**LEVERAGING WAYS TO DECARBONISE THE SUPPLY CHAIN PROCESSES IN THE OIL AND GAS INDUSTRY FOR A SUSTAINABLE GREEN ENVIRONMENT**

by

VENUGOPAL BHAT (B. TECH, PGDBA)

DISSERTATION

Presented to the Swiss School of Business and Management Geneva

In Partial Fulfillment

Of the Requirements

For the Degree

DOCTOR OF BUSINESS ADMINISTRATION

SWISS SCHOOL OF BUSINESS AND MANAGEMENT GENEVA

July 2025

**LEVERAGING WAYS TO DECARBONISE THE SUPPLY CHAIN PROCESSES IN THE OIL AND GAS INDUSTRY FOR A SUSTAINABLE GREEN ENVIRONMENT**

By

**Venugopal Bhat**

Supervised by

**Dr. Anna Provodnikova**

APPROVED BY

Iva Buljubasic

Dissertation chair

RECEIVED/APPROVED BY:

Renee Goldstein Osmic

Admissions Director

## Dedication

This thesis is devoted with deep love and gratitude to my father, Late Sri Subramanya Bhat K.M., whose presence continues to guide me in ways words can scarcely express. He was a man of quiet strength, deep values, and unwavering belief in the power of learning. From my earliest days, he instilled in me the importance of being grounded, of staying humble no matter how far I go, and of always striving to learn not just from books, but from people, nature, and life itself. He believed in me even when I doubted myself, and his faith became the groundwork upon which I constructed my ambitions. Though he is no longer physically present, his spirit has been with me through every step of this journey. His values echo in my thoughts, his lessons shape my actions, and his dreams live on through my efforts. This thesis is not just an academic milestone; it is a tribute to the man who taught me that true achievement lies not in recognition, but in purpose. He often reminded me that success is meaningful only when it uplifts others and contributes to something larger than oneself.

In that spirit, this work also reflects my commitment to a cause that I believe he would have deeply respected the responsibility we hold toward our environment. I have chosen to focus my academic efforts on understanding and contributing to the path of decarbonization and sustainable development. This thesis is a small step in that direction, driven by the belief that we owe it to future generations to act with foresight and responsibility. I hope that in some way, this work honours not only his memory but also the values he lived by integrity, simplicity, and a deep respect for the world around us.

ABSTRACT

In the contemporary era, the terms Decarbonization, Carbon Footprint, Net Zero Emission, and Sustainability have transcended their status as mere buzzwords. They have become pivotal concepts that are integral to the establishment of a green environment for future generations. The importance these issues is emphasized by the changing weather impacts and the rising recognition of the environmental impressions of industrial activities.

Today, supply chain business processes and solutions are increasingly automated and standardized on a global scale to achieve efficiency. However, this drive for efficiency often overlooks a critical question: Are all organizations across various industries actively working to decrease emissions from the supply chains? The unfortunate reality is that many are not. This gap highlights the need for a concerted effort to identify the unique roles that suppliers, logistics partners, and other key players can play in decarbonizing the value chain. Furthermore, there is a pressing need for industry-wide commitment to reducing carbon footprints, as well as careful estimation of the environmental impacts.

The key objective of this research is to provide a complete analyse the recent works and industry practices related to decarbonization initiatives. By doing so, the study aims to outline a hypothetical context for defining a methodology to measure carbon emissions across the supply chain and logistics portfolio. This framework will offer a holistic understanding of the past, present, and future directions of decarbonization and its contributions. The dissertation will delve into how governments can scale up the adoption of technologies involved in the decarbonization of supply chains, particularly within the energy sector. This exploration will be based on a combination of descriptive and analytical research methodologies, utilizing surveys

from reliable databases such as ScienceDirect, Scopus, ResearchGate, and Google Scholar. One of the key aspects of this study is the classification of emissions according to the Greenhouse Gas (GHG) Practise. The practise classifies emissions into three scopes: Scope 1 (Direct Emissions), Scope 2 (Indirect Emissions from energy consumption), and Scope 3 (Other Indirect Emissions) (GHG Protocol, 2023; IEA, 2024; World Economic Forum, 2023). By breaking down the problem statement into these categories, the research aims to provide a focused analysis of resilient and sustainable solution outcomes. These solutions are not only applicable to the oil and gas (energy) industries but also to other organizations striving to reduce their carbon footprints, particularly, those arising by Scope 3 emissions. The research will also explore the potential development of a digital product designed to track carbon emissions across various categories. These categories include Green Purchasing (GP) and Sustainable Sourcing, Green Logistics and Packaging, and collaborative carbon tracking with partners. Such a product could be a valuable tool for administrations looking for to boost their ecological accountability and transparency.

In summary, this dissertation seeks to bridge the gap between the theoretical understanding of decarbonization and its practical application within the supply chain(GHG Protocol, 2023; World Economic Forum, 2023; IEA, 2024). By critically reviewing prevailing industry practices and developing a structured framework for the measurement and management of carbon emissions, this study seeks to support the wider objective of strengthening supply-chain sustainability and resilience (GHG Protocol, 2023; World Economic Forum, 2023; CDP, 2024). The outcomes of this study are intended to guide organizations in adopting scalable and impactful decarbonisation strategies that contribute to long-term environmental sustainability (Sindhwani et al., 2023).

## TABLE OF CONTENTS

## LIST OF FIGURES AND TABLES

CHAPTER I:

INTRODUCTION

## 1.1 Introduction

As the world rapidly advances through the era of digital transformation, the urgency to address environmental sustainability has never been more critical. While technological innovation continues to reshape industries and redefine operational efficiencies, it is equally important to ensure that these advancements align with worldwideexertions to minimize carbon emissions. The dual challenge of embracing digital progress while actively contributing to a greener planet is now central to shaping a sustainable future for generations to come.In all different industrial sectors, supply chains play a pivotal role in both economic performance and environmental impact. These industries typically allocate between 35% to 45% of their total expenditure to supply chain operations, covering the full spectrum from procurement to payment and from order to cash. Despite this significant investment, the environmental footprint of supply chains often remains underaddressed. For companies that rely heavily on natural resources, calculating the total carbon footprint of a product is a complex task. This complexity stems from the diverse and often fragmented network of suppliers, logistics providers, and service partners involved in bringing a product to market.Setting ambitious net-zero targets for a companys core operations is a commendable step. However, achieving meaningful decarbonization across the entire supply chain presents a far greater challenge. Supply chains today are sprawling, global ecosystems. Their interconnected nature makes it difficult to monitor emissions consistently, let alone enforce reduction strategies.

In recent years, the global narrative around climate change has evolved from raising awareness to driving tangible action. Governments, corporations, and individuals alike are recognizing the need to transition toward low-carbon economies. Within this wider transition, the oil and gas sector has attracted heightened scrutiny, reflecting both its substantial contribution to global greenhouse gas emissions and its continuing strategic importance in meeting worldwide energy demand (IEA, 2023; World Economic Forum, 2023). In this context, the supply chain becomes both a challenge and an opportunity: a challenge due to its emissions intensity, and an opportunity because of its potential to drive systemic change.

Supply chains within the oil and gas sector are inherently complex, encompassing the large-scale movement of raw materials, specialised equipment, and supporting services across extensive geographical regions. As a result, these activities generate substantial indirect emissions, commonly classified as Scope 3 emissions, which arise beyond an organisation's direct operational boundaries but are nevertheless attributable to its value-chain activities (GHG Protocol, 2023; IEA, 2023). These emissions, stemming from suppliers, transportation networks, and end-users, are notoriously difficult to quantify and manage. As the global push toward net-zero intensifies(Agarwala, 2025), decarbonizing supply chains has emerged as a strategic imperative. It is no longer sufficient for organizations to focus solely on internal efficiencies. Instead, they must adopt a holistic approach that extends sustainability efforts throught the business processes. This transformation demands a shift in mindset, the adoption of innovative technologies, and the cultivation of collaborative partnerships that align environmental responsibility with business performance(Joppa and Willmott, 2025).

My interest in this area stems from over seventeen years of global experience in designing, developing, and automating business processes to enhance efficiency and productivity.

Throughout my career, I have observed a noteworthy gap in the execution of focused net-zero strategies within the supply chain domainparticularly in alignment with the Paris Agreement on Climate Change. This research is driven by a desire to bridge that gap by proposing a practical model or methodology for tracking and managing carbon emissions across supply chain processes in the energy sector. The goal is to contribute to a more transparent, accountable, and sustainable supply chain ecosystem that supports both environmental and economic objectives(Mani, Delgado and Hazen, 2024). By developing a framework that enables organizations to measure, monitor, and reduce their carbon emissions(Sobrino-Duque et al., 2025), this work aspires toempower businesses to take meaningful action toward sustainability.

In conclusion, the decarbonization of supply chains in the oil and gas industry is a complex but essential endeavor(Al-Ghamdi et al., 2024). Addressing this challenge necessitates a comprehensive assessment of the environmental impacts associated with supply-chain activities, alongside the adoption of targeted and effective strategies to reduce and mitigate those impacts (GHG Protocol, 2023; World Economic Forum, 2023). By leveraging digital technologies, fostering collaboration, and aligning with global climate goals, companies can make decisive progress on dropping their carbon emissions and creating a greener future for all (Mishra and Pandey, 2025).

## 1.2 Research Problem

The question of whether supply chain decarbonization is being practiced on a wide scale remains a critical concern in today's sustainability discourse. While many organizations have made public commitments to reduce their carbon footprints, the actual implementation of decarbonization strategies particularly within supply chains has been inconsistent and often superficial. According to the Global Risk Report by the World Economic Forum (2021), several barriers continue to hinder meaningful progress in this area. Chief among these is the lack of transparency at the supplier level, which makes it difficult to assess and manage emissions effectively. Without clear visibility into supplier practices, companies struggle to understand the true environmental impact of their operations (Swink and Gallo, 2023). This may also obscure the financial impacts of decarbonization. Many decision-makers perceive sustainability initiatives as costly or disruptive to performance, leading to hesitation or resistance in adopting them. As a result, sustainability is often sidelined in favour of short-term operational efficiency or cost savings. This mindset creates a significant gap between corporate sustainability goals and the practical steps needed to achieve them, particularly in complex, global supply chains (Belvedere and Grando, 2017).

Despite growing awareness and the availability of advanced technologies, many companies especially in the energy industry still face challenges in tracking and reducing emissions across their supply chains (Malacina et al., 2025). The absence of standardized methodologies for measuring emissions, coupled with fragmented supplier networks and inconsistent data reporting, makes it difficult to implement effective decarbonization strategies. These challenges are further compounded by the worldwide supply chains set up, where varying guidelines, cultural norms, and levels of technological maturity create additional layers of complexity. (Hosseini Shekarabi, Mavi and Macau, 2025).

Scope 3 emissions encompass all indirect greenhouse gas emissions generated across an organisation's value chain and are widely recognised as being particularly challenging to measure and manage due to their occurrence beyond a firm's direct operational control (Wang et al., 2024). These emissions often characterise the main share of an organizations total carbon footprint, yet they are the least understood and least controlled (Boukherroub et al., 2024). Without a clear framework for measuring and managing Scope 3 emissions, companies risk falling short of their climate commitments. This study tries to find the challenges by exploring practical, scalable solutions for measuring, managing, and reducing carbon emissions within supply chains (Mrad, Frikha and Boujelbene, 2025). The objective is to close the persistent gap between high-level sustainability ambitions and their effective translation into operational practices on the ground (World Economic Forum, 2023; EY, 2024). By establishing a structured approach that organizations can adopt and tailor to their specific needs, this study aims to provide a roadmap for effective supply chain decarbonization (Huang and Luo, 2024). This research is not just about identifying problems it is about enabling action. It aims to empower organizations with the tools, insights, and frameworks needed to transform their supply chains into engines of sustainability. In doing so, it contributes to the broader goal of building a low-carbon economy that is both resilient and responsible.

### 1.3 Purpose of Research

The increasing urgency of climate change mitigation has intensified attention on the environmental footprint of global supply chains, with particular focus on carbon-intensive industries such as oil and gas (Fournier Gabela and Freund, 2023). Although many organisations have articulated ambitious net-zero goals, a key difficulty remains in converting these pledges into effective and sustained actions across their extended value chains (World Economic Forum, 2023; EY, 2024). This includes broader network of vendors, logistics service partners that contribute to a company's overall carbon footprint (Boukherroub et al., 2024). One of the key drivers behind this research is the recognition that decarbonization cannot be achieved in isolation. It expects a collective work from all interested parties in the supply chain (Siems et al., 2023; Villena and Gioia, 2020). Suppliers, transporters, and other partners each play a unique role in shaping the environmental performance of the value chain (Stangl et al., 2024). However, their contributions are often overlooked or underutilized due to a lack of visibility, standardized practices, and integrated systems for tracking emissions. This study seeks to address this challenge by developing a practical and scalable framework that organisations can apply to operationalise decarbonisation initiatives across their supply chains (World Economic Forum, 2023; SBTi, 2023). The primary aim of this study is to develop a comprehensive approach specifically designed for the oil and gas sector, a domain characterised by high operational complexity and a substantial environmental footprint (EY, 2023; Okeke, 2024). The proposed framework begins by systematically identifying the principal emission sources across the supply chain, spanning upstream activities such as natural resource extraction and logistics, through to downstream stages including product distribution, use, and end-of-life impacts (GHG Protocol, 2023). Gaining clarity on where emissions originate across organisational and value-chain activities represents a foundational step for effectively managing and achieving meaningful emissions reductions (GHG Protocol, 2023). Next, the study will evaluate the tools and technologies currently available for tracking carbon emissions. While there are many digital solutions on the market, their integration into existing procurement and logistics systems remains a challenge. This research will explore how emission data can be seamlessly embedded into these systems to enable live tracking and informed decision-making. Another critical aspect of the framework involves engaging suppliers in sustainability initiatives. Many suppliers, especially smaller ones, may lack the resources or knowledge to implement decarbonization strategies on their own. By fostering collaboration and providing clear guidelines, companies can help their partners align with broader environmental goals.

Finally, the research will offer actionable recommendations that organizations can adopt to reduce their carbon footprint. These steps will be designed to be both practical and impactful, ensuring that companies can make measurable progress toward their sustainability targets without compromising operational efficiency. This research is about turning ambition into action. It seeks to empower organizations with the insights; strategies needed to take ownership of their supply chain emissions and lead the way toward a more sustainable future (World Economic Forum, 2023; RMI, 2022).

## 1.4 Significance of the Study

The importance of this assessment lies in its possibility to reform how the oil and gas industry approaches sustainability, particularly in the context of supply chain operations. As the global energy landscape undergoes a thoughtful change, the need for industries to evolve beyond traditional practices has become more urgent than ever. This research addresses that urgency by focusing on one of the most overlooked yet impactful areas of carbon emissions: the indirect emissions embedded within complex supply chains. In today's unified biosphere, supply chains are no longer linear or localized they are dynamic, global networks that span continents and involve countless stakeholders. Each link in this sequence, from raw material to ultimate delivery, contributes to the environmental footprint of the product. However, these contributions are often hidden, fragmented, or difficult to quantify. A key reason for the significance of this research lies in its emphasis on enhancing operational transparency, particularly in relation to the measurement and management of emissions across complex supply-chain activities (World Economic Forum, 2023).

In an era where stakeholders demand greater accountability, companies can no longer afford to operate in silos. Investors are increasingly evaluating businesses not just on financial performance but also on environmental, social, and governance (ESG) metrics (McKinsey, 2023; Harvard Business Review, 2026). Consumers are making purchasing decisions based on a brand's sustainability credentials. Employees are choosing to work for organizations that align with their values (Al Azizah and Haron, 2025). As an effect, a company's capacity to demonstrate a clear, data-driven approach to reducing its environmental impact becomes a competitive advantage (Hagiu and Wright, 2020). This study provides the tools and insights needed to build that clarity into the very frame of supply chain business ops.

Moreover, the study is forward-looking in its approach. It does not merely react to current regulatory pressures or market trends; it anticipates future challenges and opportunities. As carbon pricing mechanisms become more widespread and stringent, companies that have already embedded carbon-conscious practices into their operations will be better positioned to adapt. They will not only avoid penalties but also unlock new revenue streams through carbon credits, green financing, and sustainable partnerships. This research equips organizations with the foresight and framework to navigate that evolving landscape with confidence. Another important dimension of this study is its emphasis on innovation. Traditional supply chain models were built for efficiency and cost-effectiveness, often at the expense of environmental considerations. This research challenges that paradigm by introducing sustainability as a core design principle. It encourages companies to rethink how they source materials, manage logistics, and engage with suppliers. By doing so, it opens the door to innovative technologies, business models, collaborative ecosystems that prioritize both profitability and planetary health.

The study also holds significance in terms of organizational culture. Implementing a decarbonization strategy is not just a technical exercise it requires a shift in mindset across all levels of the organization. From procurement officers to logistics managers, from executive leadership to frontline workers, everyone must understand their role in achieving sustainability goals. This research provides a common language and a shared framework that can unify diverse teams around a single, impactful mission. It fosters a philosophy of accountability, revolution, and development. Furthermore, the study contributes to the broader societal goal of climate resilience. The energy business, due to its scale and influence, has a unique opportunity and responsibility to lead by example. By demonstrating that it is possible to decarbonize even the most complex supply chains, this research sends a powerful message to other sectors. It shows that sustainability is not a constraint but a catalyst for transformation. It proves that environmental stewardship and financial progress can grow together.

In addition, the study addresses a critical knowledge gap. While much has been written about carbon reduction in manufacturing and energy production, there is inadequate inputs on how to tackle carbon emits in the supply chain context, especially in high-impact industries. This research fills that void by offering a practical, actionable roadmap that organizations can adapt to their specific needs. It combines strategic vision with operational detail, making it both aspirational and implementable.

Lastly, the study is significant because it aligns with the values and expectations of the next generation. As younger consumers, employees, and leaders come of age, they bring with them a heightened awareness of environmental issues and a fervent desire for meaningful change. They are not satisfied with superficial commitments or green washing they want to see real progress. This research empowers organizations to meet those expectations with integrity and purpose This exploration transcends mere scholarly pursuit it emerges as a pivotal beacon in the collective journey toward sustainability. By zeroing in on the overlooked challenge of supply chain emissions within the energy sector, it illuminates a path that many have yet to tread (Hasan et al., 2024). It equips organizations not only with actionable insights but also with the strategic clarity needed to evolve responsibly (Alvarez et al., 2018). More than anything, it affirms that transformative progress is not a distant ideal it is achievable when vision aligns with **c**apability and bold decisions are made with conviction.

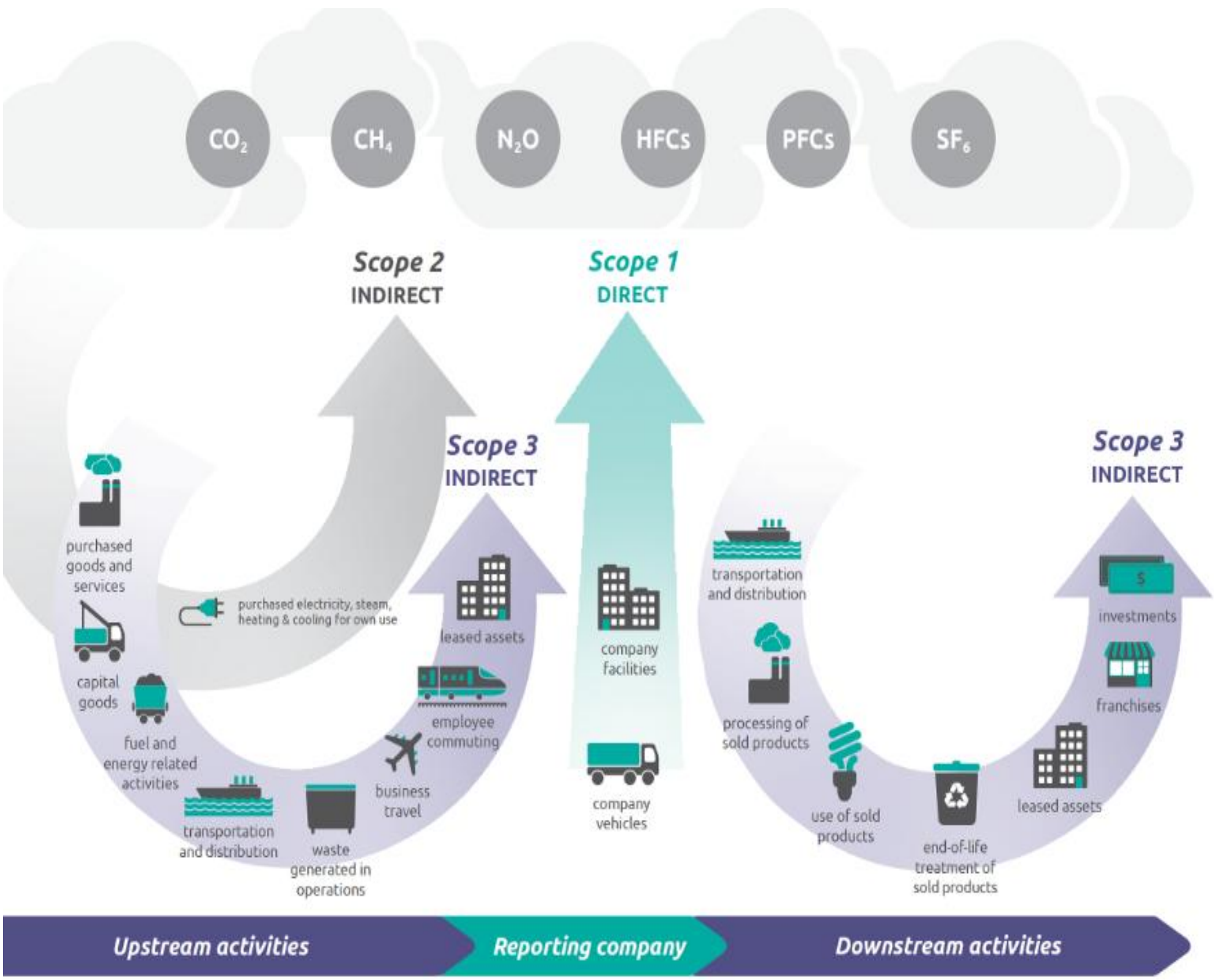


*Figure 1. Emission scope across the value chain (Source: Greenhouse Gas Protocol, 2020)*

### 1.5 Research Purpose and Questions

Tackling climate stands as one of the most urgent and complex issues tackling the globe today (Abbass et al., 2022), and for organizations operating in carbon-intensive sectors like energy, the responsibility is even greater. In November 2017, my organization made a bold commitment to lower the net carbon footprint of its energy yields, with a long-term goal of achieving a 100% reduction by 2050 (Shell, 2017). This pledge aligns with the global objectives outlined in the Paris Agreement and reflects a growing recognition that sustainability must be embedded into every aspect of business operations including the supply chain. This research is driven by the need to develop a structured, scalable, and practical approach to measuring and managing carbon emissions across the supply chain (Zhou, 2020). While many companies have made strides in reducing direct emissions (Woxday, 2023), the indirect emissions those that occur outside the organization's immediate control remain a significant blind spot. These include emissions from suppliers, logistics providers, and other third-party partners (Stangl et al., 2024). Without a clear methodology to track and reduce these emissions, achieving true net zero status remains out of reach.

The intent is to design a comprehensive framework that enables organizations, particularly in the energy sector, to measure, monitor, and mitigate carbon emissions throughout their supply chain and logistics operations. This includes evaluating current tools and technologies, identifying integration challenges, and planning tactics for decarbonization.

To guide this research, the subsequent key enquiries will be explored:

- What are the primary causes of carbon emissions of energy sector, and how can they be accurately identified and categorized?
- What existing technologies and tools are available for carbon footprint measurement, and what

are the limitations in integrating them into current procurement and logistics systems?

- How can organizations effectively track emissions based on financial spend, and what are the practical challenges in applying this model across diverse supply chain activities?
- What gaps exist between current decarbonization solutions and the specific needs of the energy industry, and how can these gaps be addressed through innovation or adaptation?
- What strategies can be employed to engage suppliers and logistics partners in decarbonization efforts, and how can these strategies be scaled across global operations?
- How can renewable energy, digital technologies, and data analytics be leveraged to enhance the operations while improving climate impact?
- By answering these questions, the research looks to contribute a meaningful and actionable framework that provisions the changeover to a low-carbon world.

# CHAPTER II:

# REVIEW OF LITERATURE

## 2.1 Theoretical Framework

The sustained dependence on fossil fuels, with the accelerating impacts of climate change on global systems, has intensified the urgency of transitioning to sustainable energy sources, making this shift a critical priority for both academic research and the energy industry (Johns Hopkins University, 2025; Nature, 2026). Environmental consequences of traditional energy consumption rising temperatures, extreme weather events, ecological degradation have prompted a global call to action. This has emerged as a critical strategy, particularly in industries where energy consumption and emissions are high (Liu and Zhang, 2024).

SC decarbonization is no more a theoretical ideal but a practical necessity (Rathnasiri, 2025). Volatile fuel prices, evolving emission regulations, and growing consumer awareness are reshaping how organizations view their environmental responsibilities (Li, Jiang and Zhou, 2025). It is no longer sufficient to focus solely on the sustainability of end products; companies must now evaluate and transform the complete life span of their operations from raw material sourcing to final delivery (Ivanov, 2022). This shift requires a fundamental rethinking of supply chain practices, with a strong emphasis on transparency, accountability, and innovation (Chelkha, Dachry and Messaoudi, 2025).

The carbon emissions generated by manufacturing industries and their downstream activities are among the leading contributors to global warming. Recognizing this, many nations have begun implementing policies aimed at reducing emissions and promoting a low-carbon economy. However, the efficiency of these policies depends heavily on the ability of industries to measure, manage, and mitigate their carbon footprints (Oh et al., 2025). This is particularly challenging in the energy sector, where supply chains are vast, complex, and often opaque (Goldthau and Hughes, 2020). The objective from this exercise is to review a wide-range review of existing works and trade practices related to supply chain decarbonization. It proposes a conceptual framework for developing methodologies and technologies that can accurately measure carbon emissions across the supply chain and logistics portfolios, particularly within the energy industry. The framework is designed for complete view of the evolution of decarbonization efforts examining where we are now, and where we need to go.

This study anchored in the ethos of eco-conscious progress and holistic environmental analysis. Sustainable development underscores the importance of achieving economic progress while simultaneously safeguarding environmental resources and promoting social equity (Mezentseva et al., 2024). Environmental systems thinking, on the other hand, encourage a holistic view of industrial processes, recognizing the interdependencies between various gears of the SC and their collective impact on the environment.

A major barrier to effective supply chain decarbonization is the lack of harmonized and widely accepted approaches for measuring carbon emissions (Peñasco, Díaz Anadón and Verdolini, 2020). Without a common framework, organizations struggle to benchmark their performance, identify inefficiencies, and implement targeted improvements (Goldthau and Hughes, 2020).The study focuses on the gap by exploring the use of advanced tools such as carbon accounting software, emission factor databases, and life cycle assessment (LCA) models (Liu and Zhang, 2024). These tools enable organizations to quantify emissions with greater accuracy, identify high-impact areas, and prioritize interventions. The literature also reveals that successful decarbonization efforts often hinge on the implementing technologies and collaborative practices (Nature, 2020). Companies that have made meaningful progress in this area tend to integrate renewable energy sources, optimize logistics networks, and invest in energy-efficient infrastructure (Oyenuga et al., 2025). Moreover, they foster strong partnerships with suppliers, stakeholders, ensuring that sustainability goals are shared collectively.

Collaboration emerges as a consistent theme within the literature, with effective decarbonization dependent on the active engagement of key stakeholders, including suppliers, customers, regulators, and internal organizational teams (e.g. Lee, 2015; CDP, 2021). Organizations must engage their partners in dialogue, share data transparently, and align incentives to drive collective action. This collaborative approach not only strengthens the effectiveness of decarbonization strategies but also contributes to greater resilience and trust across the supply chain (Lee, 2015; CDP, 2021). The framework proposed in this study offers a strong conceptual basis for examining and supporting progress in supply chain decarbonization (Stangl *et al.*, 2024). By synthesizing insights from academic research and industry practice, it offers a roadmap for organizations seeking to reduce their environmental impact while maintaining operational excellence.

### 2.2 Theory of Reasoned Action

The behavioural dynamics of decision makers and stakeholders are critical in influencing the outcomes of decarbonization initiatives (Block, Sharma and Benz, 2024). The study explores how intentions influenced by internal beliefs and external expectations drive or hinder the implementation of green habits across the SC (Siems, Seuring and Schilling, 2023). This behavioural lens is particularly relevant when analysing the challenges associated with reducing emissions across Scope 1, Scope 2, and Scope 3 categories (Agarwala, 2025).

### 2.2.1 Social Impact on Emission Reduction Strategies

The decision to implement emission reduction strategies is rarely based on technical feasibility alone. It is often shaped by how individuals and organizations perceive the benefits, risks, and social expectations associated with those strategies. For instance, a supply chain manager may recognize the long-term value of switching to low carbon logistics providers but may hesitate due to perceived cost implications or lack of peer support. These behavioural nuances are central to understanding why some initiatives succeed while others stall.

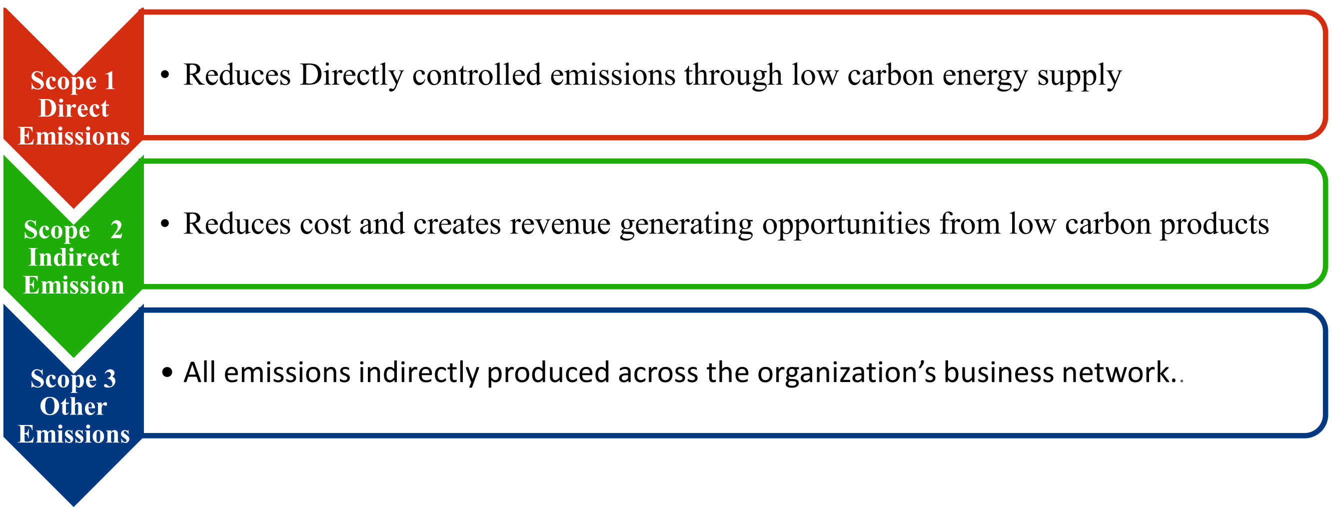


*Table 1. Types of emissions (Source: Bhat, 2025)*

Scope 1 covers greenhouse gases released straight from sources that a company directly owns or operates, such as fuel combustion in company vehicles or on-site equipment(US EPA, 2025).These emissions are typically the result of fuel combustion in company-retained services, vehicles, and equipment (US EPA, 2025;GHG Protocol, n.d.), as well as emissions from industrial methods and short emissions such as refrigerant releases. Because these emissions fall entirely within the operational boundary of the organization, they represent the most immediate and controllable category of emissions, and thus, are often the first target in corporate decarbonization strategies. The social and cultural dimensions of Scope 1 emission reduction are deeply rooted in the internal dynamics of an organization. Management plays essential role in shaping the organizational mindset toward sustainability (Agarwala, 2025). When emission reduction is positioned as a strategic priority rather than a compliance driven obligation it fosters a culture of accountability and innovation. This cultural alignment is critical, as it influences the willingness of operational teams to adopt innovative technologies, redesign processes, and engage in continuous improvement initiatives. Organizations that embed sustainability into their core values and performance metrics are more likely to see widespread engagement and successful implementation of emission reduction measures.

From a strategic standpoint, addressing Scope 1 emissions needs a widespread approach that combines operational efficiency, industrial advancements, and long-term planning (Carbon Direct, 2025). Improving energy efficiency across existing operations represents one of the most accessible and economically viable strategies for emissions reduction (Agarwala, 2025). This can include retrofitting facilities with effective lighting solutions, improving heating and cooling operations, and employing advanced energy management tools that offers periodic insights into energy consumption patterns (U.S. Department of Energy, 2025). Beyond their environmental benefits, these measures contribute to meaningful cost savings when considered over a longer time horizon (Nature, 2020). In addition to improving efficiency, many organizations are investing in on-site renewable energy generation as a way of bringing down their reliance on fossil fuels. Solar photovoltaic systems, wind turbines, and biomass energy solutions are increasingly being deployed at industrial sites to provide clean, low carbon energy (Farghali et al., 2023). These investments not only support to net zero goals (Ali et al., 2024) and enhance energy security and resilience against fluctuating energy prices (Farghali et al., 2023).

For organizations with significant transportation or industrial process emissions, replacing high emission fuels such as diesel or coal with lower carbon alternatives like natural gas, biofuels, or hydrogen can yield substantial environmental benefits. This transition often requires infrastructure upgrades and careful planning but can be a powerful lever for reducing Scope 1 emissions. Technological innovation also plays a vital role in decarbonizing direct emissions. Organizations are increasingly exploring advanced manufacturing techniques, such as additive manufacturing, which can reduce material waste and energy consumption (Narsimhachary and Phani, 2023). Carbon capture and storage (CCS) tools are also gaining traction, particularly in heavy industries where process emissions are difficult to eliminate. These technologies, while still evolving, offer promising pathways for achieving deep decarbonization. Equally important is the role of employee engagement and capacity building. Training programs that raise awareness about the environmental impact of daily operations and equip employees with the skills to identify and implement efficiency improvements are essential (Feeney et al., 2023). When employees understand the rationale behind emission reduction initiatives and see their contributions recognized, they are more likely to take ownership and drive change from within.

Beyond operational measures, organizations must also consider the broader strategic risks and opportunities associated with climate change (ERM Initiative Staff, 2010). This includes preparing for future regulatory changes, such as carbon pricing or emissions trading schemes, and evaluating the economic consequences of environment linked hazards on assets and operations (Aboagye et al., 2023; Campiglio et al., 2019). Engaging with investors, customers, and other stakeholders on sustainability performance is becoming increasingly important, as transparency and accountability are now key expectations in the corporate world. The Carbon Trust, a leading authority on carbon management, emphasizes the importance of integrating climate risk into business strategy. This involves not only compliance with current regulations but also proactive planning for future scenarios (Matsumura, Prakash and Vera-Muñoz, 2024), including shifts in market demand, supply chain disruptions, and reputational risks. Organizations that take a forward-looking approach are better positioned to capitalize on emerging opportunities, such as green financing, sustainable product innovation, and enhanced brand loyalty.

While Scope 1 emissions are inherently internal, their reduction can be significantly amplified through collaboration with external partners, particularly within the supply chain. Establishing programs that encourage suppliers to adopt low carbon technologies and practices can create a multiplier effect. For instance, co-developing energy efficient materials, sharing best practices, and providing technical or financial support to suppliers can extend the impact of an organization's decarbonization efforts beyond its immediate boundaries. In the energy industry, where supply chains are often global and complex, such collaborative approaches are particularly valuable (Tan, Bouchery & Hofstetter, 2024). By promoting innovation alongside collective accountability, organizations can develop a high-impact supply chain ecosystem that supports alignment with Scope 1 emissions reduction objectives (Teske *et al.*, 2022; Kandpal *et al.*, 2024; Zhang, 2024). This not only enhances environmental performance but also strengthens relationships with key stakeholders and contributes to long term business resilience (Heikkinen, 2017; Florez-Jimenez et al., 2024)**.**

Measurement and reporting are foundational to any emission reduction strategy. Robust data collection practices, aligned with internationally recognised frameworks such as the GHG Protocol, are essential (Bacas & Dylla, 2024)**,** enables organizations to track progress, identify hotspots, and make informed decisions. The adoption of digital technologies, including the Internet of Things (IoT), artificial intelligence (AI), and blockchain, can improve the accuracy, transparency, and traceability of emissions data (Johnson *et al.*, 2024; Budennyy *et al.*, 2023; Zhang, 2024). These tools enable real-time monitoring, predictive analytics, and automated reporting, thereby supporting organizations in managing emissions in a more proactive manner (Alotaibi & Nassif, 2024; Achebe, 2025).

In conclusion, Scope 1 emissions represent a critical starting point for organizational decarbonization. By leveraging a combination of leadership commitment, operational excellence, technological innovation, and stakeholder engagement, organizations can achieve meaningful reductions in their direct emissions. The journey toward net zero emissions is complex and multifaceted but addressing Scope 1 emissions with a strategic and integrated approach lays a sturdy foundation for broader sustainability goals. As the energy industry continues to evolve, the ability to manage and reduce direct emissions will be a key differentiator for organizations seeking to lead in a low carbon economy **(**U.S. Department of Energy, 2025). Scope 1 emissions represent direct greenhouse gas emissions from sources that are owned or controlled by an organization, whereas Scope 2 emissions relate to indirect emissions arising from the consumption of purchased electricity, steam, heating, and cooling (McKinsey and Company, 2024). These emissions are produced at the point of energy generation but are reported as part of the consuming organization's carbon footprint (US EPA, 2025; Bacas & Dylla, 2024). Consequently, Scope 2 emissions constitute a significant element of an organization's overall environmental impact and frequently represent the second-largest contributor to its carbon footprint after Scope 1 emissions (Bacas & Dylla, 2024). The significance of Scope 2 emissions lies in their indirect nature while organizations do not have direct control over the generation of the energy they purchase; they do have control over how much energy they consume and the sources from which it is procured. This duality presents both a challenge and an opportunity. On one hand, reducing Scope 2 emissions requires navigating complex energy markets and infrastructure constraints. On the other hand, it opens avenues for strategic decision-making in energy procurement (Ding, Liu, and Chang, 2023), efficiency improvements, and renewable energy investments. To decrease Scope 2 outcomes, improve energy efficiency across operations (Kang and Kang, 2022). This involves conducting detailed energy audits to identify sections of high utilization and executing ways to cut down energy use without compromising productivity (Kalair et al., 2023). For instance, investments in energy-efficient equipment, optimisation of production schedules to minimise peak electricity demand, and the deployment of automated systems for lighting, heating, and cooling can result in significant reductions in electricity consumption (Mischos *et al.*, 2023; Zhang *et al.*, 2019). These measures lower emissions and reduces expenditure, making them attractive from both an environmental and financial perspective (Ekins and Zenghelis, 2021).

However, energy efficiency alone is not sufficient to achieve significant reductions in Scope 2 emissions. A more impactful strategy involves transitioning to low-carbon or renewable energy sources. Organizations can achieve this through several mechanisms. One common approach is the purchase of green electricity from utility providers that generate power from new energy sources such as solar, wind (Pawar et al., 202). In regions where green tariffs are available, companies can opt into programs that guarantee a specific ratio of their energy comes from renewable sources (Morina et al., 2020).

An increasingly adopted approach for addressing Scope 2 emissions is the use of Power Purchase Agreements (PPAs), which are long-term contractual arrangements through which organizations procure electricity directly from specific renewable energy sources, such as wind or solar farms (Renewabl, 2025). These agreements offer greater price certainty, stimulate investment in new renewable energy projects, and enable organizations to claim the associated environmental benefits of clean energy procurement (Kwon & Kim, 2024). In addition to off-site procurement, some organizations invest in on-site renewable energy generation, including rooftop solar installations and geothermal systems for heating and cooling, thereby reducing reliance on grid-supplied electricity (Chen *et al.*, 2024). Such initiatives not only contribute to lowering Scope 2 emissions but also strengthen energy independence and operational resilience (Sustainability Magazine, 2025). Beyond direct renewable energy sourcing, organizations may address remaining Scope 2 emissions through the purchase of Renewable Energy Certificates (RECs) or Guarantees of Origin (GOs), which certify that a defined quantity of electricity has been generated from renewable sources and supplied to the grid (GHG Protocol, 2025; Climate Partner, 2025). Although these instruments do not result in direct physical emission reductions, they support renewable energy markets and allow organizations to claim the environmental attributes of clean energy consumption (Chen *et al.*, 2024). Nevertheless, the credibility and effectiveness of RECs are contingent upon robust certification standards and transparency, and they are most appropriately used as a complement to, rather than a replacement for, direct emission reduction measures.

The behavioural aspect of Scope 2 emission reduction is also noteworthy. Just as with scope one, the success of these initiatives depends on the commitment of leadership and the engagement of employees (Teske et al., 2022; Cameron and Quinn, 2006; Renwick et al., 2024). When energy conservation is embedded into the organizational culture, it becomes a shared responsibility. Simple actions such as turning off unused equipment, optimizing thermostat settings, and encouraging energy-saving habits can collectively make a significant difference (HomeAlliance, 2025). Moreover, involving employees in energy-saving campaigns and recognizing their contributions can foster a sense of ownership and motivation (Yusliza et al., 2025). From a strategic perspective, managing Scope 2 emissions also involves navigating regulatory frameworks and market situations. In many countries, governments are introducing policies that promote renewable energy adoption and penalize high-emission electricity generation. Carbon pricing mechanisms, renewable energy mandates, and emissions reporting requirements are becoming more common (OECD, 2023), and organizations must stay informed and agile to remain compliant and competitive. In some cases, participating in voluntary programs such as the Science Based Targets initiative (SBTi) or the Carbon Disclosure Project (CDP) can enhance transparency and demonstrate leadership in sustainability.

Furthermore, the adoption of digital technologies is reshaping how organizations monitor and manage energy consumption. Advanced metering infrastructure, real-time energy dashboards, and AI-driven analytics facilitate accurate tracking of energy use and associated emissions. By generating actionable insights, these tools enable data-driven decision-making and support continuous performance improvement in energy management practices (Alotaibi & Nassif, 2024; Achebe, 2025). For instance, predictive analytics can detect recurring patterns of energy inefficiency, while machine-learning algorithms can optimise energy consumption by integrating production schedules with weather-related forecasts.

In the context of the energy industry, Scope 2 emissions are particularly relevant due to the sector's high energy intensity and reliance on centralized power generation. Energy companies must not only manage their own emissions but also lead by example in promoting clean energy solutions. This includes investing in renewable energy infrastructure, supporting grid decarbonization, and offering green energy products to customers (World Economic Forum, 2025; U.S. Department of Energy, 2025). By aligning their internal practices with their external offerings, energy companies can build credibility and drive systemic change. In conclusion, Scope 2 emissions represent a vital area of focus for associations requesting to reduce carbon footprint (Carbon Direct, 2025; U.S. EPA, 2025; GHG Protocol, 2025). While these emissions are indirect, they are highly actionable through strategic energy procurement, efficiency improvements, and stakeholder engagement. Combining operational excellence, market intelligence, and technological innovation, organizations can make meaningful progress toward decarbonization. As the global energy transition accelerates, the ability to manage Scope 2 emissions effectively will be a key indicator of organizational leadership and sustainability maturity.

Representing the most complex emissions category, Scope 3 emissions include indirect impacts across the value chain and present unique behavioural challenges for organizational management and accountability (McKinsey, 2023). These emissions are influenced by the actions of suppliers, customers, and other external partners. Encouraging suppliers to adopt sustainable practices requires more than contractual obligations; it demands a shared vision and mutual trust. Organizations that foster collaborative relationships and communicate the continuing values of sustainability are more likely to see meaningful engagement from their partners (Green, 2023). For many companies, most of their greenhouse gas (GHG) emissions and cost reduction of operations (Citigroup, 2022; EPA, 2025; Shrimali, 2021; World Economic Forum, 2025). By measuring Scope 3 emissions, organizations can:

- Understand where the biggest emission challenges lie across their supply chain.
- Spot potential risks tied to resource use and energy consumption.
- Recognize which suppliers are setting the pace on sustainability and which ones are lagging.
- Discover opportunities to boost energy efficiency and cut down costs throughout.

- Work together with suppliers to roll out effective sustainability practices.
- Make their products more energy efficient by design.
- Inspire workers to actively decrease emissions from travel by fostering a culture of sustainability (Aclymate, 2024; Work for Climate, 2025; CSE, 2025).

The energy sector, by its very nature, is deeply intertwined with the global economy and society's dependence on fossil fuels. This interconnection makes Scope 3 emissions particularly critical in this industry. For instance, the combustion of fuels sold by energy companies accounts for a sizeable proportion of global carbon dioxide emissions. These emissions, although not produced directly by the firms themselves, but have direct implication of their core business actions (Normative, 2024). These emissions therefore fall squarely within Scope 3 and represent a major obstacle for organizations aiming to align with global climate goals, including the Paris Agreement (Science Based Targets initiative, 2024; EPA, 2025; MIT Climate Portal, 2022).

In recent years, leading energy companies have begun to acknowledge the importance of addressing these downstream emissions (Ceres, 2022; Yale Sustainability, 2023). This shift in perspective has led to a broader understanding of corporate responsibility, one that extends beyond operational boundaries to encompass the full lifecycle of products and services. Companies are now investing in cleaner alternatives, such as hydrogen, biofuels, and renewable electricity, to reduce the emissions associated with the use of their products (Emergen Research, 2024). These efforts are often accompanied by initiatives to educate and support customers in transitioning to lower-carbon energy solutions.

Upstream emissions, which include those generated by suppliers and contractors, are also gaining attention. The procurement of materials, the construction of infrastructure, and the operation of service providers all contribute to the overall carbon footprint of an energy company (McKinsey, 2023). Recognizing this, some organizations have begun to implement supplier engagement programs aimed at improving environmental performance across the supply chain. These programs may include setting emissions reduction targets, provide technical assistance, and incorporate sustainability criteria into procurement decisions.

The measurement and reporting of Scope 3 emissions within the energy sector require a robust and well-structured methodological framework due to the complexity of value-chain activities involved. Life cycle assessment (LCA) is among the most widely applied approaches for this purpose, as it enables systematic evaluation of emissions across multiple stages of production and consumption (Tamoor & Xing, 2025). LCA allows organizations to quantify the environmental impacts of products and services over their entire life cycle, from raw material extraction through to end-of-life disposal (NREL, 2025; U.S. DOE, 2022; EPA, 2025). By examining each phase of the value chain, LCA offers a comprehensive perspective on emissions sources and supports the identification of targeted reduction opportunities (Arbor, 2025; Chlela & Selosse, 2025). Although its analytical strengths, the reliability of LCA outcomes is highly dependent on the availability, granularity, and quality of underlying data, which remains a persistent challenge across many segments of the energy industry (Lee, 2025). To address data limitations, organizations frequently rely on emission factors derived from industry averages or economic input–output models. While these approaches provide useful approximations, they may not adequately reflect the specific operational characteristics of individual facilities or supply chains. Consequently, there is increasing emphasis on improving data accuracy, traceability, and transparency in Scope 3 emissions accounting. In this context, digital technologies such as blockchain and the Internet of Things (IoT) are being explored as enabling tools to enhance data integrity, traceability, and accountability across complex value chains

(MIT News, 2024; U.S. DOE, 2024; GAO, 2022).

Despite the challenges, there are numerous examples of companies making meaningful progress in managing Scope 3 emissions. These efforts often involve cross-sector collaboration, innovation, and a willingness to rethink traditional business models. For instance, some energy companies are partnering with technology firms to develop digital platforms that track emissions across the supply chain in real time. Others are investing in circular economy initiatives that reduce waste and expand the life of products and resources (Ellen MacArthur Foundation, 2021). Education and capacity building are also essential components of a successful Scope 3 strategy (EPA, 2025; Yale Sustainability, 2023). Employees, suppliers, and customers must be equipped using the intelligence and tools needed to construct learnt outcomes, adopt sustainable practices (United Nations and The Partnering Initiative, 2020). This requires ongoing communication, training, and the creation of incentives that align individual behaviour with organizational goals.

As the urgency of climate change continues to intensify, organizations worldwide are increasingly expected to undertake comprehensive actions to reduce greenhouse gas (GHG) emissions (United Nations, 2025). Although substantial progress has been achieved in addressing Scope 1 and Scope 2 emissions—those arising directly from organizational operations or indirectly from purchased energy—Scope 3 emissions remain the most complex and least understood element of corporate carbon accounting frameworks (Teske *et al.*, 2022). These emissions, which occur across the entire value chain, are often the most substantial in volume and the most difficult to measure and manage (World Economic Forum, 2023). Yet, they are also the most critical to address in the pursuit of net-zero goals (EPA, 2025; Shrimali, 2021; World Economic Forum, 2025).

Scope 3 emissions comprise all indirect greenhouse gas emissions that result from activities not owned or directly controlled by the reporting organization but that nevertheless occur because of its operations (World Economic Forum, 2023). These emissions arise across a wide range of value-chain activities, including the production of purchased goods and services, transportation and distribution processes, waste management, business travel, worker shuttling, and the use and end-of-life treatment of sold products (GHG Protocol, 2025; CDP, 2024; IEA, 2023). As such, Scope 3 emissions capture the full life-cycle impacts of a company's activities, extending well beyond its immediate operational boundaries. Within the energy sector, where supply chains are typically extensive, globally dispersed, and resource-intensive, Scope 3 emissions are particularly significant (GHG Protocol, 2025; CDP, 2024; IEA, 2023). Addressing these emissions therefore extends beyond regulatory compliance or corporate social responsibility and represents a strategic imperative for long-term sustainability and competitive advantage. The inherent complexity of Scope 3 emissions stems from their indirect nature, as their measurement and management depend heavily on data and actions outside an organization's direct control (World Economic Forum, 2023). Unlike Scope 1 and Scope 2 emissions, which can often be quantified using internal operational data and utility records, Scope 3 emissions require extensive collaboration, data sharing, and coordination with external stakeholders across the value chain. This includes suppliers, logistics providers, customers, and even end-users. For instance, a firm that manufactures electric automobiles must account not only for the emissions generated during production but also for those associated with the mining of raw materials (GHG Protocol, 2025; IEA, 2023; CDP, 2024), the transportation of components, and the eventual disposal or recycling of the vehicle. This complexity makes Scope 3 emissions both a challenge and an opportunity. On one hand, the data required to accurately measure these emissions is often fragmented, inconsistent, or unavailable. On the other hand, addressing Scope 3 emissions can unlock significant environmental and economic value, particularly when organizations collaborate with partners across the value chain to drive systemic change (EPA, 2025; VCMI, 2025; World Economic Forum, 2025).

One of the obstacles to effective Scope 3 emissions management is the difficulty in measurement (World Economic Forum, 2023). The indirect nature of these emissions means that organizations must rely on data from third parties, which may not be standardized or readily accessible. Many suppliers, particularly small enterprises, may lack the capacity or expertise to track and report their emissions accurately. Even when data is available, it may be based on assumptions or methodologies that vary widely across industries and regions (Cohen, 2024). Defining the boundaries of Scope 3 emissions is another complex task. Organizations must determine which activities and entities to include in their emissions inventory, a process that involves nuanced decisions about ownership, control, and influence (World Economic Forum, 2023). This can lead to significant variation in reported emissions across companies, even within the same industry. An additional challenge relates to the risk of double counting, since emissions classified as Scope 3 for one company may be recorded as Scope 1 or Scope 2 emissions by another entity within the value chain (Wang *et al.*, 2024), there is a risk of counting the same emissions multiple times across the value chain (Holzapfel et al., 2023). While this does not affect the total emissions globally, it complicates efforts to allocate responsibility and track progress. Despite these challenges, a range of methodologies and analytical tools has been developed to support organizations in the measurement and management of Scope 3 emissions (Tamoor & Xing, 2025; World Economic Forum, 2024). Among the most widely adopted frameworks is the Greenhouse Gas Protocol's Corporate Value Chain (Scope 3) Standard, which offers structured guidance for identifying, quantifying, and reporting emissions across the value chain (WRI & WBCSD, 2011). The standard encourages organizations to assess all fifteen Scope 3 categories and to prioritise those that are most material to their operations and stakeholder expectations (Hauschild *et al.*, 2018). Life cycle assessment (LCA) represents another commonly used approach for evaluating the environmental impacts of products and services across their entire life cycle (Hauschild & Huijbregts, 2018). Through LCA, organizations can identify emissions hotspots, evaluate alternative materials and processes, and support informed decision-making related to product design and sourcing strategies. However, comprehensive LCA studies can be resource-intensive, and their reliability is strongly influenced by the availability and quality of underlying data (Curran, 2014; Finkbeiner *et al.*, 2014). Economic input-output models offer a more accessible approach by linking financial expenditure data with sector-specific emission factors (Nakamura, 2023). These models can provide high-level estimates of emissions associated with purchased goods and services, but they may lack the granularity needed for detailed analysis. Hybrid methods that combine process-based and spend-based approaches are increasingly being used to balance accuracy and practicality. Digital technologies are also playing a growing role in emissions measurement. Advanced analytics, machine learning, and block chain are being used to enhance data collection, verification, and reporting (Harvard Extension School, 2026; Forbes, 2025). These technologies can improve transparency, reduce administrative burdens, and enable real-time monitoring of emissions across complex supply chains (Budennyy et al., 2023).

The strategic significance of Scope 3 emissions extends well beyond environmental considerations alone (World Economic Forum, 2023). Investors are increasingly integrating climate-related risks into their investment decisions, and organizations that fail to address their complete carbon footprint may encounter higher financing costs or constrained access to capital (Harvard Law School, 2019; *Forbes*, 2025). At the regulatory level, governing bodies are introducing more stringent disclosure requirements, with initiatives such as the Task Force on Climate-related Financial Disclosures (TCFD) and the Corporate Sustainability Reporting Directive (CSRD) driving greater consistency and transparency in emissions reporting practices (Ding, Liu & Chang, 2023). In parallel, heightened public awareness of climate change has led consumers to demand increased transparency and accountability from the companies they support (World Economic Forum, 2024). Within this context, proactive management of Scope 3 emissions can strengthen corporate reputation, foster customer trust, and generate competitive advantage (World Economic Forum, 2025). Moreover, such efforts align with the broader transition toward stakeholder capitalism, in which organizations are expected to create value not only for shareholders but also for society and the natural environment (Mejia & Kajikawa, 2024). In the energy sector, Scope 3 emissions are notably significant as the nature of the industry's operations. For oil and gas companies, for example, most emissions occur not during extraction or refining, but during the combustion of fuels by end-users. This means that even if a company reduces its operational emissions, its overall impact on the climate remains high unless it addresses the emissions associated with its products. This has led many energy companies to expand their focus beyond operational efficiency to include the total life cycle of their outcomes. It covers investing in renewable energy, developing low-carbon fuels, and supporting customers in reducing their own emissions. Industries are also exploring carbon capture and storing equipment's, as well as nature-based solutions like reforestation, to offset emissions that cannot be eliminated (Osman et al., 2021; Garre, 2024).

In addition, energy companies are increasingly engaging with their supply chains to reduce upstream emissions. This includes working with equipment manufacturers, logistics providers, and service contractors to increase efficiency, switch to renewable energy, and adopt sustainable practices (Siems, Seuring and Schilling, 2023).

Several companies across industries have emerged as leaders in Scope 3 emissions management. Unilever, for instance, has embedded sustainability into its core business strategy and collaborates closely with suppliers to promote sustainable farming practices, reduce deforestation, and improve energy efficiency. Through initiatives such as Project Gigaton, Walmart aims to reduce one billion metric tons of emissions from its global value chain by 2030 by engaging suppliers and fostering innovation (Walmart Inc., 2023). Likewise, Apple has announced its ambition to become carbon neutral across its entire business, including supply-chain activities and product life cycles, by 2030 (Wang *et al.*, 2025). These examples underline the reputation of leadership, transparency, and collaboration in managing Scope 3 emissions. They also reveal that while the path to decarbonization is complex, it is navigable with the right mix of strategy, technology, and stakeholder engagement.

The policy environment governing Scope 3 emissions is undergoing rapid transformation, driven by increasing demands from governments, investors, and civil society for more comprehensive and standardised emissions disclosure. As a result, organizations are facing growing pressure to report their full carbon footprint with greater transparency and consistency. Within the European Union, the Corporate Sustainability Reporting Directive (CSRD) requires large enterprises to disclose environmental, social, and governance impacts, explicitly including Scope 3 emissions as part of their reporting obligations (European Commission, 2024). In the United States, the Securities and Exchange Commission has proposed climate-related disclosure rules that would mandate publicly listed companies to report material climate risks and greenhouse gas emissions, including Scope 3 emissions where these are deemed material or form part of an organization's emissions reduction targets (Bloomberg, 2025). At the international level, initiatives such as the Task Force on Climate-related Financial Disclosures (TCFD) and the Science Based Targets initiative are establishing benchmarks for best practice in emissions reporting and target-setting (Science Based Targets initiative, 2024; TCFD, 2024). Collectively, these frameworks encourage organizations to align their corporate strategies with the objectives of the Paris Agreement and to clearly demonstrate how climate-related risks and opportunities are being identified, managed, and disclosed (Bjørn *et al.*, 2022). To put it briefly, Scope 3 emissions represent both the greatest challenge and the opportunity in the journey toward corporate decarbonization. Their complexity demands a holistic and integrated approach that encompasses measurement, engagement, innovation, and leadership. For the energy sector, addressing Scope 3 emissions is not only a matter of environmental stewardship but also a strategic constraint for longstanding viability in a swiftly developing global circumstances. As the world moves toward a low-carbon future, companies that embrace the full scope of their emissions and take decisive action will be best positioned to thrive and lead (Singh et al., 2022).

### 2.2.2 Organizational Intentions and Cultural Alignment

The success of decarbonization initiatives often hinges on the alignment between organizational intentions and cultural values. When sustainability is integrated into the core mission of a company, it becomes a steering theory for decision making at all levels. This alignment encourages employees to view environmental responsibility not as an additional task but as an integral part of their role. In organizations where sustainability is championed by leadership and reinforced through policies, training, and recognition, employees are more likely to take initiative. For example, procurement teams may proactively seek out green suppliers, and logistics managers may explore alternative transportation methods. These actions are not mandated they are provoked by a shared conviction in reducing environmental impact. Likewise, in industries where sustainability is treated as a compliance requirement rather than a strategic priority, efforts tend to be fragmented and short lived. Employees may lack clarity on their role in achieving environmental goals, and initiatives may struggle to gain traction. This disconnects between stated intentions and actual behaviour underscores the importance of cultural alignment in driving sustainable change.

### 2.2.3 Stakeholder Engagement and Social Expectations

External stakeholders such as investors, regulators, customers, and communities play a substantial part in influencing executive behaviour (Wells, Lehigh, and Vidmar, 2021). Their expectations can create powerful incentives for companies to adopt sustainable practices. For instance, investors increasingly assess environmental performance as part of their decision-making process. Firms that show a clear liability to decreasing emissions may gain access to green financing or attract long term investment. Customers, too, are becoming more discerning. They are not only interested in the quality and price of products but also in how those products are made and delivered. Companies that can provide transparency into their supply chain practices and demonstrate progress toward sustainability goals are more likely to earn customer loyalty and brand trust. Regulatory bodies are also tightening requirements around emissions reporting and reduction. Organizations that anticipate these changes and take proactive steps to comply are better positioned to prevent penalties and continue their authority to manage. In this context, the ability to gauge, manage emissions across the SC  becomes a strategic asset.

### 2.2.4 Technology Adoption and Behavioural Barriers

While technology acts a vital role in supporting decarbonization, its adoption is often influenced by behavioural factors. Tools such as carbon accounting software, emission tracking platforms, and data analytics systems offer valuable insights but only if they are used consistently and effectively. Confrontation to technology acceptance can vary of sources like: lack of awareness, fear of change, perceived complexity, or scepticism about the benefits. Overcoming these barriers requires targeted communication, training, and support. When employees understand how a tool aligns with their goals and simplifies their work, they are more likely to embrace it. Moreover, involving end-users in the selection and implementation of technology can increase buy-in. When people feel that their input is valued and that the solution addresses their specific needs, they are more likely to engage with it. This participatory approach not only improves adoption rates but also enhances the overall effectiveness of the technology (Cockerham, 2024).

### 2.2.5 Collaborative Models for Scope 3 Emissions

Enabling this requires change from transactional to collaborative relationships with suppliers and partners. Conventional models often prioritize cost and productivity, with limited visibility into environmental performance. To drive meaningful change, organizations must build partnerships based on shared values and mutual accountability (Bouchery et al., 2024).

This involves setting clear expectations, providing support and resources, and recognizing progress. For example, companies can offer training programs to help suppliers understand carbon accounting or co-invest in technologies that reduce emissions. They can also create platforms for knowledge sharing and innovation, where partners collaborate on sustainable solutions. Incentives can also play a role. Recognizing and rewarding suppliers who demonstrate leadership in sustainability can motivate others to follow suit. Similarly, integrating environmental criteria into supplier evaluations and procurement decisions sends a strong signal that sustainability is a priority.

### 2.2.6 Interactive Metrics and Performance Tracking

To ensure that decarbonization efforts are effective, organizations must track not only environmental outcomes but also behavioural indicators. These include participation rates in sustainability programs, adoption of green practices, and employee engagement levels. By monitoring these metrics, companies can identify areas of resistance, tailor interventions, and celebrate successes. Feedback loops are essential. Regular reporting, open communication, and opportunities for reflection help reinforce positive behaviours and sustain momentum. When employees and partners see that their efforts are making a difference, they are more likely to stay committed. The behavioural dimension of supply chain decarbonization is as critical as the technical and financial aspects. Understanding how intentions are formed, how norms influence actions, and how culture shapes decisions provide valuable insights into the success or failure of sustainability initiatives. This research integrates these behavioural insights into a broader framework for reducing emissions across the supply chain, with a particular focus on the energy sector (Niamir et al., 2020). By addressing the human side of sustainability, organizations can move beyond compliance and toward genuine transformation. They can create environments where sustainable choices are the default, where innovation is encouraged, and where every stakeholder feels empowered to contribute to a low-carbon future.

## 2.3 Human Society Theory

A substantial body of research has examined the carbon footprint of supply chains, with findings widely documented in academic studies, policy reports, popular media, and business publications (Lash & Wellington, 2007; Carbon Trust, 2006; Parry et al., 2007; Plambeck, 2012). In addition, non-governmental organizations and regulatory authorities have demonstrated increasing commitment to addressing supply chain related emissions (Benjaafar & Li, 2012). However, much of the existing literature has placed limited emphasis on strategies for reducing carbon emissions, instead focusing primarily on recycling practices, product reuse, and closed loop supply chain concepts (Guide & Van Wassenhove, 2006a, 2006b), as well as product life cycle management approaches (Matos & Hall, 2007; Guide & Van Wassenhove, 2009).

Greenhouse gases (GHGs) consist of carbon dioxide and other pollutant gases that contribute to atmospheric warming (Yoro & Daramola, 2020). The Kyoto Protocol identifies six major greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$) (UNFCCC, n.d.). Each gas is assigned a global warming potential and aggregated to calculate total greenhouse gas emissions expressed in carbon dioxide equivalents ($CO_2e$) (IPCC, 2024). Among these gases, carbon dioxide alone accounts for approximately 70% of total greenhouse gas emissions (Bell & Callan, 2011). These aggregated emissions are commonly referred to as the carbon footprint, a metric used to assess the overall impact of carbon dioxide and other greenhouse gases on the atmosphere (Pahuja, 2023). The relationship between economic growth and environmental quality has been widely analysed using the Environmental Kuznets Curve (EKC), which describes an inverted U-shaped relationship between economic development and environmental degradation (Uchiyama, 2016; Villanthenkodath et al., 2024). This framework illustrates the complex and nonlinear interaction between economic expansion and environmental impacts, highlighting the importance of targeted emission reduction strategies within supply chains.

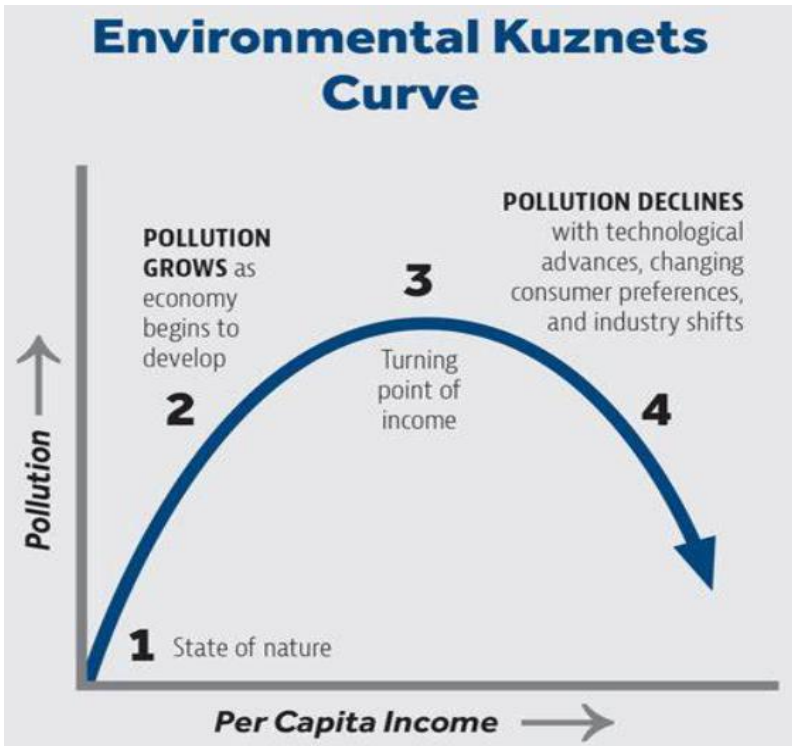


*Figure 2. Environmental Kuznets Curve representation (Source: Hossain, 2019, p. 45)*

Climate change has emerged as a critical global concern, prompting extensive scientific evaluation. One such evaluation by the Intergovernmental Panel on Climate Change highlighted that the increasing concentration of greenhouse gases has a substantial and measurable impact on atmospheric conditions (IPCC, 2007). In response, governments across the world introduced policy instruments such as carbon taxation, emissions trading mechanisms, and stricter emission standards as part of national sustainability agendas (Gonzalez *et al.*, 2012). Corporate accountability also gained momentum, as evidenced by disclosures in the Carbon Disclosure

Project report, where multinational firms including Coca-Cola, Volkswagen, and Pepsi publicly pledged to set and monitor carbon reduction targets (Carbon Disclosure Project, 2011). At the operational level, organizations began transitioning towards cleaner transportation fleets, environmentally friendly technologies, and low-impact production processes to minimize their carbon footprint (Huang and Li, 2017; Depoers, Jeanjean and Jérôme, 2016). Consumer behaviour played a pivotal role in accelerating this transition, as growing environmental awareness influenced purchasing decisions and pressured firms to adopt greener practices. Heightened societal concern over climate risks and global warming further encouraged businesses to integrate sustainability into their strategic planning (Gold *et al.*, 2010). Empirical studies have demonstrated that such sustainability-oriented strategies contribute to lower greenhouse gas emissions and mitigate adverse environmental effects (Gandhi *et al.*, 2015; Luthra *et al.*, 2014). Consequently, scholarly attention has increasingly focused on sustainable supply chain management practices, including green procurement, reverse logistics, and environmentally responsible manufacturing processes (Bai and Sarkis, 2010; Eltayeb *et al.*, 2011).

In lean manufacturing language, carbon emission is the new MUDA (Japanese phrase for waste in lean practice) (Ghosh, Jha and Sharma, 2020). Hence reducing CFP, which is waste in the supply chain life cycle that comprises of purchasing, production, warehousing, transportation, and distribution is aligned with lean supply chain management (Ghosh, Jha and Sharma, 2020). ReducingCO2 has become a particularly important part of the supply chain strategies for most of the organizations. Therefore, it is in line with the supply chain management practices (Panagiotopoulou, Stavropoulos and Chryssolouris, 2022).

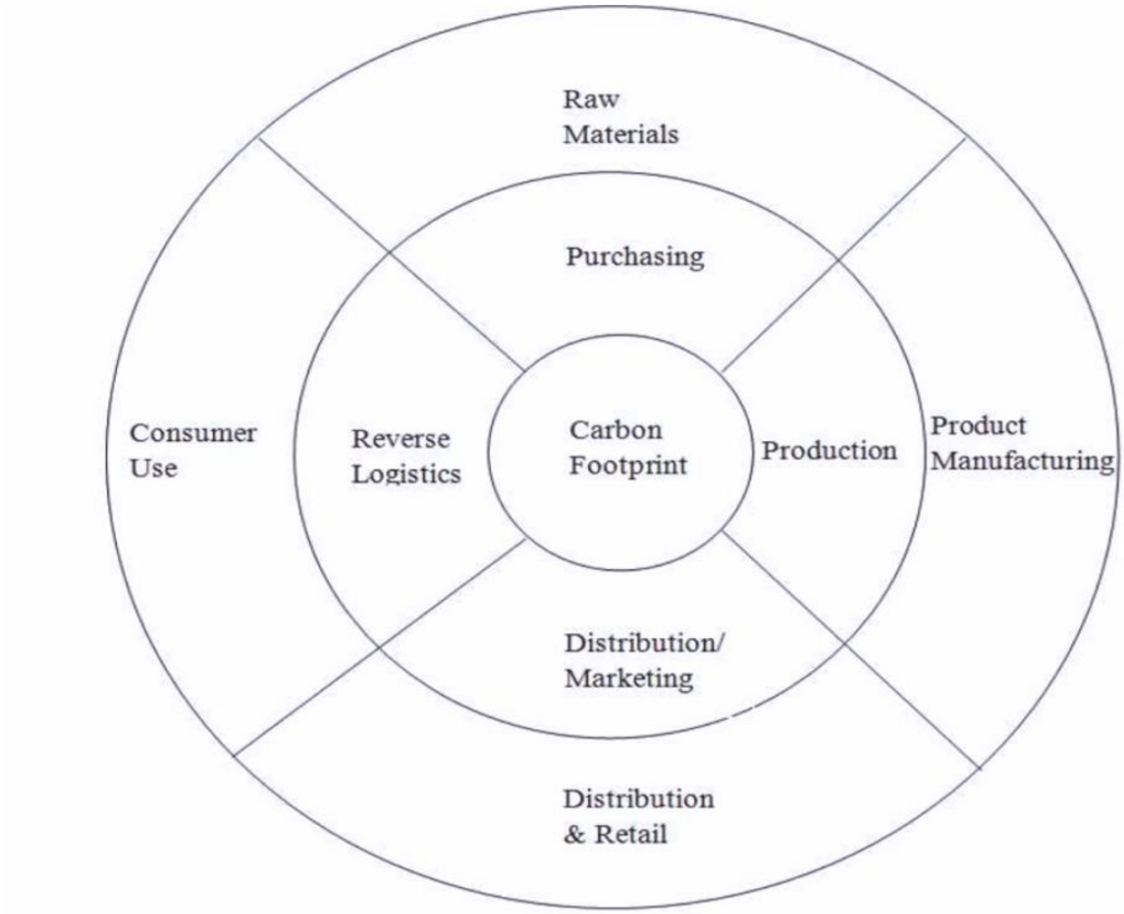


*Figure 3. Sources of carbon emission (Source: Bhat, 2025)*

Supply chain operations represent a major source of environmental impact, with carbon emissions from these activities accounting for a substantial share of global emissions (Katircioglu, 2010). Prior studies suggest that energy consumption and carbon emissions are generated throughout a closed-loop supply chain, encompassing upstream and downstream activities such as raw material sourcing, manufacturing, distribution, and final delivery, as well as reverse flows involving reuse, remanufacturing, and recycling (Sarkis, 2003; Hervani *et al.*, 2005; Sundar Akani *et al.*, 2010). As depicted in Figure 3, the outer boundary illustrates emissions arising across the firm's extended supply chain network, whereas the inner boundary reflects emissions attributable to the life cycle of an individual product. A comprehensive understanding of emission sources at each stage of the extended supply chain enables organizations to identify opportunities for mitigating their environmental footprint (Springer, 2025). Evidence also indicates a growing corporate response to climate concerns, with a significant proportion of multinational enterprises actively addressing carbon emissions associated with their operations (Jones, 2011). These efforts are commonly supported through investments in energy-efficient infrastructure, equipment, and transportation assets. In addition, firms may pursue emission reductions by optimizing supply chain decisions related to procurement, production planning, logistics, and inventory management (Pinkse and Kolk, 2011).

Scholars have proposed a range of tools and analytical approaches to accurately measure an organization's carbon footprint (CFP) as part of broader sustainability objectives. Operational strategies such as the use of shared warehouses instead of dedicated facilities have been shown to reduce both operational costs and environmental impacts. Mallidis *et al.* (2012) developed a methodology for a South-Eastern European firm and demonstrated that integrating environmental considerations, particularly $CO_2$ emission reduction, into traditional supply chain objectives does not result in a significant increase in overall supply chain costs. Further research indicates that collaboration through shared warehousing and transportation systems can lower the average level of $CO_2$ emissions generated across supply chain activities, making such arrangements both economically viable and environmentally sustainable (Jerbi *et al.*, 2022).

While managerial efforts have traditionally focused on controlling direct emissions, indirect emissions occurring across supply chain networks can also substantially contribute to an organization's overall carbon footprint (Ghosh, Jha and Sharma, 2020; Mallidis *et al.*, 2012). In this context, Cordero (2013) conducted a comprehensive literature review examining existing technologies and decision-support strategies used to quantify carbon footprints across supply chains, while also highlighting cost-efficient managerial interventions. Additionally, Shaw *et al.* (2013) proposed a multi-objective goal programming model aimed at simultaneously minimizing total supply chain costs alongside both direct and indirect carbon emissions in selected industries. Their findings suggest that such models can assist managers in adjusting operational policies to achieve reductions in logistics costs and CFP.

Economic pressures also play a critical role in driving emission reductions, as higher social costs associated with $CO_2$ emissions can incentivize firms to actively lower their carbon footprints (Pastor, Stambaugh and Taylor, 2024). Building on this premise, strategic decision-making frameworks have been developed for specific sectors such as the textile industry to support sustainable supply chain planning (Tseng and Hung, 2014). Ji *et al.* (2014, as cited in Ghosh, Jha and Sharma, 2020) examined how environmental impacts and carbon footprints can be integrated across different stages of supply chain network design. Related studies have further analysed the effectiveness of $CO_2$ reduction strategies across production, logistics, usage, and end-of-life disposal phases (Chen *et al.*, 2025). Beyond operational optimization, organizations increasingly adopt alternative sustainability methodologies to fulfil regulatory and environmental obligations (Govindan, 2025).

Limited research has examined how environmental investments, capacity expansion, and inventory management decisions interact within carbon cap-and-trade regulatory frameworks (Garcia-Alvarado *et al.*, 2016). In this context, Shaw *et al.* (2016) developed a sustainable supply chain model constrained by carbon caps and employed Benders decomposition as a solution approach. Their model quantified total emissions generated across the supply chain while providing insights into material and energy flows under multiple sources of uncertainty.

Empirical findings indicate that fluctuations in carbon credit prices significantly influence the number of production plants operated by firms, as well as associated variable costs (Xu, Pokharel and Elomri, 2023).

To further reduce emissions, organizations are increasingly adopting advanced technologies, such as drone-based logistics, as alternatives to conventional transportation systems (Zrelli *et al.*, 2024). Galve *et al.* (2016) analysed the life-cycle impacts of metallic and plastic waste collection containers and examined their implications for sustainable supply chain design. Their study proposed a mixed-integer vehicle routing model incorporating drone-assisted last-mile delivery to enhance efficiency and reduce environmental impact. This emerging technology has gained traction among multinational corporations, including Amazon, Google, and Walmart, which are actively integrating drone solutions into their logistics operations (Goldman, 2025).

Sustainability considerations have also been extended to material sourcing decisions. Hossain *et al.* (2019) proposed environmentally responsible procurement policies for the construction sector in Hong Kong by identifying twelve commonly used construction materials and estimating the greenhouse gas emissions associated with their origins (Kane, Olsson and Miller, 2025). Their analysis demonstrated that sustainable sourcing strategies could achieve emission reductions of up to 28 per cent in the examined scenario (Ghosh, Jha and Sharma, 2020). The study further identified optimal geographic locations for importing these materials to minimise environmental impact (Hossain *et al.*, 2019, as cited in Ghosh, Jha and Sharma, 2020), reinforcing the need for increased adoption of sustainable construction materials within supply chains (Oliveira, 2023).

Another widely adopted sustainability practice in supply chain management is reverse logistics, which aims to reduce environmental impact while optimising costs (Adesoga *et al.*, 2024). Aljuneidi and Bulgak (2019) proposed a reverse logistics framework integrated with a hybrid manufacturing system, demonstrating its effectiveness in lowering carbon emissions and transportation costs. Their model also supports strategic decision-making related to facility location planning, further enhancing supply chain sustainability.

Over the past few decades, the global energy system has experienced substantial change, largely driven by growing concerns over climate change and the need to reduce reliance on fossil-based energy sources ( *et al.*, 2023). Rising consumption of non-renewable resources, together with the intensifying consequences of climate change, has encouraged researchers, policymakers, and industry stakeholders to prioritise the development and adoption of sustainable energy solutions (Holechek *et al.*, 2022). Within this broader transition, the energy sector occupies a critical position, as it is both a significant contributor to greenhouse gas emissions and a central enabler of the shift toward a low-carbon and more sustainable future (Stankovich, 2021).

Supply chains, particularly in energy-intensive industries, are complex networks that span across multiple geographies and involve numerous stakeholders. These networks are responsible for a massive portion of global emissions, stemming from activities such as raw material extraction, production, transportation (Nurdiawati and Urban, 2021). As such, decarbonizing supply chains is not merely a regulatory or ethical obligation, it is a tactical obligation for corporations aiming to stay competitive and resilient in a rapidly evolving market. The urgency of this transformation has been underscored by international agreements such as the Paris Agreement (2016), which brought together nations to commit to limiting global warming to well below 2°C above pre-industrial levels (Serra and Fancello, 2020). This agreement catalysed a wave of policy reforms, corporate pledges, and technological innovations aimed at reducing carbon footprints across all sectors. In parallel, consumer awareness and demand for environmentally responsible products have surged, placing additional pressure on firms to exhibit openness and be liable in their environmental practices. This literature review aims to explore the evolution, current practices, and future directions of supply chain decarbonization within the energy industry. It seeks to synthesize academic research and industry insights to develop a conceptual structure for determining carbon emits across supply chain and logistics (Ahlstrom et al., 2020). By adopting a systematic and bibliometric approach, this study provides a comprehensive overview of how organizations are leveraging methodologies, technologies, and strategic partnerships to build sustainable supply chains. In doing so, the review will address several key questions:

- How has decarbonization initiatives evolved over time?
- What tools and technologies are being used to measure and reduce carbon emissions in supply chains?
- How can energy companies align their policies with bigger sustainability targets?
- What roles do regulatory frameworks, consumer expectations, and technological advancements play in shaping the future of sustainable supply chains?

Supply chain management is not just about managing the activities involved in delivery of Goods and Services to the consumers; it also involves administration of complete life cycle of a product in the Order to Cash (OTC) process flow. From an organizational perspective, assessing how effectively each component of the supply chain fulfils its social and environmental responsibilities is a critical consideration. A widely recognised definition of sustainable development was established in the report *Our Common Future*, published by the World Commission on Environment and Development, which emphasised the balanced integration of economic growth, environmental protection, and social equity (Brundtland *et al.*, 1987).

The concept of the *triple bottom line*, introduced by Elkington (1998), emphasised that organizational success should be evaluated not only through financial performance but also through social responsibility and environmental stewardship. From a sustainability standpoint, supply chain management literature increasingly highlights the influential role of external pressures, particularly those arising from government regulations and societal expectations, in motivating industries to adopt sustainable supply chain practices (Singh *et al.*, 2022).

With the air quality in urban society increasingly compromised due to emissions from the industrial sector, transportation, and domestic consumption, one key indicator of declining air quality is the rise in $CO_2$ emissions, which significantly contribute to greenhouse gases (GHG) (Harvard T.H. Chan School of Public Health, n.d.). There is growing consensus that carbon emissions impact Earth's atmospheric structure (IPCC, 2021). In response, countries are initiating zero carbon emission targets through strict legislation to control these emissions (UNFCCC, 2023).


*Figure 4. Triple Bottom Line framework (Source: Cascadia Updates, 2021)*

Industries across the globe are reacting to such legislation and to concerns raised by customers and shareholders by commissioning plans to reduce their carbon footprint (CDP, 2022). Although these initiatives often focus on emission reductions in core manufacturing processes, products, and services, they tend to overlook significant sources of emissions driven by industrial practices and operational policies(World Economic Forum, 2021).These include decisions such as supply frequency, mode of transport, and the selection of vendors who are already on the path to reducing their net carbon footprints (World Economic Forum, 2021). This research synthesizes the literature on sustainable supply chain practices and carbon foot printing (CFP), incorporating emerging trends and technologies. It addresses how the energy industry should measure carbon emissions within their supply chain processes and achieve net-zero goals

(IEA, 2022). The paper focus is not on introducing modern theoretical concepts, instead it seeks to draw attention to a promising and timely area of application that holds growing relevance in today's world. Accordingly, this paper is intended to serve as a catalyst for discussion rather than as an exhaustive or definitive examination of the subject (Meredith, 1993).

Studies in this area reveal that consumer demand from wealthier nations significantly contributes to biodiversity loss in developing regions (Lenzen et al., 2012). Due to strict environmental regulations, many developed countries avoid producing goods that result in high carbon emissions, effectively outsourcing the environmental burden to less regulated economies (Lenzen et al., 2012). Directly to this, people opt to import goods from countries where environmental regulations are comparatively less stringent, effectively shifting the ecological burden to regions with more relaxed oversight**.** Driven by strong consumer interest in Mexican coffee in the United States, the study explored the broader environmental consequences of meeting that demand. It shed light on how global supply chains contribute to biodiversity loss and underscored the critical consequence of push in sustainability into every step of the process (Habibullah et al., 2021). Henders *et al.* (2015) found that international trade in major agricultural commodities was a dominant driver of tropical deforestation during the period from 2000 to 2011. Their analysis examined both demand-side and supply-side policy approaches, revealing that the growing appetite of global consumers plays a significant role in driving international trade patterns (Lenzen et al., 2012). Several studies have linked global supply chain activities, particularly metal imports, to adverse environmental outcomes, identifying them as contributing factors to increased carbon emissions and ecological degradation (Murugaiyan *et al.*, 2025). In response, these authors developed a data-driven analytical framework to assess sustainability performance within the metal industry and proposed forward-looking hypotheses concerning emission reduction pathways. However, empirical evidence suggests that a considerable number of firms fail to disclose their carbon emission data and lack transparency within their supply chain networks (Caritte *et al.*, 2015). Enhanced sustainability reporting practices and the enforcement of stringent environmental regulations have been identified as effective mechanisms for compelling organizations to reduce their carbon footprints and overall greenhouse gas emissions (Caritte *et al.*, 2015).

Progress toward improved disclosure has been observed in certain contexts. For instance, a report revealed that in 2013, several large U.S. corporations successfully reported approximately 22 per cent of their supply chain-related carbon emissions, highlighting both progress and significant opportunities for improving emission measurement accuracy (Blanco *et al.*, 2016). To better understand organizational practices, Kara *et al.* (2014) conducted a large-scale survey involving 330 manufacturing firms across multiple countries to examine the extent of sustainability adoption in real operational settings. Complementing this work, recent studies have proposed strategic supply chain frameworks that align operational decision-making with evolving environmental standards, thereby supporting the development of efficient yet environmentally responsible products through centralized coordination across structured supply chain layers (Villena and Gioia, 2020; Fan, Wang and Zhao, 2018; Bhavani, Mahapatra and Kumar, 2023). Methodological advancements have also enabled more precise estimation of product-level carbon footprints within sustainable supply chains. Ghosh, Jha and Sharma (2020) successfully quantified product carbon footprints across supply chain stages and validated their approach using agricultural irrigation equipment that integrates water and fertilizer application, demonstrating its practical applicability. In developed economies, policy instruments such as progressive emission taxation have proven effective in incentivizing firms to reduce their carbon footprints within supply chain operations (He *et al.*, 2019). Building on this approach, He *et al.* (2023) introduced a mathematical framework incorporating multiple environmental regulations alongside a dynamic emission tax structure to encourage environmentally conscious operational choices. Related research has examined how regulatory interventions influence product design decisions, consumer demand patterns, aggregate emissions, and the economic performance of supply chains (Wang and Wang, 2025; Ghosh, Jha and Sharma, 2020).

Beyond regulatory measures, scholars and industry practitioners increasingly emphasize the importance of transparency and information sharing in reducing supply chain carbon footprints. A well-integrated supply chain network can be achieved when key stakeholders—including suppliers, retailers, and other partners—actively share operational challenges and strategic decisions across the entire chain (SCM Globe, n.d.). Open dialogue between producers and consumers further supports sustainability objectives, as rising environmental awareness has led consumers to demand products that reflect responsible practices and reduced ecological impact (Duan, Aloysius and Mollenkopf, 2022; Reichheld, Peto and Ritthaler, 2023). Achieving meaningful transparency and integration requires coordinated engagement among diverse stakeholders, which is essential for balancing economic performance with environmental protection and social responsibility (Dahlmann and Roehrich, 2019). Despite the growing body of research, much of the sustainable supply chain literature remains concentrated on developed economies, with comparatively limited attention devoted to challenges and practices in developing regions. Recent studies have primarily focused on three major industrial domains: the food sector, electrical and chemical industries, and energy-related enterprises (Singh *et al.*, 2022).

## 2.4 Summary

The literature on sustainable supply chains and carbon footprint (CFP) management reveals a complex and evolving landscape, shaped by growing environmental concerns, regulatory pressures, and the increasing demand for corporate accountability (Villena and Gioia, 2020). One of the most persistent challenges associated within the reviewed studies is the absence of high-quality, standardized data. This issue presents a significant obstacle not only for researchers and practitioners but also for regulators and investors who depends on reliable and similar data to assess performance, enforce compliance, and guide investment decisions (Blackhurst, Cantor and O'Donnell, 2015). The absence of a universal benchmark or standardized methodology for emissions reporting has created a fragmented data environment. Companies often rely on disparate data sources, each with varying levels of granularity, accuracy, and reliability. Emission profiles are composed of numerous data points, many of which are difficult to quantify or verify. For instance, collecting emissions data from vendors, identifying the precise sources of emissions across complex supply chains, and applying consistent quantification methodologies remain formidable tasks (Ghosh, Jha and Sharma, 2020). These challenges are further compounded by the lack of harmonized regulatory frameworks and the diversity of emissions data management systems available in the market. While several robust platforms exist, their outputs are not always directly comparable due to differences in underlying assumptions, data structures, and reporting standards. This lack of interoperability makes benchmarking performance across organizations and jurisdictions particularly difficult. Despite these challenges, the literature also highlights a growing momentum toward improvement and innovation. The drive for change is being propelled by a diverse set of stakeholders, each exerting influence in different ways. Industry actors have been pursuing emissions reduction strategies for over a decade, often motivated by corporate social responsibility (CSR) commitments and the desire to align with global sustainability goals (Villena and Gioia, 2020).These efforts have been supported by a growing body of academic research that seeks to understand, model, and optimize sustainable supply chain practices(Ghosh et al., 2020 ; Hasan et al., 2024). This literature review has synthesized a wide range of studies that explore the intersection of supply chain management and carbon footprint reduction. It has brought to light several key managerial insights and theoretical contributions that are valuable for both practitioners and future researchers. One of the central findings is the recognition of carbon regulation as a critical tool for driving sustainable growth. Regulatory frameworks, when effectively designed and implemented, can provide the necessary incentives and constraints to guide organizational behavior toward lower emissions (Blackhurst, Cantor andO'Donnell, 2015). The review also examined various modeling approachesboth quantitative and qualitativethat have been employed to aid informed choices in managing environmentally responsible supply chains.These models range from life cycle assessments and input-output analyses to simulation-based and optimization frameworks (Ghosh, Jha and Sharma, 2020). A notable trend observed in the literature is the increasing attention on newfound tools and technologies intended at enhancing the sustainability of existing supply chains. Since 2010, there has been a marked increase in research dedicated to the target and application of innovative solutions for emissions reduction. These include digital platforms for emissions tracking, blockchain-based systems for supply chain transparency, and artificial intelligence applications for predictive analytics and optimization.While these technologies hold great promise, their adoption remains uneven, and additional investigation is required to assess their elongated success and scalability. Another important insight from the review is the identification of significant research gaps. While much of the existing literature has concentrated on ecological and financial dimensions of sustainability, relatively few studies have addressed the social aspects (Sybertz, 2017). Social sustainability, which encompasses issues such as human rights, community engagement, and equitable approach to reserves, is an integral component of the broader sustainability agenda. However, it remains underexplored in the context of supply chain management(Singh et al., 2022).

As public concern about climate change has grown, consumers have become more discerning in their purchasing decisions. This shift in consumer behavior has placed additional pressure on companies to show their commitment to sustainability and to provide transparent information about the ecological effect of their operations (Villena and Gioia, 2020). One of the most pressing issues is the limited consideration of uncertainty in sustainable operations. Many existing models and frameworks assume stable conditions and predictable outcomes, which may not reflect the realities of dynamic and often volatile supply chain environments. The COVID-19 pandemic has underscored the importance of resilience and adaptability in supply chain management(Wang, 2023). It has exposed vulnerabilities in global logistics networks and highlighted the need for more robust systems that can withstand disruptions while maintaining sustainability goals (Sybertz, 2017). Future research should therefore place greater emphasis on incorporating uncertainty and risk management into sustainability models. Another limitation of the current body of literature is its reliance on a relatively narrow set of data sources. While Scopus is one of the largest and most comprehensive academic databases, it does not capture the full breadth of research being conducted in this field(El Baz and Iddik, 2021). As such, the findings presented here should be interpreted as indicative rather than exhaustive. There remains a vast and growing body of work that has yet to be systematically reviewed and synthesized (Ghosh, Jha and Sharma, 2020).

In conclusion, the literature on sustainable supply chains and carbon footprint management presents a rich and multifaceted field of inquiry. It reveals both the disputes and prospects associated with transitioning to additionalmaintainablemeans of manufacturing. The lack of standardized data and methodologies continues to hinder progress, but there is a clear trajectory toward greater integration, innovation, and accountability(El Baz and Iddik, 2021). Industry leaders, policymakers, researchers, and consumers all have a role to play in advancing this agenda. By fostering collaboration, investing in research and development, and promoting transparency and inclusivity, it is possible to build supply chains  that are competent, resilient and socially responsible (Blackhurst, Cantor and O'Donnell, 2015).

As the global community moves toward more ambitious climate targets, the importance of comprehensive and actionable research in this area will only grow. Future studies should aim to bridge existing gaps, particularly in the areas of social sustainability, uncertainty modeling, and the longstanding effects of emerging technologies(Qu and Kim, 2024). They should also strive to develop more inclusive and context-sensitive frameworks that reflect the diverse realities of supply chains across different regions and sectors. Only through such concerted efforts can we hope to achieve the transformative change needed to safeguard a sustainable and rightful future for all (Villena and Gioia, 2020).

CHAPTER III:

METHODOLOGY

### 3.1 Overview of the Research Problem

Climate change is no longer a distant threat, it is a reality we are facing right now, and greenhouse gas (GHG) emissions are at the heart of it. Over the past few decades, the steady rise in emissions, especially carbon dioxide, has been driving global temperatures upward. Scientists and climate experts have made it clear that if we want to sidestep the vilest effects of environmental variation, we need to act fast and decisively. The core objective is to reduce carbon emissions by up to 80% from the levels recorded in the year 2000, and to do so by 2050. This threshold is not arbitrary; rather, it represents the level required to limit the increase in global average temperatures to below 2 °C relative to pre-industrial levels (UNFCCC, 2015).
If we go beyond that threshold, we risk triggering a range of dangerous and unpredictable consequences, from extreme weather events to disruptions in ecosystems and human livelihoods (Ghosh, Jha and Sharma, 2020).

Despite increasing global awareness and the establishment of international agreements such as the Paris Accord, existing governmental policies and implementation efforts remain insufficient to meet climate targets. Progress has been slow, and the magnitude of change required to effectively address climate challenges is substantial. Under these circumstances, businesses—particularly those operating within the energy sector—play a critical role in accelerating the transition toward a low-carbon economy (Centre for Climate and Energy Solutions, 2024). Companies have the resources, innovation capacity, and influence to drive meaningful change. They can lead the way in cutting emissions not just because it is the right thing to do, but because it is becoming a business imperative in a world that is rapidly shifting toward sustainability (Villena and Gioia, 2020). In the energy sector, the challenge is particularly complex. The industry deals with a wide range of products liquid fuels for transportation, natural gas (both piped and liquefied), and electricity generated from both fossil fuels and renewables like solar and wind. Each of these products has its own carbon footprint and understanding that footprint requires a detailed look at the total life span from manufacturing, processing, distribution and final use. To address this, we have developed a methodology that allows us to quantify and track GHG emissions across the complete lifetime of these energy products (GHG Protocol, 2011). What makes this approach comprehensive is that it does not just focus on what is produced in house; it also includes products sourced from third parties that are eventually sold to customers. This gives us a clearer picture of the total emissions associated with our energy portfolio (Blackhurst, Cantor and O'Donnell, 2015).

However, even with this detailed life cycle analysis, there is still a major blind spot: indirect emissions. These are the emissions that do not come directly from producing or using energy, but from all the supporting activities that make energy production and distribution possible. Think of the supply chains that provide raw materials, the manufacturing of equipment, the logistics involved in moving products, and even the services outsourced to other companies. These emissions, often referred to as Scope 3 emissions, are harder to measure and manage but they can be just as significant, if not more so, than direct emissions (Ghosh, Jha and Sharma, 2020). Right now, there is no standardized or widely adopted methodology for tackling these indirect emissions in a way that is both practical and effective. This is a serious gap, especially for companies that are genuinely committed to reducing their overall carbon footprint. Without an obvious way to measure and manage these emissions, it is difficult to set meaningful targets or track progress. More importantly, it is hard to make the kind of systemic changes needed to truly decarbonize the energy sector. This investigation intends to address that gap. The goal is to explore how we can go beyond just measuring emissions and start identifying actionable strategies to reduce them especially those that are embedded deep within the supply chain. This involves looking at how companies can work with suppliers, redesign processes, and adopt modern technologies to cut emissions at different levels of the business processes. It is not just about internal changes; it is about creating a ripple effect that influences the entire ecosystem around energy production and distribution (Sybertz, 2017). What makes this challenge even more interesting is that it is not just a technical problem it is also a strategic and organizational one. Reducing indirect emissions requires companies to rethink how they operate, how they make decisions, and how they engage with partners and stakeholders. It calls for a shift in mindset, where sustainability becomes a fundamental portion of business tactic rather than a complement. It also means investing in innovation, whether that is through cleaner technologies, smarter logistics, or better data systems for tracking emissions.

The research problem at hand is about bridging the gap between ambition and action. We know what is required to overcome climate impacts, and we have some of the tools to do it. But to make real progress, especially in the energy sector, we need to develop new ways of understanding and managing the full spectrum of emissions including those that are currently hidden in the background. This research is a step toward that goal, aiming to contribute practical insights and solutions that can help companies lead the way in building a low-carbon future.

### 3.2 Operationalization of Theoretical Constructs

Temperature variation is a major threat, it is a truth we are facing right now, and greenhouse gas (GHG) emissions are at the heart of it. Over past few decades, steady rise in emissions, especially carbon dioxide, has been driving global temperatures upward. Scientists and climate experts have made it clear that to prevent the most severe consequences, we need to act fast and decisively. A central global objective is to achieve a reduction of up to 80 per cent in carbon emissions relative to levels recorded in the year 2000, with a target horizon extending to 2050 (United Nations, 2024). This target is not arbitrary; rather, it reflects the scale of emission reductions required to limit the increase in global average temperatures to below 2 °C when compared with pre-industrial levels (UNFCCC, 2015). If we go beyond that threshold, we risk triggering a range of dangerous and unpredictable consequences, from extreme weather events to disruptions in ecosystems and human livelihoods (Ghosh, Jha and Sharma, 2020).

Despite growing awareness and global contracts like the Paris Concurrence, the reality is that current government policies and actions are falling short. The current rate of progress remains inadequate, while the magnitude of change required to achieve sustainability objectives is substantial. Under these conditions, the involvement of businesses—particularly those operating within the energy sector—has become increasingly important (United Nations, 2025; World Economic Forum, 2020). Corporations possess significant financial resources, technological capabilities, and market influence that position them to drive impactful change. Emission reduction initiatives are therefore no longer solely driven by ethical considerations but are increasingly recognised as strategic imperatives, as firms adapt to an economic landscape that is rapidly transitioning toward sustainability-oriented practices (Villena and Gioia, 2020).

In the energy sector, the challenge is particularly complex. The industry deals with a wide range of products liquid fuels for transportation, natural gas (both piped and liquefied), and electricity generated from both fossil fuels and renewables like solar and wind. Each of these products has its own carbon footprint and understanding that footprint requires a detailed look at the complete tenure from order to cash flow. To address this, we have developed a methodology that allows us to quantify and track GHG emissions across the full life cycle of these energy products (IPCC, 2019; UNFCCC, 2025). What makes this approach comprehensive is that it does not just focus on what is produced in house; it also includes products sourced from third parties that are eventually sold to customers. This gives us a clearer picture of the total emissions associated with our energy portfolio (Blackhurst, Cantor and O'Donnell, 2015). However, even with this detailed life cycle analysis, there is still a major blind spot: indirect emissions. These are the emissions that do not come directly from producing or using energy, but from all the supporting activities that make energy production and distribution possible. Think of the supply chains that provide raw materials, the manufacturing of equipment, the logistics involved in moving products, and even the services outsourced to other companies. Scope 3 emissions are harder to measure, manage but they can be just as significant, if not more so, than direct emissions (Ghosh, Jha and Sharma, 2020).

Right now, there is no standardized or widely adopted methodology for tackling these indirect emissions in a way that is both practical and effective. This is a serious gap, especially for companies that are genuinely committed to reducing their overall carbon footprint. Without an obvious way to measure and manage these emissions, it is difficult to set meaningful targets or track progress. More importantly, it is hard to make the kind of systemic changes needed to truly decarbonize the energy sector. This research aims to address that gap. The goal is to explore how we can go beyond just measuring emissions and start identifying actionable strategies to reduce them especially those that are embedded deep within the supply chain. This involves looking at how companies can collaborate with suppliers, redesign processes, and adopt modern technologies to cut emissions at various levels in the organization. It is not just about internal changes; it is about creating a ripple effect that influences the entire ecosystem around energy production and distribution (Sybertz, 2017).

In the context of this research, operationalizing the theoretical construct of carbon emissions reduction, particularly Scope 3 emissions, requires translating broad sustainability goals into measurable, actionable processes. Scope 3 emissions refer to indirect greenhouse gas emissions that occur throughout a firm's value chain and are widely recognised as the most challenging to quantify and manage (Greenhouse Gas Protocol, 2011). Unlike emissions generated directly from an organization's own facilities or energy use, these emissions originate from upstream and downstream activities, including the manufacture of purchased goods and services, logistics and transportation, waste management, and the use phase of products sold to customers (EPA, 2025).

For oil and gas companies, which operate within vast and intricate supply chains, addressing Scope 3 emissions is critical encounter but can be a tactical chance (IPIECA, 2016). To bring this concept into a practical framework, this study begins by identifying a representative sample of the global oil and gas industry. The top ten companies by market capitalization in 2025Saudi Aramco, ExxonMobil, Chevron, Shell, PetroChina, Total Energies, ConocoPhillips, BP, CNOOC, and Equinor form the core of this analysis. These companies not only dominate the global energy landscape but also serve as benchmarks for industry practices, innovation, and sustainability leadership.

Within each of these companies, the focus narrows to their top ten vendors. These vendors are selected based on procurement spending, strategic importance, and the frequency of transactions. They typically supply critical components, equipment, and services such as drilling tools, compressors, turbines, valves, instrumentation, and maintenance services. Among these, fast-moving spares items that are frequently purchased, replaced, or consumed in operations are particularly significant (IEA, 2022). The operationalization process begins with the classification and integration of procurement data. This involves extracting spent data from ERP systems such as SAP or Oracle, which serve as the central repositories for purchasing transactions. Each line item in the spend data is mapped to a material or service category, vendor, and cost center. This classification is essential for understanding what is being bought, from whom, and for what purpose (Accenture, 2021).

Once the spend data is structured, it is linked to emission factor databases. Emission factors represent the average emissions related to creating a component of a given material. These factors can be sourced from publicly available databases such as the UK DEFRA, EPA, or Ecoinvent, or from proprietary product life cycle databases maintained by the companies themselves (DEFRA, 2023).

A critical aspect of this methodology is the treatment of fast-moving spares. These items, due to their high turnover and operational criticality, offer a unique opportunity for emissions tracking and reduction. By focusing on these spares, companies can execute directed involvements such as swapping to lower-emission alternatives, optimizing inventory levels, or consolidating suppliers to improve efficiency (WBCSD, 2022). To safeguard the precision and relevance of emissions information, consistent reporting practices, clear guidelines are essential, the underlying databases must be refreshed regularly. A monthly refresh cycle is recommended to capture changes in procurement patterns, vendor performance, and emission factors. This requires the automation of data extraction, transformation, and loading (ETL) processes, minimizing manual intervention and reducing the risk of errors (PwC, 2021).

The entire process must align with recognized standards and frameworks to ensure credibility and comparability. The Greenhouse Gas Protocol, jointly established by the World Resources Institute and the World Business Council for Sustainable Development, serves as the primary global framework for accounting and reporting Scope 3 emissions (Greenhouse Gas Protocol, 2011). Beyond measurement, the study explores the potential for scaling up decarbonization technologies within the energy sector. This includes reviewing emerging solutions such as carbon capture and storage (CCS), hydrogen fuel systems, electrification of operations, and digital tools for emissions monitoring (IEA, 2022). Ultimately, this work contributes to the universal struggle to achieve net-zero carbon releases and build a more justifiable energy future.

### 3.3 Research Purpose and Questions

The global energy system is undergoing a profound transformation, driven by the urgent need to address climate change and accelerate the transition toward sustainable, resilient, and low-carbon energy economies (World Economic Forum, 2025; IEA, 2025 Among the numerous challenges associated with the transition to a low-carbon economy, one of the most complex and least explored issues is the measurement and management of carbon emissions across supply chains, particularly Scope 3 emissions. These emissions originate beyond an organization's direct operational boundaries and frequently represent the largest share of a firm's overall carbon footprint (EPA, 2025). However, their dispersed nature across upstream and downstream activities, combined with the absence of consistent and standardized measurement frameworks, makes Scope 3 emissions especially difficult to quantify and manage effectively.

This research is motivated by the need to bridge this critical gap. It aims to develop a structured, scalable, and practical methodology for measuring and managing carbon emissions across the supply chain, with a specific focus on Scope 3 emissions. The study is grounded in the real-world context of the energy industry, where companies are increasingly committing to ambitious net-zero targets. For instance, in 2017, my organization publicly pledged to reduce the net carbon footprint of its energy products by 100% by 2050. This commitment aligns with the global climate goals outlined in the Paris Agreement and reflects a broader industry shift toward sustainability (Shell, 2017; Nature, 2025). However, achieving such a goal requires more than internal operational changes it demands a comprehensive understanding of emissions across the entire value chain. As many organizations have made progress in reducing direct emissions (Scope 1 and 2), emissions linked to indirect activities often referred to as Scope 3continue to be a major area of oversight. These include the environmental impact of purchased materials and services, logistics and transportation, operational waste, corporate travel, employee commuting, and how products are used after being sold. In the energy sector, these emissions are particularly complex due to the scale and diversity of operations, the global nature of supply chains, and the reliance on third-party vendors and logistics providers (GHG Protocol, 2013). To address this complexity, a methodological approach is essential. This research proposes a framework that integrates procurement data, emission factor databases, and carbon accounting tools to enable systematic tracking of discharges within the SC domain. The procedure is devised to be adaptable to different organizational contexts, scalable across global operations, and aligned among internationally acknowledged paradigms such as the Greenhouse Gas (GHG) Protocol (GHG Protocol, 2013).

The study focuses on the top ten global oil and gas companies by market capitalization in 2025, these companies represent a sizeable portion of global energy production and are at the forefront of industry efforts to Decarbonize. Within each company, the research narrows its focus to their top ten vendors, selected based on procurement spend, strategic importance, and operational relevance. A key element of the research is the analysis of fast-moving spares components and materials that are frequently purchased, replaced, or consumed in operations. These items, while often overlooked in traditional emissions accounting, represent a substantial share of procurement activity and are ideal candidates for emissions tracking due to their high volume and repeatability. By analysing emissions associated with these spares, the analysis focuses to recognize patterns, hotspots, and prospects for emissions reduction. The chief objective of this analysis is to develop a formalized process for carbon footprint measurement within the supply chain. This includes:

- Data Classification and Integration: Structuring procurement data from ERP systems to identify what is being purchased, from whom, and in what quantities. This data is then linked to emission factor databases to estimate the carbon footprint of each transaction.
- Tool Evaluation and Integration: Assessing the capabilities of carbon accounting software and emission factor databases and exploring how these tools can be integrated into existing enterprise systems to enable automated and continuous emissions tracking.
- Supplier Engagement and Data Collaboration: Developing strategies for engaging suppliers to obtain primary emissions data, and establishing protocols for data sharing, validation, and improvement.
- Fit-Gap Analysis of Decarbonization Solutions: Reviewing existing decarbonization technologies and evaluating their applicability to the energy sector, with a focus on identifying

gaps and opportunities for innovation.

- Framework Development: Synthesizing the findings into a comprehensive, scalable framework that organizations can adapt to measure, monitor, and mitigate supply chain emissions.

To guide the methodological development, the research is structured around three core questions: Firstly, how can a standardized and scalable methodology be developed to measure Scope 3 emissions across the supply chain, using procurement spend data and emission factor integration as the primary inputs?

This question addresses the foundational challenge of emissions measurement. It explores how organizations can leverage existing data sources particularly financial spend data to estimate emissions in a consistent and scalable manner. The focus is on developing a methodology that is rigorous and practical, capable of being implemented across diverse supply chain contexts. Secondly, what are the key technical and organizational challenges in embedding carbon accounting tools into existing enterprise systems, and how can these be directed to safeguard reliable, continuous emissions tracking?

This question examines the integration of emissions tracking tools into business operations. It considers the technical requirements for system integration, the data quality and governance issues that may arise, and the organizational changes needed to support adoption and use. The goal is to identify best practices and design principles that can facilitate seamless integration. Finally, how can supplier engagement and data collaboration be structured to progress the correctness and fullness of emissions statistics, particularly for frequently procured items such as fast-moving spares? This question focuses on the human and relational aspects of emissions tracking. It explores how companies can work with their suppliers to obtain more precise emissions facts, build trust, and foster a culture of transparency and collaboration. It also considers the role of incentives, standards, and digital platforms in enabling effective data exchange.

This study employs a mixed-methods research design that integrates quantitative data analysis with qualitative evidence drawn from industry reports, case studies, and expert interviews (Liu and Zhang, 2024). The quantitative component engages the extraction and analysis of procurement data from ERP systems, the application of emission factors, and the modelling of emissions across distinct categories and vendors. The qualitative component includes an evaluation of present literature on carbon accounting, sustainability reporting, and supply chain management, as well as interviews with procurement professionals, sustainability officers, and technology providers.

The study also includes a pilot implementation of the proposed methodology within a selected business unit or supply chain segment. This pilot will test the feasibility of the approach, identify practical challenges, and provide feedback for refinement. The results of the pilot will inform the final framework and recommendations.

To enhance methodological robustness and ensure consistency across studies, this research framework is aligned with the Greenhouse Gas Protocol's Corporate Value Chain (Scope 3) Accounting and Reporting Standard. This standard offers structured guidance for identifying relevant emission sources, choosing appropriate calculation approaches, gathering reliable data, and transparently reporting results. In addition, the study considers coherence with complementary frameworks and standards, including the Science Based Targets initiative (SBTi), the Task Force on Climate-related Financial Disclosures (TCFD), and ISO 14064, to strengthen credibility and comparability of the findings.

The research is focused on making several contributions to both academic knowledge and industry practice:

- Theoretical Contribution: By operationalizing the concept of Scope 3 emissions measurement, the analysis spreads the perception of how indirect emissions can be quantified and managed within complex supply chains.
- Methodological Contribution: The research provides a replicable methodology for emissions tracking that can be adapted to different organizational contexts and industry sectors.
- Practical Contribution: The study offers actionable insights and tools that firms can use to augment their sustainability performance, meet regulatory requirements, and build competitive advantage.
- Strategic Contribution: By underscoring the importance of procurement and supply chain functions in decarbonisation initiatives, this study demonstrates how sustainability can be embedded within an organization’s core business strategy.
- By implementing a structured and scalable methodology for emissions measurement, the study seeks to empower organizations to take meaningful action toward their net-zero goals. Through a combination of data analysis, tool integration, and stakeholder engagement, the study supports a comprehensive structure for supply chain decarbonization (Sindhwani et al., 2023). It is a step toward a more transparent, accountable, and sustainable energy future one where emissions are not just measured, but actively managed and reduced.

### 3.4 Research Design

The research design is guided by the objective of developing a practical and scalable approach for measuring and managing Scope 3 carbon emissions across supply chains, with particular emphasis on the energy sector (Teske *et al.*, 2022). Given the inherent complexity of indirect emissions and the wide range of activities involved across supply chain networks, a well-structured research design is essential to maintain analytical focus, methodological rigor, and alignment with the study's overarching aims. Accordingly, this research adopts a qualitative-dominant, multi-approach design that integrates data-driven analysis with the development of a conceptual framework. This approach seeks to bridge the gap between theoretical perspectives and real-world implementation, enabling organizations to operationalize carbon accounting and tracking practices in a manner that is both practical and decision-oriented (Greenhouse Gas Protocol, 2011).

The starting point of the research design involves clearly distinguishing the scale and limitations of the study. This includes detecting the operational limits within which emissions will be assessed. The study spotlights on the leading ten global oil and gas enterprises, selected based on their market capitalization and influence in the energy sector. These companies serve as a representative sample for understanding how large-scale energy producers manage their supply chain emissions (IPIECA and API, 2016). Within each company, the research narrows its focus to their top ten vendors, chosen based on procurement spend and operational relevance. The analysis is further refined by concentrating on fast-moving spares components and materials that are frequently procured and replaced in operational settings. These items, while often small in individual value, collectively represent a sizeable portion of procurement activity and are ideal for emissions tracking due to their high volume and repeatability (IEA, 2022).

The core of the research design rests in the development of a methodological framework that integrates procurement spend data with emission factor databases to estimate the carbon footmark of procured products. The rationale for using spend data is based on its availability, granularity, and alignment with procurement processes (Accenture, 2021). By linking financial transactions to emission factors, the study creates a scalable model for estimating emissions across diverse categories and vendors. Emission factors are sourced from recognized databases such as DEFRA (2023), Ecoinvent (2023), and the U.S. EPA (2023), as well as from proprietary life cycle assessment tools where available. In cases where emission factors are not readily available, the study explores the potential for supplier engagement to obtain primary emissions data. This dual approach combining standardized factors with supplier-specific data enhances the accuracy and credibility of the emissions estimates.

A significant aspect of the research involves evaluating how carbon accounting tools can be embedded into existing enterprise systems such as SAP and Oracle. This includes assessing the technical requirements for integration, the quality and structure of available data, and the organizational readiness for adopting such tools (SAP, 2024; Oracle, 2024). The goal is to develop a methodology that not only provides accurate emissions estimates but also supports continuous monitoring and improvement. This part of the research is informed by both literature review and practical case studies, drawing on industry reports, academic publications, and interviews with sustainability professionals to appreciate the recent state of carbon accounting and gaps that need to be addressed (PwC, 2021).

Given the importance of supplier data in Scope 3 emissions accounting, the research also places significant emphasis on supplier engagement. This involves developing strategies for obtaining emissions data from vendors, building trust, and fostering collaboration. The study explores different models of engagement, including data-sharing agreements, supplier scorecards, and joint sustainability initiatives. It also considers the role of digital platforms in facilitating supplier collaboration, enabling companies to work more effectively with their supply chain partners (WBCSD, 2022). By integrating supplier engagement into the research design, the study ensures that the emissions measurement framework is grounded in real-world practices and capable of driving meaningful adjustment.

To assess the possibility and ability of the proposed methodology, the research includes a pilot implementation within a selected business unit or supply chain segment. This pilot serves as a proof of concept, allowing the researcher to apply the framework in a controlled environment, identify practical challenges, and refine the approach based on feedback. The pilot involves collecting procurement data, applying emission factors, engaging with suppliers, and using carbon accounting tools to estimate emissions. The results are analysed to assess the accurateness, usability, and scalability of the practise. This iterative process ensures that the final structure is both theoretically robust and practical.

The research design is closely aligned with the overarching objectives of the study. It supports the development of a formal process for carbon footprint measurement, the evaluation of existing tools and technologies, and the identification of integration challenges. It also provides a foundation for exploring decarbonization strategies, including the use of renewable energy, digital technologies, and advanced analytics(GHG Protocol, 2023; IEA, 2024; World Economic Forum, 2023). By combining conceptual development with empirical analysis, the research design links the gap between model and exercise. It offers a comprehensive approach to Scope 3 emissions accounting that is grounded in industry realities and aligned with global sustainability standards. Altogether information used in the study will be anonymized and managed in agreement with organizational and academic guidelines. Supplier engagement will be conducted transparently, with informed consent and respect for proprietary information. Limitations of the investigation covers the accessibility and quality of emissions figures, the variability of emission factors across regions and industries, and the challenges of scaling the methodology across different organizational contexts. These limitations are acknowledged and addressed using multiple data sources, stakeholder engagement, and iterative validation.

In conclusion, the research design provides a structured and thorough methodology to assessing Scope 3 emissions in the energy sector. By focusing on procurement data, emissions modelling, tool integration, and supplier collaboration, the study aims to develop a practical and scalable methodology for carbon footprint measurement. The design is justified in real-world encounters, advised by best practices ensuring that the outcomes of the research are both academically rigorous and operationally relevant. This design not only supports the achievement of the thesis objectives but also contributes to the larger objective of enabling organizations to modify their business to support justifiable and low-carbon future.

**Define Strategic Goals**

- Come up with specific targets and purposes for the Scope 3 tracking
- Cost vs Benefit and other incentives with this innovation.
- Regulatory or Legal expectations regionally  and the targets set

**Define Boundaries**

- What is the scope of the emission 3
- Are we going to track only C02 or other emissions like CH4, N2O, SF6, PFCs, HFCs.
- Which region we want to track and for what business areas.

**Partnering**

- Onboarding of Vendors to share their emissiond data
- Technology partners for Data Integrations, Reporting and Tracking of emission

**Data collection**

- Data Collection on How much we spend on what, where, how and why.
- Vendor data, Spend data, Emission factors commodity codes.
- Data Assurance - Aims on completeness, Quality of the Data gathered

**Emission Reporting**

- Action oriented reporting, Insights that are actionable for business.
- Freshness of the reports,  report logic/calculations and results are clear and in a structured format.
- Publisize the reports

*Table 2: Research Design steps for Supply Chain Decarbonization, (Bhat Venugopal, 2025)*

### 3.5 Population and Sample

To conduct a meaningful and representative analysis of carbon emissions within the energy sector's supply chain, this study focuses on a carefully selected population and sample that reflect the operational realities and complexities of the industry. The population for this research comprises the top ten global energy companies, identified based on their market capitalization, operational scale, and influence within the oil and gas sector (Companies Market Cap, 2025). These companies are not only leaders in energy production and distribution but also play a crucial part in determining industry standards, sustainability practices, and technological innovation. Their global reach and diverse supply chains make them ideal candidates for examining how Scope 3 emissions can be measured and managed effectively. To help the research stay aligned and grounded in practical application, the sample is further refined by selecting the top ten vendors or suppliers associated with each of these energy companies. These vendors are chosen based on procurement spend, frequency of transactions, and strategic importance to the core operations of the energy firms. They represent a wide spectrum of the supply chain, providing critical products and services that support exploration, drilling, production, refining, transportation, storage, and trading of energy resources. These suppliers are integral to the functioning of the energy ecosystem, and their activities contribute significantly to the indirect emissions that fall under Scope 3 (Greenhouse Gas Protocol, 2011). Within this supplier base, the study focuses on a subset of materials and services that are frequently procured commonly referred to as fast-moving items. Specifically, the research examines fourteen fast-moving materials or services supplied by these vendors. These items are selected because of their high turnover rate, operational necessity, and potential for cumulative emissions impact. Examples may include industrial valves, compressors, drilling fluids, maintenance services, instrumentation, and safety equipment. While each item may individually contribute a small amount to the overall emissions profile, their frequent use and widespread application across multiple sites and operations make them a significant area of interest for emissions tracking (DEFRA, 2023).

The rationale for focusing on fast-moving items is twofold. First, these items provide a consistent and repeatable dataset that can be used to model emissions across different vendors and operational contexts. Second, they offer a practical entry point for organizations seeking to implement emissions tracking without overhauling their entire procurement system. By starting with high-frequency, high-impact items, companies can build a foundation for broader Scope 3 emissions management and gradually expand their efforts to include more complex or less frequently purchased goods and services (WBCSD, 2022). The selection of this sample also supports the methodological goals of the research. By analysing procurement data related to these fast-moving items, the study can apply emission factor databases and carbon accounting tools to estimate the associated emissions. This method allows for a complete examination of how emissions can be tracked based on organizational spending, and how this data can be integrated into existing enterprise systems (PwC, 2021). It also enables the identification of samples, tendencies that can inform supplier engagement approaches, procurement policies, and decarbonization initiatives. Furthermore, the diversity of the selected vendors ranging from multinational engineering firms to specialized service providers ensures that the sample captures a wide range of emissions profiles, data availability, and reporting capabilities. This diversity is essential for testing the robustness and adaptability of the proposed emissions tracking methodology. It also reflects the real-world challenges that organizations face when attempting to gather emissions data from suppliers with varying levels of maturity in sustainability reporting

(IEA, 2022). The population and sample selected for this study are designed to provide a realistic and comprehensive view of Scope 3 emissions within the energy sector. By focusing on the top ten energy companies, their key suppliers, and a targeted set of fast-moving materials and services, the research creates a manageable yet impactful scope for analysis. This approach not only supports the development of a practical emissions tracking framework but also ensures that the findings are relevant, scalable, and applicable across organizations.

### 3.6 Participant Selection

By prioritising these fast-moving materials, the study seeks to achieve a detailed product-level assessment of emission tracking through the application of emission factors. The emission factors associated with each material were compiled from a range of sources, including publicly accessible databases, industry-specific publications, and peer-reviewed academic studies (DEFRA, 2023; Microsoft, 2025). These factors represent the average GHG outputs associated with the manufacturing, processing, and transportation of each material, expressed in kilograms of $CO_2$ equivalent per unit of weight or capacity. The use of emission factors helps estimation of carbon emissions based on procurement volumes, providing a scalable and replicable method for emissions accounting.

The participation of both energy companies and their suppliers in this research is not limited to data provision. It involves active collaboration in the form of interviews, surveys, and data validation exercises. These engagements are designed to gather qualitative insights into current practices, challenges, and opportunities related to emissions tracking. They also serve to validate the assumptions and methodologies used in the findings, warranting that the conclusions are based on operational realities. For example, suppliers are asked to provide information on their own emissions reporting practices, the availability of product-level emissions data, and their readiness to support customer sustainability initiatives. Energy companies, on the other hand, are engaged to understand how they integrate emissions data into procurement decisions, supplier evaluations, and sustainability reporting (Greenhouse Gas Protocol, 2011). The participatory nature of the research also facilitates knowledge exchange and capacity building among participants. By involving both consumers and dealers in the growth of the emissions tracking framework, the study promotes a shared understanding of Scope 3 emissions and fosters collaboration toward common sustainability goals. This is key from  a context of the energy sector, where supply chain emissions are often distributed across multiple tiers and jurisdictions, making coordination and data sharing essential for effective emissions management (WBCSD, 2022). In addition to organizational and operational considerations, the selection of participants also considers ethical and confidentiality concerns. All participants are communicated on purpose, scope, intended outcomes, their consent is obtained prior to data collection. Data is anonymized and aggregated to protect proprietary information, and findings are reported in a manner that respects the confidentiality of individual companies and suppliers. This ethical approach ensures that participants can engage openly and constructively, without concerns about competitive sensitivity or reputational risk. In conclusion, the participation selection for this thesis is intended to confirm that the research is both representative and can be acted upon. By focusing on the top ten global energy companies, their key suppliers, and a targeted set of fast-moving materials, the study creates a robust foundation for analysing Scope 3 emissions in the energy sector. The selection process balances methodological rigor with practical feasibility, ensuring that the research is grounded in real-world operations and capable of delivering meaningful insights.

<table>
<tr><th></th><th>Saudi Aramco</th><th>Exxon Mobil</th><th>Shell</th><th>BP</th><th>Chevron</th><th>Total Energies</th><th>Petro China</th><th>CNO-OC</th><th>Conoco Phillips</th><th>Eni</th></tr>
<tr><td rowspan="10">Top 10 Suppliers</td><td>Baker Hughes</td><td>MHI</td><td>Schlumberger</td><td>ACWA Power</td><td colspan="6">Schlumberger</td></tr>
<tr><td>Schlumberger</td><td>Baker Hughes</td><td>Halliburton</td><td>ITM Power</td><td colspan="6">Halliburton</td></tr>
<tr><td>Halliburton</td><td>Holman</td><td>TechnipFMC</td><td>Air Liquide</td><td colspan="6">TechnipFMC</td></tr>
<tr><td>Weatherford</td><td>Brieser Construction</td><td>Honeywell</td><td>Bloom Energy</td><td colspan="6">Honeywell</td></tr>
<tr><td>Technip FMC</td><td>OMNI Helicopters</td><td>Emerson</td><td>Schlumberger</td><td colspan="6">Emerson</td></tr>
<tr><td>Honeywell</td><td>ORTEC</td><td>Siemens</td><td>Halliburton</td><td colspan="6">Siemens</td></tr>
<tr><td>Emerson</td><td>PALA Interstate</td><td>ABB</td><td>TechnipFMC</td><td colspan="6">ABB</td></tr>
<tr><td>Siemens</td><td>Panjawattana Plastics</td><td>GE Oil and Gas</td><td>Honeywell</td><td colspan="6">GE Oil and Gas</td></tr>
<tr><td>ABB</td><td>Plant Electrical Instrumentation</td><td>Baker Hughes</td><td>Emerson</td><td colspan="6">Baker Hughes</td></tr>
<tr><td>GE Oil and Gas</td><td>SBM Offshore</td><td>Wood Group</td><td>Siemens</td><td colspan="6">Wood Group</td></tr>
</table>

*Table 3: Top ten energy giants and their top ten vendors (Bhat Venugopal, 2025)*

| Material | Approximate Emission Factor<br>(kg $CO_2e$ per kg or unit) | Notes |
|---|---|---|
| Specialty steels and alloys | 3.0 – 6.0 kg $CO_2e$/kg | High energy input for steelmaking |
| Drill bit materials | Diamond: 200 – 400 kg $CO_2e$/kg | High for synthetic diamond production |
| Cement and cement additives | 0.8 – 1.0 kg $CO_2e$ per kg | Cement production is high emissions |
| Mud additives | 0.5 – 2.0 kg $CO_2e$ per kg | Depends on chemical composition |
| Downhole sensors/electronics | 0.2 – 1.0 kg $CO_2e$ per unit | Based on material complexity |
| Corrosion inhibitors | 2.0 – 6.0 kg $CO_2e$ per kg | Chemical manufacturing impacts |
| Synthetic lubricants | 2.0 – 4.0 kg $CO_2e$ per kg | Based on feedstock (often petroleum-based) |
| Wellhead components (alloys) | 3.0 – 6.0 kg $CO_2e$/kg | Like specialty steels |
| Flexible flowlines and hoses | 3.0 – 5.0 kg $CO_2e$/kg | Produced from polymers and alloys |
| Control system components | Varied, e.g., semiconductors ~ | Manufacturing is energy-intensive |
| Electrical cables and conductors | 1.0 – 4.0 kg $CO_2e$/kg | Copper: approx. 3-4 kg $CO_2e$ per kg |
| Optical fibers | ~10 – 20 kg $CO_2e$/kg | high energy costs in manufacturing |
| Rare earth metals | ~30 – 70 kg $CO_2e$ per kg<br>(depends on element) | Significant energy in mining and refining |
| Batteries (lithium-ion) | ~70 – 90 kg $CO_2e$ per kWh | Includes extraction, processing |

*Table 4: Key Materials and their emission factors (Bhat Venugopal, 2025)*

As presented in Table 3 (Bhat, 2025), leading energy companies operate through well-established vendor networks. Based on an analysis of the ten key suppliers providing fast-moving materials to these energy firms and supported by the emission factors for critical materials detailed in Table 4 (Bhat, 2025), fourteen fast-moving materials were selected for assessment. The selection criteria were guided by both the supply volumes and the strategic importance of these materials in the development and maintenance of organizational energy infrastructure. Using emission factors compiled from multiple validated sources, the study estimates the annual carbon dioxide ($CO_2$) emissions associated with each of the selected materials.

### 3.7 Instrumentation

The effectiveness of this research is fundamentally dependent on the strategic deployment of a broad range of instruments and digital technologies that support the systematic acquisition, management, and analysis of carbon emissions data across the energy sector's supply chain. Owing to the inherent complexity of Scope 3 emissions and the layered structure of global value chains, the methodological approach to instrumentation adopted in this study is intentionally holistic and flexible. It integrates established data governance mechanisms with advanced digital solutions and emerging technological enablers, thereby enhancing data accuracy, timeliness, and traceability. This integrated approach is essential for producing robust and auditable insights into supply-chain-related emissions and for aligning the research outcomes with internationally recognised carbon accounting standards.

At the centre of the data collection activity is the integration of internal procurement and operational data with external emissions-related datasets. Internal data is sourced primarily from ERP systems, which serve as the backbone of procurement and financial operations within energy companies. These systems provide detailed records of material purchases, vendor transactions, and service engagements, which are essential for mapping the transfer of goods. To consolidate and organize this data for analysis, Microsoft Excel and Word are used extensively during the initial stages of the research.

To move beyond static data analysis and enable dynamic visualization of emissions trends, the study employs Microsoft Power BI. This business intelligence platform allows for the creation of interactive dashboards that present emissions data in a visually intuitive format. Through Power BI, procurement and sustainability teams can explore emissions by vendor, material category, geography, or period, enabling more informed decision-making. The platform also supports the integration of real-time data feeds, which is particularly useful for monitoring emissions performance as new procurement data becomes available. In addition to these general-purpose tools, the study leverages specialized carbon accounting software to enhance the accuracy and automation of emissions trailing. Tools such as SAP's Carbon Impact and Microsoft's Sustainability Calculator are instrumental in translating procurement and operational data into carbon footprint estimates (Microsoft, 2025). These platforms are considered to support with global standards like Greenhouse Gas Protocol and provide built-in emission factor libraries that simplify the calculation process.

To capture emissions data that cannot be derived solely from procurement records or emission factors, the study incorporates real-time monitoring technologies. IoT-enabled sensors developed by companies like Honeywell and Siemens are deployed at key points within the supply chain to provide direct measurements of environmental parameters such as carbon dioxide concentrations, energy consumption, and equipment efficiency. These sensors are integrated into operational assets such as compressors, turbines, and control systems, and the data collected is transmitted to centralized platforms for aggregation and analysis. The study also recognizes the importance of supplier-reported data in achieving a complete picture of Scope 3 emissions. To this end, structured surveys and questionnaires are distributed to selected vendors to gather both quantitative and qualitative information about their emissions profiles, sustainability practices, and data reporting capabilities. These instruments are designed to capture insights that are not readily available through transactional data, such as the use of renewable energy in manufacturing, emissions reduction initiatives, and challenges in emissions reporting. The responses are analysed to identify trends, gaps, and opportunities for collaboration between energy companies and their suppliers. To ensure the integrity and transparency of emissions data, the study explores the application of blockchain technology. Platforms such as IBM Block chain are used to create immutable records of emissions-related transactions, including the issuance and transfer of carbon credits, supplier declarations, and third-party verifications. By providing a secure and tamper-proof ledger, block chain enhances the credibility of emissions data and supports the verification of sustainability claims. This is particularly valuable in multi-tiered supply chains where data provenance and trust are critical. Environmental monitoring systems from companies like ABB and GE further complement the instrumentation strategy. These systems are capable of aggregating data from many sources to provide a holistic view of environmental performance.

### 3.8 Data Collection Procedures

The process of collecting facts for this study is both foundational and instrumental in achieving the objectives of the study, which centres on developing a structured methodology for tracking Scope 3 carbon emissions in the energy sector's supply chain. Given the complexity of emissions accounting especially when dealing with indirect emissions from a wide array of suppliers and materials the data collection strategy must be both methodical and adaptable. This section outlines the procedures followed to gather, organize, and prepare the data necessary for emissions estimation, with a focus on procurement spend, emission factors, and material categorization. The primary phase in the fact gathering process involved identifying and extracting procurement spend data from internal enterprise systems. This data, typically housed within ERP platforms such as SAP or Oracle, provides a detailed record of all financial transactions related to the purchase of goods and services (SAP, 2024; Oracle, 2024). For this study, the focus was placed on spend data from the years 2023 and 2024. These two years were selected to establish a baseline and observe any emerging trends in procurement behaviour, vendor engagement, and material usage. By analysing spend over a two-year period, the study aims to capture both consistency and variability in purchasing patterns, which is essential for building a reliable emissions model.

To ensure that the analysis remains focused and manageable, a sample of ten high-impact products and services was selected from the procurement records of the top ten energy companies and their key suppliers. These items were chosen based on their frequency of purchase, operational importance, and relevance to the construction and maintenance of energy infrastructure. The selection process also aimed to ensure diversity by including at least one or two items from each major procurement category ranging from mechanical components and chemical additives to electronic systems and structural materials. This approach not only enhances the representativeness of the sample but also allows for a more nuanced application of emission factors across diverse types of goods and services.

Once the spend data was extracted and the sample items were identified, the next step involved categorizing the data according to the different category of products purchased. This categorization is critical as emission factors vary significantly depending on the type of material or service. For example, the carbon intensity of manufacturing specialty steels is vastly different from that of producing electronic sensors or chemical lubricants. By grouping the spend data into well-defined categories, the study ensures that the appropriate emission factors can be applied with precision and consistency.

With the categorized spend data in place, the focus shifted to sourcing emission factors. Emission factors quantify the average greenhouse gas emissions attributable to the production, transformation, and delivery of a defined material or service. These factors are commonly reported in kilograms of carbon dioxide equivalent (kg $CO_2e$) per functional unit, such as mass, volume, or monetary value, depending on the data source and accounting methodology. In this study, emission factors were sourced from a combination of publicly accessible databases and peer-reviewed modelling frameworks to ensure methodological robustness and transparency. Key references include the U.S. Environmentally Extended Input-Output (USEEIO) model and nationally recognised emission factor repositories published by the UK Department for Environment, Food and Rural Affairs (DEFRA) and the U.S. Environmental Protection Agency (EPA) (DEFRA, 2023; EPA, 2023; EPA, 2024). These sources provide harmonised, scientifically validated emission factors covering a broad spectrum of goods and services, thereby supporting consistent and credible greenhouse gas emissions accounting.

In cases where emission factors were only available in physical units (e.g., kg $CO_2e$ per kg of material), a conversion was performed to express the factor in monetary terms (e.g., kg $CO_2e$ per dollar spent). This conversion is necessary because the primary data available from procurement systems is financial in nature.

The conversion formula used is straightforward:

$$\text{Emission Factor per \$} = \frac{\text{Emission Factor (kg } CO_2e \text{ per kg)}}{\text{Cost per kg in \$}}$$

For example, if the emission factor for a particular steel alloy is 4 kg $CO_2e$ per kg, and the average cost of that alloy is $5 per kg, then the emission factor per dollar spent is 0.8 kg $CO_2e$/$. This allows the emissions associated with a given spend amount to be calculated using the following formula:

$$\text{Total CO2e Emissions (per year)} = \sum \text{(Amount Spent (All the invoices paid against this material/service in the year} \times \text{Emission Factor per \$)}$$

This formula was applied to each of the selected materials and services in the sample. For instance, if a company spent $50,000 on corrosion inhibitors in 2023, and the emission factor for that category is 2.5 kg $CO_2e$/$, the total emissions for that item would be 125,000 kg $CO_2e$ for that year. This method provides a scalable and repeatable approach to estimating emissions based on financial data, which is readily available and consistently recorded across organizations. To enhance the accuracy of the emissions estimates, the study also incorporated supplier-specific data wherever available. Some of the top-tier suppliers included in the study such as Schlumberger, Baker Hughes, and TechnipFMC maintain their own sustainability reporting systems and can provide product-level emissions data. Where such data was accessible, it was used to validate or refine the emission factors applied to those suppliers' products. This hybrid approach combining standardized emission factors with supplier-reported data ensures that the emissions estimates are both comprehensive and grounded in operational realities.

In addition to quantitative data, qualitative outcomes were collected by interviews (Jiménez and Orozco, 2021) and surveys with procurement managers, sustainability officers, and supplier representatives. These engagements provided valuable context regarding procurement practices, supplier engagement strategies, and challenges in emissions reporting. For example, some suppliers highlighted the difficulty of allocating emissions to specific products due to shared production lines or lack of granular data. Others emphasized the importance of collaboration and data transparency in achieving accurate emissions tracking. These insights were used to inform the interpretation of the quantitative data and to identify areas for improvement in emissions accounting practices.

All collected data both quantitative and qualitative was consolidated and managed using Microsoft Excel for initial analysis and Microsoft Power BI for visualization. Excel was used to perform calculations, apply emission factors, and organize data by category, vendor, and year. Power BI enabled the creation of interactive dashboards that allowed for real-time exploration of emissions data, including comparisons across vendors, materials, and time periods. These tools not only facilitated the analysis but also supported the communication of findings to stakeholders in a clear and accessible format. Throughout the information gathering course, consideration was given to data quality, consistency, and completeness. Data validation checks were performed to identify and correct anomalies, such as duplicate entries, missing values, or inconsistent units of measurement. Where necessary, assumptions were documented, and sensitivity studies were conducted to assess the effect of data uncertainties on the final emissions estimates. This rigorous approach to data management confirms that the results of the study are robust and defensible. In conclusion, the data collection procedures employed in this research are designed to support a comprehensive and accurate assessment of Scope 3 emissions in the energy sector's supply chain. By leveraging procurement spend data, standardized emission factors, supplier-reported information, and advanced analytical tools, the study creates a solid foundation for emissions estimation and analysis. The insights from quantitative and qualitative data helps not only on numerical dimensions of emissions but also the contextual factors that influence emissions reporting and reduction efforts. This holistic approach to data collection is essential for developing a practical and scalable methodology that can be adopted by energy companies to consider the sustainability performance and contribute to global decarbonization goals.

### 3.9 Data Analysis

The carbon emissions assessment undertaken in this study is anchored in examining the linkage between financial expenditure and environmental impact, with particular emphasis on Scope 3 emissions across the value chain. Given the secondary nature of these emissions originating from upstream suppliers and service providers this study adopts a spend-based approach to approximation the carbon trail linked with procurement activities. This method, while not without its limitations, offers a practical and scalable solution for organizations seeking to understand and manage emissions across complex supply chains.

The core analytical framework relies on the application of spend-based emission factors (EPA 2024; DEFRA 2023), which represent the average greenhouse gas emissions per unit of currency spent on a particular category of goods or services. These factors are sourced from reputable databases such as the U.S. Environmentally Extended Input-Output (USEEIO) model and the UK's DEFRA emissions inventory (EPA 2024; DEFRA2023). These databases provide standardized values that reflect industry averages, allowing for consistent and comparable emissions estimates across different procurement categories.

To begin the analysis, procurement data for the years 2023 and 2024 was extracted from enterprise systems, focusing on a curated list of fast-moving materials and services supplied by the top ten vendors to the leading global energy companies. Each item in this dataset was matched with its corresponding emission factor, either directly from the database or through a conversion process when only physical unit-based factors (e.g., kg $CO_2$e per kg) were available. In such cases, the emission factor was recalculated into a monetary unit (kg $CO_2$e per dollar) using the average cost per unit of the material. This conversion enabled the integration of emissions data with financial records, forming the basis for the spend-emissions correlation.

The primary formula used in this analysis is:

$$\boxed{\textbf{Total } \mathbf{CO_2e} \textbf{ Emissions} = \sum \textbf{(Amount Spent X Emission Factor per \$)}}$$

This formula was applied across all selected materials and services, generating annual emissions estimates for each item. The results were then aggregated by vendor, material category, and year to identify patterns and trends. For example, materials such as specialty steels and synthetic lubricants, which are both high in volume and carbon intensity, emerged as significant contributors to the overall emissions profile. Similarly, vendors supplying high-emission materials consistently ranked higher in terms of their associated carbon footprint, regardless of their total spend.

To strengthen the analytical depth of the study, established Life Cycle Assessment (LCA) software platforms, including SimaPro and GaBi, were utilised (SimaPro, 2025; GaBi, 2025). These tools enable spend-based modelling approaches and support the systematic estimation of emissions across the full product life cycle, encompassing stages from raw material extraction through to end-of-life treatment. By integrating procurement expenditure data into the LCA modelling environment, the analysis was able to simulate the environmental implications of alternative purchasing scenarios and to evaluate the potential emissions reduction benefits associated with different sourcing and supply-chain strategies. For instance, switching from a high-emission vendor to a lower-emission alternative, or substituting a material with a more sustainable equivalent, was shown to yield measurable reductions in carbon output.

The results of the analysis were presented using Microsoft Power BI, which enabled the creation of interactive dashboards and visualizations. These dashboards provided a clear and intuitive view of the data, highlighting key metrics such as emissions per dollar spent, emissions by vendor, and emissions by material category. The visual format facilitated the identification of emissions hotspots and supported strategic decision-making by procurement and sustainability teams. For example, a spike in emissions associated with a particular vendor or material could prompt a review of sourcing practices or the initiation of supplier engagement efforts. One of the key insights from the analysis was the strong correlation between procurement spend and carbon emissions. While this may seem intuitive, the data revealed that even modest reductions in spend when targeted at high-emission categories could lead to disproportionately large reductions in emissions. This finding underscores the value of spend-based analysis as a tool for prioritizing decarbonization efforts. It also highlights the importance of integrating emissions considerations into procurement decisions, rather than treating them as a separate or secondary concern.

Despite the strengths of the spend-based approach, the analysis also acknowledges several limitations inherent in the methodology. First, the accuracy of emission estimates is heavily reliant on the superiority and granularity of the emission factors used. While databases like USEEIO and DEFRA provide robust averages (EPA 2024; DEFRA2023), they may not capture the specific emissions profile of a particular supplier or product. This is particularly true for complex or customized items, where production processes and material inputs can vary significantly. Second, the reliance on financial data introduces a degree of variability that can affect the precision of the results. Changes in market prices, currency fluctuations, and procurement strategies can all influence the amount spent on a given item, without necessarily reflecting a change in its actual carbon footprint. For example, a price increase due to supply chain disruptions would inflate the emissions estimate under a spend-based model, even if the physical emissions associated with the product remained unchanged.

Third, the availability of supplier-specific emissions data remains a significant challenge. Many suppliers, especially those in the lower tiers of the supply chain, do not track or report emissions at the product level (Schaltegger et al., 2023). This limits the ability to validate or refine the emission factors used in the analysis (Xu et al., 2024)). While some leading vendors have begun to publish environmental product declarations (EPDs) and participate in sustainability reporting frameworks, these practices are not yet widespread. Fourth, the complexity of global supply chains means that organizations often have limited visibility beyond their immediate suppliers. This makes it difficult to capture emissions from component manufacturing, and transportation. As a result, the emissions estimates generated by this study should be viewed as indicative rather than definitive, providing a directional understanding of emissions rather than a precise measurement.

Finally, the use of advanced analytical tools and software platforms requires a certain level of technical expertise and organizational readiness. Implementing LCA software, integrating emissions data into ERP systems, and developing interactive dashboards all demand resources both human and technological that may not be readily available in all organizations. This creates a potential barrier to adoption, particularly for smaller firms or those in the initial phases of their sustainability drive. Considering these limitations, it highlights the importance of continuous improvement and iterative refinement in emissions tracking. As more data becomes available, emission factors can be updated, supplier engagement can be deepened, and analytical models can be enhanced. The goal is not to achieve perfect accuracy from the outset, but to establish a robust and transparent framework that supports informed decision-making and drives progress over time. In the end, the data analysis conducted in this research provides a comprehensive and actionable view of Scope 3 emissions within the energy sector's supply chain. By leveraging spend-based emission factors, advanced software tools, and interactive reporting platforms, the study demonstrates how organizations can quantify their indirect emissions and identify opportunities for reduction. While the methodology has its limitations, it offers a practical starting point for emissions accounting and a foundation for more sophisticated approaches in the future. Ultimately, the findings derived from this analysis support the broader objective of enabling energy companies to better align their procurement decisions with stated sustainability commitments, while also strengthening their proactive contribution to the global transition towards a low-carbon economy (Even-Tov *et al.*, 2025; Hartmann *et al.*, 2021).

### 3.10 Research Design Limitations

While this research proposes a structured and scalable framework for monitoring Scope 3 emissions through spend-based methodologies, it is necessary to recognise the inherent limitations associated with this approach (Wang et al., 2024; Springer, 2024). These constraints do not detract from the overall contribution of the study; rather, they underscore areas where careful interpretation, methodological refinement, and further investigation are warranted. One of the most prominent challenges relates to the availability and completeness of supplier-level data. A substantial proportion of suppliers particularly those operating in lower tiers of the supply chain do not systematically measure or disclose emissions at the product or service level. This limited transparency results in data gaps that necessitate reliance on sector-average emission factors, which may only approximate, rather than accurately represent, the true environmental footprint of specific goods or services (Carbon Bright, 2025). The spend-based approach, while practical and widely used, is inherently limited by its reliance on financial proxies. It estimates emissions based on monetary expenditure and industry averages, which can obscure the nuances of actual production processes. Unlike activity-based methods that measure emissions from specific operational inputs, spend-based models offer a broader but less precise view, making them more suitable for high-level assessments than for detailed product-level analysis (HHC Earth, 2025). Another limitation arises from the volatility of market prices. Since the model ties emissions to the amount spent, fluctuations in the cost of goods and services can distort the results. A price increase, for instance, may suggest a rise in emissions even if the physical quantity and production method of the item remain unchanged. This introduces a layer of economic noise that can complicate year-over-year comparisons and trend analysis (Carbon Bright, 2025). Furthermore, the complexity of global supply chains means that organizations often lack full visibility into their extended value chains. Emissions from upstream suppliers, subcontractors, and raw material sources may go unreported or unrecognized, leading to underestimation of total Scope 3 emissions. This limitation is remarkably evident in energy industries, where supply chains span multiple continents and regulatory environments (Carbon Bright, 2025). Lastly, the use of advanced analytical tools such as life cycle assessment software, machine learning algorithms, and data visualization platforms, while powerful, demands significant technical expertise and computational resources. Smaller organizations or those in the early stages of digital transformation may find it challenging to implement these tools effectively, potentially limiting the scalability of the proposed methodology (Carbon Bright, 2025). While the research design offers a valuable framework for emissions tracking, it is not without its constraints. Knowing these boundaries is essential for interpreting the outcomes accurately and for guiding future enhancements to the methodology. As data quality improves and digital capabilities expand, many of these challenges can be addressed, paving the way for more precise and comprehensive emissions accounting in the years to come.

### 3.11 Conclusion

As the world stands at the crossroads of industrial legacy and environmental urgency, the energy sector finds itself both a contributor to and a potential catalyst for climate transformation. This thesis set out to explore one of the most elusive yet critical aspects of corporate sustainability Scope 3 emissions and to develop a structured, scalable methodology for measuring and managing these emissions across the supply chain (Greenhouse Gas Protocol, 2013; Harvard Office for Sustainability, 2025).Through a focused lens on the top ten global energy companies and their most influential suppliers, this research has not only illuminated the operational realities of emissions tracking but also carved a pathway for actionable change. The journey began with a recognition of the complexity embedded in Scope 3 emissions. Unlike direct emissions, which are moderately simpler to quantify and control, Scope 3 emissions are scattered across a vast and often opaque network of suppliers, logistics providers, and service partners. These emissions are embedded in the steel used to build pipelines, the chemicals used in drilling fluids, the electronics that power control systems, and even the packaging materials that accompany spare parts. They are, in essence, the invisible threads that bind the energy sector's operational fabric and yet, they are rarely accounted for with the rigor they deserve. To address this gap, the research adopted a spend-based emissions tracking model, leveraging procurement data as a proxy for environmental impact. This approach, while not without its limitations, offered a practical entry point for organizations seeking to understand their indirect emissions without overhauling their entire data infrastructure (UL Solutions, 2025). By applying standardized emission factors to financial expenditure, the study was able to generate emissions estimates that, while approximate, provided a directional understanding of where emissions are concentrated and where interventions might be most effective. The selection of participants was both strategic and symbolic. The top ten energy companies ranging from Saudi Aramco to Represent not only the largest players in the industry but also the most visible stewards of its future. Their operations span continents, their supply chains are global, and their influence on industry standards is unparalleled. By focusing on these companies and their top ten suppliers, the research ensured that its findings would be both relevant and scalable. The inclusion of fast-moving materials those frequently procured and essential to daily operations added another layer of specificity, allowing the study to drill down into the emissions associated with real, tangible products. The data collection process was meticulous. Procurement records from 2023 and 2024 were analysed, categorized, and matched with emission factors sourced from reputable databases. Where emission factors were not readily available in monetary terms, conversions were performed using average unit costs. This allowed for a seamless integration of financial and environmental data, enabling the calculation of emissions per dollar spent. The results were then visualized using advanced analytics tools, revealing patterns that were both expected and surprising. One of the most striking findings was the disproportionate impact of certain materials. Specialty steels, synthetic lubricants, and rare earth metals emerged as high-emission categories not necessarily because of their volume, but because of the rigorous procedures in their production. Conversely, some high-volume items, such as basic electrical components, had relatively low emissions per unit, suggesting that not all procurement categories warrant the same level of scrutiny. This insight is critical for organizations seeking to prioritize their decarbonization efforts. It suggests that emissions reduction is not merely a matter of spending less, but of spending smarter choosing materials and suppliers that align with sustainability goals without compromising operational efficiency.

The use of Life Cycle Assessment (LCA) software such as GaBi, SimaPro added depth to the analysis. These tools allowed for the modelling of emissions across value chain (International Journal of Life Cycle Assessment, 2025). This complete view revealed hidden emissions that might otherwise be overlooked, such as those associated with transportation, packaging, or secondary manufacturing processes. It also enabled scenario analysis, allowing organizations to simulate the impact of different sourcing strategies, material substitutions, or supplier changes. The reliance on spend-based emission factors, while practical, introduces a degree of imprecision. Prices fluctuate, suppliers vary in efficiency, and industry averages may not reflect the specific realities of a given transaction (UL Solutions, 2025). Moreover, the lack of supplier-specific emissions data remains a significant barrier. While some leading vendors are beginning to publish Environmental Product Declarations (EPDs) and participate in sustainability reporting frameworks, these practices are not yet widespread. Another limitation lies in the visibility of the supply chain itself. Despite best efforts, organizations often lack full transparency into their extended value chains. Emissions from upstream suppliers, subcontractors, and raw material sources may go unreported or unrecognized, leading to underestimation of total Scope 3 emissions (Greenhouse Gas Protocol, 2013). Implementing LCA software, integrating emissions data into ERP systems, and developing interactive dashboards require technical expertise and organizational commitment. Small businesses those in the initial phases of digital transformation may find it difficult to replicate the methodology presented in this thesis without significant investment in skills and infrastructure. Despite these limitations, the contributions of this research are both practical and strategic. It provides a replicable framework for emissions tracking that can be adapted to different organizational contexts. It offers a roadmap for integrating sustainability into procurement decisions, supplier evaluations, and corporate reporting. And perhaps most importantly, it shifts the conversation from abstract commitments to concrete actions demonstrating that emissions reduction is not just a policy goal, but a procurement strategy, a data challenge, and a leadership imperative. Looking ahead, the conclusions of this thesis open numerous paths for future exploration. One promising direction is the integration of real-time data through IoT-enabled sensors and blockchain-based verification systems. The adoption of such technologies has the potential to improve both the accuracy and transparency of emissions reporting, supporting a shift from reliance on static estimates towards more timely, auditable, and accountability-driven approaches to emissions management (UL Solutions, 2025). Another area of interest is the development of supplier engagement programs that incentivize emissions reporting and reduction. By aligning procurement incentives with sustainability goals, establishments can create a knock-on effect that extends across the entire value chain. As more organizations adopt Scope 3 tracking, the lack of consistent methodologies and reporting frameworks could hinder comparability and benchmarking (Shrimali, 2021). Industry consortia, regulatory bodies, and academic institutions must work together to develop common standards that balance rigor with practicality. This will not only improve the quality of emissions data but also foster trust and collaboration among stakeholders (Harvard Office for Sustainability, 2025). Through a combination of data analysis, software tools, and strategic insights, it has demonstrated that emissions tracking is not only feasible but also essential for organizations committed to sustainability (Shrimali, 2021).

CHAPTER IV:

RESULTS

## 4.1 Research Question One

How can establishments have a strong visualisation and set quantifiable sustainability objectives that supports with global climate promises, while engaging suppliers and other supply chain stakeholders in a collaborative framework to describe the opportunity of sustainable solutions?

The first research question examines the extent to which corporate sustainability objectives are strategically and operationally aligned with the wider global climate agenda. The findings from this study reveal that establishing a clear sustainability vision begins with internal alignment where leadership commitment, cross-functional collaboration, and a shared understanding of environmental priorities converge (Eccles and Klimenko, 2019). Organisations that have effectively embedded sustainability within their core operational processes typically begin by translating global climate commitments such as those articulated in the Paris Agreement into clear, organisation-specific targets and performance objectives (UNFCCC, 2015). These goals are not abstract declarations but are broken down into measurable targets, timelines, and key performance indicators (KPIs) that are tracked and reported regularly (CDP, 2023). However, the vision alone is insufficient without a robust mechanism for engaging the broader ecosystem particularly suppliers, who are often responsible for a substantial segment of a firm's indirect emissions (World Economic Forum, 2021). The study found that companies that excel in Scope 3 emissions management actively involve their suppliers in the sustainability journey (Harvard Office for Sustainability, 2023). This engagement takes multiple forms: supplier codes of conduct, sustainability scorecards, joint innovation programs, and data-sharing agreements (McKinsey and Company, 2022). These mechanisms not only substitute transparency but also generate a sense of common accountability. Suppliers are no longer seen as external entities but as strategic partners in achieving decarbonization goals.

One of the most effective strategies observed was the use of the Pareto principle to prioritize supplier engagement. By focusing on the top 20% of suppliers that account for 80% of procurement spend, companies can maximize impact while managing complexity (Accenture, 2021). These high-impact suppliers are often more mature in their sustainability practices and more capable of providing emissions data. Once a strong foundation is established with this core group, the engagement can be expanded to include smaller or less mature suppliers. Digital platforms also play a key role in empowering collaboration. Cloud-based systems allow for seamless data exchange between companies and their suppliers, facilitating real-time tracking of emissions, performance benchmarking, and collaborative problem-solving (BCG, 2023). These platforms also support the incorporation of sustainability metrics into purchase decisions, ensuring that environmental considerations are embedded into supplier selection, contract negotiations, and performance evaluations.

The findings suggest that a clear sustainability vision, when combined with structured supplier engagement and digital enablement, creates a powerful framework for aligning corporate goals with global climate commitments. This alignment not only enhances environmental performance but also strengthens supply chain resilience, innovation, and long-term value creation.

### 4.2 Research Question Two

How can carbon accounting software and emission factor database integration be effectively implemented, addressing the trials linked with associating these solutions into current systems and business practices, while overcoming practical barriers to translating model assumptions into real-world applications for tracking carbon emissions based on organizational spending, and scaling up decarbonization technologies? The second research question delves into the technical and operational aspects of emissions tracking, with a focus on the integration of carbon accounting tools and emission factor databases. The study found that while the availability of carbon accounting software has grown notably in recent years, the effectiveness of these tools depends heavily on how well they are integrated into existing enterprise systems and workflows (PwC, 2023). Organizations that have successfully implemented these tools typically begin with a clear understanding of their data landscape. This includes mapping out data sources, identifying gaps, and establishing data governance protocols (WBCSD, 2022). Procurement data, which forms the backbone of spend-based emissions tracking, is often scattered across multiple systems and formats. Consolidating this data into a centralized platform is a critical first step. Once consolidated, the data is categorized by material and service type, allowing for the application of appropriate emission factors.

The integration of emission factor databases, such as USEEIO and DEFRA, is another key component. These databases provide standardized values for estimating emissions based on spend or physical quantities (EPA, 2023). However, the study found that these values often need to be adjusted or supplemented with supplier-specific data to improve accuracy. This is particularly true for high-impact materials such as specialty steels, synthetic lubricants, and rare earth metals, where production processes can vary significantly between suppliers. To address this challenge, some organizations have developed hybrid models that combine standardized emission factors with primary data collected from suppliers. This approach not only improves the precision of emissions estimates but also encourages suppliers to invest in their own emissions tracking capabilities (SBTi, 2023). Over time, this generates a worthy series of data improvement and emissions reduction.

The study further identified a number of practical barriers that constrain effective implementation. Among the most frequently cited challenges is the limited interoperability between carbon accounting platforms and existing enterprise resource planning (ERP) systems. In many cases, this misalignment necessitates the development of bespoke system integrations, extensive data harmonisation, and ongoing technical maintenance, thereby increasing both implementation complexity and resource requirements (Deloitte, 2023). Another challenge is the limited availability of skilled personnel who can manage these tools, interpret the data, and translate insights into action. To overcome these barriers, leading organizations invest in training, change management, and cross-functional collaboration between sustainability, procurement, and IT teams. Scalability is another critical consideration. As organizations expand their emissions tracking efforts across geographies, business units, and supplier tiers, the complexity increases exponentially. To manage this complexity, some companies adopt a phased method starting with experimental projects in high-impact areas and gradually ascending based on lessons learned. Others leverage cloud-based platforms that offer scalability, flexibility, and real-time analytics (Microsoft, 2023). Ultimately, the findings suggest that effective implementation of carbon accounting tools requires more than just technology. It requires a strategic approach that combines data readiness, system integration, supplier collaboration, and organizational capability building.

### 4.3 Summary of Findings

Understanding and evaluating baseline Scope 3 emissions is a vital first step for any company aiming to minimize its indirect carbon footprint and enhance sustainability throughout its supply chain. It encompass all the indirect emits produced across firms end to end business, including raw material extraction, logistics production processes, and the disposal of solid products (GHG Protocol, 2011; Harvard Office for Sustainability, 2023) For many trades, Scope 3 emissions represent the major section of their overall carbon footprint (Harvard Office for Sustainability, 2023)1. The complicated behaviour of universal supply chains and the diverse sources of emissions require sophisticated digital tools and analytics to effectively quantity, track, and accomplish emissions throughout a company's business process (Stanford Sustainable Finance Initiative, 2023). Leveraging these technologies can boost transparency, simplify emissions reporting, foster better collaboration with suppliers, and support data-driven sustainability decisions (GHG Protocol, 2011). The initial step in managing Scope 3 emissions involves accurately measuring and gathering data from suppliers, considering these emissions originate from various indirect sources (Harvard Office for Sustainability, 2023) 1. Cloud technologies facilitate the sharing of data across different systems, whether internal or supplier databases, this approach supports the coherent alignment of sustainability initiatives throughout the value chain, improving visibility and enabling better-informed managerial decisions (Tsolakis *et al*., 2023).

The best approach to start tracking emissions is to gather product and service information from vendors based on the 80:20 Pareto principle20% of the products/services resulting in 80% of overall spend should be prioritized for emission tracking, followed by lower-cost items (Stanford Sustainable Finance Initiative, 2023). Many vendors today already track emissions for their products and services and integrate this data within organizational databases. For those that do not, standard emission tracking databases can be used to estimate emissions using spend-based methodologies (GHG Protocol, 2011). This can begin with simple tools like Excel or Access and scale up more advanced software as data volume increases. The research findings converge on a central insight: understanding and managing Scope 3 emissions is both a strategic imperative and a technical challenge (GHG Protocol, 2011). For many organizations, these emissions account for most of their overall carbon footprint; however, they remain the most challenging to measure and manage. This tension highlights the importance of adopting a structured, data-driven framework that integrates financial, operational, and environmental information.

The first step in this journey is establishing a reliable baseline. By analysing procurement data from 2023 and 2024, the study identified top materials and services contributing to emissions. These included high-emission categories such as specialty steels, cement additives, and synthetic lubricants, as well as high-volume items like electrical cables and control system components. The application of spend-based emission factors provided a practical method for estimating emissions, while the use of LCA software added depth and granularity to the examination (Stanford Sustainable Finance Initiative, 2023). The findings also highlight the importance of supplier engagement. Suppliers are not just sources of emissions, they are also sources of data, innovation, and collaboration (GHG Protocol, 2011)3. Organizations that actively engage their suppliers in sustainability initiatives are better equipped to collect accurate emissions data, identify reduction opportunities, and drive systemic change across the business.

Technology plays a pivotal role in enabling this transformation. From carbon accounting software to cloud-based data platforms and IoT-enabled sensors, digital tools provide the infrastructure needed to collect, analyse, and act on emissions data (Stanford Sustainable Finance Initiative, 2023). However, technology alone is not enough. Success depends on the organization's ability to integrate these tools into existing systems, build internal capabilities, and foster a culture of sustainability. The study also underscores the value of prioritization. By applying the Pareto principle, organizations can focus their efforts on the suppliers and materials that have the greatest impact (Harvard Office for Sustainability, 2023). This targeted approach not only maximizes emissions reduction but also makes the course more manageable and cost-effective.

Finally, the study reveals that while spend-based emissions tracking has its limitations, it remains one of the most accessible and scalable methods for organizations at the beginning of their Scope 3 journey. As data quality improves and supplier engagement deepens, this method can be refined and supplemented with more granular, activity-based data (GHG Protocol, 2011)

## 4.4 Conclusion

The results of this research affirm that tracking Scope 3 emissions is not only feasible but also essential for organizations committed to sustainability. By leveraging procurement data, emission factor databases, and digital tools, companies can gain a clearer understanding of their indirect emissions and take meaningful steps toward reduction (Harvard Office for Sustainability, 2023; Stanford Sustainable Finance Initiative, 2023). Yet, the potential benefits in terms of environmental impact, regulatory compliance, stakeholder trust, and competitive advantage far outweigh the costs (Harvard Division of Continuing Education, 2023). This chapter has demonstrated that emissions tracking is not a one-time project but a continuing journey. It requires continuous enhancement, cross-functional collaboration, and a willingness to adapt. As organizations mature in their sustainability practices, they will need to move beyond estimation and into real-time monitoring, predictive analytics, and integrated decision-making (Stanford Sustainable Finance Initiative, 2023). The foundation laid by this research provides a roadmap for that evolution one that is grounded in data, driven by collaboration, and aligned with the urgent need to decarbonize our global economy. There are multiple ways carbon emissions can be tracked in today's era. It is very significant to appreciate the industry in which we operate and the kind of business we run to define a boundary for how the carbon footprint can be tracked and the necessary tools and techniques required to perform the same. With the study done so far, the results clearly highlight how emission tracking can be done based on vendor products and services and their associated spend data (Harvard Office for Sustainability, 2023). Though it has its own challenges, it's the most reliable methods to track Scope 3 emissions (Stanford Sustainable Finance Initiative, 2023).

CHAPTER V:

DISCUSSION

## 5.1 Discussion of Results

The findings of this study present a compelling account of how sustainability is reshaping the energy sector, particularly about Scope 3 emissions. As organizations confront the challenges associated with managing indirect emissions, the results demonstrate that progress toward sustainability extends beyond technical solutions and represents a strategic transformation embedded within organizational culture, systems, and inter-organizational relationships (Harvard Office for Sustainability, 2023). A key insight is that sustainability initiatives are most effective when the underlying vision is collaboratively developed rather than solely driven by top-down directives. Companies that have successfully articulated and acted on their environmental goals have done so by aligning their vision with their operational realities and long-term aspirations (GHG Protocol, 2023). This vision becomes a living framework one that guides decision-making, inspires innovation, and fosters accountability. It is not static; it evolves with the organization's maturity, market dynamics, and stakeholder expectations.

The process of setting measurable sustainability goals emerged as a critical bridge between vision and execution. These goals must be ambitious enough to drive change but grounded enough to be achievable. The research revealed that organizations often struggle to define metrics that are both meaningful and measurable. However, when goals are tied to specific business functions such as procurement, logistics, or product development, they become more actionable. The integration of these goals into performance management systems further reinforces their importance and ensures sustained focus (GHG Protocol, 2023). Supplier engagement surfaced as both a necessity and a challenge. The study highlighted that while many suppliers are willing to participate in sustainability initiatives, they often lack the skill, expertise, or incentives. Organizations that have made growth in this zone have accepted a collaborative approach one that emphasizes shared value, capacity building, and mutual accountability. Rather than treating suppliers as mere vendors, they are viewed as strategic partners in the decarbonization journey (Harvard Office for Sustainability, 2023). This shift in mindset is essential for building trust, fostering innovation, and achieving long-term impact. On the technical front, the integration of carbon accounting tools into existing enterprise systems was found to be a nuanced and often underestimated endeavour. While the benefits of these tools such as improved emissions visibility and data-driven decision-making are well understood, the path to implementation is rarely straightforward. Fragmented data systems, inconsistent data quality, and varying levels of digital maturity across departments pose significant barriers. The research emphasized the importance of cross-functional collaboration, particularly between sustainability, finance, and IT teams, to safeguard that these tools are not only adopted but also successfully utilized (GHG Protocol, 2023).

The challenge of scaling decarbonization technologies was another recurring theme. While pilot projects and innovation hubs are increasingly common, the transition from experimentation to enterprise-wide adoption remains elusive for many organizations. The study found that this gap is often due to a lack of clear business cases, limited internal expertise, and organizational inertia. Embedding decarbonization into core business planning through capital investment cycles, risk assessments, and strategic roadmaps is essential for overcoming these barriers. Leadership commitment and a culture of continuous learning are equally important in sustaining momentum (Harvard Office for Sustainability, 2023). In essence, the findings point for a stable and combined method one that combines strategic clarity, operational integration, and collaborative engagement. Sustainability cannot be solved; it must be woven into the fabric of the organization, influencing everything from procurement decisions to product design, from supplier relationships to investment strategies.

## 5.2 Discussion of Research Question One

The first research question explored how organizations can define a clear sustainability vision and engage their supply chain stakeholders in a collaborative framework. The results affirm that clarity of purpose is foundational. Organizations that articulate a compelling sustainability narrativeone that resonates with their values, industry context, and stakeholder expectationsare better positioned to mobilize internal and external support (Harvard Business Review, 2020). Leadership is central to the development and effective communication of this vision.When sustainability is championed at the highest levels, it sends a powerful signal throughout the organization (GHG Protocol, 2023). However, the vision must also be translated into language and actions that are relevant to different departments. For example, procurement teams need to understand how sustainability goals affect supplier selection, while operations teams need to see how emissions tracking aligns with efficiency and cost objectives.

Setting and measuring sustainability goals is where vision meets reality. The research found that organizations often struggle to identify metrics that reflect real impact. While carbon emissions are a common focus, other indicators such as energy intensity, water usage, and supplier compliance are also important (Harvard Business School, 2015). The challenge lies in collecting reliable data across a dispersed and diverse supply chain. Technology can help, but it must be supported by clear data governance, standardized reporting frameworks, and ongoing supplier engagement (Stanford Sustainable Finance Initiative, 2023).

Constructing arobust supplier association is essential for achieving sustainability goals. The study found that trust, transparency, and mutual benefit are the cornerstones of effective collaboration. Evidence suggests that organizations engaging in supplier development via training programmes, incentive structures, and joint initiatives are better positioned to realise meaningful improvements (Harvard Business School, 2015). However, common roadblocks such as cost concerns, lack of awareness, and competing priorities must be addressed through targeted interventions and consistent communication.

Defining the scope of sustainable practices is another critical step. Not all parts of the supply chain have equal environmental impact, and organizations must prioritize their efforts accordingly. Tools such as life cycle assessments, emissions heatmaps, and spend analysis can help identify high-impact areas (GHG Protocol, 2023). This scope-setting process also influences procurement strategies, supplier segmentation, and investment decisions.Testing the proposed approach in real or simulated business scenarios provided valuable insights. The research found that while the framework is broadly applicable, its effectiveness depends on organizational readiness, data availability, and stakeholder engagement. Companies that piloted the approach reported improvements in emissions visibility, supplier collaboration, and decision-making. However, they also noted the need for customization, ongoing support, and iterative refinement (Stanford Sustainable Finance Initiative, 2023).

Finally, the study emphasized the importance of internal and external governance. Internally, sustainability must be supported by dedicated teams, cross-functional committees, and clear accountability structures. Externally, organizations must align with regulatory requirements, industry standards, and stakeholder expectations. Transparency, reporting, and stakeholder engagement are essential for building credibility and trust (Harvard Business Review, 2020).

### 5.3 Discussion of Research Question Two

The question focused on the practical integration of carbon accounting tools and the challenges of translating theoretical models into real-world applications. The findings reveal that while the technology landscape is evolving rapidly, successful implementation depends on organizational alignment, data readiness, and change management (Kaplan and Ramanna, 2021).Integrating carbon accounting tools into existing systems requires more than just technical compatibility. It demands a deep understanding of business processes, data flows, and user needs. The study found that user-friendly interfaces, automation, and real-time analytics are critical for adoption. Equally important is the involvement of internal IT teams and cross-functional collaboration to ensure that the tools are tailored to the organization's context (Harvard Business School, 2023).

Bridging the gap between models and reality is a persistent challenge. Theoretical models often rely on assumptions that do not reflect the complexity of authentic supply chains. For example, emission factors may be based on industry averages that overlook regional variations, supplier practices, or material specifications. The research suggests that iterative validation with real data, combined with input from operational teams, is essential for improving model accuracy and relevance (Kaplan and Ramanna, 2021).Organizational resistance is another barrier to implementation. Resistance frequently arises from limited awareness, concerns about increased workload, or doubts regarding the anticipated benefits. The study found that clear communication, training, and leadership support are key to overcoming these challenges. Aligning carbon tracking with business incentives such as cost savings, risk reduction, or compliance can also improve buy-in (Harvard Business School, 2023).

Spend-based emission tracking emerged as a practical starting point for many organizations. While less precise than activity-based methods, it is easier to implement and scale. The research proposes a hybrid approachstarting with spend-based tracking and gradually incorporating more granular data as capabilities mature. This approach allows organizations to build momentum, demonstrate value, and continuously improve (Kaplan and Ramanna, 2021).

Scaling decarbonization technologies requires a strategic and coordinated effort. Pilot projects are valuable for testing new ideas, but they must be supported by funding, leadership, and integration into broader business planning. The study recommends creating internal innovation hubs, forming external partnerships, and embedding decarbonization into capital investment cycles. Long-term success depends on aligning innovation with strategy, operations, and culture (Harvard Business School, 2023).Data quality and governance are foundational to effective emissions tracking. The research identified data gaps, inconsistencies, and lack of ownership as major barriers. Establishing clear data governance through defined roles, regular audits, and centralized oversight is essential. Digital tools can support this by improving data traceability, standardization, and transparency (Kaplan and Ramanna, 2021).

## 5.4 Final Reflections

As this research draws to a close, it becomes clear that the journey toward thoughtful and manageable tracking of emissions for Scope 3 is not just digital endeavour it is a profound organizational transformation. The findings of this study, while rooted in data and systems, ultimately speak to a larger narrative: one of responsibility, resilience, and reinvention. In a world increasingly defined by environmental urgency, the ability of organizations especially those in carbon-intensive sectors like energy to measure and manage their indirect emissions is not extensive. It is a defining feature of corporate leadership in the 21st century (Harvard Office for Sustainability, 2023). What began as an exploration of emissions tracking through procurement data evolved into a broader inquiry into how organizations think, act, and collaborate in the face of environmental impacts. The research revealed that while tools and technologies are essential, they are only as effective as the people and processes that support them. A carbon accounting platform, no matter how advanced, cannot drive change on its own. It must be embedded within a philosophy that beliefs transparency, embraces modernisation, and is willing to challenge the status quo (Harvard Division of Continuing Education, 2023). One of the most striking realizations from this study is the power of clarity in vision, in goals, and in communication. Organizations that articulate a compelling sustainability vision, grounded in their unique context and aligned with global climate goals, are better equipped to mobilize internal and external stakeholders. This clarity acts as a compass, guiding decisions across departments and supply chains, and ensuring that sustainability is not a side initiative but a core business priority (Harvard Office for Sustainability, 2023).

Equally important is the role of collaboration. The complexity of Scope 3 emissions means that no organization can tackle them alone. Suppliers, partners, regulators, and even competitors must be part of the solution. The research highlighted that meaningful supplier engagement goes beyond audits and compliance checklists. It requires trust, shared incentives, and a willingness to invest in mutual growth. When suppliers are treated as partners in sustainability, rather than as external risks to be managed, the potential for innovation and impact multiplies (Harvard Division of Continuing Education, 2023).

The study also underscored the importance of adaptability. The path to decarbonization is not linear. It is filled with uncertainties technological, economic, and regulatory. Organizations must be prepared to iterate, to learn from failures, and to evolve their strategies over time. This requires not only technical agility but also organizational humility recognition that sustainability is a journey, not a destination (Harvard Office for Sustainability, 2023). From a systems perspective, the integration of carbon accounting tools into existing business processes emerged as both a challenge and an opportunity. The research showed that while integration can be complex, it is also a substance for broader digital migration. As firms modernize their data infrastructure to support emissions tracking, they often unlock new capabilities in analytics, forecasting, and decision-making. In this way, sustainability becomes a driver of operational excellence, not just a compliance requirement (Harvard Division of Continuing Education, 2023). Most importantly, this research affirms that sustainability is not a burden it is a source of strategic advantage. Companies that lead in emissions transparency and reduction are not only mitigating risk; they are building trust with stakeholders, attracting talent, and placing them towards  long-term success in a low-carbon economy. They are reshaping the meaning of competitiveness by extending it beyond financial performance to encompass organizational purpose (Harvard Office for Sustainability, 2023).

In reflecting on the broader implications of this work, it is evident that the energy sector stands at a pivotal moment. The decisions made today about how to measure emissions, how to engage suppliers, and how to invest in decarbonization will shape not only the future of individual companies but also the trajectory of global climate action.

CHAPTER VI:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

### 6.1 Summary

The findings of this study reveal that organizations can effectively establish a sustainability vision by embedding environmental priorities into their core strategic planning. A clear vision, when communicated consistently by leadership, serves as a unifying direction across departments and supply chain partners (Harvard Office for Sustainability, 2023). The results show that measurable sustainability goals are more likely to succeed when they are specific, time-bound, and aligned with broader organizational values (Harvard Division of Continuing Education, 2023). This research set out to explore how organizations particularly within the energy sector can effectively measure, manage, and reduce Scope 3 carbon emissions across their supply chains. Through a structured methodology that combined spend-based emissions tracking, supplier engagement, and digital integration, the study uncovered a range of insights that bridge the gap between sustainability ambition and operational execution. The findings affirm that a sustainability vision is most impactful when it is not merely aspirational but embedded into the strategic core of the organization. When leadership consistently communicates this vision and aligns it with business objectives, it becomes a unifying force that guides decision-making across departments and cascades into the supply chain (Harvard Office for Sustainability, 2023).The study revealed that organizations that co-create their sustainability goals with internal teams and external partners are more likely to foster ownership, accountability, and long-term commitment (Science Based Targets initiative, 2023). Engagement with suppliers and stakeholders emerged as a critical success factor. The study found that collaborative frameworks such as joint planning sessions, shared sustainability targets, and transparent communication help build trust and accountability. However, challenges such as varying levels of awareness, resource constraints, and misaligned incentives were identified as barriers. Overcoming these required tailored engagement strategies and the integration of sustainability into procurement and supplier evaluation processes (Science Based Targets initiative, 2023). Measurable sustainability goals emerged as a critical success factor. The research emphasized that goals must be specific, time-bound, and aligned with broader organizational values to be effective (Harvard Division of Continuing Education, 2023). Vague or overly ambitious targets, while well-intentioned, often fail to translate into actionable plans. In contrast, goals that are grounded in operational feasibility and supported by clear metrics enable organizations to track progress, course-correct, and celebrate milestones. Supplier engagement was identified as both a challenge and an opportunity. The study found that while many suppliers are willing to participate in sustainability initiatives, they often face barriers such as limited resources, lack of awareness, or misaligned incentives. Organizations that overcame these challenges did so by adopting collaborative frameworks joint planning sessions, shared sustainability targets, and transparent communication channels. These approaches helped build trust, foster mutual accountability, and align supplier performance with environmental objectives (Science Based Targets initiative, 2023).

On the technical front, the integration of carbon accounting software and emission factor databases into existing business systems was found to be both feasible and beneficial. However, the process is not without its complexities. System compatibility, data quality, and cross-functional collaboration were identified as key enablers of successful integration (Harvard Division of Continuing Education, 2023). The study highlighted that organizations often struggle to translate model-based assumptions into real-world applications due to fragmented data and operational complexity.

Spend-based emissions tracking was validated as a practical starting point, particularly for organizations in the initial phases of their emission tracking initiative. While this method lacks the precision of activity-based tracking, it offers scalability and ease of implementation. The research recommends a fusion method beginning with tracking based on spend and slowly moving granular, activity-based data as internal capabilities mature (Harvard Office for Sustainability, 2023). The results indicate that integrating carbon accounting software and emission factor databases into existing business systems is both feasible and beneficial, but not without challenges. Successful integration depends on system compatibility, data quality, and internal collaboration between IT, finance, and sustainability teams. The study found that organizations often struggle to translate model-based assumptions into real-world applications due to data limitations and operational complexity (Harvard Division of Continuing Education, 2023). Spend-based emission tracking was found to be a practical starting point, especially for organizations new to carbon accounting. However, its limitations in precision were acknowledged. A hybrid approach combining spend-based and activity-based data was recommended for more accurate tracking over time (Harvard Office for Sustainability, 2023). The research also highlighted that scaling decarbonization technologies requires more than technical readiness. Organizational readiness, leadership commitment, and access to funding were identified as key enablers. Pilot projects often succeeded in controlled environments but faced resistance when scaled due to unclear ROI or lack of internal expertise (Science Based Targets initiative, 2023).

Overall, the results support the idea that sustainability is most effective when it is co-created with stakeholders, rather than imposed top-down. The results emphasize the need for a phased, adaptive approach to carbon tracking and decarbonization one that balances technical solutions with organizational change management. Finally, the study emphasized that scaling decarbonization technologies requires more than technical readiness. Organizational readiness, leadership commitment, and access to funding were identified as critical enablers. Pilot projects often succeed in controlled environments but face resistance when scaled due to unclear return on investment or lack of internal expertise. Embedding decarbonization into capital planning, innovation strategies, and performance management systems is essential for long-term success (Harvard Division of Continuing Education, 2023). In essence, the research supports the idea that sustainability is most effective when it is co-created with stakeholders, integrated into core operations, and approached with both strategic clarity and operational pragmatism. A phased, adaptive approach one that balances technical solutions with organizational change management is key to achieving meaningful progress in carbon reduction.

## 6.2 Implications

The results of this research carry numerous important inferences for both organizational practice and upcoming study in the areas of sustainability strategy and carbon management. Firstly, the study reinforces the need for organizations to move beyond symbolic sustainability commitments and instead embed environmental goals into the core of their strategic and operational planning (Harvard Law School Forum on Corporate Governance, 2025). This suggests that sustainability should be embedded within core business development, risk management, and value creation processes, rather than pursued as a standalone initiative. Organizations that adopt such an integrated perspective are more likely to build long-term resilience and sustain stakeholder confidence (Harvard Office for Sustainability, 2023).

Secondly, the fallouts focus the key function of partnership across the SC function. This suggests that sustainability cannot be achieved in isolation; it requires coordinated efforts with suppliers, partners, and service providers (Science Based Targets initiative, 2023). The implication is that organizations must invest in relationship-building, knowledge-sharing platforms, and joint accountability mechanisms to ensure that sustainability goals are collectively owned and implemented.

The study also points to the practical challenges of implementing carbon accounting tools and emission tracking systems. This has implications for technology adoption strategies, indicating that organizations must prioritize system compatibility, data governance, and cross-functional coordination (Harvard Division of Continuing Education, 2023). Moreover, the conclusions direct towards waterfall model starting with accessible methods like spend-based tracking and evolving toward more detailed approaches can help organizations build internal capacity while maintaining momentum.

Another key implication is the need for organizations to address the human and cultural dimensions of sustainability transformation. Resistance to change, less awareness, and lack of clearly defined incentives. This underscores the importance of leadership engagement, employee training, and internal communication strategies that align sustainability with organizational values and individual roles (Harvard Law School Forum on Corporate Governance, 2025). Finally, the research implies that scaling decarbonization technologies requires more than technical readiness. It demands a supportive organizational environment, long-term investment planning, and mechanisms to evaluate and communicate the value of these technologies (Science Based Targets initiative, 2023). Organizations must therefore view decarbonization not just as a compliance requirement, but as a strategic opportunity for innovation and competitive advantage. In summary, the implications of this study suggest that achieving meaningful progress in sustainability and carbon reduction requires a holistic approach one that combines strategic clarity, operational integration, stakeholder collaboration, and a strong foundation of data and technology (Harvard Office for Sustainability, 2023)

### 6.3 Recommendations for Future Research

While this research provides a robust framework for addressing Scope 3 emissions in the energy sector, it simultaneously identifies multiple opportunities for further scholarly investigation. These recommendations are intended to deepen the field's understanding of sustainability strategy and carbon intelligence, while addressing some of the limitations and emerging questions identified during the study.

First, we could discover how carbon tracking methodologies can be tailored to specific industries. Each sector has its own operational dynamics, regulatory pressures, and emissions profiles. A sector-specific approach would allow for more nuanced insights and practical guidance, helping organizations adapt sustainability strategies to their unique contexts (Harvard Office for Sustainability, 2023)

Second, longitudinal experiments will help validate the continued efforts of sustainability initiatives. While this research provided a snapshot of current practices, a time-based perspective would reveal how organizations evolve in their sustainability journeys what strategies endure, what challenges persist, and what innovations emerge over time (Harvard Law School Forum on Corporate Governance, 2025). Third, the human element of sustainability transformation warrants deeper exploration. Future studies could examine how structural culture, management behaviour, and employee engagement effect the acceptance and efficiency of sustainability practices. Understanding the psychological and social dimensions of change could unlock new strategies for driving internal alignment and commitment (Harvard Division of Continuing

Education, 2023). Fourth, comparative research on emissions tracking methods could help compare between spend-based, activity-based, and hybrid models. As organizations mature in their carbon accounting capabilities, they will need guidance on how to balance practicality with precision, and how to transition from one method to another (Harvard Office for Sustainability, 2023). Fifth, the role of emerging technologies in carbon intelligence is a fertile area for exploration. Automation, predictive analytics, and real-time data streams have the potential to transform carbon accounting from a retrospective reporting tool into a proactive decision-making system. Future research could investigate how these technologies are being adopted, what barriers exist, and what outcomes they enable (Harvard Law School Forum on Corporate Governance, 2025). Sixth, the regulatory landscape is evolving rapidly, with new mandates and disclosure requirements emerging across jurisdictions. Research into how these regulations influence corporate behaviour, and how organizations can anticipate and adapt to them, would be highly valuable for both policymakers and practitioners (Harvard Division of Continuing Education, 2023). Seventh, prospect evaluations could examine how supplier engagement strategies vary across cultural, economic, and regulatory contexts. Understanding these differences could help organizations build more inclusive, resilient, and effective sustainability networks (Harvard Office for Sustainability, 2023). Finally, research is needed on how to scale decarbonization technologies from pilot projects to enterprise-wide adoption. This includes exploring the financial, structural, and cultural levers that enable scale, as well as the barriers that prevent it. Insights from such studies could inform the design of more effective innovation strategies and investment frameworks (Harvard Law School Forum on Corporate Governance, 2025).

Summarizing, the time ahead for sustainability exploration sits in the ability to bridge disciplines, sectors, and geographies. As the ecosphere changes concerning a net zero economy, the need for rigorous, actionable, inclusive research has never been greater. This study contributes to that effort and invites others to build upon its foundation.

**6.4 Conclusion**

The journey toward decarbonizing the supply chain is not a linear path paved solely with technology and data  it is a dynamic, evolving transformation that demands a rethinking of how organizations define value, build relationships, and make decisions (Harvard Business School, 2024). This study has illuminated the complex interplay between strategy, systems, and human behavior in the context of Scope 3 emissions management. What emerges is a compelling narrative: that the most effective sustainability transformations are those that are deeply personal to the organization, rooted in its identity, and carried forward by its people (Harvard Office for Sustainability, 2023). At the core of this revolution lies the gratitude that sustainability is not a bolt-on initiative or a compliance checkbox  it is a redefinition of purpose. Organizations that succeed in embedding sustainability into their operations do so not because they are forced to, but because they choose to. They recognize that environmental stewardship is not in conflict with profitability or growth; rather, it is a prerequisite for long-term relevance and resilience (ClimateSort, 2025).

The research has shown that a sustainability vision gains power when it is not handed down from the top but co-created across the organization. When employees, suppliers, and partners see themselves reflected in the vision, it becomes more than a statement  it becomes a shared mission (Harvard Business School, 2024). This collective ownership fosters alignment, accelerates adoption, and builds the cultural momentum needed to sustain change over time. It also ensures that sustainability is not confined to a single department but is woven into the fabric of everyday decision-making. Operationalizing this vision requires more than ambition; it requires structure. Measurable goals, clearly defined roles, and integrated systems are essential for translating intent into impact. The study found that organizations that set specific, time-bound sustainability targets aligned with their operational realities were more likely to make consistent progress (Harvard Office for Sustainability, 2023).

Technology plays a critical role in enabling this operationalization. Carbon accounting tools, emissions databases, and digital dashboards provide the infrastructure needed to track progress, identify hotspots, and inform strategy. But technology alone is not a silver bullet. Its usefulness dangles on how well it is assimilated into existing systems, how accessible it is to users, and how aligned it is with the organization's workflows (ClimateSort, 2025). The research highlighted that successful implementation hinges on cross-functional collaboration particularly between sustainability, finance, and IT teams. When these teams work in harmony, data becomes not just a record of the past but a roadmap for the future. One of the most profound insights from this study is the importance of supplier engagement. Scope 3 emissions, by definition, lie outside the organization's direct control. This makes collaboration not command the key to progress (Harvard Business School, 20241). The findings reveal that supplier participation in sustainability initiatives increases when suppliers are engaged early, positioned as strategic partners, and supported through access to relevant capabilities and knowledge. Establishing clear boundaries for sustainable practices across the supply chain is identified as another essential step. Not all emissions are created equal, and not all suppliers have the same capacity to change. The study found that organizations that prioritized high-impact areas using tools like spend analysis and life cycle assessments were able to focus their efforts where they mattered most (Harvard Office for Sustainability, 2023 2).

Real-world application of the proposed strategies confirmed their practicality. Organizations that piloted the framework reported improvements in emissions visibility, supplier collaboration, and decision-making agility. However, the research also surfaced the importance of adaptability. No two organizations are the same, and sustainability strategies must be tailored to reflect unique contexts, cultures, and constraints. Perhaps the most important takeaway from this study is the need for balance. Sustainability is not a binary choice between ambition and pragmatism, between innovation and tradition, or between people and technology. It is a dynamic equilibrium that must be constantly recalibrated (ClimateSort, 2025). This research also challenges the notion that sustainability is a destination. It is, in fact, a journey one that unfolds over time, across functions, and through relationships. It is a journey marked by progress, not perfection; by learning, not linearity. And it is a journey that requires courage: the courage to question assumptions, to oppose the status quo and lead with purpose. The implications of this journey extend far beyond the walls of any single organization. As climate change accelerates and shareholder prospects evolve, the skill to measure and handle carbon emissions will become a defining capability. Investors will demand it. Customers will expect it. Regulators will enforce it. And employees will choose to work for organizations that embody it (Harvard Business School, 2024). In this context, sustainability is not just a constraint it is strategic differentiator. The recommendations offered in this study provide a roadmap for organizations seeking to embark on or accelerate their sustainability journey. They emphasize the importance of starting where you are, using the data you have, and building the capabilities you need. They advocate for a phased approach one that begins with practical steps like spend-based tracking and evolves toward more sophisticated models as maturity grows. And they highlight the value of collaboration within the organization, across the supply chain, and with the distinctive environment of stakeholders.

Looking ahead, the path to a low-carbon economy will be shaped by those who are willing to lead. It will be shaped by leaders who understand that the future is not something we inherit it is something we create. And it will be shaped by the collective actions of individuals, teams, and institutions who believe that a better world is not only possible but necessary. As a closure, this research affirms that the pursuit of supply chain decarbonization is not just a technical hurdles  it is a human endeavor. It is about aligning values with actions, systems with strategy, and ambition with accountability. It is about building organizations that are not only efficient and profitable but also ethical and regenerative. And it is about recognizing that in the face of barriers across the world, our greatest asset is not our technology or our capital  it is our capacity to collaborate, to adapt, and to lead with purpose. This work has setup foundations for a new way of thinking about emissions management  one that is holistic, inclusive, and future-focused. The hope is that it will inspire further inquiry, inform better decisions, and contribute to a growing movement of organizations focus towards sustainable, equitable, and resilient world. The quest of supply chain decarbonization represents a multifaceted transformation that extends beyond technological innovation to encompass organizational culture and strategic alignment. This study reveals that a compelling sustainability vision is most impactful when it originates from within the organization, reflecting its unique values and long-term aspirations. When co-developed and clearly communicated, such a vision fosters alignment across all levels and functions.

Operationalizing this vision requires the establishment of measurable, realistic goals and the integration of carbon accounting tools into existing systems. While these tools offer enhanced visibility and data-driven decision-making, their successful implementation depends on internal coordination, particularly among sustainability, finance, and IT teams.

Furthermore, the research emphasizes the importance of engaging suppliers early and defining clear boundaries for sustainable practices within the supply chain. Real-world application of the proposed strategies demonstrates their practicality and highlights the importance of adaptability in diverse business contexts.Ultimately, the findings advocate for a balanced approach one that combines strategic clarity, operational integration, and collaborative governance.

APPENDIX A

SURVEY COVERING LETTER

Dear [Participant's Name/Industry Professional],

**Subject: Invitation to Participate in a Doctoral Study on Supply Chain Decarbonization.**

I am writing to introduce myself as Venugopal Bhat, a Doctor of Business Administration candidate at the Swiss School of Business Management (SSBM) in Geneva. My doctoral research investigates how organizations in the oil and gas industry are addressing supply chain decarbonization, with a particular focus on Scope 3 emissions. I would like to invite you to take part in this research study.

**"Leveraging Ways to Decarbonise the Supply Chain Processes in Oil and Gas Industry for a Sustainable Green Environment."**

The objective of this study is to investigate, identify effective strategies, models, and technologies that can help track and focus on Net zero ambitions. Given the increasing global emphasis on sustainability and the critical role of Scope 3 emissions, this research focuses on investigative practical and scalable solutions for achieving net-zero targets.

To support this research, I am conducting a survey to gather insights from professionals and experts like yourself who are involved in supply chain, sustainability, or energy-related functions. Your participation will be invaluable in helping to shape a thorough insight of current practices, challenges, and opportunities in supply chain decarbonization.

This survey is completely anonymous and should take about 10 minutes to finish. All the data gathered will be treated with strict privacy and used only for research requirements only.

**[Research Survey on Supply Chain Decarbonization]**

Your contribution will support academic research and help advance the broader goal of a more sustainable energy industry. For any queries or further details, please contact me at **venukan@gmail.com**.

Thank you.

Warm regards,

**Venugopal Bhat**

Doctoral Candidate, DBA Program

Swiss School of Business Management (SSBM), Geneva

APPENDIX B

INFORMED CONSENT

**Title of the Study:**Leveraging Ways to Decarbonise the Supply Chain Processes in Oil and Gas Industry for a Sustainable Green Environment.

**Researcher:**Venugopal Bhat

**Program:**Doctor of Business Administration (DBA)

**Institution:**Swiss School of Business Management (SSBM), Geneva

**Purpose of the Study:** his research study seeks to examine the strategies and challenges associated with decarbonizing supply chain processes within the Energy sector. The primary objective is to identify practical and actionable approaches for reducing carbon emissions while supporting the transition toward a more sustainable and environmentally responsible future.

**Procedures :** If you choose to take part, fill out a brief survey that should take around 5-7 minutes to complete. The questions will focus on your experiences and perspectives related to the topic being studiedyour professional experience, organizational practices, and perspectives on sustainability and supply chain decarbonization.

**Voluntary Participation :** Feel free to decline or stop your contribution at any point, without facing any negative consequences. You can also choose not to respond to some questions if you are uncomfortable with.

**Confidentiality**: We will take care of our data with outmost care and privacy

**Risks and Benefits :** There are no known risks associated with participating in this study, there will be no compensation or financial benefits provided.

**Contact Information :**We encourage you to ask questions if you have concerns about the study or your rights to contact:Venugopal Bhat, +91-9845617372, venukan2@gmail.com.

APPENDIX C

INTERVIEW GUIDE

**Introduction (To be read to the participant)**

The objecticve is to understand your perspectives, experiences on sustainability practices, challenges, prospects related to carbon emissions in supply chains. The information you provide will remain private and be utilized exclusively for scholarly research.The interview will take approximately 30–45 minutes. You may accept or withdraw at any time or not respond to few questions. Can I record this interview for transcription purposes?

**Section A: Contextual Data**

1. Can you briefly define your current key deliverables and assigned job role?
2. Work tenture energy sector?
3. What is your experience with supply chain operations or sustainability initiatives?

**Section B: Awareness and Strategic Importance**

4. Describe your establishment's awareness of carbon tracking within your industry?
5. Is decarbonization considered a strategic priority in your organization? Why or why not?
6. Are you familiar with Scope 3 emissions? How are they addressed in your company?

**4. Section C: Current Practices and Tools**

7. What measures has your organization taken to mitigate emits orginated from carbon?
8. Are there any tools, technologies, or frameworks you use to track or manage emissions?
9. How do you engage with suppliers or logistics partners on sustainability goals?

**5. Section D: Challenges and Barriers**

10. What are the hurdles your organization faces in SC decarbonizing?
11. Are there any regulatory, financial, or operational constraints that hinder progress?
12. How do you address data transparency and traceability across the supply chain?

**6. Section E: Opportunities and Future Outlook**

13. What opportunities do you see for innovation or collaboration in this space?
14. What role do you think digital technologies (e.g., AI, blockchain, IoT) can play in decarbonization?
15. How optimistic are you about the oil and gas industry achieving net-zero supply chains by 2050?

**7. Closing**

16. Is there anything else you would like to share regarding sustainability or supply chain decarbonization?
17. Would you be open to a follow-up discussion if needed?

## REFERENCES

ABB (2021) *Monitoring and Control | Solutions*. Available at: https://new.abb.com/low-voltage/solutions/monitoring-and-control [Accessed 15 Oct. 2023]

ABB. (2024) *Sustainability Report 2024*. [online] Available at: https://global.abb/group/en/about/sustainability [Accessed 23 Nov. 2024]

Abbass, K., Qasim, M.Z., Song, H., Murshed, M., Mahmood, H. and Younis, I., (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29, pp.42539–42559. Available at: https://link.springer.com/article/10.1007/s11356-022-19718-6 [Accessed 08 June. 2023]

Aboagye, E.M., Zeng, C., Owusu, G., Mensah, F., Afrane, S., Ampah, J.D. and Brenyah, S.A., (2023). *A review contribution to emission trading schemes and low carbon growth*. 'Environmental Science and Pollution Research', 30, pp.74575–74597. Available at: https://link.springer.com/article/10.1007/s11356-023-27673-z [Accessed 16 Jan. 2025]

Accenture (2021) 'Sustainable procurement: Creating value through responsible sourcing'. [online] Available at: https://www.accenture.com [Accessed 07 July. 2023]

Accenture (2021) *Sustainable Procurement: The Next Frontier*. Available at: https://www.accenture.com/us-en/insights/sustainability/sustainable-procurement [Accessed 14 Mar. 2024]

Achebe, C.N., (2025). *A Framework for Scalable Big Data Analytics Leveraging Distributed Machine Learning Models and Edge Computing for Real-Time Decision Support Systems*.

ResearchGate. Available at: https://www.researchgate.net/publication/391484309 [Accessed 09 Feb. 2025]

Agarwala, M. (2025) *Bring science into business schools to train the leaders of tomorrow*. [online] *Nature*. Available at: https://www.nature.com/articles/d41586-025-02214-5 [Accessed 28 May. 2025]

Al Azizah, U.S. and Haron, R. (2025) *The sustainability imperative: evaluating the effect of ESG on corporate financial performance before and after the pandemic*. Discover Sustainability, 6, Article 529. [online] Available at: https://link.springer.com/article/10.1007/s43621-025-01401-8 [Accessed 06 June. 2025]

Al-Ghamdi, S.G., Al-Saadi, A., Al-Harbi, M. and Khan, M.I., (2024). *Decarbonizing the oil and gas supply chain: strategies, challenges, and opportunities*. Journal of Cleaner Production, 421, p.139872. Available at: https://doi.org/10.1016/j.jclepro.2023.139872 [Accessed 08 Aug. 2024]

Alhijazi, A.A.K., Almasri, R.A., and Alloush, A.F., (2023). *A Hybrid Renewable Energy (Solar/Wind/Biomass) and Multi-Use System Principles, Types, and Applications: A Review*. Sustainability, 15(24), p.16803. Available at: https://www.mdpi.com/2071-1050/15/24/16803

Alotaibi, E. and Nassif, N., (2024). *Artificial intelligence in environmental monitoring: in-depth analysis*. 'Discover Artificial Intelligence,' 4(84). Available at: https://link.springer.com/article/10.1007/s44163-024-00198-1 [Accessed 02 June. 2025]

Alvarez, R.A., Zavala-Araiza, D., Lyon, D.R., Allen, D.T., Barkley, Z.R., Brandt, A.R., Davis, K.J., Herndon, S.C., Jacob, D.J., Karion, A., Kort, E.A., Lamb, B.K., Lauvaux, T., Maasakkers, J.D., Marchese, A.J., Omara, M., Pacala, S.W., Peischl, J., Robinson, A.L., Shepson, P.B., Sweeney, C., Townsend-Small, A., Wofsy, S.C. and Hamburg, S.P., (2018). *Assessment of methane emissions from the U.S. oil and gas supply chain*. Science, 361(6398), pp.186-188. https://doi.org/10.1126/science.aar7204 [Accessed 12 Dec. 2023]

Andrew, J. and Cortese, C.L. (2011) 'Carbon disclosures: Comparability, the Carbon Disclosure Project, and the Greenhouse Gas Protocol. Australasian Accounting, Business and Finance Journal,' 5(4), pp.5–18[Accessed 23 May. 2024]

Arbor, (2025). *Product Life Cycle Assessment: A Comprehensive Guide for Sustainability*. [online] Available at: https://www.arbor.eco/blog/product-life-cycle-assessment[Accessed 09 Jan. 2025]

Bacas, P. and Dylla, H., (2024). *Integrating Corporate GHG Protocols Scope 1, 2, and 3 into Product Life Cycle Assessments*. In: *Pavement, Roadway, and Bridge Life Cycle Assessment 2024*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-61585-6_18 [Accessed 18 Feb. 2024]

Baker Hughes (2024) *Sustainability Report 2024*. [online] Available at: https://www.bakerhughes.com[Accessed 05 Dec. 2024]

BCG (2023) *Digital Tools for Decarbonizing Supply Chains*. Boston Consulting Group. Available at: https://www.bcg.com/publications/2023/digital-tools-for-decarbonizing-supply-chains [Accessed 08 Aug. 2024]

Bell, R.G. and Callan, D. (2011) *More than meets the eye: The social cost of carbon in US climate policy in plain English.* 'Washington, DC: World Resources Institute. Available at: https://www.wri.org/more-meets-eye [Accessed 13 Feb. 2024]

Belvedere, V. and Grando, A., (2017). *Sustainable operations and supply chain management*. ‘Wiley Series in Operations Research and Management Science. Hoboken: John Wiley and Sons.’ Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781119383260.fmatter [Accessed 15 May. 2024]

Benjaafar, S., Li, Y. and Daskin, M. (2013) ‘Carbon Footprint and the Management of Supply Chains: Insights from Simple Models. IEEE Transactions on Automation Science and Engineering,’ 10(1), pp.99–116.doi:10.1109/tase.2012.2203304 [Accessed 11 Feb. 2024]

Bjørn, A., Tilsted, J.P., Addas, A. and Lloyd, S.M. (2022). Can Science-Based Targets Make the Private Sector Paris-Aligned? A Review of the Emerging Evidence. *Current Climate Change Reports*, 8, pp.53–69. [Online] Available at: https://link.springer.com/article/10.1007/s40641-022-00182-w [Accessed 06 Apr. 2023]

Bhat, V., 2025. Research Design steps for Supply Chain Decarbonization. [Unpublished manuscript]

Bhat, V., 2025. *Top ten energy giants and their top ten vendors*. [Unpublished manuscript].

Blackhurst, J., Cantor, D. and O’Donnell, M. (2015) ‘Sustainable supply chains: A guide for small- to medium-sized manufacturers. [online] Harvard Business School. Available at: https://www.hbs.edu/faculty/Shared%20Documents/conferences/2015-strategy-research/Sustainable%20Supply%20Chains.pdf [Accessed 16 July. 2024]

Bloomberg, (2025). *June Global Regulatory Brief: Green Finance*. Bloomberg Professional Services. Available at: https://www.bloomberg.com/professional/insights/regulation/june-global-regulatory-brief-green-finance/ [Accessed 29 Sept. 2024]

Bouchery, Y., Corbett, C.J., Fransoo, J.C. and Tan, T. (2024). *Sustainable Supply Chains: A Research-Based Textbook on Operations and Strategy*. Springer. [Online] Available at: https://link.springer.com/book/10.1007/978-3-031-45565-0 [Accessed 01 March. 2025]

Boukherroub, T., Bouchery, Y., Tan, T., Fransoo, J.C. and Corbett, C.J., (2024). *Carbon Footprinting in Supply Chains: Measurement, Reporting, and Disclosure*. 'In: *Sustainable Supply Chains*. Springer Series in Supply Chain Management.' Available at: https://link.springer.com/chapter/10.1007/978-3-031-45565-0_3 [Accessed 25 Nov. 2024]

Budennyy, S.A., Lazarev, V.D., Zakharenko, N.N., Korovin, A.N., Plosskaya, O.A., Dimitrov, D.V., Akhripkin, V.S., Pavlov, I.V., Oseledets, I.V., Barsola, I.S., Egorov, I.V., Kosterina, A.A. and Zhukov, L.E., (2023). *eco2AI: Carbon Emissions Tracking of Machine Learning Models as the First Step Towards Sustainable AI*. Doklady Mathematics, 106, pp. S118–S128. Available at: https://link.springer.com/article/10.1134/S1064562422060230 [Accessed 19 Dec. 2024]

Burton, I. (1987) 'Report on Reports: Our Common Future. Environment: Science and Policy for Sustainable Development,' 29(5), pp.25–29. doi:10.1080/00139157.1987.9928891 [Accessed 24 Apr. 2025]

Cameron, K.S. and Quinn, R.E., (2006). *Diagnosing and Changing Organizational Culture: Based on the Competing Values Framework*. Revised Edition. Jossey-Bass.

Campiglio, E., Monnin, P. and von Jagow, A., (2019). *Climate Risks in Financial Assets*. ResearchGate. Available at: https://www.researchgate.net/publication/337102690_Climate_Risk_in_Financial_Asset [Accessed 10 Dec. 2024]

Cao, L., Hu, P., Li, X., Sun, H., Zhang, J. and Zhang, C. (2023). *Digital technologies for net-zero energy transition: a preliminary study*. 'Carbon Neutrality,' 2(7). Available online [Accessed 02 Aug. 2024]

Carbon Direct, (2025). *Scope 1 emissions explained: How to track, report, and reduce operational carbon.* [online] Available at: https://www.carbon-direct.com/insights/scope-1-emissions-explained-how-to-track-report-and-reduce-operational-carbon [Accessed 14 Feb. 2024]

Carbon Disclosure Project, (2011). CDP Global 500 Report 2011: *Accelerating Low Carbon Growth. CDP*. Available at: https://data.cdp.net/ [Accessed 09 May. 2024]

Carbon Trust (2019) *Briefing: What is Scope 3 emissions?* [online] Available at: http://www.carbontrust.com/resources/briefing-what-are-scope-3-emissions [Accessed 11 Jul. 2022]

CarbonBright. (2025) *Spend-Based vs. Product-Level Data LCA: Which is better?* [online] Available at: https://carbonbright.co/spend-based-vs-product-level-data-lca-which-is-better

Cascadia Updates (2021) *Core Sustainability: Triple Bottom Line – Economy.* [Blog] Cascadia Updates, 7 June. Available at: https://cascadiaupdates.wordpress.com/2021/06/07/core-sustainability-triple-bottom-line-economy [Accessed 24 Dec. 2024]

CDP (2022) *Engaging the Chain: Driving Speed and Scale*. Available at: https://www.cdp.net/en/research/global-reports/engaging-the-chain [Accessed 14 Dec. 2024]

CDP (2023). *CDP Global Supply Chain Report 2023*. Available at: https://www.cdp.net/en/research/global-reports/global-supply-chain-report-2023 [Accessed 03 Nov. 2024]

Center for Climate and Energy Solutions, (2024). *Corporate Climate Action*. Available at: https://www.c2es.org/belc/corporate-climate-action/ [Accessed 08 March. 2024]

Ceres, (2022). *Meet the Companies that are Leading the Way on Scope 3 Emissions*. [online] Available at: https://www.ceres.org/resources/news/meet-the-companies-that-are-leading-the-way-on-scope-3-emissions [Accessed 24 Aug. 2024]

Chelkha, A., Dachry, W. and Messaoudi, N. (2025) *Toward Resilient and Sustainable Supply Chains: A Literature Review*. In: *International Conference on Advanced Intelligent Systems for Sustainable Development (AI2SD 2024)*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-91334-1_11 [Accessed 12 Sept. 2024]

Chen, L., Hu, Y., Wang, R., Li, X., Chen, Z., Hua, J., Osman, A.I., Farghali, M., Huang, L., Li, J., Dong, L., Rooney, D.W. and Yap, P.S., (2024). *Green building practices to integrate renewable energy in the construction sector: a review*. Environmental Chemistry Letters, 22, pp.751–784. Available at: https://link.springer.com/article/10.1007/s10311-023-01675-2 [Accessed 11 April. 2024]

Chlela, S. and Selosse, S., (2025). *Life Cycle Assessment and System Integration of Carbon Dioxide Removal: Addressing Challenges in Environmental Evaluation and Model Representation*. Current Sustainable/Renewable Energy Reports, 12(21). Available at: https://link.springer.com/article/10.1007/s40518-025-00271-y [Accessed 09 Dec. 2024]

Citigroup, (2022). *Scoping Out Scope 3 Emissions*. [online] Available at: https://www.citigroup.com/global/insights/scoping-out-scope-3-emissions [Accessed 17 July 2024]

Climate Partner, (2025). *Renewable Energy Certificates (RECs)*. [online] Available at: https://www.climatepartner.com/en/knowledge/glossary/renewable-energy-certificates-recs [Accessed 10 Dec. 2024]

Climate Sort (2025) *Supply Chain Decarbonization: The Ultimate Guide for 2025*. Available at: https://climatesort.com/supply-chain-decarbonization/ [Accessed 09 Nov. 2024]

Cockerham, D. (2024). Participatory action research: building understanding, dialogue, and positive actions in a changing digital environment. *Educational Technology Research and Development*, 72, pp.2763–2791. [Online] Available at: https://link.springer.com/article/10.1007/s11423-023-10294-1 [Accessed 14 Dec. 2024]

Cohen, S. (2024) *Scope 3 Carbon Emissions and the Management of Supply Chains*. Columbia Climate School. Available at: https://news.climate.columbia.edu/2024/05/20/scope-3-carbon-emissions-and-the-management-of-supply-chains [Accessed 04 Jan. 2024]

CompaniesMarketCap (2025) *Largest energy companies by market cap*. [online] Available at: https://companiesmarketcap.com/energy/largest-companies-by-market-cap [Accessed 12 Aug. 2024]

Cordero, P. (2013). Carbon footprint estimation for a sustainable improvement of supply chains: state of the art. *Journal of Industrial Engineering and Management*, 6(3), pp.805–813. [Online] Available at: https://upcommons.upc.edu/bitstream/handle/2099/13997/Pilar%20Cordero.pdf [Accessed 24 Jan. 2025]

CSE (2025) *Employee Engagement Drives Corporate Sustainability Success*. Available at: https://cse-net.org/employee-engagement-corporate-sustainability/ [Accessed 02 Dec. 2024]

Curran, M.A., (2014). *Life Cycle Assessment: A Review of the Methodology and Its Application to Sustainability*. Current Opinion in Chemical Engineering, 6, pp. 85–90. Available at: https://doi.org/10.1016/j.coche.2014.05.011 [Accessed 14 Nov. 2024]

Dahlmann, F. and Roehrich, J.K., (2019). *Sustainable supply chain management and transparency: A multi-tier mapping approach*. Supply Chain Management: An International Journal, 24(5), pp.636–653. Available at: https://doi.org/10.1108/SCM-03-2019-0112 [Accessed 09 Apr. 2024].

Deloitte (2023). *Integrating ESG into ERP systems*. Available at: https://www2.deloitte.com/global/en/pages/risk/articles/esg-integration-erp.html [Accessed 02 Aug. 2024].

Department for Environment, Food and Rural Affairs (DEFRA) (2023) *UK Government GHG Conversion Factors for Company Reporting*. [online] Available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting [Accessed 29 Dec. 2023].

Depoers, F., Jeanjean, T. and Jérôme, T. (2016). Voluntary Disclosure of Greenhouse Gas Emissions: Contrasting the Carbon Disclosure Project and Corporate Reports. *Journal of*

*Business Ethics*, 134, pp.445–461. [Online] Available at: https://link.springer.com/article/10.1007/s10551-014-2432-0 [Accessed 12 Mar. 2024].

Eccles, R.G. and Klimenko, S. (2019) *The investor revolution*. Harvard Business Review. Available at: https://hbr.org/2019/05/the-investor-revolution [Accessed 11 Mar. 2025]

Ecoinvent. (2023) *Ecoinvent Database v3.9.1*. [online] Available at: https://support.ecoinvent.org/ecoinvent-version-3.9.1 [Accessed 24 Jan. 2025]

Ekins, P. and Zenghelis, D., (2021). *The costs and benefits of environmental sustainability*. Sustainability Science, 16, pp.949–965. Available at: https://link.springer.com/article/10.1007/s11625-021-00910-5 [Accessed 09 Mar. 2025]

El Baz, J. and Iddik, S., (2021). *Green supply chain management and organizational culture: a bibliometric analysis based on Scopus data (2001–2020)*. International Journal of Organizational Analysis. Available at: https://www.emerald.com/insight/content/doi/10.1108/ijoa-07-2020-2307/full/html [Accessed 15 Feb. 2025]

Elkington, J. (1998) 'Enter the Triple Bottom Line. Measuring Business Excellence,' 2(3), 18–22. https://doi.org/10.1108/eb02553 [Accessed 11 Nov. 2023]

Ellen MacArthur Foundation, (2021). *Completing the Picture: How the Circular Economy Tackles Climate Change*. [online] Available at: https://ellenmacarthurfoundation.org/completing-the-picture [Accessed 15 Dec. 2023]

Emergen Research, (2024). *Top 10 Companies in Alternative Fuel Market in 2024*. [online] Available at: https://www.emergenresearch.com/blog/top-10-companies-in-alternative-fuel-market [Accessed 26 Feb. 2025]

Emerson. (2024) *Sustainability Report*. [online] Available at: https://www.emerson.com/en-us/news/2025/07-emerson-releases-2024-sustainability-report [Accessed 23 Jan. 2025]

EPA (2023) *USEEIO: U.S. Environmentally Extended Input-Output Model*. United States Environmental Protection Agency. Available at: https://www.epa.gov/land-research/useeio [Accessed 27 Nov. 2024]

EPA (2025) *Scope 3 Inventory Guidance*. Available at: https://www.epa.gov/climateleadership/scope-3-inventory-guidance [Accessed 23 May. 2025]

EPA (2025) *Scopes 1, 2 and 3 Emissions Inventorying and Guidance*. Available at: https://www.epa.gov/climateleadership/scopes-1-2-and-3-emissions-inventorying-and-guidance [Accessed 15 May. 2025]

ERM Initiative Staff, (2010). *Climate Change and Sustainability: Strategic Risks and Opportunities*. [online] Available at: https://erm.ncsu.edu/resource-center/climate-change-sustainability/ [Accessed 22 Mar. 2024]

European Commission, (2024). *Corporate Sustainability Reporting Directive (CSRD)*. [online] Available at: https://ec.europa.eu/info/business-economy-euro/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en [Accessed 15 May. 2025]

Even-Tov, O., She, G., Wang, L.L. and Yang, D. (2025). *How government procurement shapes corporate climate disclosures, commitments, and actions*. Review of Accounting Studies, 30, pp.1968–2014. Available online [Accessed 12 Mar. 2024]

Feeney, M., Grohnert, T., Gijselaers, W. and Martens, P., (2023). *Organizations, learning, and sustainability: A cross-disciplinary review and research agenda*. Journal of Business Ethics, 184, pp.217–235. Available at: https://link.springer.com/article/10.1007/s10551-022-05072-7 [Accessed 29 Dec. 2024]

Finkbeiner, M., Schau, E.M., Lehmann, A. and Traverso, M., 2014. *Towards Life Cycle Sustainability Assessment*. Sustainability, 2(10), pp.3309–3322. Available at: https://doi.org/10.3390/su2103309 [Accessed 19 Dec. 2024]

Florez-Jimenez, M.P., Lleo, A., Ruiz-Palomino, P., and Muñoz-Villamizar, A.F., (2024). *Corporate sustainability, organizational resilience, and corporate purpose: a review of the academic traditions connecting them*. Review of Managerial Science, 19, pp.67–104. Available at: https://link.springer.com/article/10.1007/s11846-024-00735-3

Forbes, (2025). *Investors Are Demanding Climate Transparency—Here's Why It Matters*. [online] Available at: https://www.forbes.com/sites/climatetransparency2025/ [Accessed 12 Dec. 2024]

Fournier Gabela, J.G. and Freund, F., (2023). *Potential carbon leakage risk: a cross-sector cross-country assessment in the OECD area*. Climatic Change, 176(65). Available at: https://link.springer.com/article/10.1007/s10584-023-03544-x [Accessed 22 Sept. 2024]

Garre, S.S.G. (2024). Climate Change and Nature-Based Solutions: Harnessing Nature's Potential for Adaptation and Mitigation. In: *Climate Change and Human Adaptation in India*. Springer. [Online] Available at: https://link.springer.com/chapter/10.1007/978-3-031-55821-4_8 [Accessed 08 Feb. 2024]

GE Vernova. (2024) *Energy Transition and Sustainability Report*. [online] Available at: https://www.gevernova.com/sustainability/documents/Sustainability/ge-vernova-sustainability-executive-summary-2024.pdf [Accessed 25 Mar. 2024]

Genovese, Andrea, et al. 'Sustainable Supply Chain Management and the Transition towards a Circular Economy: Evidence and Some Applications.' Omega, vol. 66, no. B, Jan. 2017, pp. 344–357, https://doi.org/10.1016/j.omega.2015.05.015 [Accessed 07 Dec. 2024]

GHG Protocol (n.d.) *Scope 1 and 2 GHG Inventory Guidance*. [online] Available at: https://ghgprotocol.org/sites/default/files/Guidance_Handbook_2019_FINAL.pdf [Accessed 02 Dec. 2024]

GHG Protocol, (2011). *Product Life Cycle Accounting and Reporting Standard*. World Resources Institute and World Business Council for Sustainable Development. Available at: https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf [Accessed 05 Dec. 2024]

Ghosh, P., Jha, A. and Sharma, R.R.K. (2020) 'Managing carbon footprint for a sustainable supply chain: a systematic literature review. Modern Supply Chain Research and Applications,' 2(3). [online] Available at: https://www.emerald.com/insight/content/doi/10.1108/mscra-06-2020-0016/full/html [Accessed 23 Feb. 2024]

Goldthau, A. and Hughes, L. (2020) *Protect global supply chains for low-carbon technologies*. Nature. [online] Available at: https://www.nature.com/articles/d41586-020-02499-8 [Accessed 15 Aug. 2024]

Gonzalez, F. (2012) *Distributional effects of carbon taxes: The case of Mexico. Energy Economics*, 34(6), pp.2102–2115. doi: 10.1016/j.eneco.2012.03.004 [Accessed 24 Dec. 2024]

Green, M., (2023). *The Power of Collaboration: Fostering Effective Partnerships*. 'Entrepreneurship and Organization Management,' 12(3). Available at: https://www.hilarispublisher.com/open-access/the-power-of-collaboration-fostering-effective-partnerships-100511.html [Accessed 28 Dec. 2024]

Greenhouse Gas Protocol (2011) *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*. [online] Available at: https://ghgprotocol.org/corporate-value-chain-scope-3-standard [Accessed 21 Nov. 2024]

Greenhouse Gas Protocol. (2013) *Technical Guidance for Calculating Scope 3 Emissions (version 1.0)*. [online] 'World Resources Institute and World Business Council for Sustainable Development.' Available at: https://ghgprotocol.org/sites/default/files/2023-03/Scope3_Calculation_Guidance_0%5B1%5D.pdf [Accessed 11 Dec. 2024]

Guide, V.D.R. and Van Wassenhove, L.N. (2003) 'Closed-Loop Supply Chains: Practice and Potential'. *Interfaces*, 33(6), pp.1–2. doi: https://doi.org/10.1287/inte.33.6.1.25185 [Accessed 10 Dec. 2024]

Habibullah, M.S., Din, B.H., Tan, S.-H. and Zahid, H., (2021). *Impact of climate change on biodiversity loss: global evidence*. Environmental Science and Pollution Research, 29, pp.1073–1086. Available at: https://link.springer.com/article/10.1007/s11356-021-15702-8 [Accessed 27 Dec. 2024]

Halliburton. (2024) *2024 Annual and Sustainability Report*. [online] Available at: https://www.halliburton.com/en/resources/2024-annual---sustainability-report [Accessed 27 Apr. 2024]

Hartmann, J., Inkpen, A.C. and Ramaswamy, K. (2021). *Different shades of green: Global oil and gas companies and renewable energy*. Journal of International Business Studies, 52, pp.879–903. Available online [Accessed 25 Nov. 2024]

Harvard Business School (2023) *Primer on Carbon Accounting for Corporate Leaders*. Available at: https://hbsp.harvard.edu/product/UV8992-PDF-ENG [Accessed 11 Dec. 2024]

Harvard Business School (2024) *How Could Harvard Decarbonize Its Supply Chain?* Cold Call Podcast. Available at: https://hbr.org/podcast/2024/02/how-could-harvard-decarbonize-its-supply-chain [Accessed 15 Dec. 2024]

Harvard Division of Continuing Education (2023) *Measuring and Mitigating Indirect Greenhouse Gas Emissions*. Available at: https://coursebrowser.dce.harvard.edu/course/measuring-and-mitigating-indirect-greenhouse-gas-emissions/ [Accessed 18 Apr. 2024]

Harvard Law School, (2019). *Climate Change and the Cost of Capital*. [online] Harvard Law School Forum on Corporate Governance. Available at: https://corpgov.law.harvard.edu/2019/10/15/climate-change-and-the-cost-of-capital/ [Accessed 20 Nov. 2024]

Harvard Office for Sustainability (2023) *Scope 3 Emissions*. Available at: https://sustainable.harvard.edu/scope-3-emissions/ [Accessed 19 Dec. 2024]

Harvard T.H. Chan School of Public Health (n.d.) *Air Pollution*. Available at: https://hsph.harvard.edu/department/environmental-health/research/air-pollution/ [Accessed 13 May. 2024]

Hasan, J., Thomas, A. and Tomos, O., (2024). *Sustainable Supply Chain Practices in the Oil and Gas Industry: A Case Study. Sustainability*, 16(5), p.1720. https://doi.org/10.3390/su16051720 [Accessed 16 May. 2024]

Hasan, M.R., Shawon, R.E.R., Rahman, A., Al Mukaddim, A.A., Khan, M.A., Hider, M.A., and Zeeshan, M.A.F., (2024). *Optimizing Sustainable Supply Chains: Integrating Environmental Concerns and Carbon Footprint Reduction through AI-Enhanced Decision-Making in the USA*. Journal of Economics, Finance and Accounting Studies. Available at: https://www.researchgate.net/publication/383338436 [Accessed 27 Mar. 2025]

Hauschild, M.Z. andHuijbregts, M.A.J., (2018). *Introducing Life Cycle Impact Assessment*. In: M.Z. Hauschild and M.A.J. Huijbregts, eds. Life Cycle Impact Assessment. LCA Compendium – The Complete World of Life Cycle Assessment. Springer. Available at: https://link.springer.com/chapter/10.1007/978-94-017-9744-3_1 [Accessed 19 Mar. 2024]

Hauschild, M.Z., Rosenbaum, R.K. and Olsen, S.I. (2018). *Life Cycle Assessment: Theory and Practice*. Springer, Cham. [Online] Available at: https://link.springer.com/book/10.1007/978-3-319-56475-3 [Accessed 11 Mar. 2024]

He, Y., Liu, Y., and Wang, Y., (2019). *Carbon footprint evaluation of irrigation equipment in sustainable agriculture*. Journal of Cleaner Production, 234, pp.1234–1245. Available at: https://doi.org/10.1016/j.jclepro.2019.06.234 [Accessed 08 Oct. 2024]

Henders, S., Persson, U.M. and Kastner, T., (2015). *Trading forests: land-use change, and carbon emissions embodied in production and exports of forest-risk commodities*. Environmental Research Letters, 10(12), p.125012. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/10/12/125012 [Accessed 08 June. 2024]

Hervani, A.A., Helms, M.M. and Sarkis, J. (2005) 'Performance measurement for green supply chain management. Benchmarking: An International Journal,' 12(4), pp.330–353. doi: https://doi.org/10.1108/14635770510609015 [Accessed 11 Sept. 2024]

HHC Earth. (2025) *Choosing the right carbon accounting method: your guide to data quality and accuracy*. [online] Available at: https://www.hhc.earth/knowledge-base/articles/choosing-the-right-carbon-accounting-method-your-guide-to-data-quality-and-accuracy [Accessed 12 May. 2025]

HomeAlliance, (2025). *Smart Ways to Cut Energy Waste This Daylight-Saving Time*. [online] Available at: https://homealliance.com/blogs/smart-ways-to-cut-energy-waste-this-daylight-saving-time [Accessed 14 May. 2025]

Honeywell. Environmental Sustainability *Overview*. [online] Available at: https://www.honeywell.com [Accessed 16 May. 2024]

Hosseini Shekarabi, S.A., Mavi, R.K. and Macau, F.R., (2025). *Supply chain resilience: A critical review of risk mitigation, robust optimisation, and technological solutions*. Global Journal of Flexible Systems Management. Available at: https://link.springer.com/article/10.1007/s40171-025-00458-8 [Accessed 05 Apr. 2025]

Huang, J.-W. and Li, Y.-H., (2017). *Green Innovation and Performance: The View of Organizational Capability and Social Reciprocity*. Journal of Business Ethics, 145(2), pp.309–324. Available at: https://link.springer.com/article/10.1007/s10551-015-2903-y [Accessed 23 Jan. 2024]

Huang, R. and Luo, X., (2024). *Achieving supply chain sustainable development within the framework of carbon neutrality scenario—A bibliometric analysis*. Business Strategy and the Environment, 34(2), pp.2297–2319. Available at: https://doi.org/10.1002/bse.4094 [Accessed 04 Nov. 2024]

IEA (2022) *Energy Technology Perspectives (2023)*. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 [Accessed 04 Mar. 2024]

International Energy Agency (IEA). (2022) *Tracking Clean Energy Progress*. [online] Available at: https://www.iea.org [Accessed 28 Nov. 2024]

IPCC (2021) *Climate Change 2021: The Physical Science Basis*. Available at: https://www.ipcc.ch/report/ar6/wg1/ [Accessed 14 Dec. 2024]

IPIECA and API. (2016) *Estimating petroleum industry value chain (Scope 3) greenhouse gas emissions: Overview of methodologies*. [online] Available [Accessed 08 Oct. 2024] at: https://www.api.org/~/media/files/ehs/climate-change/scope-3-emissions-reporting-guidance-2016.pdf [Accessed 15 Aug. 2024]

Ivanov, D., (2022). *Viable supply chain model: integrating agility, resilience, and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic*.

Annals of Operations Research, 319, pp.1411–1431. Available at: https://link.springer.com/article/10.1007/s10479-020-03640-6 [Accessed 05 Dec. 2024]

Jiménez, T.R. and Orozco, M. (2021) *Prompts, Not Questions: Four Techniques for Crafting Better Interview Protocols*. Available at: https://link.springer.com/article/10.1007/s11133-021-09483-2 [Accessed 09 Dec. 2024]

Johnson, J., Eniola, J., Frank, E. and Ok, E., (2024). *AI-Driven Carbon Accounting: Paving the Way for Transparent ESG Reporting*. ResearchGate. Available at: https://www.researchgate.net/publication/389901945 [Accessed 01 May. 2025]

Joppa, L. and Willmott, E. (2025) *Six roadblocks to net zero — and how to get around them*. [online] *Nature*. Available at: https://www.nature.com/articles/d41586-025-00935-1 [Accessed 04 May. 2024]

Kaika, D. and Zervas, E. (2013) *The Environmental Kuznets Curve (EKC) theory Part A: Concept, causes and the $CO_2$ emissions case. Energy Policy*, [online] 62, pp.1392–1402. doi: 10.1016/j.enpol.2013.07.131 [Accessed 07 June. 2024]

Kalair, A.R., Seyedmahmoudian, M., Abas, N., Saleem, M.S., Stojcevski, A., Mekhilef, S. and Koh, K., (2023). *Energy Audit in Buildings for Sustainable Economic Development*. In: *Advances in Empirical Economic Research*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-22749-3_37 [Accessed 04 Sept. 2024]

Kandpal, V., Jaswal, A., Santibanez Gonzalez, E.D.R. and Agarwal, N., 2024. *Challenges and Opportunities for Sustainable Energy Transition and Circular Economy*. In: *Sustainable*

*Energy Transition*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-52943-6_11 [Accessed 16 Aug. 2024]

Kang, M. and Kang, S., (2022). *Energy intensity efficiency and the effect of changes in GDP and $CO_2$ emission*. Energy Efficiency, 15(8). Available at: https://link.springer.com/article/10.1007/s12053-021-10002-z [Accessed 18 Jan. 2024]

Kaplan, R.S. and Ramanna, K. (2021) *Accounting for Climate Change*. Harvard Business Review, November–December. Available at: https://hbr.org/2021/11/accounting-for-climate-change [Accessed 17 Aug. 2024]

Kara, S., et al., (2014). *Survey on sustainable practices among 330 manufacturers*. In: Ghosh, P., Jha, A. and Sharma, R.R.K., 2020. *Managing carbon footprint for a sustainable supply chain: a systematic literature review*. Modern Supply Chain Research and Applications, 2(3). Available at: https://www.emerald.com/insight/content/doi/10.1108/mscra-06-2020-0016/full/html [Accessed 08 Sept. 2024]

Karsch, N.M. (2019) *Examining the validity of the Environmental Kuznets Curve. Undergraduate Journal of Global Citizenship*, 21(1), pp.32–50. Available at: https://www.jstor.org/stable/26775082 [Accessed 02 Sept. 2024]

Kwon, T. and Kim, S., (2024). *Pioneering Renewable Energy Transition in US: A Comparative Case Study of Google, Apple, and Microsoft's Utilization of Power Purchase Agreements*. In: *Cultural Perspectives of Human-Centered and Technological Innovations*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-77012-8_18 [Accessed 13 Nov. 2024]

Lee, S., (2025). *LCA Best Practices and Challenges*. [online] Number Analytics. Available at: https://www.numberanalytics.com/blog/lca-best-practices-challenges [Accessed 12 Oct. 2024]

Lehmann, S., (2025). *Transforming the Construction Industry to Become More Resourceful: The Knowledge Gaps in Mass Timber Construction Systems*. In: *After Oil: A Comparative Analysis of Oil Heritage, Urban Transformations, and Resilience Paradigms*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-92188-9_16 [Accessed 22 Nov. 2024]

León Bravo, V., Moretto, A. and Caniato, F. (2019) 'A roadmap for sustainability assessment in the food supply chain. British Food Journal, ahead-of-print(ahead-of-print).' doi: https://doi.org/10.1108/bfj-04-2020-0293 [Accessed 20 Aug. 2024]

Liu, X. and Zhang, Y. (2024) *Digital transformation, green innovation, and carbon emission reduction performance of energy-intensive enterprises*. 'Nature Scientific Reports.' Available at: https://www.nature.com/articles/s41598-024-54587-8.pdf [Accessed 17 Oct. 2024]

Liu, Z., Hu, J., and Xu, Y., 2017. *Carbon emission reduction decisions in the supply chain with vertical tax-sharing contract*. 'Journal of Cleaner Production,' 140, pp.1316–1328. Available at: https://doi.org/10.1016/j.jclepro.2016.10.104 [Accessed 09 Nov. 2024]

Lock, J.H., Sharma, P. and Benz, L., (2024). *Stakeholder pressures and decarbonization strategies in Mittelstand firms*. Journal of Business Ethics, 193, pp.511–533. Available at: https://link.springer.com/article/10.1007/s10551-023-05576-w [Accessed 12 Jan. 2024]

Luthra, S., and Mangla, S. K. (2018) 'Evaluating Challenges to Industry 4.0 Initiatives for Supply Chain Sustainability in Emerging Economies. Process Safety and Environmental

Protection,' 117, 168–179'. https://doi.org/10.1016/j.psep.2018.04.018 [Accessed 10 Dec. 2024]

Malacina, I., Kimpimäki, J.P., Arminen, H. and Zehendner, A., (2025). *Decoupling firm growth from carbon emissions: A supply network role perspective*. Journal of Operations Management. Available at: https://onlinelibrary.wiley.com/doi/10.1002/joom.70008 [Accessed 11 June. 2024]

Mani, V., Delgado, C., and Hazen, B.T., 2024. *Transparency and accountability in sustainable supply chains: A stakeholder perspective*. Journal of Business Research, 168, p.114213. Available at: https://doi.org/10.1016/j.jbusres.2023.114213 [Accessed 04 Oct. 2024]

Matos, S. and Hall, J. (2007) 'Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology. Journal of Operations Management,' 25(6), pp.1083–1102. doi: 10.1016/j.jom.2007.01.013 [Accessed 16 June. 2024]

Matsumura, E.M., Prakash, R. and Vera-Muñoz, S.C., 2024. *Climate-risk materiality and firm risk*. Review of Accounting Studies, 29, pp.33–74. Available at: https://link.springer.com/article/10.1007/s11142-022-09718-9 [Accessed 01 Aug. 2024]

McKinsey and Company (2022) *How to build a sustainable supply chain*. Available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/how-to-build-a-sustainable-supply-chain [Accessed 11 July. 2024]

McKinsey and Company (2023) *Tackling Scope 3 emissions through supplier collaboration*. Available at: https://www.mckinsey.com/capabilities/sustainability/our-insights/sustainability-blog/tackling-scope-3-emissions-through-supplier-collaboration [Accessed 03 Sept. 2024]

McKinsey and Company, (2024). *What is Scope 1, 2, and 3 emissions?* [online] Available at: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-scope-1-2-and-3-emissions [Accessed 19 Nov. 2024]

McKinsey, (2023). *The strategic era of procurement in construction*. [online] Available at: https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/the-strategic-era-of-procurement-in-construction [Accessed 12 Dec. 2024]

Mejia, C. and Kajikawa, Y. (2024). Estimating scope three greenhouse gas emissions through the shareholder network of publicly traded firms. *Sustainability Science*, 19, pp.1409–1425. [Online] Available at: https://link.springer.com/article/10.1007/s11625-023-01460-8 [Accessed 10 Oct. 2024]

Meredith, J.R., (1993). *Theory building through conceptual methods*. International Journal of Operations and Production Management, 13(5), pp.3–11. Available at: https://doi.org/10.1108/01443579310028120 [Accessed 08 Oct. 2024]

Mezentseva, E., Baysaeva, M. and Fayzullaev, N., (2024). *The impact of sustainable development on economic growth: Balancing environmental, social, and economic factors*. [online] Available at: https://www.gnedenko.net/Journal/2024/SI_062024/RTA_SI062024-163_44_Elena%20Mezentseva%20Malika%20Baysaeva%20%20The%20Impact%20of%20Sustainable%20Developments.pdf [Accessed 12 Jan. 2025]

Microsoft (2023) *Cloud for Sustainability: Emissions Impact Dashboard*. Available at: https://www.microsoft.com/en-us/sustainability/emissions-impact-dashboard

Microsoft. (2025) *Configure emission factors - Microsoft Cloud for Sustainability*. [online] Available at: https://learn.microsoft.com/en-us/industry/sustainability/calculate-emission-factors [Accessed 27 Feb. 2025]

Microsoft. (2025) *Microsoft Power BI and Excel for Sustainability Reporting*. [online] Available at: https://learn.microsoft.com/en-us/power-bi/ and https://www.microsoft.com/en-us/microsoft-365/excel [Accessed 19 Jan. 2025]

Mischos, S., Dalagdi, E. and Vrakas, D., (2023). *Intelligent energy management systems: a review*. Artificial Intelligence Review, 56, pp.11635–11674. Available at: https://link.springer.com/article/10.1007/s10462-023-10441-3 [Accessed 21 Apr. 2024]

Mishra, P. and Pandey, V.K., (2025). *Triple bottom line and environmental sustainability: evolution of global ESG research—a bibliometric analysis*. Environmental Sciences Europe, 37(136). Available at: https://link.springer.com/article/10.1186/s12302-025-01184-9 [Accessed 29 Jan. 2025]

Morana, J. (2013) *Sustainable Supply Chain Management.* Chichester: John Wiley and Sons.

Morina, F., Balomenou, C. and Ergün, U., 2020. *Determinants of Profitability: Evidence of Renewable Energy Companies*. In: *Global, Regional and Local Perspectives on the Economies of Southeastern Europe*. Springer Proceedings in Business and Economics. Available at: https://link.springer.com/chapter/10.1007/978-3-030-57953-1_15 [Accessed 13 Feb. 2025]

Mrad, M., Frikha, M.A. and Boujelbene, Y., (2025). *A comprehensive survey of artificial intelligence and robotics for reducing carbon emissions in supply chain management*. Logistics, 9(3), p.104. Available at: https://doi.org/10.3390/logistics9030104 [Accessed 02 July. 2025]

Murugaiyan, Sinduja, Mathiyarasi, K., Mohan, D., Akila, S., Gowtham, M., Shankar, S., Murali, S. and Karthikeyan, G., (2025). *Heavy Metals in the Environment: The Global Scope*. In: *Global Perspectives of Toxic Metals in Bio Environs*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-031-89725-2_1 [Accessed 10 Mar. 2025]

Nakamura, S. (2023). *Environmentally Extended Input-Output Analysis (EEIO) and Hybrid LCA*. In: A Practical Guide to Industrial Ecology by Input-Output Analysis. Springer. [Online] Available at: https://link.springer.com/chapter/10.1007/978-3-031-43684-0_5 [Accessed 12 Mar. 2025]

Narsimhachary, D. and Phani, M.K., (2023). *Additive Manufacturing: Environmental Impact, and Future Perspective*. In: *Practical Implementations of Additive Manufacturing Technologies*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-981-99-5949-5_14 [Accessed 23 Feb. 2025]

National Renewable Energy Laboratory (NREL) (2025) *U.S. Life Cycle Inventory Database*. Available at: https://www.nrel.gov/analysis/lci [Accessed 15 Feb. 2025]

Nature (2020) *Innovating on energy-efficient technologies*. [online] Available at: https://www.nature.com/articles/d42473-020-00342-2 [Accessed 12 Mar. 2025]

Nature (2025) *Net-zero emissions commitments are more threatened than ever*. [online] Available at: https://www.nature.com/articles/d41586-025-00353-3 [Accessed 27 Feb. 2025]

Niamir, L., Kiesewetter, G., Wagner, F., Schöpp, W., Filatova, T., Voinov, A. and Bressers, H. (2020). Assessing the macroeconomic impacts of individual behavioural changes on carbon emissions. *Climatic Change*, 158, pp.141–160. [Online] Available at: https://link.springer.com/article/10.1007/s10584-019-02566-8 [Accessed 02 Apr. 2025]

Normative, (2024). *Upstream and downstream emissions, explained*. [online] Available at: https://normative.io/insight/upstream-downstream-emissions/ [Accessed 07 Jan. 2025]

Nurdiawati, A. and Urban, F., (2021). *Towards Deep Decarbonisation of Energy-Intensive Industries: A Review of Current Status, Technologies, and Policies*. Energies, 14(9), p.2408. Available at: https://www.researchgate.net/publication/351098028 [Accessed 13 Apr. 2025]

OECD, (2023). *Effective Carbon Rates (2023): Pricing Carbon Emissions Through Taxes and Emissions Trading*. OECD Publishing, Paris. Available at: https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2023.htm [Accessed 08 Jan. 2025]

Oh, S., Eberenz, S., Honegger, M., Wallis, O., Michaelowa, A. and Poralla, M., (2025). *Effective and fair policy to mobilize industrial carbon dioxide removal*. Mitigation and Adaptation Strategies for Global Change, 30(47). Available at: https://link.springer.com/article/10.1007/s11027-025-10235-8 [Accessed 11 May. 2025]

Oracle. (2024) *Oracle Cloud ERP for Sustainable Procurement*. [online] Available at: https://www.oracle.com/erp/ [Accessed 29 June. 2025]

Oracle. (2024) *Oracle Cloud for Sustainable Supply Chains*. [online] Available at: https://www.oracle.com/sustainability/ [Accessed 29 July. 2024]

Osman, A.I., Hefny, M., Abdel Maksoud, M.I.A., Elgarahy, A.M. and Rooney, D.W. (2021). Recent advances in carbon capture storage and utilisation technologies: a review. *Environmental Chemistry Letters*, 19, pp.797–849. [Online] Available at: https://link.springer.com/article/10.1007/s10311-020-01133-3 [Accessed 12 Mar. 2025]

Oyenuga, M.O., Singh, R., Apata, S.B., Khan, S. and Kumar, V. (2025) *Smart Technologies for Climate Change and Net Zero Policies: Practical Approaches Towards Sustainability*. Springer. [online] Available at: https://link.springer.com/book/10.1007/978-3-031-92221-3

Pahuja, S. (2023). Kyoto Protocol. In: *Encyclopedia of Sustainable Management*. Springer. [Online] Available at: https://link.springer.com/rwe/10.1007/978-3-031-25984-5_562 [Accessed 17 Jan. 2025]

Panagiotopoulou, V.C., Stavropoulos, P. and Chryssolouris, G. (2022). A critical review on the environmental impact of manufacturing: a holistic perspective. *The International Journal of Advanced Manufacturing Technology*, 118, pp.603–625. [Online] Available at: https://link.springer.com/article/10.1007/s00170-021-07980-w [Accessed 21 Feb. 2025]

Parry, M.L. and On, P. (2007) *Climate Change 2007: impacts, adaptation, and vulnerability: contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. [Accessed 03 Mar. 2025]

Pawar, R., Dalsania, K.P., Sircar, A., Yadav, K. and Bist, N., (2024). *Renewable energy hybridization: a comprehensive review of integration strategies for efficient and sustainable power generation*. Clean Technologies and Environmental Policy, 26, pp.4041–4058.

Available at: https://link.springer.com/article/10.1007/s10098-024-02951-7 [Accessed 08 Feb. 2025]

Peñasco, C., Díaz Anadón, L. and Verdolini, E. (2020) *Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments*. Nature Climate Change. [online] Available at: https://www.nature.com/articles/s41558-020-00971-x.pdf [Accessed 27 Jan. 2025]

Perotti, S., Zorzini, M., Cagno, E. and Micheli, G.J.L. (2012) 'Green supply chain practices and company performance: the case of 3PLs in Italy'. *International Journal of Physical Distribution and Logistics Management*, 42(7), pp.640–672. doi: https://doi.org/10.1108/09600031211258138 [Accessed 02 Feb. 2025]

Pinkse, J. and Kolk, A. (2011). Multinational enterprises and climate change: Exploring institutional failures and embeddedness. *Journal of International Business Studies*, 43, pp.332–341. [Online] Available at: https://link.springer.com/article/10.1057/jibs.2011.56 [Accessed 19 Mar. 2025]

Plambeck, E.L. (2012)' Reducing greenhouse gas emissions through operations and supply.

PricewaterhouseCoopers (PwC). (2021) *Automating sustainability data management*. [online] Available at: https://www.pwc.com/gx/en/issues/esg/sustainability-data-from-reporting-to-value-creation.html [Accessed 06 Feb. 2025]

PwC (2023) *Carbon accounting software: Implementation challenges and solutions*. Available at: https://www.pwc.com/gx/en/services/sustainability/carbon-accounting.html [Accessed 03 Feb. 2025]

Qu, C. and Kim, E., (2024). *Reviewing the Roles of AI-Integrated Technologies in Sustainable Supply Chain Management: Research Propositions and a Framework for Future Directions*. Sustainability, 16(14), 6186. Available at: https://www.mdpi.com/2071-1050/16/14/6186 [Accessed 19 Feb. 2025]

Rathnasiri, M.S.H., 2025. *Supply Chain Decarbonisation and its Impact on the Environment and Society*. In: *Zero Carbon Industry, Eco-Innovation and Environmental Sustainability*. SpringerLink. Available at: https://link.springer.com/chapter/10.1007/978-3-031-80220-1_9 [Accessed 29 Jan. 2025]

Renewabl, (2025). *PPAs explained: The complete guide to Power Purchase Agreements*. [online] Available at: https://www.renewabl.com/post/ppas-explained-the-complete-guide-to-power-purchase-agreements [Accessed 14 Aug. 2024]

Renwick, D.W.S., Redman, T. and Maguire, S., (2024). *Employee Green Behavior: Transforming HR for a Sustainable Tomorrow*. Springer. Available at: https://link.springer.com/book/9789819514212 SAP. (2024) *SAP ERP and Carbon Impact Solutions*. [online] Available at: https://www.sap.com/products/scm/sustainability-footprint-management.html [Accessed 12 Jan. 2025]

SAP. (2024) *SAP Sustainability Control Tower*. [online] Available at : https://www-.sap.com/products/scm/sustainability-control-tower.html [Accessed 09 Oct. 2024]

SBTi (2023). *Supplier Engagement Guidance*. Science Based Targets initiative. Available at: https://sciencebasedtargets.org/resources/files/SBTi-Supplier-Engagement-Guidance.pdf [Accessed 24 Aug. 2024]

Schaltegger, S., Naffin, J., and Klewitz, J. (2023). *Sustainable development of supplier performance: An empirical analysis of relationship characteristics in the automotive sector*. Corporate Social Responsibility and Environmental Management. Available online [Accessed 29 Oct. 2024]

Schlumberger (2024) *Climate Action Plan: Road Map to Net Zero*. [online] Available at: https://www.slb.com/sustainability/climate-action/road-map-to-net-zero [Accessed 19 June. 2024]

Science Based Targets initiative (2023) *Supplier Engagement Guidance*. Available at: https://sciencebasedtargets.org/resources/files/SBTi-Supplier-Engagement-Guidance.pdf

Serra, P. and Fancello, G., (2020). *Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping*. ResearchGate. Available at: https://www.researchgate.net/publication/340666540 [Accessed 24 June. 2024]

Shaw, A., Jha, A. and Sharma, R.R.K. (2013). Managing carbon footprint for a sustainable supply chain: a systematic literature review. *Modern Supply Chain Research and Applications*, 2(3). [Online] Available at: https://www.emerald.com/insight/content/doi-/10.1108/mscra-06-2020-0016/full/html [Accessed 03 June. 2024]

Shell (2017) *The Net Carbon Footprint Model: Methodology (Public)*. [online] Available at: https://www.shell.de/content/dam/shell/assets/en/business-functions/energy-and-innovation/documents/the-net-carbon-footprint-model.pdf [Accessed 03 Oct. 2023]

Shrimali, G. (2021) *Scope 3 Emissions: Measurement and Management*. Stanford Sustainable Finance Initiative. Available at: https://sfi.stanford.edu/sites/sfi/files/media-/file/scope_3_emissions__measurement_and_management.pdf [Accessed 26 Dec. 2024]

Siemens (2024) *Sustainability Report (2024): Decarbonization Strategy*. [online] Available at: https://press.siemens.com/global/en/pressrelease/siemens-achieves-strong-progress-sustainability-targets [Accessed 02 Oct. 2024]

Siems, E., Seuring, S. and Schilling, L. (2023). Stakeholder roles in sustainable supply chain management: a literature review. *Journal of Business Economics*, 93, pp.747–775. [Online] Available at: https://link.springer.com/article/10.1007/s11573-022-01117-5 [Accessed 20 Apr. 2025]

Siems, E., Seuring, S. and Schilling, L., (2023). *Stakeholder roles in sustainable supply chain management: a literature review*. Journal of Business Economics, 93, pp.747–775. Available at: https://link.springer.com/article/10.1007/s11573-022-01117-5 [Accessed 18 Jan. 2025]

Sindhwani, R., Hasteer, N., Behl, A., Chatterjee, C. and Hamzi, L. (2023). *Analysis of sustainable supply chain and industry 4.0 enablers: a step towards decarbonization of supply chains*. [online] Springer. Available at: https://link.springer.com/article/10.1007/s10479-023-05598-7 [Accessed 23 Feb. 2024]

Singh, J., Pandey, K.K., Kumar, A., Naz, F. and Luthra, S. (2022). Drivers, barriers, and practices of net zero economy: An exploratory knowledge-based supply chain multi-stakeholder perspective framework. *ResearchGate*. [Online] Available at: https://www.researchgate.net/publication/358041268 [Accessed 17 Jan. 2024]

Sobrino-Duque, R., Plasencia, J.A., Nicolás, J., Fernández-Alemán, J.L., Moraga, M.Á., García, F. and Moros, B., (2025). *Evaluating sustainability through business processes indicators: A case study*. Journal of Software: Evolution and Process. Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1002/smr.70042 [Accessed 11 Oct. 2024]

Springer, (2024). *Renewable energy hybridization: a comprehensive review of integration strategies*. Available at: https://link.springer.com/article/10.1007/s10098-024-02951-7 [Accessed 10 Apr. 2024]

Springer, C. (2025). *Carbon Footprints of Organizations and Products*. In: Muthu, S.S. (ed.) *Assessing Carbon Footprint in the Supply Chain*. Springer. [Online] Available at: https://link.springer.com/rwe/10.1007/978-3-319-95726-5_12 [Accessed 04 Nov. 2024]

Springer, N. (2024). *Comparative Analysis of Activity-Based and Spend-Based Methods for Scope 3 Emissions*. In: Advances in Green Energy and Sustainable Systems. Springer. Available online [Accessed 19 Dec. 2024]

Stanford Sustainable Finance Initiative (2023) *Scope 3 Emissions: Measurement and Management*. Available https://sfi.stanford.edu/sites/sfi/files/media/file/scope_3_emissions_-_measurement_and_management_0_0_0_0.pdf [Accessed 01 Apr. 2024]

Stangl, J., Borsos, A., Diem, C., Reisch, T. and Thurner, S. (2024). *Firm-level supply chains to minimize unemployment and economic losses in rapid decarbonization scenarios*. Nature Sustainability. [online] Available at: https://www.nature.com/articles/s41893-024-01321-x.pdf [Accessed 14 Dec. 2024]

Stankovich, M., (2021). *Use of Digital Tools in Fighting Climate Change: A Review of Best Practices*. ResearchGate. Available at: https://www.researchgate.net/publication/349505553 stephanclassen (2021) *Core Sustainability: Triple Bottom Line – Economy.* [Blog] Integrate, 7 June. Available at: https://cascadiaupdates.wordpress.com/2021/06/07/core-sustainability-triple-bottom-line-economy [Accessed 07 Apr. 2024]

Swink, M. and Gallo, I.S., (2023) *Supply chain visibility types and contextual characteristics: A literature-based synthesis*. 'Journal of Business Logistics.' Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jbl.12366 [Accessed 19 Sept. 2024]

Sybertz, J. (2017) 'Sustainability and effective supply chain management: A literature review. [online] NYU Stern School of Business.' Available at: https://www.stern.nyu.edu/sites/default/files/assets/documents/Supply%20Chain%20Literature%20Review_Jeff%20Sybertz_April%202017.pdf [Accessed 22 Oct. 2024]

Tamoor, M. and Xing, J., (2025) *PET life cycle analysis development for environmental sustainability: global scenario*. 'Environment, Development and Sustainability.' Available at: https://link.springer.com/article/10.1007/s10668-025-06629-y [Accessed 21 Aug. 2024]

Tan, T., Bouchery, Y. and Hofstetter, J., (2024) *Supply Chain Collaboration for Sustainability*. In: *Sustainable Supply Chains*. 'Springer Series in Supply Chain Management.' [online] Available at: https://link.springer.com/chapter/10.1007/978-3-031-45565-0_11 [Accessed 14 Apr. 2024]

TechnipFMC. Sustainability *Performance Report*. [online] Available at: https://www.technipfmc.com/en/about-us/sustainability/ [Accessed 03 Oct. 2023]

Teske, S., Nagrath, K., Niklas, S., Talwar, S., Atherton, A., Guerrero Orbe, J., Assaf, J. and Giurco, D., (2022) *Scopes 1, 2, and 3 Industry Emissions and Future Pathways*. In: S. Teske, ed. 'Achieving the Paris Climate Agreement Goals. Springer.' Available at: https://link.springer.com/chapter/10.1007/978-3-030-99177-7_13 [Accessed 04 Mar. 2024]

Teske, S., Nagrath, K., Niklas, S., Talwar, S., Atherton, A., Orbe, J.G., Assaf, J. and Giurco, D., (2022) *Scopes 1, 2, and 3 Industry Emissions and Future Pathways*. In: *Achieving the Paris Climate Agreement Goals*. Springer. Available at: https://link.springer.com/chapter/10.1007/978-3-030-99177-7_13 [Accessed 11 Dec. 2024]

Tseng, M.-L., Islam, M.S., Karia, N., Fauzi, F.A. and Afrin, S. (2019) 'A literature review on green supply chain management: Trends and future challenges. Resources, Conservation and Recycling,' [online] 141, pp.145–162. doi: https://doi.org/10.1016/j.resconrec.2018.10.009 [Accessed 06 Nov. 2024]

Tsolakis, N., Schumacher, R., Dora, M. and Kumar, M. (2023) *Artificial intelligence and blockchain implementation in supply chains: a pathway to sustainability and data monetisation?* Annals of Operations Research, 327, pp.157–210. Available online [Accessed 29 Oct. 2024]

U.S. Department of Energy (2022) *Introduction to Life Cycle Assessment*. Available at: https://www.energy.gov/sites/default/files/2022-07/2022-07-14%20-%20Intro%20to%20LCA%20-%20Slides%20and%20Transcript_compliant_0.pdf [Accessed 24 Oct. 2024]

U.S. Department of Energy, (2025) *Advanced Energy Retrofit Guides*. [online] Available at: https://www.energy.gov/eere/buildings/advanced-energy-retrofit-guides [Accessed 21 Oct. 2024]

U.S. Department of Energy, (2025) *Carbon Management*. [online] Available at: https://www.energy.gov/topics/carbon-management [Accessed 08 Apr. 2024]

U.S. Environmental Protection Agency (2025) *Scope 3 Inventory Guidance*. Available at: https://www.epa.gov/climateleadership/scope-3-inventory-guidance [Accessed 21 Dec. 2024]

U.S. Environmental Protection Agency (EPA) (2023) *Emission Factors for Greenhouse Gas Inventories*. [online] Available at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub [Accessed 19 Aug. 2024]

U.S. Environmental Protection Agency (EPA) (2024) *US Environmentally Extended Input-Output (USEEIO) Technical Content*. [online] Available at: https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content [Accessed 23 Oct. 2025]

Uchiyama, K. (2016) Environmental Kuznets Curve Hypothesis and Carbon Dioxide Emissions. In: *Environmental Kuznets Curve Hypothesis*. Springer Briefs in Economics. Springer. [Online] Available at: https://link.springer.com/chapter/10.1007/978-4-431-55921-4_2 [Accessed 11 Sept. 2024]

UL Solutions. (2025) *Measuring Scope 3 Emissions with the Spend-Based Approach*. [online] Available at: https://www.ul.com/insights/measuring-scope-3-emissions-spend-based-approach [Accessed 14 Nov. 2023]

UNFCCC (2015) *The Paris Agreement*. 'United Nations Framework Convention on Climate Change.' Available at: https://unfccc.int/process-and-meetings/the-paris-agreement [Accessed 28 Oct. 2023]

United Nations and the Partnering Initiative, (2020) *The SDG Partnership Guidebook: A practical guide to building high-impact multi-stakeholder partnerships for the Sustainable Development Goals*. [pdf] Available at: https://sdgs.un.org/sites/default/files/2020-10/SDG%20Partnership%20Guidebook%201.01%20web.pdf [Accessed 07 July. 2024]

United Nations (2024) *Net Zero Coalition*. Available at: https://www.un.org/en/climatechange/net-zero-coalition [Accessed 21 Oct. 2024]

United Nations, (2025) *Climate Action - United Nations Sustainable Development*. [online] Available at: https://www.un.org/sustainabledevelopment/climate-action/ [Accessed 01 Jun. 2024]

US EPA, (2025) *Scope 1 and Scope 2 Inventory Guidance*. [online] Available at: https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance [Accessed 21 Oct. 2024]

Villanthenkodath, M.A., Ansari, M.A., Balsalobre-Lorente, D. andSatrovic, E., (2024) *The Comprehensive Impact of Economic Growth on Environmental Quality: Insight Established on Material, Carbon, and Ecological Footprint*. Operations Research Forum, 5(70) Available at: https://link.springer.com/article/10.1007/s43069-024-00355-3 [Accessed 07 Feb. 2024].

Villena, V.H. and Gioia, D.A. (2020) A more sustainable supply chain. [online] Harvard Business Review. Available at: https://hbr.org/2020/03/a-more-sustainable-supply-chain [Accessed 29 May. 2024]

von Berlepsch, D., Lemke, F. and Gorton, M. (2022) ‘The Importance of Corporate Reputation for Sustainable Supply Chains: A Systematic Literature Review, Bibliometric

Mapping, and Research Agenda. Journal of Business Ethics,' [online] 1(1). https://doi.org/10.1007/s10551-022-05268-x [Accessed 12 July. 2024]

Wang, Y., (2023) *Digital Transformation and Resilience in Global Supply Chains: A Comprehensive Review and Future Directions in the Post-COVID-19 Era*. University of Zurich. Available at: https://www.researchgate.net/publication/376132229 [Accessed 09 May. 2024]

Wang, Y., Hao, Y., Hou, Y., Quan, Q. and Li, Y. (2024) *Optimizing Scope 3 emissions in the automotive manufacturing industry: a multidisciplinary approach*. 'Carbon Research.' Available online [Accessed 21 Aug. 2024]

WBCSD (2022) *Guidance on Scope 3 Emissions Accounting and Reporting*. 'World Business Council for Sustainable Development.' Available at: https://www.wbcsd.org [Accessed 29 May. 2024]

Wells, E.C., Lehigh, G.R. and Vidmar, A.M. (2021) 'Stakeholder Engagement for Sustainable Communities'. In: *The Palgrave Handbook of Global Sustainability*. Springer. [Online] Available at: https://link.springer.com/rwe/10.1007/978-3-030-38948-2_10-1 [Accessed 21 Jan. 2025]

Work for Climate (2025) *Shades of green: how employees drive climate action at work*. Available at: https://www.workforclimate.org/post/shades-of-green-how-employees-drive-climate-action-at-work [Accessed 05 Feb. 2025]

World Business Council for Sustainable Development (WBCSD) (2022) *Decarbonizing supply chains: A practical guide*. [online] Available at: https://www.wbcsd.org [Accessed 02 Jan. 2025]

World Economic Forum (2021) *Net-Zero Challenge: The Supply Chain Opportunity*. Available at: https://www.weforum.org/reports/net-zero-challenge-the-supply-chain-opportunity [Accessed 09 Jan. 2025]

World Economic Forum (2025) *Why companies should tackle Scope 3 downstream emissions*. Available at: https://www.weforum.org/stories/2025/07/tackling-scope-3-downstream-emissions/ [Accessed 28 Mar. 2025]

World Economic Forum, (2023) *Emissions Measurement in Supply Chains: Business Realities and Challenges*. [pdf] Available at : https://www3.weforum.org/docs/-WEF_Emissions_Measurement_in_Supply_Chains_2023.pdf [Accessed 04 Feb. 2025]

World Economic Forum, (2024) *Practitioners' Guide to Whole Life Carbon Assessments*. [pdf] Available at : https://www3.weforum.org/docs/WEF_Practitioners_Guidance-_on_Whole_Life_Carbon_Assessments_2024.pdf [Accessed 27 Apr. 2025]

Woxday, (2023) *Understanding Scope 3 Emissions: The Key to Corporate Sustainability*. [online] Woxday. Available at: https://woxday.com/blog/scope-3-emissions-corporate-sustainability [Accessed 05 May. 2024]

WRI and WBCSD. (2011) *Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard*. 'World Resources Institute and World Business Council for Sustainable Development.' [Online] Available at: https://ghgprotocol.org/sites/default-/files/202507/Green_Asia_Network_Revised_Translated_GHGP_Standards.pdf [Accessed 19 Jan. 2025]

Xu, R., Tong, D., Xiao, Q., Qin, X., Chen, C., Yan, L., and Zhang, Q. (2024) *MEIC-global-CO2: A new global CO2 emission inventory with highly resolved source category and sub-*

*country information*. 'Science China Earth Sciences.' Available online [Accessed 08 Feb. 2025]

Xu, Z., Pokharel, S. and Elomri, A., (2023) *An eco-friendly closed-loop supply chain facing demand and carbon price uncertainty*. 'Annals of Operations Research,' 320, pp.1041–1067. Available at: https://link.springer.com/article/10.1007/s10479-021-04499-x [Accessed 09 Nov. 2025]

Yale Sustainability (2023) *Yale Experts Explain Scope 3 Emissions*. Available at: https://sustainability.yale.edu/explainers/yale-experts-explain-scope-3-emissions [Accessed 01 Jan. 2025]

Yoro, K.O. and Daramola, M.O. (2020) $CO_2$ emission sources, greenhouse gases, and the global warming effect. In: *Advances in Carbon Capture*. Elsevier. [Online] Available at: https://www.researchgate.net/publication/343508726 [Accessed 02 Jan. 2025]

Yu, M. and Cruz, J.M., (2019) *Sustainable supply chain management under progressive carbon tax policy*. 'European Journal of Operational Research,' 278(2), pp.486–498. Available at: https://doi.org/10.1016/j.ejor.2019.04.012 [Accessed 15 Mar. 2024]

Yusliza, M.Y., Renwick, D.W.S., Yong, J.Y. and Mohd Kamil, N.L., (2025) *Employee Green Behavior: Transforming HR for a Sustainable Tomorrow*. Springer. Available at: https://link.springer.com/book/9789819514212 [Accessed 08 Jan. 2025]

Zhang, Y., (2024) *Supply Chain Collaborative Innovation: Theoretical Evolution, Hotspot Analysis, and Future Trends*. In: *Springer Series on Supply Chain Innovation*. Available at: https://link.springer.com/chapter/10.1007/978-981-97-4045-1_7 [Accessed 05 Apr. 2025]

Zhou, S.W.W., (2020) *Carbon Management for a Sustainable Environment*. SpringerLink. Available at: https://link.springer.com/book/10.1007/978-3-030-35062-8 [Accessed 14 Mar. 2025]

Zrelli, I., Rejeb, A., Abusulaiman, R., AlSahafi, R., Rejeb, K. and Iranmanesh, M., (2024) *Drone applications in logistics and supply chain management: A systematic review using latent Dirichlet allocation*. Arabian Journal for Science and Engineering, 49, pp.12411–12430. Available at: https://link.springer.com/article/10.1007/s13369-023-08681-0 [Accessed 05 Mar. 2025]