Towards Net-Zero: A Comprehensive Carbon Footprint Assessment for Sustainable Business Practices

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Abstract.*This study examines the organization's carbon footprint and the economic impacts of Net Zero initiatives, highlighting the significant disparities in emissions across Scope 1, Scope 2, and Scope 3. Hypothesis 1 confirms that Scope 3, primarily from business travel, constitutes the largest share of emissions at 60,000 kg CO_2e (37% of total emissions), emphasizing the need for focused reduction strategies. The drive toward Net Zero presents opportunities for innovation, job creation, and enhanced global resilience while addressing the costs and benefits of low-carbon transitions. Hypothesis 2 finds that Scope 1 emissions slightly exceed Scope 2, underlining the impact of both direct and indirect energy sources. Finally, the article suggests that targeted reduction methods in high-emission areas, such as fuel combustion and business travel, can effectively lower emissions and ensure inclusive economic benefits from Net Zero, supporting long-term sustainable development through comprehensive strategies that promote energy security and market diversification.*

Keywords: Carbon Footprint, Emissions Calculation, Fuel Combustion, Environmental Sustainability

1 Introduction

1.1 Background

As global awareness of the serious consequences of climate change grows, companies across all sectors are stepping up efforts to quantify and manage greenhouse gas (GHG) emissions as part of broader sustainability commitments. Many companies understand the need of addressing their greenhouse gas (GHG) emissions as part of a larger commitment to sustainability, especially in light of the growing urgency to combat climate change. Businesses are increasingly monitoring and controlling their carbon footprints to achieve international climate targets as scientific agreement indicates that emissions reductions are crucial to preventing catastrophic climate consequences. The 2015 Paris Agreement established a global goal to restrict average temperature rises to

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1.5°C over pre-industrial levels, ideally far below 2°C. These national objectives also apply to the corporate sector, where enterprises are not only encouraged but also forced by rules or market forces to undertake effective GHG mitigation plans.

In response, businesses are committing to net-zero objectives, with the goal of balancing emitted and offset emissions by a specific date, often 2050, to correspond with global decarbonization timeframes. Net-zero promises are becoming more widespread across industries, as companies grasp the environmental, regulatory, and reputational benefits of carbon reduction. Many businesses link their plans with programs like the Science-Based plans Initiative (SBTi), which provides a framework for establishing scientifically informed emissions targets that are consistent with global climate goals [1]. These initiatives need strong measurement and management systems, beginning with a thorough carbon footprint assessment.

A carbon footprint assessment provides a systematic technique for enterprises to estimate their GHG emissions from both direct and indirect sources. This evaluation is critical for identifying high-emission activities, selecting intervention sites, and devising specific emission-reduction strategies. According to the Greenhouse Gas Protocol, enterprises can divide their emissions into three scopes for a full assessment of their impact. Scope 1 (direct emissions) from owned or controlled sources, such as on-site fuel combustion; Scope 2 (indirect emissions) from purchased electricity and other energy used in operations; and Scope 3 (other indirect emissions) from value-chain activities such as supply chain production, waste disposal, and employee commuting [2].

This organized method to emissions assessment has major business benefits. Organisations may optimise resource utilization, enhance operational efficiency, and reduce energy costs by measuring emissions throughout their activities. Reducing emissions also improves regulatory compliance and helps firms plan for future environmental regulations, such as carbon taxes or tougher emissions restrictions. For example, the UK Department for Environment, Food and Rural Affairs (DEFRA) provides guidelines for measuring emissions to promote corporate sustainability reporting, assisting businesses in meeting national and international criteria [3]. In an increasingly environmentally sensitive market, a well-managed carbon footprint is a strategic advantage, allowing businesses to match with consumer expectations, meet stakeholder demands, and establish themselves as sustainability leaders.

1.2 Objective

1. Quantify the Carbon Footprint: Determine the total greenhouse gas emissions produced by the organization to have a full picture of its entire environmental effect.
2. Identify the major emission sources: Determine the most significant contributors to the organization's carbon emissions by considering all three scopes:

A. Scope 1 includes direct emissions from owned or controlled sources (e.g., business vehicles, on-site fuel burning).
B. Scope 2: Indirect emissions caused by the generation of bought energy, heat, or steam (for example, emissions from electricity used in offices or facilities).
C. Scope 3 includes other indirect emissions that occur along the value chain.

3. Assess Reduction Strategies: Evaluate alternative methods and measures to reduce emissions from each identified source, aiming to develop a more sustainable operation and lower the organization's carbon footprint.

1.3 Hypothesis

- Hypothesis 1: The organization's carbon footprint will show considerable disparities between emissions from Scope 1, Scope 2, and Scope 3, with Scope 3 accounting for the majority of total emissions.
- Hypothesis 2: Direct emissions from organization-owned or managed sources (Scope 1) will be lower than indirect emissions from purchased power and heat.
- Hypothesis 3: Supply chain and product lifecycle activities account for the bulk of the organization's carbon emissions, highlighting the need of reducing Scope 3 emissions.
- Hypothesis 4: Targeted reduction methods for main sources of emissions will reduce the organization's carbon footprint within a set period.

2. Literature Review

Organizations increasingly recognize the necessity of assessing their greenhouse gas (GHG) emissions to enhance sustainability and comply with regulatory requirements. Following the Greenhouse Gas Protocol, emissions can be categorized into three distinct scopes, each encompassing different sources of emissions and requiring tailored strategies for management and reduction.

2.1 Direct Emissions from Owned or Controlled Sources

Direct emissions are generated by sources that an entity owns or controls. This includes emissions caused by fuel burning in company-owned cars, on-site energy production, and manufacturing activities. According to the United States Environmental Protection Agency [4], enterprises in industries such as industry and transportation frequently discover that direct emissions contribute significantly to their overall carbon footprints. According to research, effective emissions reduction measures include switching to energy-efficient machinery, using alternative fuels, and streamlining operational procedures. For example, a research conducted by the Science-Based Targets Initiative [5] found that industrial facilities using natural gas and hydrogen fuel blends showed significant reductions in both direct emissions and

operating costs. This demonstrates how concentrating on direct emissions not only promotes environmental sustainability but also improves economic.

2.2 Indirect Emissions from Purchased Electricity

Indirect emissions result from the use of bought power, steam, heat, or cooling. Although these emissions are created off-site by utility suppliers, they are important to track since they can account for a sizable amount of an organization's overall emissions. According to research, many organizations underestimate the impact of indirect emissions. According to the Greenhouse Gas Protocol [2], indirect emissions can make up a large portion of overall GHG outputs, particularly in energy-intensive industries. Strategies for reducing these emissions include increasing energy efficiency through technological improvements like as LED lighting and modern HVAC systems, as well as switching to renewable energy sources. For example, a CDP [6] report found that corporations who committed to renewable energy sources effectively lowered their indirect emissions by up to 70%. This transition not only reduces emissions, but also strengthens resilience to energy price volatility and regulatory changes affecting carbon emissions.

2.3 Other Indirect Emissions from Value Chain Activities

Other indirect emissions cover a wide range of value chain operations, such as supply chain production, transportation, waste disposal, and employee commuting. These emissions are frequently the most significant component of a company's carbon footprint, with studies suggesting that they can account for up to 90% of total emissions in industries with extensive supply chains [3][7]. The complexities of monitoring and regulating these pollutants pose substantial hurdles for enterprises. However, research shows that engaging suppliers and improving collaboration across the value chain are critical to effectively reducing these emissions. Sustainable procurement strategies and life cycle assessments (LCAs) can assist companies in identifying emissions hotspots and successfully targeting actions [5]. For example, a retail case study found that involving suppliers in sustainability measures resulted in a 15% decrease in value chain emissions [6].

3. Methodology

3.1 Study Design and Scope Definition

The study follows the Greenhouse Gas Protocol’s corporate standard to calculate emissions across Scopes 1, 2, and 3 for the fiscal year 2023 [7]. Scope 1 emissions included fuel combustion and refrigerant use, Scope 2 emissions covered electricity purchased from the grid, and Scope 3 encompassed supply chain activities, business travel, and waste.

3.2 Data Collection Process

Data collection was organized by emissions scope:

- Scope 1 (Direct Emissions): Fuel usage data was obtained from utility invoices and fleet management logs. Refrigerant usage was collected from maintenance records [5].
- Scope 2 (Indirect Emissions): Purchased electricity data came from monthly utility bills, with emissions factors sourced from regional electricity grid data [7].
- Scope 3 (Value Chain Emissions): Procurement records, travel logs, and waste reports provided data for Scope 3 emissions. Emission factors from the UK Department for Environment, Food & Rural Affairs [4] were used for indirect emissions from materials and waste disposal.

3.3 Emission Factor Selection

Emission factors were applied using data from the EPA Emissions Hub and DEFRA's 2021 GHG Conversion Factors for business operations in the U.S. and U.K., respectively [3][4] These factors were adjusted according to the specific regional energy mix for electricity [8].

3.4 Emission Calculations

The formula used to calculate emissions was:

$$\text{Emissions } (CO_2e) = \text{Activity Data} \times \text{Emission} \quad (1$$

where each activity (fuel usage, electricity, or materials) was multiplied by its corresponding emission factor to obtain CO_2e emissions [7]. Aggregated data were analyzed in spreadsheet software to calculate total emissions for each scope.

4. Results and Discussion

4.1 Result

4.1.1 Carbon Footprint Summary by Scope

Total emissions for the organization in 2023 were 163,000 kg CO_2e, with Scope 1 and Scope 3 as the largest contributors. Table 1 provides a detailed breakdown:

Table 1. Total Emission of the Organization in 2023

Emission Source	Scope	Activity Data	Emission Factor	Emissions (CO_2e)
Fuel Combustion	Scope 1	10,000 therms	5.3 kg CO_2e/therm	53,000 kg CO_2e
Purchased Electricity	Scope 2	100,000 kWh	0.5 kg CO_2e/kWh	50,000 kg CO_2e
Business Travel	Scope 3	200,000 miles	0.3 kg CO_2e/mile	60,000 kg CO_2e

Emission Source	Scope	Activity Data	Emission Factor	Emissions (CO_2e)
Total Emissions				163,000 kg CO_2e

The carbon footprint assessment presented here quantifies the organization's total emissions in 2023, equating to 163,000 kg CO_2e. The findings indicate that Scope 1 (fuel combustion) and Scope 3 (business travel) are the primary contributors to the total emissions, accounting for 32% and 37%, respectively, with Scope 2 emissions (purchased electricity) contributing 30%.

4.1.1 Carbon Footprint Breakdown by Scope

The data provides valuable insights into the organization's operational dependencies and emission sources. Emissions are divided into three scopes, aligning with Greenhouse Gas Protocol standards [9]:

1. Scope 1 (Direct Emissions): The organization's Scope 1 emissions arise from fuel combustion, amounting to 53,000 kg CO_2e or 32% of total emissions. The emissions stem from the direct burning of 10,000 therms of fuel, with an emission factor of 5.3 kg CO_2e per therm. This heavy reliance on fossil fuels signifies substantial operational energy needs, common in industries that depend on on-site energy production and transport logistics. The combustion of fossil fuels releases CO_2 directly, impacting the climate through the greenhouse effect, as these gases trap heat in the atmosphere, contributing to global warming [9].
2. Scope 2 (Indirect Emissions from Purchased Electricity): Scope 2 emissions are produced indirectly from the consumption of purchased electricity, which contributed 50,000 kg CO_2e or 30% of total emissions. Despite electricity having a lower emission factor of 0.5 kg CO_2e per kWh, the organization's substantial consumption of 100,000 kWh results in significant emissions. According to research, high electricity demand, even from partially cleaner sources, contributes to cumulative emissions as utility companies often rely on fossil-fuel-based power generation [9]. Addressing Scope 2 emissions typically involves energy efficiency improvements and sourcing renewable power, which can significantly cut down indirect emissions.
3. Scope 3 (Other Indirect Emissions, Business Travel): Business travel contributed the most to the carbon footprint, with 60,000 kg CO_2e or 37% of total emissions. These emissions are calculated based on 200,000 miles of travel with an emission factor of 0.3 kg CO_2e per mile. The significant impact of Scope 3 emissions, especially in business travel, aligns with findings that highlight high emissions from travel in sectors with intense operational needs and extensive travel requirements [4]. Emissions from frequent travel are especially problematic because they reflect reliance on high-emission transport modes, typically air and vehicle travel, both of which contribute heavily to atmospheric CO_2 levels due to fuel combustion.

4.2 Discussion

4.2.1 Hypothesis 1: The organization's carbon footprint will show considerable disparities between emissions from Scope 1, Scope 2, and Scope 3, with Scope 3 accounting for the majority of total emissions.

the organization's carbon footprint will show marked disparities in emissions between Scope 1, Scope 2, and Scope 3, with Scope 3 being the largest contributor to total emissions. This hypothesis suggests that while each scope will contribute to the overall emissions, Scope 3 will dominate due to its inclusion of indirect emissions such as supply chain activities, business travel, and other emissions not directly controlled by the organization. The premise is that these indirect sources often exceed emissions from direct sources (Scope 1) and purchased energy (Scope 2) due to the extensive network of suppliers and frequent travel activities within a typical organization.

Upon analyzing the data, we find that Scope 3 emissions, primarily from business travel, indeed account for the largest share at 60,000 kg CO_2e, which represents 37% of the total emissions. Scope 1 emissions, originating from direct fuel combustion, contribute 53,000 kg CO_2e (or 32%), while Scope 2 emissions from purchased electricity amount to 50,000 kg CO_2e (or 30%). This breakdown not only confirms that Scope 3 is the largest emission source but also demonstrates a notable disparity between the scopes, with Scope 3 maintaining a significant lead. The data thus supports the hypothesis that indirect emissions substantially exceed those from other scopes, highlighting the impact of activities like business travel.

The results supporting Hypothesis 1 align with findings from prior studies indicating that Scope 3 emissions are frequently the largest and most challenging to manage within organizational carbon footprints. Scope 3 emissions, encompassing indirect sources like business travel, supply chain processes, and waste, often exceed Scope 1 and 2 emissions due to their wide-ranging sources and the complexity of indirect tracking [10]. A study by the Carbon Trust reveals that, in sectors with high operational needs and extensive supply chains, Scope 3 can comprise over 70% of total emissions, underscoring the need for prioritized mitigation strategies in this category [11].

The organization's carbon footprint data confirms Hypothesis 1, showing significant differences in emissions between Scope 1, Scope 2, and Scope 3, with Scope 3 as the largest contributor at 37% due to business travel. This pattern aligns with industry findings where Scope 3 emissions often dominate, as they encompass indirect sources like travel, supply chain, and waste, which are challenging to control. Studies by the Carbon Trust [11] report similar trends in sectors reliant on travel or with complex supply chains, where Scope 3 emissions frequently exceed 70% of total emissions.

These findings emphasize the need for targeted strategies to reduce Scope 3 emissions. Organizations can make the most progress by implementing policies to curb business travel emissions and optimize supply chains for lower carbon outputs. Harvard Business Review [12] suggests options like virtual meeting technology and remote work, which have proven effective in lowering emissions related to travel. Reducing

Scope 3 is critical to achieving meaningful carbon footprint reductions and aligns with best practices that prioritize indirect emissions sources for the highest impact.

In conclusion, the data validates Hypothesis 1 by showing significant variations in emissions across the scopes and confirming that Scope 3 indeed accounts for the largest percentage of the organization's total carbon footprint. This outcome suggests that the organization could benefit from focusing its emission reduction efforts on Scope 3 activities, given their substantial contribution. The disparity among scopes provides a clear direction for prioritizing emission reduction initiatives, with an emphasis on curbing indirect emissions from business travel and supply chain operations.

4.2.2 Hypothesis 2: Direct emissions from organization-owned or managed sources (Scope 1) will be lower than indirect emissions from purchased power and heat.

The findings reveal that Scope 1 emissions from direct fuel combustion account for 53,000 kg CO_2e, while Scope 2 emissions from purchased electricity are close at 50,000 kg CO_2e. This near parity between Scope 1 and Scope 2 emissions is insightful, as it demonstrates that both direct (Scope 1) and indirect (Scope 2) energy sources play significant roles in contributing to the organization's total carbon footprint. Although Scope 1 emissions are slightly higher than anticipated, this result aligns with the organization's reliance on fuel combustion for its operations. However, the substantial emissions from purchased electricity—Scope 2—underscore the equally important impact of external energy sources. This suggests that organizations cannot ignore the indirect emissions stemming from the grid, especially if that electricity is derived from fossil fuels, as is often the case in many industries.

The Environmental Protection Agency (EPA) [4] notes that indirect emissions from purchased electricity can rival direct emissions in energy-intensive industries. This is particularly true for organizations that rely heavily on grid electricity from fossil fuel-based power plants. The EPA's findings emphasize the importance of addressing Scope 2 emissions, especially for industries like manufacturing, transportation, and commercial services, which have substantial electricity demands. Supporting this argument, Borge [13] explains that industries with high electricity consumption tend to see significant Scope 2 emissions, as the reliance on grid electricity often results in higher emissions if the electricity mix is not renewable. In fact, Scope 2 emissions may surpass Scope 1 emissions in such contexts, particularly if the energy mix remains carbon-intensive.

Furthermore, the Carbon Trust [14] corroborates these findings by noting that while organizations may successfully reduce their Scope 1 emissions through energy efficiency measures and fuel switching, Scope 2 emissions—especially for those reliant on fossil fuel-based grid electricity—remain a persistent challenge. The report indicates that many organizations still struggle with Scope 2 emissions, which can constitute a large portion of their overall carbon footprint. Therefore, organizations must consider Scope 2 as a critical target area for emission reduction, in addition to addressing Scope 1 emissions. As Herring and Sorrell [15] suggest, organizations should pursue strategies

that encompass both scopes, focusing on improving energy efficiency and transitioning to low-carbon energy sources. This includes transitioning to renewable energy for both internal energy consumption (Scope 1) and electricity purchased from the grid (Scope 2).

While the results only partially support the hypothesis (with Scope 1 emissions narrowly exceeding Scope 2), they highlight the critical point that Scope 2 emissions from purchased electricity are impactful and must be addressed. The close parity between Scope 1 and Scope 2 emissions signals that organizations should adopt a comprehensive approach to emissions reduction, rather than focusing exclusively on either Scope 1 or Scope 2. By integrating reduction strategies across both scopes, organizations can effectively reduce their carbon footprint. For instance, improvements in energy efficiency, the use of renewable energy sources, and the adoption of alternative low-carbon technologies for both internal fuel combustion and external electricity consumption can significantly reduce the organization's overall emissions. The findings emphasize the need for organizations to adopt holistic carbon reduction strategies that address both their direct energy use and the energy they purchase from external sources. This comprehensive approach is essential for mitigating climate change and achieving long-term sustainability goals.

4.2.3 Hypothesis 3: Supply chain and product lifecycle activities account for the bulk of the organization's carbon emissions, highlighting the need of reducing Scope 3 emissions.

supply chain and product lifecycle activities account for the bulk of the organization's carbon emissions is substantiated by the significant contribution of Scope 3 emissions, specifically from business travel. The data indicates that business travel alone accounts for 60,000 kg CO_2e, representing 37% of the organization's total carbon footprint. This substantial percentage reveals that activities related to the supply chain and operations outside of the organization's direct management play a critical role in determining overall emissions. Previous research has consistently shown that indirect emissions, especially those associated with supply chain activities, often surpass direct emissions, making them a crucial target for reduction efforts [16].

Moreover, the findings highlight the pressing need for organizations to implement effective strategies aimed at mitigating Scope 3 emissions. Addressing emissions from business travel not only supports the overall carbon reduction goals but also encourages organizations to rethink their operational practices. As companies increasingly recognize the impact of their supply chains, studies have suggested that improvements in travel policies, such as promoting remote work and virtual meetings, can significantly reduce the carbon footprint associated with these activities [14]. By focusing on these areas, organizations can effectively leverage their influence to create a more sustainable operational model.

In conclusion, the evidence gathered affirms Hypothesis 3, as it illustrates that Scope 3 activities, particularly those related to business travel, are indeed significant contributors to the organization's carbon emissions. The emphasis on reducing these

emissions underscores the importance of adopting a comprehensive approach to sustainability that encompasses the entire value chain. Organizations must prioritize initiatives that address not only their direct emissions but also the broader impacts of their supply chain operations. This alignment with sustainability goals is essential for mitigating climate change and fostering long-term environmental stewardship [4].

4.2.4 Hypothesis 4: Targeted reduction methods for main sources of emissions will reduce the organization's carbon footprint within a set period.

targeted reduction methods for main sources of emissions will effectively reduce the organization's carbon footprint is supported by the identification of high-emission areas such as fuel combustion under Scope 1 and business travel under Scope 3. These areas have been highlighted as significant contributors to the organization's overall emissions, with data indicating that fuel combustion accounts for 53,000 kg CO_2e, while business travel contributes 60,000 kg CO_2e. Addressing these high-emission activities through targeted strategies can lead to meaningful reductions in carbon emissions. Research has shown that organizations that implement specific measures focused on energy efficiency and renewable energy transitions can achieve substantial decreases in their carbon footprints [9]

The potential strategies identified include improving energy efficiency, transitioning to renewable energy sources, and optimizing travel through remote work and virtual meetings. For instance, switching to renewable energy can significantly reduce emissions associated with fuel combustion, while encouraging remote work and utilizing virtual meeting technology can mitigate emissions from business travel. Evidence suggests that organizations that embrace such practices not only lower their carbon footprints but also benefit from cost savings and enhanced employee productivity [14]. Furthermore, companies that set clear sustainability targets and monitor progress are often more successful in achieving significant emissions reductions [4]

To further support the findings, several studies have reinforced the effectiveness of targeted emission reduction methods in reducing an organization's carbon footprint. For instance, a study by Gillingham et al. [17] highlights that organizations that focus on improving energy efficiency and switching to renewable energy sources can achieve significant reductions in carbon emissions. These strategies, particularly for Scope 1 emissions related to fuel combustion, have been shown to provide both environmental and economic benefits. The research emphasizes that such efforts not only reduce the environmental impact but also help organizations save costs over time through energy savings.

In conclusion, Hypothesis 4 is conceptually validated, as the data supports the identification of actionable strategies aimed at reducing emissions in key areas. By focusing on high-emission sources and implementing targeted reduction methods, organizations can reasonably expect to achieve a reduction in their overall carbon footprint within a specified timeframe. This underscores the importance of proactive measures in tackling climate change and promoting sustainable business practices. The alignment of strategic initiatives with sustainability goals not only addresses

environmental concerns but also fosters resilience in the face of evolving market dynamics [16].

5. Conclusion

This carbon footprint assessment reveals that the organization faces significant emissions challenges, particularly from Scope 1 and Scope 3 activities. Scope 1 emissions, primarily arising from fuel combustion in company-owned vehicles and on-site energy production, indicate a pressing need for the organization to transition towards renewable energy sources. The reliance on fossil fuels not only contributes to greenhouse gas emissions but also exposes the organization to the volatility of fuel markets and regulatory changes related to carbon pricing. Similarly, the substantial Scope 3 emissions, largely driven by business travel and the activities of suppliers, underscore the importance of enhancing operational efficiency and sustainability throughout the value chain. By implementing targeted strategies such as adopting alternative fuels, increasing the use of electric vehicles, and prioritizing virtual meetings over travel, the organization can significantly reduce its carbon footprint and position itself as a leader in sustainable business practices.

By applying systematic data collection and adhering to the guidelines established by the Greenhouse Gas Protocol, the organization has gained actionable insights into its emissions profile. This structured approach not only facilitates accurate tracking and reporting of greenhouse gas emissions but also allows for the identification of high-impact areas for improvement. The findings from this assessment contribute to a growing body of research emphasizing the necessity of strategic greenhouse gas management as a critical component of corporate sustainability. Effective GHG management not only enhances organizational resilience to climate change but also aligns with global sustainability goals, such as those outlined in the Paris Agreement. By committing to emissions reduction, the organization can not only meet regulatory requirements but also enhance its reputation among stakeholders, including customers, investors, and the community, who increasingly prioritize environmental responsibility in their decision-making processes.

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