ecosystems like mangroves, salt marshes, seagrasses (Ladage *et al.*, 2021; Whittaker *et al.*, 2016)

Source(s): Authors' own work

Table 1. Comparison of reduction and offset mechanisms for climate neutrality

its goal to achieve net-zero GHG emissions across its operations and supply chain by 2040. However, it did not provide details on how it will measure and verify its emissions reductions or what kind of offsets it will use (Fields, 2021).

3.3 Theme 3: mitigation strategies for all GHG

Mitigation of all GHGs refers to the efforts to reduce emissions of all GHG, including CO_2 and non-CO_2 gases such as methane and nitrogen (Mayer and Ding, 2022). Literature on climate neutrality discussed emissions mitigation strategies in different sectors, including aviation and forestry, and emphasized the need to consider both CO_2 and non-CO_2 emissions (Dahlmann *et al.*, 2023; Wang *et al.*, 2022). For example, to meet its ambitious targets, the aviation sector will have to neutralize CO_2 emissions and reduce non-CO_2 climatic effects. However, most of aviation sector's non-CO_2 gases are currently excluded from climate mitigation efforts, and simply neutralizing CO_2 emissions without reducing non-CO_2 could lead to additional warming of up to 0.4 °C, compromising the 1.5 °C target (Brazzola *et al.*, 2022).

While CO_2 emissions can be directly calculated, the estimation of non-CO_2 emissions are more complex and require detailed analysis (Dahlmann *et al.*, 2023). For example, in the forestry sector, assessing climate change mitigation involves techniques such as wood product LCA and forest management analysis (Wang *et al.*, 2022). The approaches evaluate the sector's contribution to emission reduction and biodiversity conservation. Municipal solid waste management is also significant in this regard, as it directly or indirectly influences the emissions of both CO_2 and non-CO_2 GHG, including methane (Pikoń and Gaska, 2010).

Researchers identified several key pillars for achieving net-zero GHG emissions, including end-use efficiency and electrification, clean electricity supply, clean fuels supply, GHG capture, storage and utilization, enhanced land sinks [1], and reduced non-CO_2 emissions (Zhang *et al.*, 2022a; Fragkos and Fragkiadakis, 2022; Fujimori *et al.*, 2022). Researchers around the globe emphasized the importance of policy feasibility, technological uncertainty and required capability building for modeling energy systems and achieving climate neutrality (Capros *et al.*, 2019; Fragkos and Fragkiadakis, 2022).

4. Key themes on non-CO_2 gases: emissions, impacts and mitigation strategies

4.1 Theme 1: methane

Methane is a potent GHG produced by production and transportation of natural gas, livestock and agricultural practices (Sargent *et al.*, 2021; Habib, 2018; Wiedemann *et al.*, 2016). It has a GWP that is 86–125 times that of CO_2 over 20 years and 25–36 times that of CO_2 over 100 years (Sargent *et al.*, 2021). Methane emissions lead to rising temperatures, more frequent and intense heatwaves, changes in precipitation patterns and more severe weather events. Methane emissions also contribute to smog formation which is associated with respiratory diseases (Ingwersen *et al.*, 2016). In addition, methane can dissolve in water and escape into the atmosphere, leading to a decrease in dissolved oxygen levels, negatively impacting aquatic life, thus having a far greater impact on climate and human health than CO_2 (Ma *et al.*, 2022). Negative economic impacts of methane emissions are increasing cost of production for natural gas and negatively impacting tourism and recreation industries (Yuan *et al.*, 2019; Hammitt, 2021).

The literature discussed a myriad of sources of methane emissions across multiple industries. First, natural gas production and its transportation are key sources of methane emissions in the power sector (Ladage *et al.*, 2021; Marks, 2022). These emissions result from leaks in pipelines, valves and other equipment in the oil and gas industry (Charabi, 2021). The emissions from production and transport are substantial, particularly during well completion and processing (Cooper *et al.*, 2021). Furthermore, methane emissions intensity of natural gas supply chains varies greatly across regions and even individual supply chains, highlighting the importance of accurately quantifying emissions at different supply chain levels (Marks, 2022). Ruminant livestock is another significant contributor where methane is emitted in different stages of the livestock supply chain, including manure management and feed production (Habib, 2018; Wiedemann *et al.*, 2016). Researchers utilized an LCA approach to estimate methane emissions associated with various stages of meat production and consumption, including animal rearing, processing and transport (Crow *et al.*, 2019; Plant *et al.*, 2019). Finally, multiple studies examined the sources of emissions at various stages of the supply chain such as raw material extraction, processing and transport (Tan and Lim, 2019; Vitali *et al.*, 2018). Specifically, in the industry of ceramic tile production, the majority of GHG emissions come from the firing process, which requires high temperatures and significant amounts of energy (Ma *et al.*, 2022).

Multiple strategies can mitigate the consequences of methane emissions. One approach involves minimizing methane release during the production, transportation and storage of fossil fuels (Yuan *et al.*, 2019). To achieve this, it is essential to enhance equipment maintenance, limit leaks and cut down on venting and flaring (Balcombe *et al.*, 2022; Ladage *et al.*, 2021). For instance, employing advanced technologies like optical gas imaging cameras, drones and robots can more efficiently detect leaks than traditional methods (Balcombe *et al.*, 2022; Charabi, 2021). Another method focuses on reducing methane emissions resulting from livestock farming due to animals' digestive processes and how manure is stored and handled (Bekkering *et al.*, 2020). Adopting practices like improving animal nutrition quality, optimizing diets and managing manure better can effectively curb methane emissions (Habib, 2018; Whittaker *et al.*, 2016). Collecting methane from manure to use it as an energy source in biogas production further helps reduce these emissions (Röder *et al.*, 2015). Enhancing the deployment of renewable energy sources like solar power, wind energy and hydropower offers another avenue for curbing methane emissions (Tan and Lim, 2019; Ma *et al.*, 2022). Additionally, using renewable energy sources in combination with energy storage technologies can help mitigate the variability of these sources and provide a stable source of power (Allen *et al.*, 2022).

4.2 Theme 2: nitrous oxide

The next non-CO_2 gas we focus on is nitrous oxide (N_2O), a potent GHG that contributes to climate change. Its GWP is 298 times greater than CO_2 over a 100-year time horizon (Wiedemann *et al.*, 2016; Singh *et al.*, 2015). N_2O emissions in supply chain and logistics are observed in various agricultural industries, such as pork, beef and dairy farming (Singh *et al.*, 2015; Lovett *et al.*, 2008; Gregory *et al.*, 2005) owing to feed production, manure management and fertilizer application (Hasler *et al.*, 2015; Ingrao *et al.*, 2018). N_2O is released at different stages throughout the livestock industry's supply chain (Oquendo *et al.*, 2022) when nitrogen fertilizers are used in feed production and manure is decomposed (Hasler *et al.*, 2015; Oquendo *et al.*, 2022). For instance, in Australia's pork industry, N_2O emissions accounted for 9% of total GHG emissions. Manure contributed to 63% of these emissions, while feed production and meat processing accounted for 24 and 10%, respectively (Wiedemann *et al.*, 2016). Similarly, significant contributors to N_2O emissions are beef and dairy supply chains. In Ireland's pastoral-based dairying systems, N_2O ranked the second GHG emitted after methane (Lovett *et al.*, 2008). Lastly, N_2O is emitted from diesel trucks or ships. These releases lead to various environmental impacts like acidification, eutrophication and GWP (Sim and Sim, 2017).

Researchers have documented various methods of reducing N_2O emissions. For example, Cloud Computing Technology (CCT), used to collect, analyze and share data among different participants, helps measuring and minimizing N_2O emissions (Singh *et al.*, 2015). With CCT, the farm can monitor feed production and decrease the usage of nitrogen fertilizer, and hence N_2O emissions. Similarly, optimizing manure management practices using CCT can help mitigate N_2O emitted during manure decomposition and storage. Additionally, modifying management strategies can curb GHG emissions by 12%, depending on production systems and pricing scenarios (Wang and Dalal, 2015; Gregory *et al.*, 2005).

Furthermore, emissions at various stages of the supply chain can be reduced by minimizing nitrogen fertilizer use during feed production or optimizing manure storage (Ingrao *et al.*, 2018). Lastly but importantly, dairy farming systems stand to achieve substantial reductions in GHG emissions by embracing sustainable approaches such as precision fertilization and soil management (Hasler *et al.*, 2015).

4.3 Theme 3: ozone

Ozone emissions encompass the dissemination of substances that can contribute to the genesis of ozone in the atmosphere. Ozone, as a GHG, has the capacity to be advantageous or detrimental to life depending on its location (Paulikienė *et al.*, 2020). Increased levels of ozone within the lower part of the atmosphere (known as the troposphere) have adverse effects on human well-being and environmental conditions. Determining the impact of ozone emissions necessitates employing an LCA, which considers several impact categories such as GWP, ozone depletion potential (ODP), photochemical ozone creation potential (POCP) and human toxicity potential (HTP) (Pierobon *et al.*, 2015). The ODP metric gauges the potential for disintegration in stratospheric ozone layers, leading to amplified ultraviolet radiation exposure that adversely affects humans, living organisms and ecosystems at large scales (Liu *et al.*, 2014). Conversely, POCP evaluates probable photochemical smog development linked with respiratory issues in humans while detrimentally impacting vegetation. Lastly, HTP serves to measure conceivable damage caused by airborne chemicals released into our surroundings (Pierobon *et al.*, 2015).

Ozone emissions arise at various points within the supply chains of producing goods and providing services. Numerous factors, such as combustion, transportation and disposal, influence their production (Castellani *et al.*, 2019; Paulikienė *et al.*, 2020). To illustrate, specific chemicals used in manufacturing processes, the transport of goods and waste disposal practices all have the potential to emit ozone and other harmful gases (Ou *et al.*, 2020; Guntuka *et al.*, 2019). Polluting substances like ozone and other contaminants can be emitted while transporting items between different locations (Liu *et al.*, 2014). Similarly, the energy consumed in housing, such as heating, cooling and lighting, can also contribute to ozone emissions (Giuntoli *et al.*, 2015).

Different supply chains across multiple industries contribute to ozone emissions in a variety of ways. First, biomass supply chains can indirectly contribute to ozone formation. A study examined the effects of several residential heating methods employing forest logging waste and various combustion techniques on the creation of photochemical ozone over their entire life cycles (Giuntoli *et al.*, 2015). Second, global supply chains also have a significant impact on ozone formation. Production for export in China contributes significantly to domestic non-methane volatile organic compound (NMVOCs) emissions, leading to an increase of NMVOCs concentration and peak ozone levels in coastal areas (Ou *et al.*, 2020). These emissions are responsible for an estimated 16,889 premature deaths annually, combining the effects of NMVOCs and ozone. The relocation of global supply chains from developed to developing regions has shifted a large proportion of ozone precursor emissions from developed to developing regions. Therefore, addressing the indirect connections between the supply chain and ozone formation is crucial for achieving climate neutrality.

The entire supply chain of a product should be assessed when evaluating its environmental impact, including its contribution to ozone formation. First, by reducing the emissions of ozone precursors, i.e. NO_x, VOCs and carbon monoxide (CO), from sources such as transportation, manufacturing and agriculture, the formation and concentration of ozone can be mitigated (Temporelli *et al.*, 2022). Second, as burning fossil fuels is a significant source of ozone precursors, using renewable energy sources such as wind, solar and hydroelectric power can help reduce the use of fossil fuels and, as a result, mitigate ozone formation (Pierobon *et al.*, 2015). Third, regular monitoring and reporting of ozone concentrations and precursor emissions can help identify ozone formation sources and hotspots (Marinello *et al.*, 2021). This information can be used to develop targeted mitigation measures.

4.4 Differences between CO_2 and non-CO_2 producing activities

Table 2 provides an overview of the key distinctions between CO_2 and non-CO_2 emissions practices. Although there have been significant advancements in reducing and capturing CO_2 emissions, the progress in mitigating non-CO_2 emissions is still in its infancy (Ou *et al.*, 2021). Several factors contribute to the limited progress made in reducing and capturing non-CO_2 emissions compared to CO_2 emissions. As most CO_2 emissions originate from point sources such as power plants or industrial facilities, capturing and/or reducing efforts can be relatively concentrated and targeted. On the other hand, the emission of non-CO_2 gases, such as methane, can occur from sources other than point sources, also known as area sources, which include wetlands and livestock pastures. As a result of this dispersion, direct capture techniques are harder to implement at area sources.

There are several other challenges involved in preventing the emissions of non-CO_2 gases. For example, it may seem logical to prohibit the release of methane gas in mining areas. However, methane gas is highly flammable and, if trapped, could cause explosions, which pose a safety risk to workers. Therefore, it is not feasible to reduce methane emissions through the implementation of bans or restrictions. We present an overview of the diverse strategies used and challenges encountered by various industry sectors in their efforts to reduce their GHG emissions. Table A4 (see Online Appendix) provides a detailed discussion of themes and examples of buyer-supplier engagement for climate neutrality in various industries.

5. Managerial implications and policy suggestions

The relevance of climate neutrality's managerial and policy implications on supply chains is growing for firms of all sizes. Often, firms such as Royal Dutch Shell set ambitious emissions reduction targets but struggle to achieve them. According to a Bloomberg report published in October 2021, Shell was on track to miss its own targets for reducing its carbon emissions despite announcing a net-zero target for 2050 (Hurst, 2021). With the increasing drive to set targets for climate-neutral supply chains, supply chain partners must be prepared to engage all stakeholders. Top-level executives and government officials must recognize that pursuing certain environmental initiatives, such as zero-emissions or other commercial environmental technologies, may not generate immediate results. These stakeholders (managers and policymakers) play a critical role in shaping strategies for achieving climate neutrality. Below are a few implications that we built upon the findings from the literature.

5.1 Non-CO_2 emissions reduction

The articles on Australian pork production, low-emission wheat production, and alpaca production suggest that the agricultural sector can implement practices that reduce methane emissions, such as using low-emission feed, improving manure management and reducing tillage (Wiedemann *et al.*, 2016; Oquendo *et al.*, 2022). Managers in the agricultural sector could consider adopting these practices to reduce their operations' environmental impact and

Table 2.
Differences between CO_2 and Non-CO_2 practices

Dimension	CO_2	Non-CO_2 Methane	Nitrous oxide	Ozone
Sectors most contributing	Power utilities, manufacturing, transportation (Ćetković *et al.*, 2021)	Natural gas, livestock farming, agriculture, product manufacturing (Oquendo *et al.*, 2022)	Agricultural industry, specifically pork, beef, and dairy farming (Oquendo *et al.*, 2022)	It is not directly emitted, but rather is the result of chemical reactions that occur when volatile organic compounds (VOCs) react with other pollutants emitted by cars, power plants, industrial boilers, refineries and chemical plants (Ou *et al.*, 2020)
Accounts for total GHG	About 80%	About 12%	About 7%	Less than 1%
Heat Potential (Impact)	Baseline reference for non-CO_2	86–125 times higher than CO_2 over 20 years and 25–36 times higher over 100 years (Cooper *et al.*, 2021)	298 times higher than CO_2 over 100 years (Hasler *et al.*, 2015)	Not available
Source	By-product of mainly from combustion of fossil fuels (such as coal, natural gas) and industrial processes (such as extracting/refining metals) and transportation (tailpipe emissions)	Natural gas production and transportation, livestock and agricultural practices, and various stages of supply chains in industries such as product manufacturing Leaks in pipelines and equipment, well completion and processing, animal digestion, manure management (Charabi, 2021)	Feed production, meat processing, manure management and fertilizer application (Schauer, 2015)	Surface-level ozone primarily originates from precursor chemical reactions, such as those occurring in combustion, transportation, waste disposal and chemical manufacturing processes. Specific precursor emissions like nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO) also contribute to ozone formation (Schauer, 2015)

(continued)

Dimension	CO_2	Non-CO_2 Methane	Nitrous oxide	Ozone
Mitigation Practices	Reduction/Capture/Offset Reduction: electrification, removing fossil fuels in operations Capture: Deploying CO_2 capture and utilization or storage (CCUS) units Offset: Carbon credits (Antimiani *et al.*, 2023; Zhang *et al.*, 2022b)	Leak detection (by satellite images, sensor equipment) Better equipment maintenance, leak reduction, and minimizing venting and flaring in the natural gas industry. In agriculture, practices such as improving animal nutrition, optimizing diets and effective manure management. The capture of methane from manure and its use in biogas production. Transitioning to renewable energy sources like solar, wind and hydropower (Littlefield *et al.*, 2017)	Use of cloud computing technology (CCT) to minimize and measure emissions by enabling data collection, analysis, and sharing among stakeholders Management changes such as reducing fertilizer use, improving animal genetics and optimizing feed efficiency can contribute to reducing GHG emissions in the livestock industry (Singh *et al.*, 2015)	Reducing emissions of ozone precursors (NO_x, VOCs and CO) from transportation, industry and agriculture Using renewable energy sources to reduce fossil fuel consumption and, consequently, mitigate ozone formation (Ou *et al.*, 2020)
Challenges in evaluation and mitigation	Mitigation actions for CO_2 and non-CO_2 are intertwined across sectors. For instance, phasing out fossil fuels, such as coal, oil and gas, reduces both direct CO_2 emissions from fuel combustions and upstream methane emissions from fossil fuel extraction (Ou *et al.*, 2021)	Some bans and/or restrictions on vent/leakages can't be put in place (e.g. in coal mines, methane is allowed to vent out to prevent explosions) Measurement and monitoring, leakage detection and repair, agricultural practices, and international cooperation (Charabi, 2021; Marks, 2022; Sargent *et al.*, 2021)	Complexity of managing emissions throughout the supply chain, as well as the need for accurate measurement and monitoring systems Implementing sustainable management practices and adopting new technologies may require significant investments and changes in existing agricultural systems (Uwizeye *et al.*, 2020)	Complexity of global supply chains, the need for cooperation among multiple stakeholders, the cost and availability of renewable energy sources, and the potential resistance to regulatory changes (Schauer, 2015)

(*continued*)

Table 2.

Table 2.

Dimension	CO_2	Non-CO_2 Methane	Nitrous oxide	Ozone
New opportunities within the framework of supply chains	CO_2 capturing technologies at various stages of value chain system To effectively reduce Scope 3 emissions, strategies can include establishing emission reduction targets for suppliers, ensuring the involvement of tier-1 and tier-2 suppliers in reporting, implementing financial incentives or disincentives, promoting international agreements and cooperation, enforcing regulatory compliance, and allocating funding for research and development	Reducing methane emissions from both point sources and area sources Methane mitigation can have benefits such as improving air quality, reducing health risks associated with smog formation, and enhancing sustainable development. Additionally, transitioning to renewable energy sources can provide opportunities for innovation, job creation, and economic growth in the clean energy sector	Promote regenerative agricultural supply chains to reverse the environmental damages	Development and adoption of cleaner technologies, promotion of sustainable supply chains, creation of green jobs in renewable energy sectors, and enhancement of international cooperation to address global ozone issues
Empowering the supply chains for climate neutrality	Firms and their suppliers collaborate to reduce carbon emissions by taking responsibility for their own pollution activities instead of outsourcing them to lower-tier partners Although suppliers are commonly regarded as external to a firm's boundaries, it is essential to acknowledge their role and empower suppliers to be the integral parts of the system when addressing carbon emissions	The implementation of targeted mitigation strategies in supply chains is critical, and for this, understanding emission sources and intensities across supply chain stages (e.g. raw material extraction, processing, and transportation) is important. Thus, internal transparency among supply chain partners is crucial Firms can expand their boundaries through collaboration and engagement across the supply chain, fostering the adoption of best practices, enhancing transparency and bolstering efforts to reduce emissions	By optimizing stages of the supply chain, such as reducing nitrogen fertilizer use in feed production, improving manure management practices and optimizing storage, supply chains can contribute to reducing N_2O emissions Collaboration and information sharing among supply chain stakeholders can also facilitate the adoption of sustainable practices and technologies, leading to more effective mitigation of N_2O emissions	Supply chain managers should ensure that there are not engaged in intentional relocation of precursor emissions (surface-level ozone)

Source(s): Authors' own work

potentially costs. The articles on methane emissions from shale gas development, natural gas production and upstream oil and gas well sites suggest that the natural gas industry can implement technologies and practices to reduce methane emissions. These technologies and practices include using more efficient equipment, detecting and repairing leaks, and capturing and using methane emissions (Littlefield *et al.*, 2017; Charabi, 2021). Managers in the natural gas industry could consider investing in these technologies and practices to reduce their operations' environmental impact and potentially costs.

5.2 Climate-neutral transportation

Climate-neutral transportation refers to the idea of achieving net-zero GHG emissions from transportation by reducing emissions as much as possible and compensating for the remaining emissions through offsetting. This goal can be achieved through a combination of technological innovation, operational efficiency improvements, and the use of sustainable fuels (Ou *et al.*, 2021). One of the managerial implications of climate-neutral transportation is that commercial and passenger transportation firms need to develop and implement comprehensive sustainability strategies that encompass their entire operations (Guntuka, 2022). This involves setting ambitious emission reduction targets, identifying areas where emissions can be reduced and investing in the development and deployment of new technologies that can reduce emissions (Frank *et al.*, 2021). Another implication is the need to collaborate with industry stakeholders, such as airports, manufacturers and fuel suppliers, to develop sustainable ecosystems (Paleari, 2022; Schmelzle and Mukandwal, 2023). Governments can provide support by funding research and development of sustainable aviation technologies, providing incentives for operators to adopt sustainable practices and implementing policies that promote the use of sustainable fuels (Bullerdiek *et al., 2021*; Santos and Delina, 2021).

5.3 Regulatory compliance

Regulatory compliance and policy implications are vast with multiple topics, including climate change mitigation, GHG emissions, carbon pricing, sustainability and energy production. However, in general, the articles highlight the need for policies and regulations that can reduce GHG emissions from different sectors such as agriculture, transportation and energy production. For instance, articles on aviation discuss the need for regulatory compliance to mitigate the GHG footprint of the aviation sector (Sovacool *et al.*, 2021). This can be achieved by implementing carbon pricing policies or investing in renewable aviation fuels. Similarly, articles related to methane emissions from natural gas production and agricultural activities suggest the need for policy interventions to reduce methane emissions (Fernández-Amador *et al.*, 2020). Additionally, articles on LCA suggest that policies should focus on reducing the environmental impact of products throughout their lifecycle, from production to use and disposal. Similarly, articles related to food production and agriculture highlight the need for policies that promote sustainable and low-emission practices, such as improving nitrogen management, reducing food waste and investing in renewable energy (Whittaker *et al.*, 2016). Overall, the articles suggest that regulatory compliance and policy implications are crucial for reducing GHG emissions and achieving a more sustainable future.

5.4 Life cycle assessment

The use of LCA can help identify hotspots in the supply chain that contribute significantly to emissions and prioritize mitigation measures. LCA can be used to assess the environmental impacts of different agricultural production systems and identify ways to reduce emissions while maintaining food security (Gregory *et al.*, 2005; Wang and Dalal, 2015). The impact of policy initiatives, such as carbon pricing and fossil fuel subsidy removal, on emissions can be evaluated through LCA to ensure that they are effective in reducing emissions (Mayer and Ding, 2022). The use of LCA can help evaluate the environmental impacts of different transportation systems, such as green supply chain networks and cold chain logistics. LCA can be used to evaluate the impact of different energy sources on emissions, such as the use of biogas and natural gas (Sovacool *et al.*, 2021). By evaluating the environmental impacts of different processes and technologies, LCA can help guide the development of sustainable and low-emissions systems.

6. Future research directions [2]

6.1 The role of consumers in achieving climate-neutral supply chains

As consumers become more aware of climate change, their desire for environmentally friendly products and services is on the rise (Dögl and Behnam, 2015). This presents a unique opportunity for businesses to set themselves apart by adopting sustainable practices throughout their supply chains and logistics operations, effectively reducing their GHG emissions. The work of Lim (2017) explored three main theoretical viewpoints regarding consumer behavior: responsible consumption, anti-consumption and mindful consumption.

To propel the field of climate neutrality in supply chains and logistics, it is crucial for future research to explore the impact of consumers on stimulating demand for sustainable products and services. More specifically, investigations should center around grasping consumer preferences and behaviors such as mindful consumption, assessing the effectiveness of sustainability initiatives, identifying barriers to adoption and devising strategies to overcome these obstacles (Gupta *et al.*, 2023). By engaging in these research endeavors, scholars can make valuable contributions towards crafting effective strategies for companies and policymakers to achieve their sustainability goals while reducing GHG emissions.

6.2 Global trends affecting climate change

Global trends such as urbanization, e-commerce, automation, artificial intelligence and regenerative supply chains have significant implications for supply chain and logistics operations, particularly about their impact on climate neutrality (Chen *et al.*, 2020; Grover and Ashraf, 2023). As such, future research in this area needs to consider these trends. In recent years, urbanization has significantly influenced the logistics and supply chain industry. With more people choosing to reside in urban areas, there is a growing demand for goods and services within cities resulting in a spike in transportation activities that significantly contribute to GHG emissions. As a result, it becomes imperative for research efforts to focus on devising strategies that can effectively reduce emissions stemming from transportation and other supply chain activities within urban environments. Furthermore, another noteworthy trend shaping the retail sector is the emergence of e-commerce as a dominant force, especially since the advent of the COVID-19 pandemic. The rise of online shopping has resulted in a substantial increase in merchandise that needs to be transported – particularly with last-mile deliveries. Regrettably, this surge not only gives rise to heightened emissions generated by delivery vehicles but also contributes adversely toward packaging waste concerns. Hence, future research should focus on optimizing last-mile delivery operations to reduce emissions and exploring alternative delivery models such as drones and electric vehicles.

6.3 Policymaking to incentivize climate-neutral operations

As governments across the world are moving in the direction of climate neutrality, there is a huge responsibility and opportunity for researchers to assist in this transition. First, future research in climate neutrality in the policymaking space can focus on assessing the impact of existing policies and regulations on supply chain sustainability and climate change. Second, future research can explore opportunities for collaboration between governments, businesses and other stakeholders of supply chains. This can include exploring the potential for public-private partnerships, stakeholder engagement and other collaborative approaches to address sustainability and climate change challenges. Finally, future research can also focus on the governance of supply chain and logistics sustainability and climate change policies. This can include exploring the role of different levels of government (local, regional, national, international) in policy development and implementation and assessing the effectiveness of governance mechanisms in promoting climate neutrality in supply chain and logistics.

Moreover, emerging technologies like blockchain can revolutionize transparency, accountability and trust among participating stakeholders. More specifically, blockchain technology offers secure and decentralized platforms for sharing data collaboratively while ensuring verification mechanisms are dependable – ultimately consolidating consensus-building efforts integral to policymaking procedures and upholding the credibility of climate-related initiatives. Through the utilization of these and similar technologies, policymakers can bring together individuals with diverse backgrounds and perspectives. This inclusive approach allows for the harnessing of collective wisdom and expertise from a variety of actors, including government agencies, industry representatives, nongovernmental organizations and community groups. By fostering collaboration in policymaking processes, stakeholders are encouraged to take ownership in the decision-making process while also promoting knowledge-sharing. As we move forward, further research must delve into how technology-enabled platforms can be applied in policy-making contexts and what impact they have. More specifically, these platforms should facilitate tracking mechanisms to assess how different policies contribute toward reducing carbon emissions as well as offsetting methane, nitrous oxide, and ozone emissions.

6.4 COVID-19 highlighting the urgency of the need for climate neutrality

In the context of achieving climate neutrality in supply chain and logistics, future research can investigate the impact of the COVID-19 pandemic, i.e. how this global crisis has influenced progress toward reaching climate neutrality. Notably, this pandemic has triggered transformations in consumer behavior, disruptions along supply chains and transportation patterns (Carnovale *et al.*, 2023). Consequently, exploring how businesses have reacted to these changes could uncover whether they have adopted more sustainable transportation methods or experienced reduced emissions due to shifts in customer habits. Overall, there is a need for further research to better understand the complex interactions between the COVID-19 pandemic, supply chain and logistics, and climate neutrality and to identify strategies for companies and policymakers to move towards a more sustainable and resilient future. The COVID-19 pandemic has disrupted global supply chains and revealed the flaws in existing systems. It has served as a reminder of the pressing need for resilient and sustainable supply chains capable of effectively handling global crises (Lim, 2021).

7. Conclusion

Our research identifies a critical gap in the existing supply chain management literature, as non-CO_2 emissions are often overlooked despite accounting for a substantial proportion of total GHG emissions. By emphasizing the importance of accounting for non-CO_2 emissions, this study enhances our understanding of the complexities associated with transitioning to climate-neutral supply chains. The study also provides valuable insights into the diverse pathways pursued by various industries to achieve climate neutrality, including the crucial role of non-CO_2 gases in supply chain emissions.

Theoretical implications of our research can be summarized in four key categories (Mukherjee *et al.*, 2022) as follows: (1) *The factors of interest* for climate-neutral supply chains are sources of emissions controlled and uncontrolled by the organization and its wider supply chain. (2) *These factors are interrelated* as they collectively affect how climate neutrality can be achieved in the supply chain. The source of emission can be classified as point (e.g. power plants) or area (e.g. wetlands). (3) *The reasons for factors to be interrelated* are the cause-effect relationships between decisions taken to optimize different supply chain objectives (e.g. lower production cost may mean higher transportation cost; higher service levels translate into higher inventories which need to be stored and maintained). (4) Temporal and contextual factors that act as *boundary conditions* are sectors, the size and complexity of the supply chain, and commitments made by the organizations to achieving decarbonization and climate neutrality. Organizations may have internal or external projects that facilitate collaboration among various stakeholders, such as local communities, government initiatives and the organization itself.

We acknowledge some limitations of this study. First, we do not consider the potential trade-offs between different approaches to achieving climate-neutral supply chains. For example, reducing non-CO_2 emissions may be more difficult or expensive than reducing CO_2 emissions. Second, the literature included in this multidisciplinary literature review may be biased toward certain perspectives or methodologies, as an outcome of the papers included in the review. Despite these limitations, we strongly believe that the findings of this research offer guidance for researchers and practitioners seeking to develop effective strategies for achieving climate-neutral supply chains.

Notes

1. An enhanced land sink is a natural process that removes harmful gases from the atmosphere through the growth of plants and trees.
2. Table A5 provides an overview of the future research directions and illustrative research questions.

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Appendix

The supplementary material for this article can be found online.

Corresponding author
Laharish Guntuka can be contacted at: lguntuka@saunders.rit.edu