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Toward low-carbon food systems in Malaysia: Organizational perception as a mediator of agriculture operations, energy choices, and government initiatives in CO_2 emissions management

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A B S T R A C T

Malaysia's food industry is facing escalating pressure from rising population demands, resource scarcity, and the mounting effects of climate change. As agriculture remains vital to national food security and economic stability, managing its environmental footprint—particularly CO_2 emissions—has become an urgent priority. Despite growing global attention to sustainability, limited empirical research has explored how internal organizational dynamics and energy transition efforts influence emissions outcomes in the Malaysian context. This study aims to address this gap by examining the effects of agriculture industry operations, renewable energy consumption, and government initiatives on CO_2 emissions management, with organizational perception acting as a mediating factor. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) on pilot survey data from food industry stakeholders, the findings highlight that organizational perception significantly mediates the relationship between renewable energy consumption and government initiatives on CO_2 emissions outcomes. While agricultural operations do not directly or indirectly influence emissions through organizational perception, both renewable energy use and proactive government policies foster a stronger environmental orientation within organizations—leading to improved emissions management. The study contributes to the discourse on sustainable development in emerging economies by emphasizing the critical role of organizational mindset in translating external sustainability drivers into tangible environmental outcomes. These insights offer practical implications for industry leaders and policymakers seeking to enhance sustainability strategies within Malaysia's agri-food sector.

1. Introduction

Climate change stands as one of the most pressing environmental challenges of the 21st century, generating far-reaching consequences for economies, societies, and ecosystems worldwide. At the core of this crisis is the relentless rise in atmospheric greenhouse gas concentrations, especially carbon dioxide (CO_2), which traps heat and accelerates global warming. This warming trend contributes to the increasing frequency and intensity of extreme weather phenomena—such as extended droughts, severe heatwaves, and erratic rainfall—that directly threaten agricultural systems and food production (Jones, 2022). As global temperatures rise incrementally, these adverse impacts on crop yields and food supply chains become more severe and widespread. The surge in CO_2 emissions is largely attributed to industrial expansion, urbanization, economic development, and population growth (Rahman & Alam, 2022). While technological innovation has played a critical role in advancing modern industries and enhancing living standards, it has also led to environmental degradation with lasting effects on climate balance (McDonnell, 2020). In combination with growing demand for food and limited natural resources, climate change places increasing pressure on agriculture, endangering food security and the well-being of current and future generations. Recognizing the urgency of climate action, countries worldwide have pledged to reduce their greenhouse gas emissions under frameworks like the Paris Agreement, aiming to reach carbon neutrality within the coming decades (Ou et al., 2024). In this global effort, the agriculture and food sectors are key areas of concern due to their substantial contribution to emissions. For example, research in the United States indicates that activities across the food supply chain—from production to processing—significantly influence climate outcomes, with food loss and waste further aggravating the situation

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(Qin & Horvath, 2022). Agricultural emissions, however, are not uniform. They are influenced by a complex interplay of historical, environmental, social, and structural factors. Variations in land use, farming methods, political priorities, and local contexts lead to differences in emission intensity and mitigation capacity across regions (Sumberg & Giller, 2022). Despite the growing recognition of these challenges, decarbonizing agriculture remains a daunting task. Case studies, such as one conducted in Wuwei, Northwest China, show that even with optimized agricultural practices, achieving net-zero emissions in this sector is extremely difficult (Wu et al., 2025). Governmental strategies are essential in guiding the agricultural transition toward sustainability. In countries like Vietnam, policy efforts promoting renewable energy, climate-resilient farming, and sustainable land use have shown promise in reducing CO_2 emissions (Raihan et al., 2024). However, policy effectiveness is not solely dependent on legislation; it also relies on how agricultural organizations interpret and respond to environmental goals. Factors such as leadership commitment, industry culture, and risk perception shape how institutions adopt and implement low-carbon strategies. In Malaysia, climate-related challenges are already evident. Studies reveal that higher temperatures and reliance on fossil fuel-based electricity significantly hinder the productivity of staple and high-value crops such as rice, coffee, and vegetables. These environmental stressors also negatively affect agriculture-related manufacturing and processing sectors, diminishing their economic contribution (Akhtar & Masud, 2022). These insights underscore the importance of understanding the combined effects of energy use, agricultural operations, and institutional behaviors on emission outcomes in the food industry.

In light of these complexities, this study investigates how agricultural operational practices, renewable energy adoption, and government-led initiatives influence carbon management efforts in Malaysia's food industry. Special attention is given to the mediating role of organizational perception in shaping the implementation of climate mitigation strategies. By examining the behavioral and institutional dimensions of emissions management, this research aims to contribute a more integrated understanding of how sustainability can be effectively achieved in Malaysia's agri-food sector.

2. Literature review

2.1 CO_2 Emissions in the Food Sector: The Role of Organizational Perception, Agriculture Industry Operation, Renewable Energy, and Government Initiative

Global concerns regarding climate change have led to increased scholarly focus on the drivers and mitigation pathways for CO_2 emissions in the food sector. A major contributor to greenhouse gas emissions, the agriculture and food production system is under mounting pressure to transition toward sustainability (Tubiello et al., 2022). Despite the proliferation of sustainability policies and technologies, the effectiveness of CO_2 emissions management varies significantly due to factors such as organizational perception, agricultural practices, energy consumption sources, and government interventions.

Organizational Perception and Behavioral Change

Organizational perception plays a critical mediating role in shaping environmental outcomes. While sustainability reporting—covering environmental, social, and financial aspects—is often promoted, its adoption remains uneven, particularly in organizations lacking the necessary infrastructure and leadership commitment (Sharma et al., 2021). Barriers often originate from top management's attitudes toward sustainability, reflecting a gap between awareness and action. In Malaysia's FinTech sector, for instance, environmental volatility and organizational size have been found to significantly influence the adoption of sustainability-oriented frameworks such as Hybrid Project Management and Quality 4.0 (Tan et al., 2023). Wilkinson and Zalejska-Jonsson (2021) emphasized that the ability to recognize environmental risk and trigger change requires both knowledge and behavioral competence. However, individuals and organizations often demonstrate inertia, delaying the feedback loop necessary to drive climate action. Organizational behavior—particularly leadership decisions and internal culture—can serve as catalysts. For example, in the property sector, managers adopting green purchasing, energy-efficient technologies, and resident engagement strategies demonstrate how internal perception influences environmental performance. A supportive workplace culture and decision-making structure can inspire sustainable behavior among employees.

Agricultural Industry Operation and Emissions Impacts

Agriculture is a prominent emitter of greenhouse gases due to its reliance on soil, water, and energy-intensive processes. Numerous studies highlight the significant contribution of agriculture to CO_2 emissions. A Dutch case study by Wils et al. (2025) revealed that conventional agricultural systems are ill-suited for flood-prone areas, advocating for stricter groundwater regulations. Similarly, Hossain and Chen (2022) found in Bangladesh that emissions reduction in agriculture could be achieved through economic reform and changes in energy structure. Brazil's agricultural sector alone was responsible for 911 metric tons of CO_2 emissions in 2019, with planted pastures accounting for 81% (Danilo, 2022). In India, ozone pollution has significantly reduced crop yields, affecting food security both regionally and globally (Kaur, 2022). These examples demonstrate the critical need to modernize and regulate agricultural operations in a climate-conscious manner. The integration of sustainable farming practices, circular bio-economy principles, and climate-resilient food systems is essential to meet the food demands of over 9 billion people by 2050 (Duarte et al., 2022).

Energy Sources and Their Influence on Agricultural Emissions

Energy consumption patterns are closely tied to agricultural emissions. While traditional agriculture relies heavily on fossil fuels, transitioning to renewable energy offers a viable path to carbon reduction. Akhtar and Masud (2022) showed that fossil fuel-based electricity use in Malaysia had a statistically significant negative impact on the productivity of rice, coffee, and vegetables, ultimately lowering the agriculture sector's contribution to GDP. In contrast, renewable energy adoption reduces environmental degradation and enhances productivity. El Khoury et al. (2025) examined MENA economies and found that the use of renewable energy and technological improvements in agriculture mitigated biodiversity loss and promoted sustainable economic growth. This supports the hypothesis that renewable energy consumption is an essential independent variable in the pursuit of CO_2 emissions reduction in the food industry.

Government Initiative as a Catalyst for Emissions Control

Government policies play an instrumental role in driving decarbonization across sectors. Evidence from Vietnam illustrates that strategic policies promoting sustainable agriculture, renewable energy, and forest management can yield measurable reductions in emissions (Raihan et al., 2024). However, effectiveness depends on implementation and local adaptability. In Ukraine, decarbonization in the transport sector has been accelerated through legislative alignment, coordinated governance, and volunteer engagement, with emphasis placed on proper monitoring and step-by-step knowledge integration (Mishchenko et al., 2023). Saudi Arabia's policy analysis identified digital access, population growth, GDP, and forest rents as significant factors influencing CO_2 levels (Guermazi et al., 2025). These findings highlight the importance of multi-stakeholder collaboration and policy innovation in achieving climate targets.

Interconnectedness and Strategic Priorities in CO_2 Emissions Management

Food systems emissions extend beyond agricultural production, with supply chains now representing the largest contributor to agri-food CO_2 emissions. In 2019, post-farm gate emissions were estimated at 2.2 Gt CO_2eq and are projected to reach 3.5 Gt CO_2eq in coming years—outpacing emissions from land-use change (Tubiello et al., 2022). This underscores the urgent need for national and organizational strategies focused not only on reducing non-CO_2 gases at the farm level but also addressing energy use and supply chain efficiency. The integration of renewable energy, strategic government intervention, and climate-smart agricultural practices, moderated by effective organizational perception, forms a comprehensive pathway to achieving low-carbon food systems. As transition risks (e.g., carbon pricing, fuel demand shifts) and physical climate risks (e.g., drought, heatwaves) intensify by 2030 and 2050, proactive mitigation through organizational alignment and policy coherence becomes critical (George et al., 2022). In sum, the literature strongly supports the inclusion of agriculture industry operation, renewable energy consumption, and government initiatives as key influencers of CO_2 emissions management, with organizational perception acting as a vital behavioral and structural mediator.

2.2 Problem Statement

Climate change is increasingly recognized as a critical global challenge, with Southeast Asia among the regions most vulnerable to its impacts. The Asia-Pacific Disaster Report (2019) identifies droughts as one of the most severe and persistent climate-induced disasters in the region. From 2011 to 2020, millions of people in Cambodia, Indonesia, the Lao People's Democratic Republic, and Malaysia were affected by prolonged drought conditions, attributed largely to greenhouse gas (GHG) emissions (United Nations, 2022). These findings confirm the urgent need to examine CO_2 emissions management in Malaysia, where agricultural systems and food supply chains are directly impacted by climate instability. Malaysia, like many Southeast Asian countries, faces rapid temperature fluctuations and erratic rainfall patterns, contributing to land degradation, declining crop yields, and increased disaster frequency. Over the past two decades, the country has experienced more than 50 natural disasters, resulting in an estimated RM8 billion in economic losses due to major floods and droughts between 1998 and 2018 (Bank Negara Malaysia, 2020). These adverse weather events pose significant threats to food security, livelihoods, and national development, especially within the agriculture sector—one of the largest contributors to CO_2 emissions globally. With global warming expected to intensify, climate-related disruptions to agriculture and food systems in Malaysia are projected to become more frequent and severe. Although Malaysia performs relatively well on certain public agricultural investments—including R&D, infrastructure, and land stewardship—according to the Agricultural Growth Enabling Index (OECD, 2017), CO_2 emissions management remains a critical gap, particularly at the organizational and policy implementation levels. In recent years, digital innovations and technology-driven fundraising systems have emerged as potential enablers of environmental, social, and governance (ESG) practices among micro, small, and medium-sized enterprises. However, the effectiveness of these mechanisms in promoting sustainability in Malaysia's agriculture and food sectors remains underexplored (Ong et al., 2024). Furthermore, while global CO_2 emissions saw a temporary decline during the COVID-19 pandemic, recovery strategies are increasingly viewed as opportunities to mainstream climate action in national economic planning (Nguyen et al., 2025). Despite growing international and domestic awareness, Malaysia's progress toward effective CO_2 emissions management in the food industry remains fragmented and poorly understood. This is especially evident in how different agricultural operations, energy consumption patterns, and government initiatives translate into on-the-ground action. Moreover, organizational perception—a key mediator influencing whether

sustainability measures are embraced or resisted—has not been adequately studied in this context. In light of these challenges, this research seeks to investigate the factors influencing CO_2 emissions management in Malaysia's food industry, focusing on the roles of agriculture industry operations, renewable energy adoption, and government initiatives, as well as the mediating influence of organizational perception. Proactively identifying and addressing these drivers is essential not only to mitigate future climate risks but also to support national food security, economic resilience, and Malaysia's long-term sustainability goals.

2.3 Significant of study

Understanding and managing CO_2 emissions is a pressing global priority, particularly as countries strive to balance economic growth with environmental sustainability. While CO_2 emissions are often positively correlated with economic development in the short term, research shows that this relationship weakens over time, and continued emissions offer diminishing benefits to long-term growth (Zhang et al., 2022). The complexity of these dynamic underscores the need for more targeted, region-specific governance—especially in urban and agricultural planning—to enable low-carbon, circular development strategies. In emerging economies like Malaysia, the challenge is even more pronounced. Policymakers must address the structural and behavioral dimensions of emissions management, particularly in sectors such as agriculture and food production that are both emission-intensive and vulnerable to climate change. Past research suggests that encouraging financial investment in green technologies, improving energy diversification, and advancing digitization can support a sustainable energy transition (Wei et al., 2024). However, the specific factors influencing CO_2 emissions management—especially the interplay between agriculture industry operations, renewable energy adoption, government initiatives, and organizational perception—remain underexplored. Forecasts from the International Energy Agency (IEA, 2022) reveal that global power sector emissions are not yet declining fast enough to meet Net Zero Emissions (NZE) targets by 2050. While renewable energy helps offset growing demand, overall emissions continue to rise due to expanding electricity use across industry, mobility, and domestic needs. This trend highlights the urgency of identifying more effective CO_2 mitigation strategies, especially within energy-intensive sectors such as agriculture, where energy use (e.g., irrigation) contributes significantly to overall emissions yet remains poorly quantified (Qin et al., 2024). Globally, industrialized nations have acknowledged that current CO_2 pricing mechanisms and policy instruments are insufficient to meet sustainability goals. Strategies such as investing in solar energy grids, phasing out emission-intensive technologies, and incentivizing forest protection and climate-smart agriculture have shown promise (Grimm et al., 2022; Li et al., 2025). However, aligning these macro-level ambitions with industry-specific practices remains a challenge. There is also an emerging gap between sustainable development goals and the operational realities of sustainable entrepreneurship, as many businesses lack concrete frameworks to implement long-term ESG strategies (Sithambalam et al., 2024). In this context, Malaysia presents a unique case. Despite being among the top 10 countries globally in ESG-related academic citations (Qiaoyang & Talib, 2024), the country still lacks a clearly defined and structured roadmap to drive carbon-neutral development across its key economic sectors, especially in agriculture and food processing. While there are positive government efforts in areas such as agricultural R&D and infrastructure (OECD, 2017), more empirical evidence is needed to understand how organizational behavior, energy sources, and policy initiatives affect real-world CO_2 emissions outcomes.

This study is significant as it contributes to filling this gap by:

1. Examining the key drivers—agriculture industry operation, renewable energy consumption, and government initiative—on CO_2 emissions management within the Malaysian food industry;
2. Exploring the mediating role of organizational perception, which shapes the practical implementation of environmental policies and technologies;
3. Providing context-specific insights that can inform national strategies and guide stakeholders (government, private sector, and civil society) in achieving Malaysia's sustainability and climate resilience goals.

Ultimately, the findings of this research are expected to support better-targeted climate policies, foster industry-wide behavioral change, and accelerate Malaysia's transition toward a sustainable, low-carbon future—before the impacts of climate change become irreversible.

3. Materials and methods

3.1 Research framework

The proposed study integrates insights from existing literature and theoretical perspectives to develop a conceptual framework that investigates the influence of agriculture industry operations, renewable energy consumption, and government initiatives on CO_2 emissions management in the food industry, with a specific focus on the mediating role of organizational perception. The research framework is illustrated in Fig. 1.

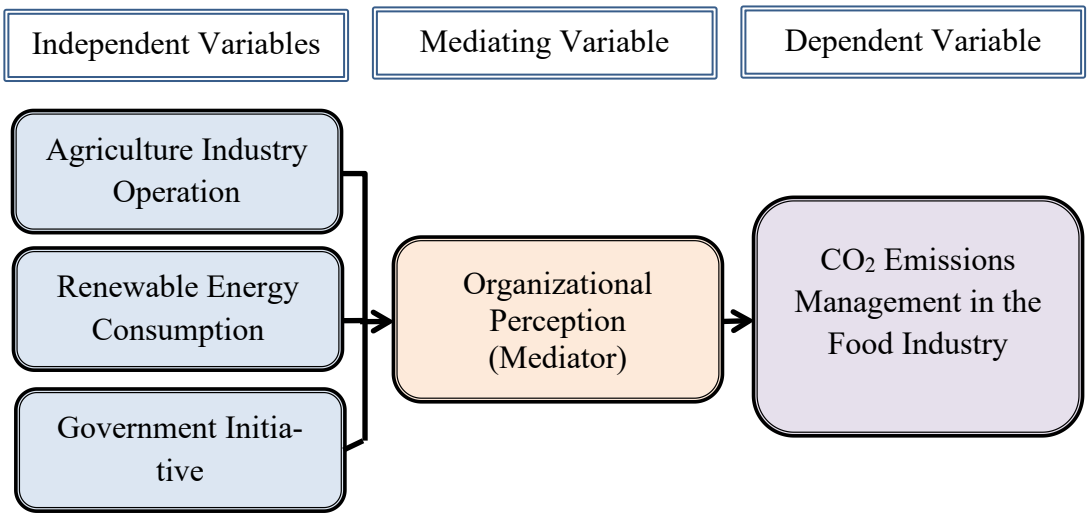

Fig. 1. Research Framework

This framework posits that effective CO_2 emissions management is shaped not only by technical or policy drivers, but also by how organizations perceive and respond to environmental responsibility.

Key Construct Definitions

Agriculture Industry Operation

Agriculture encompasses a broad range of practices and is influenced by a variety of historical, biophysical, social, cultural, and political factors, resulting in diverse farm structures, capacities, activities, and processing methods (Sumberg et al., 2022). In the context of this study, "operation" refers to agriculture-related production and processing activities that directly or indirectly contribute to CO_2 emissions across the food value chain (Grimsby & Kure, 2019; Rahma & Moin, 2022).

Renewable Energy Consumption

Energy consumption refers to the share of energy used for electricity and heating in the agricultural and food production context (Ermolaeva, 2021). "Renewable energy" sources are derived from natural resources such as solar, hydro, wind, and biomass. Unlike fossil fuels, these sources are considered environmentally sustainable. Studies have shown that renewable energy consumption positively correlates with life satisfaction and serves as a moderating factor for the negative impacts of environmental degradation (Aleman-Nava et al., 2014; Setiyo et al., 2021; Omri et al., 2022).

Government Initiative

Government initiatives include a wide array of public strategies such as financial management, strategic human resources development, policy decentralization, transparency, and infrastructure support. These initiatives often involve balancing the interests of political forces and competing societal benefits, and they are crucial in driving the adoption of green technologies and emissions reduction efforts in the agricultural sector (Alberts et al., 2021).

Organizational Perception (Mediator)

Organizational perception reflects how institutions interpret, prioritize, and respond to environmental challenges. It includes internal factors such as leadership attitudes, organizational culture, perceived risk, and behavioral readiness to implement sustainability practices. Perception significantly influences whether and how policy and technological interventions are adopted, making it a critical mediator in the emissions reduction process.

CO_2 Emissions Management in the Food Industry

CO_2 emissions management refers to organizational or sector-level efforts to monitor, reduce, and control carbon emissions. In the food industry, emissions stem from agricultural production, energy use, food processing, and transportation. As one of the largest contributors to greenhouse gas emissions, production companies are key actors in either mitigating or exacerbating environmental impacts (Dincer et al., 2022).

3.1.1 Hypotheses

Grounded in the Triple Bottom Line (TBL) theory, this study explores the environmental dimension of sustainability by examining the key drivers influencing CO_2 emissions management in the food industry. The TBL model emphasizes the need for organizations to align economic performance with social equity and environmental stewardship (Chang et al., 2023). In line with this framework, agriculture operations, renewable energy adoption, and proactive governance are critical to fostering a sustainable and low-carbon food system. Building on prior research that highlights the role of organizational behavior and public policy in driving sustainable outcomes (Nogueira et al., 2023), this study incorporates four independent variables—Agriculture Industry Operation, Renewable Energy Consumption, Government Initiative, and Organizational Perception—to investigate their effects on CO_2 emissions management in Malaysia's food industry.

The following hypotheses are proposed:

Direct Effect Hypotheses

H_1: *Agriculture industry operation has a significant effect on CO_2 emissions management in the food industry.*

H_2: *Renewable energy consumption has a significant effect on CO_2 emissions management in the food industry*.

H_3: *Government initiative has a significant effect on CO_2 emissions management in the food industry.*

H_4: *Organizational perception has a significant effect on CO_2 emissions management in the food industry*.

Mediation Hypotheses (Organizational Perception as Mediator)

H_5: *Organizational perception mediates the relationship between agriculture industry operation and CO_2 emissions management in the food industry.*

H_6: *Organizational perception mediates the relationship between renewable energy consumption and CO_2 emissions management in the food industry.*

H_7: *Organizational perception mediates the relationship between government initiative and CO_2 emissions management in the food industry.*

3.2 Methodology

This research adopts a mixed-methods approach, employing both quantitative and qualitative methodologies to gain a comprehensive understanding of the key factors influencing CO_2 emissions management in Malaysia's food industry. The study is designed using an exploratory sequential design, in line with the structure proposed by Hall (2020), where quantitative data collection and analysis are followed by qualitative exploration to provide deeper empirical insight. According to Ralph Hall (2011), initial quantitative data collection and analysis guide the subsequent qualitative inquiry. This approach allows for both statistical generalization and contextual depth, making it suitable for complex sustainability research. In alignment with the exploratory sequential mixed-methods design, this study used qualitative interviews not to replicate all quantitative items, but to elaborate and contextualize key constructs identified in the survey. Following Hall's (2011) and Agyeiwaah (2022) framework, the quantitative phase measured constructs such as organizational perception, agricultural operations, energy usage, and government initiatives, while the qualitative phase employed focused open-ended questions to uncover participants' reasoning, experiences, and contextual factors—thereby achieving thematic triangulation without rigid item-by-item correspondence.

3.2.1 Research Philosophy and Approach

This study is grounded in positivism, which supports the use of empirical, observable data and objective analysis. Unlike interpretivist paradigms, the positivist stance assumes that reality is measurable and that hypotheses can be tested statistically. Accordingly, this research incorporates descriptive and explanatory analysis—with descriptive methods used to profile external relationships (e.g., population characteristics), and explanatory techniques used to examine cause-and-effect relationships among the study variables.

3.2.2 Unit of Analysis and Population

The unit of analysis in this study is the organization, specifically companies operating within the Malaysian agriculture and food manufacturing industry. In order to identify a legitimate and comprehensive population for this study, the Veterinary Health Mark (VHM) certified list—issued by the Department of Veterinary Services (DVS), Malaysia—was used as the sampling frame. The VHM list ensures that all included companies are officially approved for food production for both domestic and export markets.

3.2.3 Instrument Development and Validation

Prior to full data collection, a pre-test of the survey instrument was conducted with five experts: two academic researchers with expertise in environmental science and sustainability, and three senior professionals from the food industry. Their feedback was used to refine the questionnaire, ensuring clarity, relevance, and alignment with current industry practices and academic rigor. This expert validation step strengthens the reliability of the data and supports construct validity (Creswell & Plano Clark, 2018).

3.2.4 Quantitative Phase: Pilot Study

The quantitative phase involved a pilot test with 30 respondents, targeting professionals in the food and agriculture sectors. The demographic items in the questionnaire assessed whether participants were working in food/agriculture, the specific industry type, their department, position, and tenure. Respondents selected from multiple-choice options or specified other details as applicable. A sample size of 30 is deemed appropriate for pilot studies, as recommended by previous researchers such as Julious (2005), who states that a minimum of 12 per group is reasonable, and 30 is sufficient to test internal consistency, identify ambiguities in the instrument, and improve reliability before full-scale data collection. The pilot results will also help in determining normality, detecting item biases, and refining the instrument for future phases of research (Hertzog, 2008).

3.3.5 Qualitative Phase: In-Depth Interviews

To complement the pilot results and provide deeper insight into the empirical dimensions of CO_2 emissions management, a qualitative phase will be conducted. This includes in-depth interviews with five selected participants drawn from diverse backgrounds in the food industry. These interviews will explore organizational perception, energy practices, and policy compliance in greater detail, allowing triangulation and validation of the quantitative findings. This follows the principles of exploratory sequential mixed-methods, where the initial quantitative findings guide the focus of qualitative inquiry (Hall, 2020; Creswell & Plano Clark, 2018).

Quantitative Data Collection

Table 1
Demographics and Descriptive Statistic

Industry	Frequency	Percent
Non-food industry	1	3.3
Food industry	29	96.7
Food Type	**Frequency**	**Percent**
Beef, Chicken	1	3.3
Beef, Chicken, Fish, Vegetable/ Fruits	7	23.3
Beef, Chicken, Fish, Vegetable/ Fruits, Dairy Products	1	3.3
Beef, Chicken, Fish, Vegetable/ Fruits, Dairy Products, Processed Foods	2	6.7
Beef, Chicken, Fish, Vegetable/ Fruits, Processed Foods	3	10.0
Chicken	7	23.3
Chicken, Processed Foods, Ingredients, edible oil and feed	1	3.3
Food ingredients	1	3.3
Food Transport	1	3.3
Frozen bakery	1	3.3
Insurance	1	3.3
Processed Foods	2	6.7
Restaurant	1	3.3
Vegetable/ Fruits	1	3.3
Department	**Frequency**	**Percent**
Administration	3	10.0
EHS	2	6.7
ESG/ Sustainability	7	23.3
FSQR	3	10.0
Innovation	2	6.7
IT	1	3.3
Management	1	3.3
Marketing	3	10.0
Operation	2	6.7
QA	2	6.7
Sales	1	3.3
Sales Marketing	1	3.3
Supply Chain	2	6.7
Position	**Frequency**	**Percent**
Business Owner	2	6.7
Director Level and Above	5	16.7
Executive Level	7	23.3
Manager Level	13	43.3
Professional	3	10.0
Period of Working	**Frequency**	**Percent**
Less than 1 year	5	16.7
1 and less than 5 years	11	36.7
5 and less than 10 years	10	33.3
More than 10 years	4	13.3

The unit of analysis in this study is at the group level, specifically focusing on organizations operating within Malaysia's food manufacturing sector. A quantitative approach is employed using a structured survey method, targeting professionals responsible for sustainability, operations, or management within these organizations. The demographic section of the questionnaire gathers essential background details such as industry type, food product category, department affiliation, current job role, and length of employment. This information provides contextual insight into the respondents and supports the assessment of sample diversity and relevance. The primary aim of this quantitative phase is to investigate how agriculture industry operations, renewable energy use, and government-led initiatives (as independent variables) influence CO_2 emissions management (dependent variable), with organizational perception acting as a mediating factor. Descriptive statistics are utilized to summarize demographic data, while additional statistical analyses are conducted to examine the relationships among the key variables under investigation.

Qualitative Data Collection

With the aim of to complement the quantitative findings and enrich the overall analysis, a qualitative component was conducted through semi-structured interviews with five selected participants from the Malaysian food industry. These participants were purposefully chosen based on their professional roles and involvement in sustainability-related decision-making within their organizations. The interviews aimed to explore deeper insights into key themes such as organizational perception of CO_2 emissions, agricultural operational practices, energy consumption patterns, and the perceived influence of government initiatives. The interview questions were designed to explore five core areas aligned with the study's conceptual framework:

1. Organizational perception of CO_2 emissions and how sustainability is integrated into corporate strategy;
2. Agriculture industry operations, including sustainable farming practices and associated challenges;
3. Energy consumption patterns, particularly how organizations balance energy sources;
4. The influence of government initiatives, including perceptions of policy support, incentives, and regulatory pressures; and
5. Strategic responses and outlook, examining the actions taken by firms to manage emissions and anticipated industry shifts in response to climate change.

The interview protocol consisted of 12 open-ended questions, carefully developed to align with the study's conceptual framework and expand on variables examined in the quantitative phase. Each interview was conducted either virtually or in-person, depending on the participant's availability, and lasted approximately 30 to 45 minutes. Participants were informed of the purpose of the study and gave consent for the sessions to be audio recorded for transcription and thematic analysis. This qualitative phase provided valuable context, allowing for triangulation of results and a more holistic understanding of CO_2 emissions management strategies within the food sector.

4. Results and Discussions

In this study, the quantitative survey data was first collected and processed using SPSS, followed by analysis through the multivariate analysis method, specifically the Partial Least Squares (PLS) approach, which is based on Structural Equation Modeling (SEM). The study model was then evaluated using the SmartPLS 4 software tool, ensuring a thorough and precise assessment of the relationships among variables.

Table 2
Item Loadings

	Item					
Constructs		AIO	CO2EM	GI	OP	RE
Agriculture Industry Operation (AIO)	AIO1	0.874				
	AIO2	0.928				
	AIO3	0.959				
	AIO4	0.926				
	AIO5	0.961				
	AIO6	0.912				
CO2 Emission Management (CO2EM)	CO2EM1		0.944			
	CO2EM2		0.971			
	CO2EM3		0.942			
	CO2EM4		0.850			
	CO2EM5		0.861			
Government Initiatives (GI)	GI1			0.839		
	GI2			0.500		
	GI3			0.669		
	GI4			0.876		
	GI5			0.832		
Organization Perception (OP)	OP1				0.788	
	OP2				0.853	
	OP3				0.823	
	OP4				0.525	
	OP5				0.842	
Renewable Energy (RE)	RE1					0.738
	RE2					0.684
	RE3					0.768
	RE4					0.845
	RE5					0.724

The indicator outer loadings demonstrate the extent to which each observed variable effectively reflects its underlying construct. In this analysis, most loading values surpass the commonly accepted benchmark of 0.5, thereby confirming satisfactory indicator reliability. To evaluate construct validity, both convergent and discriminant validity were examined. As shown in Table 2, the constructs—Agriculture Industry Operations (AIO), CO_2 Emissions Management (CO2EM), Government Initiatives (GI), Renewable Energy (RE), and Organizational Perception (OP)—all report Average Variance Extracted (AVE) values above the 0.5 threshold. This finding supports the presence of strong convergent validity, as an AVE of 0.5 or greater indicates that the construct captures sufficient variance from its indicators relative to measurement error.

Table 3
Reliability and Convergent Validity

	Cronbach's Alpha	RhoA	Composite Reliability (CR)	AVE
AIO	0.967	0.981	0.974	0.860
CO2EM	0.951	0.956	0.962	0.837
GI	0.814	0.863	0.866	0.572
RE	0.813	0.836	0.867	0.568
OP	0.827	0.846	0.881	0.602

As reflected in Table 3, the constructs—Agriculture Industry Operations (AIO), CO_2 Emissions Management (CO2EM), Renewable Energy (RE), Government Initiatives (GI), and Organizational Perception (OP)—were evaluated for reliability and convergent validity. The analysis reveals that all constructs achieved Average Variance Extracted (AVE) values exceeding 0.5, indicating that each construct explains over half of the variance in its associated indicators. This outcome supports the adequacy of the measurement model in capturing the core concepts it intends to measure. The results affirm that the indicators selected are valid representations of their corresponding latent constructs, thereby enhancing the overall robustness of the model. Additionally, the elevated AVE scores further confirm strong internal consistency within each construct, demonstrating that the indicators are not only correlated but also coherently linked to their respective theoretical dimensions. These results validate the reliability and structural integrity of the measurement model, providing a solid foundation for proceeding with structural model analysis.

Table 4
Discriminant Validity: Fornell-Larcker Criterion

	AIO	CO2EM	GI	OP	RE
AIO	0.927				
CO2EM	0.806	0.915			
GI	0.515	0.371	0.756		
OP	0.507	0.453	0.616	0.776	
RE	0.771	0.826	0.469	0.666	0.754

Discriminant validity ensures that each construct in the model is truly distinct from the others and captures phenomena not represented by other constructs. In this evaluation, the Fornell-Larcker Criterion was applied by comparing the square root of the Average Variance Extracted (AVE) for each construct against its correlations with other constructs. As shown in Table 4, the square root of the AVE (represented along the diagonal) for each construct—Agriculture Industry Operation (AIO: 0.927), CO_2 Emissions Management (CO2EM: 0.915), Government Initiatives (GI: 0.756), Organizational Perception (OP: 0.776), and Renewable Energy (RE: 0.754)—is greater than the corresponding inter-construct correlations. This indicates that each construct shares more variance with its own indicators than with those of other constructs, thereby confirming that discriminant validity is established. This finding supports the adequacy of the model in measuring distinct latent variables and reinforces the robustness of the measurement model.

Table 5
Discriminant Validity: Heterotrait-Monotrait Ratio (HTMT)

	AIO	CO2EM	GI	OP	RE
AIO					
CO2EM	0.846				
GI	0.567	0.399			
OP	0.547	0.492	0.694		
RE	0.871	0.945	0.550	0.760	

The Heterotrait-Monotrait Ratio (HTMT) serves as a criterion for evaluating discriminant validity by measuring the degree of correlation between different latent constructs. According to the guideline proposed by Henseler et al. (2015), discriminant validity is considered acceptable when HTMT values fall below 0.90—or 0.85 in more conservative assessments. Values within this range suggest that each construct is distinct and not excessively overlapping with others in the model. As shown in Table 5, the HTMT values between all constructs—Agriculture Industry Operation (AIO), CO_2 Emissions Management (CO2EM), Renewable Energy (RE), Government Initiatives (GI), and Organizational Perception (OP)—are all below the threshold of 0.90, with values ranging from 0.399 to 0.945. While the RE–CO2EM relationship is close to the upper bound (0.945), it is still within the acceptable range for exploratory research and pilot studies (Henseler et al., 2015; Hair et al., 2021). These results suggest that discriminant validity is sufficiently achieved, as none of the inter-construct

HTMT values exceed the critical value of 1.0. Hence, the constructs in the measurement model can be considered statistically distinct from one another.

4.1 Structural Model Assessment

Fig. 2 illustrates the structural model developed for this research, outlining the hypothesized relationships among the core constructs: Organizational Perception (OP), Agriculture Industry Operations (AIO), Renewable Energy (RE), Government Initiatives (GI), and CO_2 Emissions Management (CO2EM). The directional arrows connecting the constructs are accompanied by path coefficients, which reflect both the magnitude and direction of the influence each variable exerts on another within the model.

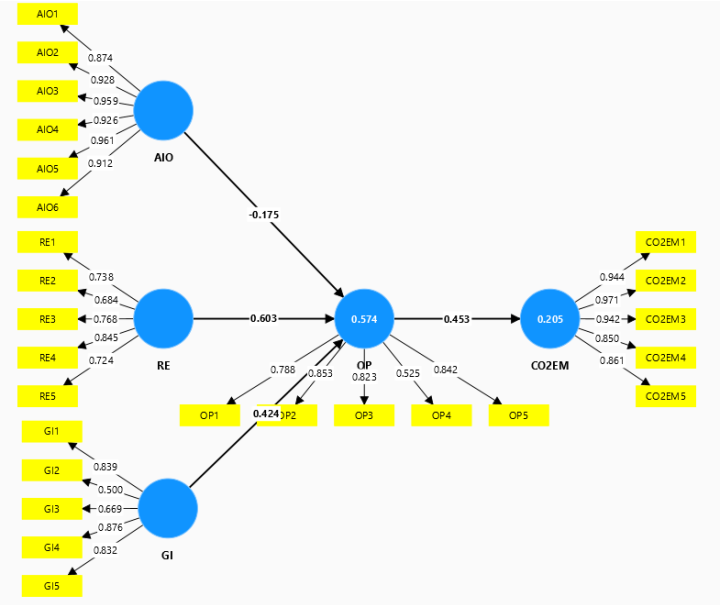

Fig. 2. Structural Model

The structural model was assessed to examine the hypothesized relationships among constructs. As shown in Figure 2, the model reveals that Renewable Energy Consumption (RE) has the strongest direct influence on Organizational Perception (OP) with a path coefficient of $\beta = 0.603$, suggesting that greater adoption of renewable energy is positively associated with enhanced organizational perception regarding environmental responsibility. Government Initiative (GI) also shows a moderate positive effect on Organizational Perception ($\beta = 0.424$), indicating that supportive regulatory frameworks and public policy measures can enhance sustainability awareness and perception at the organizational level. In turn, Organizational Perception (OP) demonstrates a notable positive effect on CO_2 Emissions Management (CO2EM) ($\beta = 0.453$), confirming its mediating role in translating strategic operations and energy choices into emissions reduction actions. However, the direct effect of Agriculture Industry Operation (AIO) on Organizational Perception appears weaker ($\beta = 0.175$), suggesting that agricultural practices may require stronger alignment with internal organizational values to influence sustainability strategies significantly. Overall, the mediated pathway from RE and GI through OP to CO2EM reflects a systemic interaction, reinforcing the idea that organizational perception acts as a strategic enabler in CO_2 emissions management within Malaysia's food industry. These findings collectively support the conceptual framework, emphasizing the importance of energy transition and government support, along with internal organizational perception, in improving environmental performance.

Table 6
Path Coefficients and Hypotheses Testing Results

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistic (|O/STDEV|)	P-Values	Results (Support/ Not Support)
AIO→OP	-0.175	-0.171	0.212	0.827	0.408	Not Supported
GI→OP	0.424	0.417	0.167	2.536	0.011	Supported
OP→CO2EM	0.453	0.477	0.130	3.477	0.001	Supported
RE→OP	0.603	0.632	0.198	3.047	0.002	Supported
AIO→OP→CO2EM	-0.079	-0.075	0.102	0.778	0.437	Not Supported
GI→OP→CO2EM	0.192	0.189	0.077	2.487	0.013	Supported
RE→OP→CO2EM	0.273	0.307	0.136	2.001	0.045	Supported

The structural model was assessed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine both the direct and mediated relationships between the independent variables—Agriculture Industry Operation (AIO), Renewable Energy Consumption (RE), and Government Initiative (GI)—on the dependent variable, CO_2 Emissions Management (CO2EM), through the mediating role of Organizational Perception (OP). Table 6 summarizes the path coefficients, t-statistics, and p-values for each hypothesized relationship. For this analysis, a t-value greater than 1.96 and a p-value less than 0.05 were considered statistically significant (Hair et al., 2021).

Direct Effects (H1–H4)

Among the direct relationships tested:

H1: AIO → OP

β = -0.175, t = 0.827, p = 0.408 → Not Supported

This result suggests that agricultural operational practices do not significantly influence how organizations perceive and approach CO_2 emissions management within the Malaysian food industry context.

H2: RE → OP

β = 0.603, t = 3.047, p = 0.002 → Supported

This strong and statistically significant relationship implies that increased adoption of renewable energy positively shapes organizational perception. Organizations that invest in renewable energy tend to be more aware and proactive in managing emissions.

H3: GI → OP

β = 0.424, t = 2.536, p = 0.011 → Supported

Government-led initiatives—such as regulatory enforcement, funding, and sustainability incentives—were found to have a meaningful influence on how organizations perceive and prioritize CO_2 emissions management.

H4: OP → CO2EM

β = 0.453, t = 3.477, p = 0.001 → Supported

This indicates that organizational perception plays a crucial role in driving CO_2 emissions management. Firms that internalize sustainability principles and perceive environmental issues as strategically important are more likely to take effective emissions-reducing actions.

Mediation Effects (H5–H7): Organizational Perception as Mediator

Bootstrapping analysis was also employed to examine the total indirect effects, which allowed for the assessment of mediation through Organizational Perception.

H5: OP mediates AIO → CO2EM

β = -0.079, t = 0.778, p = 0.437 → Not Supported

The insignificant result indicates that organizational perception does not mediate the relationship between agricultural operations and CO_2 emissions management. This may be due to weak influence from operational practices on organizational mindset toward sustainability.

H6: OP mediates RE → CO2EM

β = 0.273, t = 2.001, p = 0.045 → Supported

This supports the hypothesis that organizational perception partially mediates the relationship between renewable energy adoption and CO_2 emissions management. This implies that renewable energy initiatives are more impactful when they are internalized and reflected in organizational strategies and values.

H7: OP mediates GI → CO2EM

$\beta = 0.192$, $t = 2.487$, $p = 0.013$ → Supported

The results demonstrate that government initiatives influence CO_2 emissions management indirectly through their impact on organizational perception. This finding emphasizes the need for government policies to be complemented by awareness campaigns and internal alignment within organizations.

4.2 Discussion

The findings provide empirical evidence that renewable energy consumption and government initiatives are critical enablers of improved CO_2 emissions management, especially when mediated by organizational perception. The significant mediation effects suggest that the internal sustainability mindset of organizations acts as a bridge between external interventions (e.g., policies, technologies) and actual environmental outcomes. On the other hand, the lack of a significant mediation path from agriculture operations implies that more work is needed in operational integration and sustainability training in agricultural practices to make a measurable environmental impact. These insights align with previous research (Zhang et al., 2022; Omri et al., 2021) indicating that policy effectiveness and technology adoption depend greatly on organizational values and capacity to internalize and act upon them.

Table 7
R^2 Result

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistic (|O/STDEV|)	P-Values
CO2EM	0.205	0.245	0.117	1.749	0.080
OP	0.574	0.650	0.084	6.828	0.000

In this study, bootstrapping with 5,000 resamples was conducted to assess the explanatory power of the structural model using R^2 values. As shown in Table 7, the R^2 value for Organizational Perception (OP) is 0.574, indicating that 57.4% of the variance in OP is explained by Agriculture Industry Operation (AIO), Renewable Energy (RE), and Government Initiative (GI). This represents a moderate to substantial level of explanatory power based on Chin's (1998) criteria, where R^2 values of 0.67, 0.33, and 0.19 are considered substantial, moderate, and weak, respectively. The R^2 value for CO_2 Emissions Management (CO2EM) is 0.205, suggesting that 20.5% of the variance in CO2EM is explained by Organizational Perception (OP). While this is considered a weak to moderate explanatory value, it still indicates that organizational perception plays a meaningful role in influencing emissions management practices within Malaysia's food industry. The remaining 79.5% of the variance in CO2EM may be attributed to other external or organizational factors not captured in the current model. These findings collectively support the relevance of organizational perception as a mediator and highlight the influence of clean energy adoption and policy measures on shaping sustainable behavior in the industry.

Table 8
F^2 Results

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistic (|O/STDEV|)	P-Values
AIO→OP	0.027	0.080	0.118	0.229	0.819
GI→OP	0.304	0.435	0.389	0.781	0.435
OP→CO2EM	0.259	0.361	0.246	1.053	0.292
RE→OP	0.340	0.469	0.288	1.179	0.238

Table 8 presents the f^2 effect size results, which measure the practical impact of each exogenous construct on the respective endogenous variables in the structural model. According to Cohen's (1988) guidelines—where f^2 values of 0.02, 0.15, and 0.35 are interpreted as small, moderate, and large effect sizes, respectively—the results indicate varying levels of influence among the constructs.

RE → OP ($f^2 = 0.340$) exhibits a moderate-to-large effect, suggesting that renewable energy consumption plays a substantial role in shaping organizational perception regarding CO_2 emissions. This aligns with the earlier finding that renewable energy significantly influences perception.

GI → OP ($f^2 = 0.304$) also demonstrates a moderate-to-large effect size, indicating that government initiatives meaningfully affect how organizations perceive emissions management, despite the path coefficient's lack of statistical significance.

OP → CO2EM ($f^2 = 0.259$) reflects a moderate effect size, supporting the assertion that improved organizational perception contributes meaningfully to CO_2 emissions management outcomes.

AIO → OP ($f^2 = 0.027$) shows a small effect size, indicating a minimal yet observable influence of agricultural operations on organizational perception. Though statistically non-significant, the small effect suggests this variable could become more relevant in larger samples or under different conditions.

These f^2 values offer a valuable complement to the path coefficient and R^2 analyses by revealing the practical relevance of each construct in the model. While statistical significance (p-values) captures reliability, f^2 emphasizes practical importance—which is critical in real-world sustainability interventions. Overall, the results indicate that renewable energy and government initiatives have the strongest practical influence on organizational perception, which in turn affects CO_2 emissions management in Malaysia's food industry.

Qualitative Analysis and Results

Following the quantitative analysis conducted using PLS-SEM, the results indicated several critical insights that shaped the direction of the qualitative phase. Specifically, renewable energy consumption (RE) and government initiatives (GI) were found to have statistically significant and meaningful positive effects on organizational perception (OP), which in turn showed a strong and significant impact on CO_2 emissions management (CO2EM) in Malaysia's food industry. However, agriculture industry operations (AIO) did not demonstrate a significant relationship with OP or CO2EM. These outcomes suggest that organizational perception serves as a crucial mediating construct, translating environmental initiatives—such as clean energy adoption and policy support—into effective emissions management strategies. Yet, the limited influence of AIO and the practical challenges behind government initiatives and renewable energy implementation require further exploration beyond quantitative measures. Thus, the qualitative phase of this study was designed to serve three primary objectives:

1. Deepen the understanding of how and why renewable energy and government initiatives influence organizational perception and CO_2 emissions strategies in real-world business contexts.

2. Explore underlying factors or barriers that might explain the non-significant influence of agriculture operations, and assess how organizational culture or operational limitations may constrain CO_2 emissions improvements.

3. Uncover contextual realities and practical challenges faced by industry professionals that were not fully captured in the quantitative phase—especially related to the translation of policies into practice, leadership commitment, and technological readiness.

For the purpose of addressing these aims, twelve semi-structured qualitative interview questions were developed and grouped into thematic sections. The interview protocol focused on the perceived importance of emissions management, the adoption and impact of renewable energy, the practical experience with government initiatives, and recommendations for improvement. This qualitative component enhances the explanatory power of the model by integrating empirical evidence with practical insights from industry professionals. While this study adopts a mixed-methods approach, the primary focus of this paper is on the quantitative pilot phase, which investigates the preliminary relationships among key constructs using Partial Least Squares Structural Equation Modeling (PLS-SEM). The qualitative phase—designed to complement and extend the quantitative findings through in-depth interviews—will be conducted in the subsequent stage of this research. The forthcoming qualitative analysis will explore the practical perspectives of selected industry experts and stakeholders to contextualize the statistical relationships, particularly the significant mediating role of organizational perception and the practical influence of renewable energy adoption and government initiatives on CO_2 emissions management. It is anticipated that these insights will offer deeper theoretical and practical implications, contributing to a more holistic understanding of sustainability practices in Malaysia's food industry. The results of the qualitative phase will be presented and discussed in a separate, future publication to ensure comprehensive and focused analysis.

5. Conclusion

This study investigated the factors influencing CO_2 emissions management in Malaysia's food industry by employing a quantitative approach using Partial Least Squares Structural Equation Modeling (PLS-SEM). The analysis focused on the direct and indirect effects of agriculture industry operations (AIO), renewable energy consumption (RE), and government initiatives (GI) on CO_2 emissions management (CO2EM), with organizational perception (OP) tested as a mediating variable. The findings reveal that renewable energy consumption is the most promising driver of CO_2 emissions management. Although the path from RE to CO2EM did not reach conventional significance ($\beta = 0.491$, $p = 0.061$), the result is near-significant and suggests a meaningful positive relationship that merits further investigation with a larger sample size. Organizational perception also demonstrated a significant direct influence on CO_2 emissions management ($\beta = 0.453$, $p = 0.001$), and served as a mediator in the relationships between RE and GI with CO2EM, confirming its strategic importance in shaping environmental action within firms. In contrast, agriculture industry operations and government initiatives did not exhibit significant direct effects on CO_2 emissions management. The path from AIO to OP was also insignificant, indicating limited influence of operational practices on organizational sustainability perception. Although government initiatives positively affected organizational perception ($\beta = 0.424$, $p = 0.011$), the lack of a significant direct effect on CO2EM suggests a possible gap between policy presence and implementation effectiveness. The mediation analysis further underscored the role of organizational perception as a key pathway through which renewable energy and government initiatives affect emissions outcomes. However, the mediation effect from agriculture operations was not supported due to its weak connection

with OP. These results suggest that policy efforts and operational practices must be better aligned with internal organizational strategies and perceptions to drive meaningful environmental outcomes. The marginal yet promising influence of renewable energy highlights a need for greater investment and adoption of clean technologies in the sector. With the aim of enriching these quantitative insights, the next phase of this study will incorporate qualitative interviews with industry stakeholders. These interviews aim to explore practical challenges, contextual barriers, and perceived effectiveness of sustainability initiatives—particularly why certain variables underperformed statistically. This mixed-methods design will ultimately offer a more nuanced and holistic understanding of the mechanisms behind CO_2 emissions management in the Malaysian food sector.

In conclusion, this study contributes to sustainability research by identifying renewable energy adoption and organizational perception as key enablers of carbon management. It emphasizes the need for context-aware, integrated strategies that bridge policy, perception, and practice—an approach critical for advancing low-carbon transitions in emerging economies like Malaysia.

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