

Enablers and Barriers of Businesses Towards Net-Zero Emissions Economy: A Systematic Review

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Abstract

The transition to a net-zero emissions economy is critical for mitigating climate change and achieving sustainable development goals (SDGs). However, the pathway is fraught with complex challenges, particularly at the enterprise level, where economic pressures and technological limitations exist. This study addresses the research gap concerning the enablers and barriers influencing firms' adoption of net zero strategies by conducting a systematic literature review. Utilising PRISMA guidelines and the Tranfield framework, the review synthesises key themes, including policy and regulatory challenges, financial constraints, technological and infrastructure barriers, organisational dynamics, and market limitations. The findings reveal a scattered emerging nature in the literature. Additionally, the collected number of 191 barriers and 101 enablers, highlight the pivotal role of strategic policy frameworks, financial incentives, technological innovation, and stakeholder collaboration in overcoming implementation obstacles. These insights provide strategic direction for policymakers, business leaders, and researchers to design adaptive policies, foster collaborative ecosystems, and develop sustainable business models, ultimately supporting the transition to a net-zero emissions economy. This review makes a distinct contribution by systematically consolidating and comprehensively presenting a state-of-the-art collection of enablers and barriers influencing firms' adoption of net-zero strategies across multiple contexts. It offers a collective overview of enterprise-level challenges and opportunities, paving the way for more informed practices and future research.

Word count: 5760

1. Introduction

The increasing levels of greenhouse gases (GHG) emissions have become an unintended consequence of modern civilisation's advancements (Filonchyk et al., 2024). As challenging as that statement sounds, yet it remains a reality that stems from the environmental degradation that has been unfolding since the dawn of the industrial revolution (Wang et al., 2023). For instance, the global GHG emissions in 2023, accounted for 53 GT CO_{2eq} with CO₂ being the main contributor representing 76.6%, this number soars to a record high in 2024 (European Commission, 2024). Subsequently, global Carbon emissions reached an all-time high recording a staggering 41.6 GT, compared to the six GT emitted in 1950 (Liu et al., 2024; WMO, 2024). The implications with this rising magnitude have profound impacts across multiple aspects, including disruption in the global ecosystem, extinction of over 30,652 species, heightened recorded risks to human mortality, not to mention the climate change and rising in sea level that has been a factor of great magnitude contributing to numerous severe and increasingly frequent environmental disasters, such as hurricanes, fires, tsunamis, and other extreme unstoppable weather events (IPCC, 2023). Hence, transitioning towards Net-Zero (NZ) emissions has become a key component of the global agenda to combat climate change, particularly in the wake of growing awareness of the environmental consequences of industrial and business activities over three decades (Berry et al., 1998). Fundamentally, NZ strategies (NZSs) aim to eliminate or at least offset the amount of GHG emissions produced with an equivalent amount removed from the atmosphere, thereby achieving a state of environmental impact neutrality (Wang et al., 2023; Azevedo et al., 2021).

Conceptually, systems that abide by NZSs shall not have any negative emissions including CO₂, NO_x, and SO_x or rather offset them with an equivalent uptake by technological advances such as carbon capture technologies, which in this scenario, the resulting product or service is considered sustainable and carbon neutral (Su et al., 2022). Thus, NZSs are considered as a central phase in achieving SDGs set forth by the United Nations, particularly circling SDG 7, 8, 9, 12 and 13 (United Nations, 2024). Notably, the business sector energy consumption collectively plays a crucial role in this transition, as firm's energy usage is major contributor to global emissions with more the 52% of the total carbon emissions (Ritchie et al., 2024; Capros et al., 2019).

However, while the imperative to achieve NZ is undeniable, the ability of businesses to adopt energy-efficient strategies or innovative technologies have been arguably intrinsically tied to their economic growth (Bag, 2023; Stern and Valero, 2021). Consequently, firms operating under resource or financially constrained environments struggle to prioritise sustainability as immediate survival often outweighs long-term climate goals (Bag, 2023; Uğur Soytaş et al., 2019).

As a response, many countries have pledged to reach NZ emissions. For instance, the UK, EU, and Japan aim to achieve climate neutral goals by 2050, China by 2060, and later India by 2070 (van Soest et al., 2021; GOV.UK, 2021). However, many firms, particularly small and medium-sized enterprises (SMEs), face significant barriers to implementing these strategies. For SMEs in particular, this balancing act is critical, as their constrained budgets and operational limitations often leave them at a disadvantage in adopting costly long-term NZ measures without jeopardising their financial stability and their short-term growth (Bag, 2023; Blundel, 2021). On the other hand, larger corporations, while often better resourced, also face complexities in integrating sustainability goals with growth objectives. However, the complex relationship between NZSs, firms' energy efficiency, and economic growth remains inadequately understood. Specifically, firms' ability to adopt NZSs is influenced by multifaceted challenges, which appears to be fragmented throughout the body of literature. That goes back to the limited empirical studies exploring the impact of NZSs on firms' energy efficiency and economic growth. Hence, it is crucial to consolidate existing knowledge by comprehensively identifying and categorising the diverse barriers and enablers detailed across the fragmented body of literature that influence the path of NZ transition at the enterprise level. To achieve this aim, this systematic literature review explores the key themes within the literature, identifying eight themes that are the spotlight of research. Additionally, the study collected 191 barrier and 101 enabler that can serve as a guide for future policy, research, and development within the scope of transitioning to a NZ economy. Moreover, the research is driven by targeting to answer these two questions:

1. What is the current state of research on the transition to net-zero emissions economy?
2. What are the key themes, challenges, and enablers influencing the transition to net-zero emissions?

Furthermore, this paper structure is organised to provide a comprehensive exploration of the

research aim, starting with a methodology section that outlines the systematic literature review approach, detailing the search strategy, inclusion and exclusion criteria. Followed by findings and discussion section presenting a synthesis of the literature, identifying key themes, challenges, and enablers influencing the adoption of NZSs. Finally, the conclusion summarising the key findings, theoretical and practical contributions, and policy implications, underscoring the need for a holistic and interdisciplinary approach to achieving sustainable NZ transitions.

2. Methodology

In order to explore and bridge the existing gaps within the body of knowledge, a literature review is essential to evaluate the present state of advances within the scope of NZSs. Hence, researchers have been following one of two paths in reaching this aim. One path involves conducting systematic literature review (SLR), in which a framework is developed and employed acting as a guide along the process of synthesising all relevant studies (Petticrew and Roberts, 2006). The alternative, a narrative approach, is not framework-specific and offers adaptability during the research process. However, this adaptability comes with significant limitations, particularly concerning validity, reliability, and the possibility for researcher bias, which can compromise the credibility of the findings (Grant and Booth, 2009; Tranfield et al., 2003). While both narrative reviews and SLRs utilise precise search techniques and define a specific scope for reviewing literature, the inherent drawbacks of the narrative approach make it less suitable for achieving the aims of this study. Therefore, to ensure a robust and objective synthesis of the existing knowledge, the SLR approach was followed. That is due to its ability to offer methodological rigor, ensuring a transparent, reproducible, and comprehensive assessment to the present body of knowledge, which can be easily audited. Additionally, SLR provides a structured process that minimises author's bias, thereby reducing the potential for error, and facilitates a thorough synthesis of up to date existing evidence, making it highly effective for generating new insights, identifying gaps, and uncovering areas for future research and development (Tranfield et al., 2003).

Among the numerous frameworks proposed for conducting a rigorous SLR, scholars tend to adopt a single or a mix of frameworks that best serve the research aim while answering their intended research questions. However, irrespective of the chosen framework, a robust SLR is reviewed based on the quality of comprehensive research and assessment method, collection and analysis of relevant data from selected studies, results reporting, and most importantly, the clarity

of the addressed formulated research questions that the study aims to review (Tranfield et al., 2003). This approach helps eliminates the redundancy in addressing the same questions among researchers of similar topics.

Hence, to ensure methodological rigor, employing “Preferred reporting items for systematic reviews and meta-analyses” (PRISMA) guidelines, is recognised for their strength in conducting SLR among various disciplines. In addition, the framework proposed by Tranfield et al. (2003) in SLR will also be employed. This combination will enable the research to best adopt the topic aim. Moreover, this approach ensures to be transparent, reproducible, and provides a rigorous and systematic process that enhances reliability, incorporates the latest evidence in the body of knowledge, and helps uncover research gaps and opportunities for further exploration.

The PRISMA guidelines provide a rigorous and standardised framework designed to enhance the transparency, consistency, and reproducibility of systematic reviews (Moher, 2019). They consist of a 27-item checklist covering aspects of a review structure, including the title, abstract, rationale, objectives, protocol registration, eligibility criteria, data sources, search strategy, study selection, data collection, synthesis of results, and discussion. Each of these items was followed in conducting and reporting this review. Additionally, the PRISMA framework includes a four-phase flow diagram, which is followed in Figure 2 below, outlining the study selection process from initial identification to final inclusion. By ensuring a structured and methodical approach throughout the review process, PRISMA helps reduce bias and improve the reliability of findings. Its adaptability across disciplines (Pahlevan-Sharif et al., 2019) further strengthens the robustness of this systematic literature review and supports the overall aim of this study.

To complement the PRISMA guidelines, this study will also adopt the framework proposed by Tranfield et al. (2003), which was initially developed to address some of the limitations of traditional narrative reviews within management research. Particularly, the framework emphasises the importance of systematic, transparent, replicable review processes, borrowing principles from medical sciences to enhance the quality of evidence synthesis in management studies. Additionally, it introduces a rigorous approach that reduces research bias by clearly defining each of the three main stages explained in their study including planning, conducting the SLR, and reporting and discussion. Moreover, this structured method facilitates making the SLR findings more relevant to both academic and practitioner communities by synthesising contemporary evidence, thereby supports decision making and policy formulation, which is one of the main aims of this study. Furthermore, the methodology involves creating a detailed review

process that defines the research questions, inclusion and exclusion criteria of relevant studies from the body of literature, and the information extraction process. Consequently, this structured approach not only ensures consistency and reduce various errors while conducting SLR, but also allows for a more thorough understanding of the topic by integrating evidence across different studies, which will be of aid in addressing the explored gaps. Given the multidisciplinary nature of the topic of NZ in relation to EE and economic growth, this approach is particularly suitable for integrating evidence from diverse fields and addressing the identified research gaps. Hence, by employing this systematic framework in combination with PRISMA guidelines, this study can bridge the existing knowledge gaps and contribute reliable insights, ultimately supporting the development of further studies in this topic as well as an informed practices and policies.

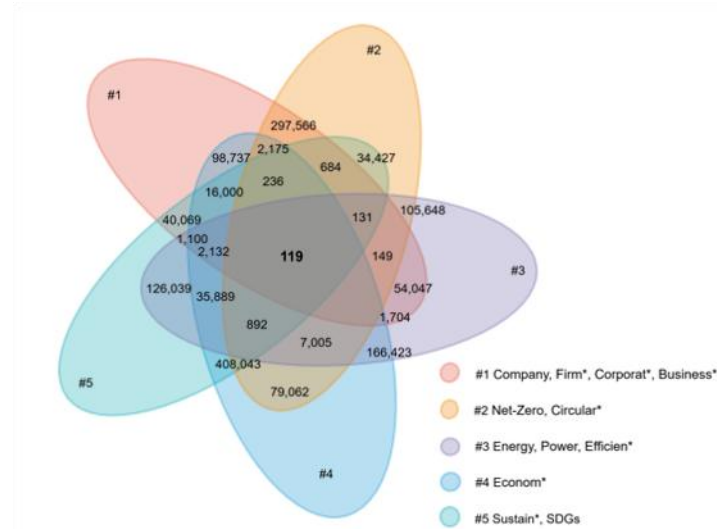


Figure 1 Mapping keywords search Results in Research areas

Beginning with the initial planning stage, a process of conceptualisation and categorisation took place among the authors, resulting the formulation of the previously discussed research questions, which then provided the keywords for conducting the bibliographic inquiry, as shown in Figure 1. A set of keywords including Net-Zero, circular*, energy, power, efficien*, sustain, company, firm*, corporat*, business*, and econom*, were repeatedly matched with the search criteria undergone iterative refinement to narrow down the relevant studies using Boolean operators as well as the asterisk (*) to capture different word variations of the intended root words. The search criteria included title, abstract, authors' keywords, and followed by full text filtration process to ensure relevance. Additionally, the search was inclusive to all subject areas, document types, and publication stages. However, the exclusion criteria included:

- I. Research that does not have a direct focus to net-zero transitions, energy efficiency, or economic growth.
- II. Studies focusing solely on environmental science such as climate change.
- III. Studies presenting claims without empirical validation or those demonstrating insufficient clarity in how data was collected, analysed, or reported.
- IV. Articles not written in English or published before 2010.
- V. Studies focused on sectors outside the scope, such as healthcare, tourism, individual consumer behaviour.

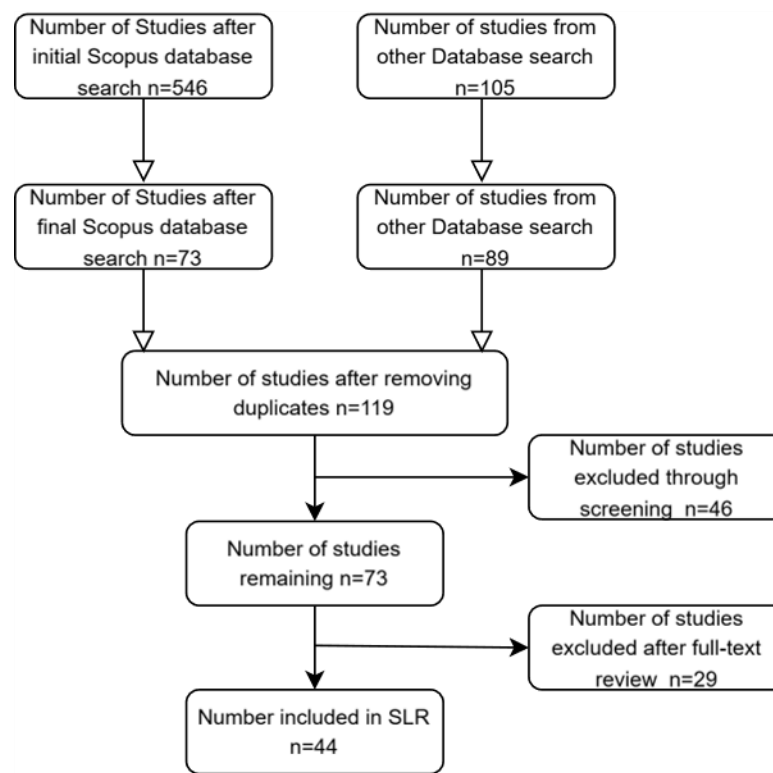


Figure 2 Resulted Studies Filtration Process Flowchart

In the conducting stage, as shown in Figure 2, the initial search query using the previously mentioned keywords resulted 546 papers on Scopus database. Additionally, searches from other bibliographic databases were included, in which a total of 105 papers using similar search query on GoogleScholar, and ScienceDirect. However, after removing duplicate studies, the majority of the resulted papers from the previous search query showed that the focus of the studies revolves around circular economy (CE) not NZ, yet the relevance to the NZ wasn't strong as the focus was on various aspects of CE. Hence, after a series of filtration, as shown in Figure 2, 44 papers

emerged based on the condition of including “Net-Zero” term in the title to ensure relevance. These final 44 studies were drawn from the searches conducted across Scopus, Google Scholar, and ScienceDirect after the described filtration process. Additionally, to explicitly align the search results with businesses’ related studies, relevant business terminology was incorporated into the title, as the research focuses on firm-level. Moreover, the root word for CE was also included in the title, as there are many studies that focused on CE yet explored the relationship between CE and NZ in their research, thus makes them relevant to the included body of knowledge. Additionally, the root words for energy, efficiency, economy, and sustainability, were included in title, abstract, or keywords, to ensure the inclusion of studies that revolve around the same scope of this research.

This phase was followed by a further filtration, aiming to remove relevance ambiguity, based on the full text of the resulted papers, which yielded a total of 44 papers scattered on 11 fields, of whom will be the focus of the SLR as shown in Figure 2. Additionally, this full text selection process is based on multiple factors applied on the initial search, to ensure that the scope of selected studies was strictly aligned with the core research objective, these factors include, (a) Explicit Contextual relevance to Net-Zero Strategies and EE. (b) Elimination of any duplication.

In the final stage of reporting, the presented results followed two main categories, descriptive analysis and synthesis. The descriptive analysis provides a factual overview, incorporating statistical and visual representations of data to illustrate trends and relationships identified throughout the literature research. In contrast, the synthesis aims to interpret the data in depth, drawing conclusions about the broader implications. Hence, this combined approach ensured thorough reporting of findings, enhancing both transparency and comprehensiveness of the SLR. Additionally, it facilitates answering the research questions by uncovering the current knowledge landscape of NZ initiatives and highlighting key areas for future research and development, thereby demonstrating the robustness and relevance of this methodology.

3. Findings and Discussion

3.1. Descriptive Analysis

This section presents a descriptive analysis of the 44 sources included in this SLR, focusing on their distribution across publication years, dissemination outlets, subject areas, and interdisciplinary fields. It also examines the methodological approaches employed, including quantitative, qualitative, and mixed methods designs. Hence, this analysis provides a nuanced understanding of the research landscape thus far, highlighting emerging trends, multidisciplinary intersections, and methodological preferences that shape the academic discourse on NZ transitions.

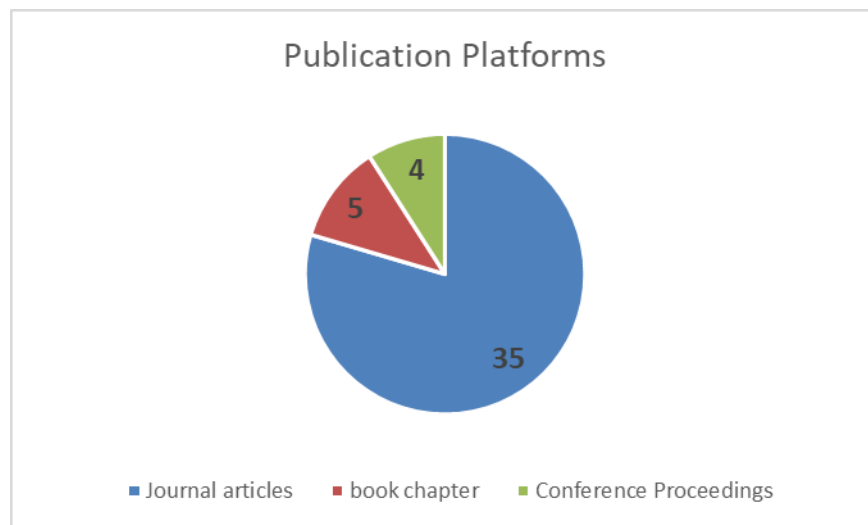


Figure 3 Distribution of Included Studies by Type of Publication Outlet

As illustrated in Figure 3, the final set of 44 studies, most studies were published in peer-reviewed journals representing 80%, reflecting the strong academic engagement within NZ research. Additionally, 11% of the studies were disseminated as book chapters, while 9% appeared in conference proceedings indicating the presence of ongoing discussions in specialized forums. The journal articles were published across a broad range of academic outlets, with the majority appearing only once spanning across 30 different journals. However, five journals emerged as recurrent academic channels, featuring two or more articles on the topic, which are: Journal of Cleaner Production, Sustainability, Business Strategy and the Environment, Journal of Environmental Management, and Energies.

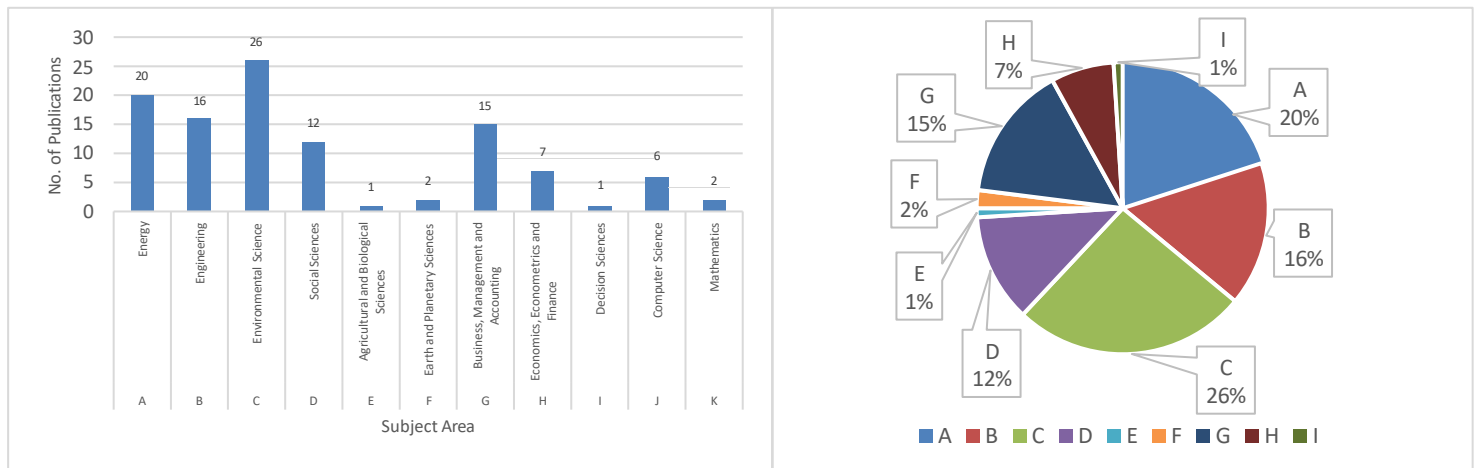


Figure 4 Interdisciplinary Distribution of Net-Zero Research Across Multiple Fields

As illustrated in Figure 4, the selected studies span 11 distinct subject areas, with several papers overlapping across multiple disciplines, reinforcing the inherently multidisciplinary nature of NZ research as it is influenced by various aspects. The distribution of studies across fields such as energy, engineering, environmental science, business management, and economics highlights the fragmented yet interconnected nature of this research domain. Additionally, the subject areas with the highest concentration of research is Environmental Science, representing 26% of the total publications, indicating a strong academic focus on sustainability and environmental impact within the context of NZSs. This is followed by Energy, accounting for 20%, which reflects the critical role of energy systems in achieving NZ targets. Business, Management, and Accounting is the third most researched area, comprising 15% of the studies, highlighting the growing interest in corporate sustainability practices and strategic management related to NZ transitions. Hence, this dispersion underscores the necessity for cross-disciplinary approaches to fully comprehend the complexities of NZSs, integrating technological advancements, policy frameworks, economic implications, and corporate sustainability practices, which is yet to be uncovered by further research and technological advances.

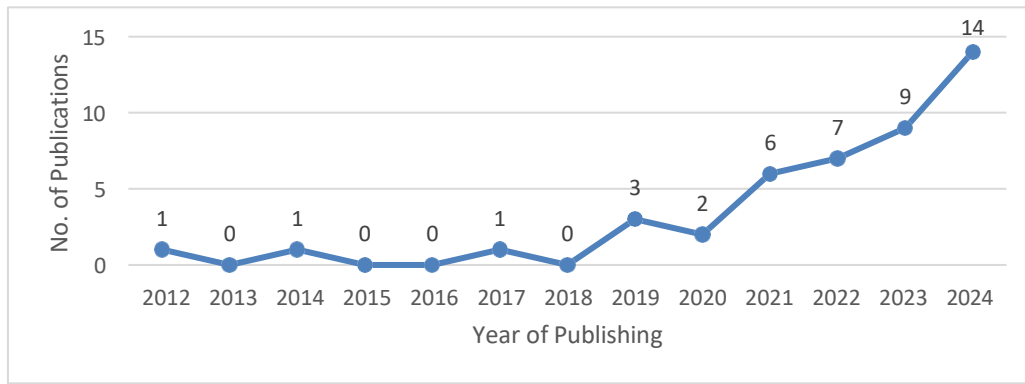


Figure 5 Resulted Number of Publications Per Year

Moreover, the longitudinal distribution of studies shown in Figure 5, reveals a notable surge in the combined research activity on NZSs, energy efficiency, and economic growth in recent years. The majority of studies published between 2022 and 2024 representing 68%, reflecting a heightened academic and policy-driven focus on sustainability transitions. This trend aligns with increasing global commitments to NZ targets and the evolving regulatory landscape. Earlier studies, particularly those published before 2020, laid the fragmented groundwork for foundational theories and conceptual discussions, providing critical insights that have since been expanded upon in more recent empirical and applied research. Additionally, the majority of the literature appears to have an empirical nature, with 44% of studies adopting quantitative approaches, predominantly utilising econometric modelling, Autoregressive Distributed Lag (ARDL) (Han et al., 2023), Partial Least Squares Structural Equation Modelling (PLS-SEM) (Rahman et al., 2024), Multi-Criteria Decision Making (MCDM) (Agrawal et al., 2023), simulation-based optimization and statistical analysis. Qualitative methodologies account for 31% of the studies, offering in-depth insights through case studies, policy reviews, and thematic analyses, which contribute to a nuanced understanding of strategic and policy-oriented aspects of NZ initiatives. Meanwhile, mixed-methods studies represent 25% of the selected papers, integrating surveys with statistical modelling to blend empirical data with contextual interpretation. Notably, a smaller proportion of studies employed mathematical, simulation, and modelling techniques, underlining the field's inclination towards data-driven analyses.

3.2. Synthesis

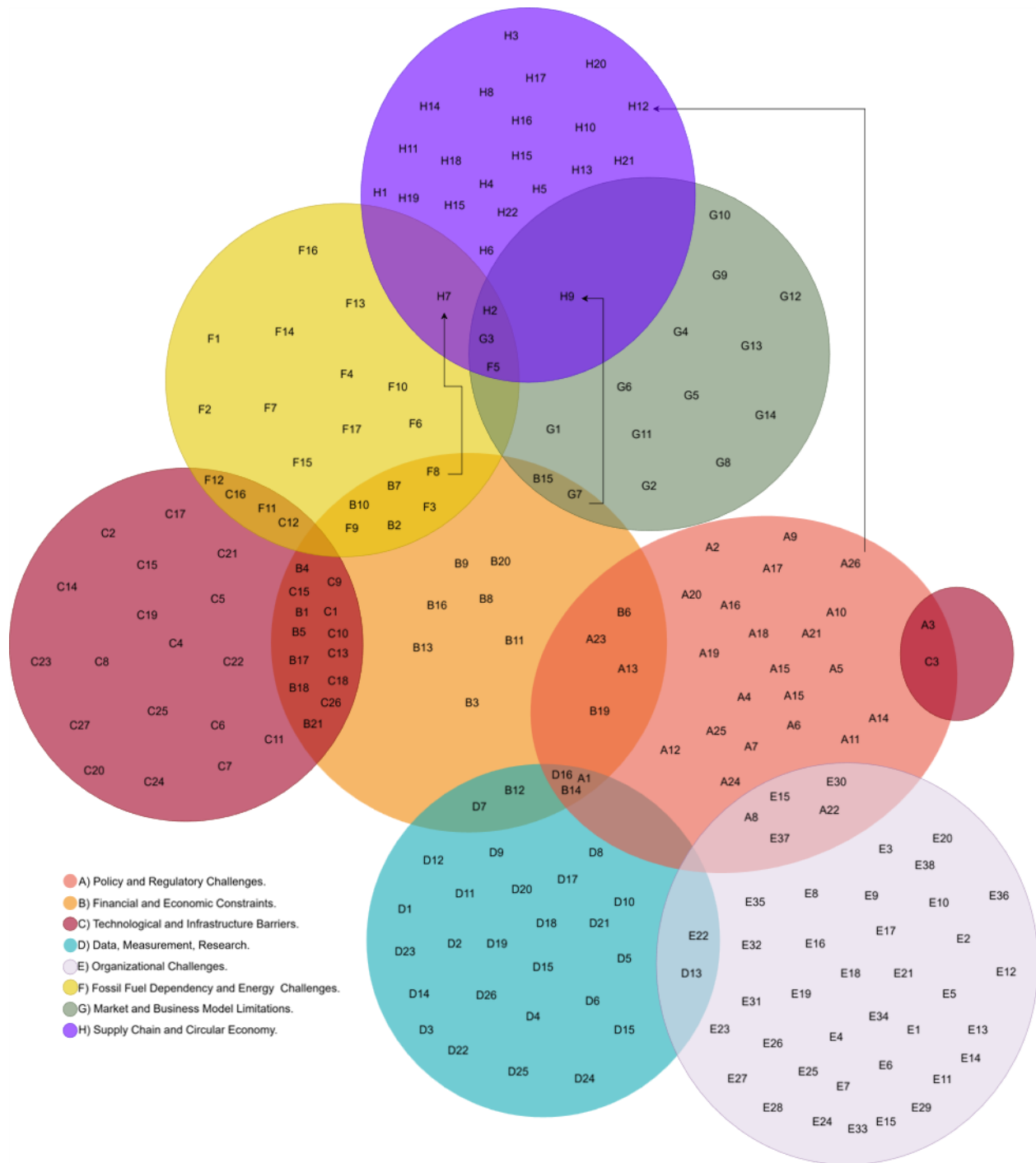


Figure 6 Thematic Classification of Barriers to Net-Zero Transition: A Venn Diagram Representation

The analysis of barriers and enablers within the literature on NZSs reveals eight interconnected themes, as shown in Figure 6 and Table 1 below, each representing critical challenges and potential pathways for progress. Figure 6 visually illustrates the complex

interdependencies of barriers within these themes, highlighting the multifaceted nature of NZ transitions, while Table 1 below, systematically categorizes the barriers and enablers collected from the body of literature, providing a comprehensive overview of the factors influencing these strategies. Additionally, as detailed in Table 1, each theme labelled from A to H, is accompanied by a numbered list of barriers and enablers. In Figure 6, each circle within the Venn diagram represents a theme, with its corresponding barriers identified by the theme's letter and the barrier's number within that theme. These themes are Policy and regulatory challenges, financial and economic constraints, technological and infrastructure barriers, data, measurement, and research, organisational challenges, fossil fuel dependency and energy challenges, market and business model limitations, and supply chain and circular economy. Hence, the following synthesis provides an in-depth overview on each theme, highlighting their interdependencies and implications for achieving NZ objectives, thereby building on the foundational overview presented in Figure 6 and Table 1.

Table 1 Thematic Classification of Barriers and Enablers to Net-Zero Transition

Theme	Barrier	Enablers	Reference
A) Policy and Regulatory Challenges	1. Uncertainty and inconsistency of regulations and lack of clear, certain, and stable policy frameworks which can cause double counting, and unstable policy support.	1. Government incentives aiming to facilitate implementation.	(Riedel, 2024) (Ferdaus et al., 2024) (Omrany et al., 2022)
	2. Lack of research, regulations and Inadequate Government incentives.	2. Refining regulations in the adoption of advanced technologies such as AI, blockchain, quantum computing, digital twin, cloud computing, big data, IoT, and robotics.	(Han et al., 2023) (Virmani et al., 2022) (Hakovirta et al., 2022) (Mushafiq et al., 2024)
	3. Complex relationship between infrastructure, legislation and environmental impact.	3. Implementation of smart grids and AI-driven energy management systems.	(Rahman et al., 2024) (Nyangchak, 2022) (Bag, 2023) (Deng, Wang and Dai, 2014)
	4. Mismatch Between Policy Targets and Business Practices.	4. Development of universal standards and protocols for blockchain-based energy trading systems.	(Stern and Valero, 2021) (Markouizou, 2023) (Sartori et al., 2012) (Wang et al., 2023) (Asif et al., 2023) (Renné, 2022)
	5. Slow Corporate Transition to Net-Zero depends on governmental policies.	5. Standardized building codes.	(Rosenow and Eyre, 2022) (Su et al., 2022)
	6. Short-term financial risks associated with net-zero policies.	6. Policy Incentives and Market Reforms for Energy Sharing.	(Zipse et al., 2023)
	7. Green Extra-activism Concerns.	7. Government Incentives and Policy Support.	(Tian et al., 2023) (Xu et al., 2023) (Pinkse,
	8. Heterogeneous and fragmented factors of green industry.		
	9. Overlooking social structures where green industry is embedded.		

	10. Contested theoretical claims and practical methods of green growth and degrowth.	8. Supportive institutional framework for energy firms.	Demirel and Marino, 2023)
	11. Regional Disparities in Green Technology Adoption and Lack of Global Cooperation in Energy Transition.	9. Gradual Implementation of net-zero policies that lower long-term financial risks and Long-term policy planning.	(Virginia, Ryan and James, 2012)
	12. Unprepared institutional and policy frameworks.	10. Energy price changes and consumption permits.	(Loveday, Morrison and Martin, 2022)
	13. Lack of Integrated Economics and Climate Policies.	11. Policy Incentives and Government Regulations.	
	14. Weak Global Coordination on Net-Zero Goals.	12. Strong and Stable Policy Frameworks.	
	15. Complex regulatory environments.	13. Developing country analytics that lead to a comprehensive national energy plan and clear regulations.	
	16. Policy and Regulatory Variability Across Countries.	14. Financial incentives, Policy Alignment and Standardized global Regulations.	
	17. Geopolitical Challenges in Oil and Gas Decarbonization.	15. Stronger Government Policies and Carbon Pricing Mechanisms.	
	18. Regulatory and Policy Uncertainty in Carbon Reporting.	16. Clearer policies and Targeted Policy Support for Hard to Decarbonize Sectors and Renewable Energy Adoption.	
	19. Policy implementation gaps and commitment referring to Current pledges by national governments are far less ambitious than needed to remain within the 1.5°C goal.	17. Regional Customization of Renewable Energy Policies.	
	20. Lack of Policy Support for Demand-Side Energy Efficiency Measures.	18. Policy reforms and Utilization of Government Carbon Reduction Incentives.	
	21. Lack of Comprehensive Policy Frameworks for Renewable Energy Expansion.	19. International policy frameworks and standardisation.	
	22. Potential negative impact of environmental regulation on businesses competitiveness.	20. Improved stakeholder collaboration on net-zero policy development.	
	23. Economic and policy trade-offs in implementing green innovation.		
	24. Uncertainty in the effectiveness of environmental regulations.		
	25. Inconsistent energy policies.		
	26. Incomplete Consideration of Life-Cycle Carbon Emissions.		
B) Financial and Economic Constraints	1. High initial, installation, investment, and transitioning costs for digital	1. Government incentives aim to facilitate implementation of	(Riedel, 2024) (Ferdaus et al., 2024)

solutions and Clean Technology Deployment.	Net zero strategies.	(Omran et al., 2022)
2. Challenges in decoupling fossil fuel energy usage and economic growth given the continuous increase in energy demand due to economic growth and population increase.	2. Public-private partnerships and collaborations.	(Lopes et al., 2016)
3. Financial Constraints for Net-Zero Investments and Limited access to green capital and Limited financial resources.	3. Policy Incentives and Market Reforms for Energy Sharing.	(Han et al., 2023)
4. High Capital Intensity of Decarbonization Technologies.	4. Growth in Green Financing, Investment and schemes such as green bonds.	(Virmani et al., 2022)
5. High initial capital expenditure on infrastructure and stranded assets.	5. Subsidies for renewable energy.	(Ahmed et al., 2022)
6. Short-term financial risks associated with net-zero policies.	6. Creating compensation, financial support, and investment schemes for provinces that switch away from fossil fuel.	(Hakovirta et al., 2022)
7. Increased compliance costs for energy firms reliant on fossil fuels.	7. Expansion of Green Financing and ESG Investments.	(Mushafiq et al., 2024)
8. Limited adoption and access to green finance across companies.	8. Carbon Pricing and Market-Based Incentives.	(Rahman et al., 2024)
9. High logistics transition costs.	9. Financial incentives, Policy Alignment and Standardized global Regulations.	(Nyangchak, 2022)
10. Delayed decoupling from Carbon-Intensive Growth, economic inequality, and stranded assets.	10. Government Backed Financial Incentives and Subsidies for EVs.	(Stern and Valero, 2021)
11. Green Extra-activism Concerns of hindering economic growth.	11. Diversified energy investments.	(Di Vaio et al., 2024)
12. Contested theoretical claims and practical methods of green growth and degrowth.	12. Economic Incentives and Cost reduction strategies.	(Sartori et al., 2012)
13. Growth-environmental dilemma.		(Bonsu, 2021)
14. Lack of Integrated Economic and Climate Policies.		(Azevedo et al., 2021)
15. High Transition Costs for Net-Zero, and sustainable circular economy Business Models.		(Wang et al., 2023)
16. Inadequate Government Incentives for Low-Income Households.		(Asif et al., 2023)
17. Grid inflexibility and High Costs of Net-Zero Energy Infrastructure.		(Rosenow and Eyre, 2022)
18. Risk of stranded assets and Financial Constraints for Decarbonization		(Su et al., 2022)
		(Su et al., 2022) (Xu et al., 2023) (Agrawal et al., 2023) (Pinkse, Demirel and Marino, 2023)

	Projects.		
	19. Economic and policy trade-offs in implementing green innovation. and Economic Dependence on Fossil Fuels.		
	20. widespread of Linear economic practices.		
	21. Financial factors' involvement in technology transformations and Net-Zero Innovation.		
C)Technological and Infrastructure Barriers	1. High initial and investment costs of transitioning technologies and digital solutions and Clean Technology Deployment. 2. Challenges in adopting and enhancing decentralized energy markets i.e. blockchain, quantum computing, and digital twin technology, IOT. 3. Complex relationship between infrastructure, legislation and environmental impact. 4. Lack of a unified definition for NZEBs/NZCBs. 5. Technological and Design Challenges. 6. Current research is mainly focused on individual buildings rather than community integrated level. 7. Limited Adoption of Information and Communication Technology (ICT) in Carbon Reduction. 8. Limited grid Infrastructure for Renewable Energy Adoption causing gaps. 9. High Capital Intensity of Decarbonization Technologies. 10. High initial capital expenditure on infrastructure and stranded assets. 11. Slow innovation adoption and R&D investments. 12. Path Dependence on Fossil Fuel	1. Technological advancements in emission reduction start with large corporations. 2. Refining regulations in the adoption of advanced technologies such as AI, blockchain, quantum computing, digital twin, cloud computing, big data, IoT, and robotics. 3. Implementation of smart grids and AI-driven energy management systems. 4. Research and development efforts focus on improving AI algorithms for energy demand forecasting and system optimization. 5. Adopting sustainable building design standards. 6. Adoption of Smart Grid and AI Technologies. 7. Investment in ICT and smart energy management systems for Emissions Management. 8. Localized technology adoption. 9. Investment in grid upgrades and infrastructure. 10. Integration of AI and Smart Grids for Energy Efficiency. 11. Use of Industry 4.0-based	(Riedel, 2024) (Ferdaus et al., 2024) (Omrany et al., 2022) (Lopes et al., 2016) (Han et al., 2023) (Virmani et al., 2022) (Ahmed et al., 2022) (Hakovirta et al., 2022) (Mushafiq et al., 2024) (Bag, 2023) (Stern and Valero, 2021) (Azevedo et al., 2021) (Wang et al., 2023) (Asif et al., 2023) (Renné, 2022) (Rosenow and Eyre, 2022) (Su et al., 2022) (Zipse et al., 2023) (Tian et al., 2023) (Agrawal et al., 2023) (Pinkse, Demirel and Marino, 2023)

	Infrastructure.	digital technologies.	
	13. Grid inflexibility and High Costs of Net-Zero Energy Infrastructure.	12. Use of high energy efficiency technologies, i.e. lighting, AC.	
	14. Limited Progress in Carbon Dioxide Removal (CDR) Technologies.	13. Technological integration, innovations and education initiatives.	
	15. Risk of stranded assets and Financial Constraints for Decarbonization Projects.	14. Expansion of charging networks.	
	16. Dependence on Fossil Fuels for Global Energy Demand including Infrastructure and Workforce.	15. Renewable energy integration.	
	17. Technological Immaturity of Low-Carbon Oil and Gas Solutions.	16. Implementing Smart grid technologies.	
	18. Slow Progress in Decarbonizing Transportation and Heating Sectors.	17. Carbon capture technologies adoption.	
	19. Infrastructure and Grid Stability Issues for Renewable Integration.	18. Development of Low-Carbon Oil Extraction and Processing Technologies.	
	20. Limited Advancements in Long-Duration Energy Storage.	19. Large scale renewable energy deployments and integration.	
	21. Lack of efficient technologies.	20. Energy-saving technologies i.e. Smart Grid and Flexible Energy Systems.	
	22. Grid connection challenges.	21. Advanced grid and infrastructure technologies.	
	23. Limited Impact of Technological Innovation on Emission Reduction compared to renewable energy reliance.	22. Electricity Savings through Smart Infrastructure Investments.	
	24. Rebound Effect of Technological Innovation.	23. Leveraging Digital and Smart Technologies and Smart metering systems.	
	25. Limited Effectiveness of Energy-Saving Renovations Alone.		
	26. Financial factors' involvement in technology transformations.		
	27. Innovation resistance and Technological Immaturity.		
D)Data, Measurement, Research	1. Lack of information about companies' emission intensity.	1. Research and development efforts focus on improving AI algorithms for energy demand forecasting and system optimization.	(Riedel, 2024) (Omrany et al., 2022) (Virmani et al., 2022)
	2. Gaps in Energy Performance Data.	2. Standardized building codes.	(Hakovirta et al., 2022) (Di Vaio et al., 2024)
	3. Lack of Research and Development (R&D) Support and analytical validation.	3. Development of KPIs.	(Rahman et al., 2024) (Nyangchak, 2022)
	4. Lack of Understanding of Climate Solutions.	4. Adoption of benchmarking systems.	(Bag, 2023) (Deng, Wang and Dai, 2014)
	5. Inconsistent reporting standards.		

6. Gaps in the sustainability accounting research field.	5. Development of reporting frameworks i.e. Integrated Reporting (IR).	(Di Vaio et al., 2024) (Markouizou, 2023)
7. Contested theoretical claims and practical methods of green growth and degrowth.	6. Analysing the impact of net-zero based SBMs on social, economic, and policy dimensions.	(Sartori et al., 2012) (Asif et al., 2023) (Zipse et al., 2023) (Agrawal et al., 2023)
8. Literature on net zero economies is fragmented.	7. Enhancing Scope 3 Emissions Transparency Through Carbon Disclosure.	(Virginia, Ryan and James, 2012)
9. Lack of studies examining the effect of resources on net zero economies.	8. Carbon Pricing and Market-Based Mechanisms.	(Loveday, Morrison and Martin, 2022)
10. Lack of standard performance metrics and indicators.	9. Incorporation of dynamic life-cycle assessment methodologies.	
11. Limited Adoption of Life Cycle Assessment (LCA).	10. Development of governance frameworks for measurement and verification.	
12. Knowledge gaps regarding measurement and reporting of intellectual capital (IC), and carbon accounting in terms of IC and HDCs.		
13. Resistance to change and lack of transparency.		
14. Lack of uniform standards.		
15. Challenges in Measuring Net Zero Energy Balance.		
16. Regulatory and Policy Uncertainty in Carbon Reporting.		
17. Ambiguous (lack of clear, standardized indicators for sustainability goals) and Volatility of net-zero targets.		
18. Narrow focus on innovation through R&D.		
19. Lack of transparency on carbon credits.		
20. Knowledge transfer barriers and lack of adoption.		
21. Inefficient metering systems.		
22. Absence of clear system boundaries in net-zero assessments.		
23. Inconsistent methodologies for measuring net-zero performance.		
24. Limited inclusion of life-cycle emissions in net-zero targets.		
25. Global Measurement and		

	Verification Issues.		
	26. Divergent Net-Zero Boundaries.		
E) Organizational Challenges	1. Huge variations among companies' strategies.	1. Development of clear company guidelines that vary upon the company criteria.	(Riedel, 2024) (Omrany et al., 2022)
	2. Fragile commitments by companies and executives.	2. Public-private partnerships and collaborations.	(Lopes et al., 2016) (Han et al., 2023)
	3. Stakeholders lack of knowledge, suspicion, Insufficient alignment, and criticism.	3. Stakeholder collaboration on conservation of energy production and storage.	(Virmani et al., 2022) (Hakovirta et al., 2022) (Mushafiq et al., 2024)
	4. Lack of stakeholder engagement.	4. Cooperative Net Zero Energy Community between companies to enhance load matching at a wider level.	(Rahman et al., 2024) (Nyangchak, 2022)
	5. Limited Demand Side Management (DSM) Adoption.	5. Circular Economy and Sustainability-Focused Business Models.	(Bag, 2023) (Bag, 2023) (Stern and Valero, 2021) (Di Vaio et al., 2024)
	6. Lack of management commitment and effective corporate governance for carbon management.	6. Stakeholder collaboration on a strategic level.	(Markouizou, 2023) (Azevedo et al., 2021) (Wang et al., 2023)
	7. Short-Term Focus Over Long-Term Sustainability.	7. Collaborative innovation networks.	(Asif et al., 2023) (Zipse et al., 2023) (Tian et al., 2023) (Xu et al., 2023) (Agrawal et al., 2023) (Pinkse, Demirel and Marino, 2023)
	8. Limited Availability of Green Suppliers.	8. Managerial Support for sustainability.	
	9. Lack of Skilled Workforce for Net-Zero Transition.	9. Holistic frameworks and systems thinking.	
	10. High competition, Economic trade-offs, and initial capital.	10. Focus on Intangible resources i.e. sustainability culture, employee training, and knowledge management.	
	11. Lack of Collaboration Between Corporations and Startups and suppliers.	11. Change management practices including country inward investment that supports climate resilience.	
	12. Short-term economic focus.	12. Stakeholder engagement.	
	13. Limited adoption and access to green finance.	13. Business innovation accelerators.	
	14. Lack of skilled workforce.	14. Combinative Capabilities and Innovation ecosystems.	
	15. Heterogeneous and fragmented factors of green industry.		
	16. Limited Human Skills, Technical Expertise, and resource scarcity.		
	17. Slow Adoption of Sustainability Culture in SMEs.		
	18. Resistance to Change from Employees and Stakeholders.		
	19. Risk Aversion Among Investors.		
	20. Lack in HR capabilities regarding compliance and adoption.		
	21. Firms face pressure from institutions		

	and stakeholders.		
	22. Resistance to change and lack of transparency.		
	23. Challenges in Coordinating Global and National Net-Zero Strategies.		
	24. Limited Progress in Carbon Pricing Mechanisms.		
	25. Geopolitical Challenges in Oil and Gas Decarbonization.		
	26. Lack of Incentives for SMEs.		
	27. Sectoral and Regional Variability in Renewable Energy Effectiveness.		
	28. Complexity of businesses dynamics regarding stakeholders, climate dynamics, and carbon budget revisions, complicates long-term strategy planning.		
	29. Potential "Greenwashing" Issues with Carbon Reduction Purchases.		
	30. Potential negative impact of environmental regulation on business competitiveness.		
	31. Resource constraints.		
	32. Ambiguous obstacles and barriers in regulating emissions.		
	33. Higher technological cost, management norms, and uncertain subsidies.		
	34. Workforce resistance.		
	35. Short-Term Profit Focus Over Long-Term Sustainability.		
	36. Systemic Complexity in Transitioning to Net-Zero.		
	37. Insufficient Organizational Capabilities to Drive Net-Zero Transitions.		
	38. Unrestricted waste incineration and landfilling.		
F) Fossil Fuel Dependency and Energy Challenges	1. over-reliance on carbon offsets which can trigger distribution injustice.	1. Implementation of smart grids and AI-driven energy management systems.	(Riedel, 2024) (Ferdaus et al., 2024) (Omrany et al., 2022)
	2. Integration with traditional power	2. Localized technology	(Lopes et al., 2016)

	systems.	adoption.	(Han et al., 2023)
	3. Challenges in decoupling fossil fuel energy usage and economic growth given the continuous increase in energy demand due to economic growth and population increase.	3. Renewable energy integration.	(Ahmed et al., 2022)
	4. Complexity of Energy Storage Systems and integration.	4. Scaling Electrification Across All Sectors.	(Mushafiq et al., 2024)
	5. Variability in Renewable Energy Generation leads to supply fluctuation and instability.	5. Development and Integration of Energy Efficiency with Renewable Energy Growth.	(Nyangchak, 2022)
	6. Inefficient resource utilization causes increased energy expenditure and contributes to higher carbon emissions.		(Bag, 2023) (Stern and Valero, 2021)
	7. Exponential growth in energy demand.		(Azevedo et al., 2021)
	8. Increased compliance costs for energy firms reliant on fossil fuels.		(Wang et al., 2023)
	9. Delayed decoupling from Carbon-Intensive Growth, economic inequality, and stranded assets.		(Renné, 2022)
	10. Over reliance on non-renewables.		(Rosenow and Eyre, 2022) (Tian et al., 2023) (Xu et al., 2023)
	11. Path Dependence on Fossil Fuel Infrastructure.		(Pinkse, Demirel and Marino, 2023)
	12. Dependence on Fossil Fuels for Global Energy Demand including Infrastructure and Workforce.		
	13. Limited Role of Traditional Energy Efficiency Approaches causing energy waste.		
	14. Misalignment of Energy Efficiency and Carbon Reduction Goals.		
	15. Hidden Carbon Footprint of Renewable Energy Manufacturing.		
	16. Challenges in Integrating Renewable Energy.		
	17. Path Dependency and Industrial Lock-In to Fossil Fuels.		
G) Market and Business Model Limitations	1. Market uncertainty, Resistance and Lack of Awareness and expertise.	1. Development of clear company guidelines and SBMs that vary upon the	(Omran et al., 2022)
	2. Limited user/consumer awareness of		(Lopes et al., 2016)
			(Ahmed et al., 2022)

	net-zero benefits.	company criteria.	(Hakovirta et al., 2022)
	3. Variability in Renewable Energy Generation leading to supply fluctuation.	2. Awareness campaigns.	(Di Vaio et al., 2024)
	4. Volatility in Climate Investment Markets.	3. Scaling Circular Economy and Sustainable Business Models.	(Mushafiq et al., 2024)
	5. Overlooking social structures where green industry is embedded.	4. Standardisation of Corporate social responsibility and Sustainability Reporting.	(Nyangchak, 2022)
	6. Weak market demand reflects lack of customer awareness.	5. Decoupling Strategies for Economic Growth and Sustainability.	(Nyangchak, 2022)
	7. High Transition Costs for Net-Zero, and sustainable circular economy Business Models.	6. Expansion of Circular Economy and Sustainable Industrial Policies.	(Bag, 2023) (Di Vaio et al., 2024) (Bonsu, 2021) (Azevedo et al., 2021) (Asif et al., 2023) (Su et al., 2022) (Tian et al., 2023)
	8. Lack of Business Models Addressing Equity in Net-Zero Transition.	7. Business innovation accelerators.	(Agrawal et al., 2023) (Pinkse, Demirel and Marino, 2023)
	9. Slow business model standardization and transformation towards social and economic sustainable business models (SBMs).	8. Customer Engagement and Market Readiness Strategies.	
	10. Insufficient Supplier and Stakeholder Engagement in Sustainability.		
	11. Sectoral and Regional Variability in Renewable Energy Effectiveness.		
	12. Uncertainty in Carbon Offset Product Market.		
	13. Lack of Standardized Decision Models for Net Zero.		
	14. Market Uncertainty and Consumer Acceptance Issues.		
H) Supply Chain and Circular Economy	1. Limited supplier customer collaboration.	1. Implementing Sustainable supply chain practices.	(Riedel, 2024) (Lopes et al., 2016) (Virmani et al., 2022) (Hakovirta et al., 2022) (Rahman et al., 2024) (Bag, 2023) (Deng, Wang and Dai, 2014) (Di Vaio et al., 2024)
	2. Variability in Renewable Energy Generation leading to supply fluctuation.	2. Circular Economy Integration in Industrial Policies.	(Sartori et al., 2012) (Bonsu, 2021)
	3. Limited Availability of Green Suppliers.	3. Development of sustainable Circular economy models, Resource management, and efficiency technologies.	(Azevedo et al., 2021) (Asif et al., 2023)
	4. Lack of Collaboration Between Corporations and Startups and suppliers.	4. Analysing the impact of net-zero based SBMs on social, economic, and policy dimensions.	(Renné, 2022) (Zipse
	5. High logistics and initial costs.	5. Circular Economy	
	6. Supply Chain Disruptions in Green Logistics.		

7. Limited Access to Sustainable Supply Chains.	Approaches and initiatives.	et al., 2023) (Agrawal
8. Mismatch Between Energy Demand and Renewable Energy Supply.	6. Material recycling and Maximizing Resource Value Retention.	et al., 2023) (Loveday, Morrison and Martin, 2022)
9. High Transition Costs for Net-Zero, and sustainable circular economy Business Models.	7. Restructuring Supply Chain for Circular Economy.	
10. Difficulty in Matching Energy Demand and Renewable Energy Supply.	8. Extended Product Life Cycle Strategies.	
11. Supply Chain and Resource Dependency Issues.	9. Integration of Circular Economy Principles.	
12. Incomplete Consideration of Life-Cycle Carbon Emissions.		
13. Limited Scope 3 Emissions Management.		
14. Resistance to Circular Economy and Closed-Loop Supply Chains.		
15. Mismatch Between Energy Demand Growth and Renewable Expansion.		
16. The unpredictability of systemic interdependencies.		
17. Supply Chain Vulnerabilities.		
18. Supply chain (SC) emissions are harder to abate.		
19. SC tracking complexity making it harder for SMEs.		
20. Deficiency in SC integration.		
21. Limited inclusion of life-cycle emissions in net-zero targets.		
22. Slow Integration of Circular Economy Principles.		

3.2.1. Policy and Regulatory Challenges

Policy and regulatory frameworks are foundational to the implementation of NZ strategies, yet inconsistencies and uncertainties within these frameworks significantly hinder progress (Riedel, 2024). The lack of clear, stable policy environments, and incongruity between policy targets and business practices leads to various challenges, as mentioned in Table 1, such as, double counting, and regional disparities in green technology adoption (Riedel, 2024; Ferdaus et al., 2024; Han et al., 2023). Additionally, complex relationships between infrastructure, legislation, and environmental impact further exacerbate the difficulties in aligning national and international NZ policies (Omran et al., 2022). Moreover, geopolitical challenges and regulatory variability across countries create fragmented pathways toward decarbonization, impacting global cooperation in achieving NZ goals (Wang et al., 2023). Inadequate government incentives and policy gaps continue to obstruct abiding efforts, especially in emerging economies and SMEs (Bag, 2023; Virmani et al., 2022). To counter these issues, literature suggests the need for comprehensive policy frameworks, stronger government incentives, gradual implementation, and regional customization of regulations (Markouizou, 2023). Hence, these measures can drive more consistent policy implementation, adoption, and facilitate long-term financial stability and economic growth (Mushafiq et al., 2024).

3.2.2. Financial and Economic Constraints

Financial barriers are a recurrent theme in the transition to NZ, primarily due to high initial capital expenditures for digital solutions, infrastructure upgrades, and clean technology deployment (Ferdaus et al., 2024; Ahmed et al., 2022). Additionally, financial constraints are exacerbated by limited access to green capital, high compliance costs for fossil fuel-reliant firms, and the economic trade-offs associated with green innovation (Riedel, 2024; Mushafiq et al., 2024). Additionally, given the widespread of linear economic practices the complexities of decoupling economic growth from fossil fuel dependency present significant challenges, particularly in economies experiencing rapid population growth influencing increased energy demand (Agrawal et al., 2023; Han et al., 2023). However, economic policies such as carbon pricing and market-based incentives have been identified as essential enablers, driving investment in renewable energy and fostering public-private partnerships (Hakovirta et al., 2022). Furthermore, the expansion of green financing, including environmental, social, and governance (ESG) investments and green bonds, offers strategic pathways to overcome a portion

of the financial constraints (Su et al., 2022).

3.2.3. Technological and Infrastructure Barriers

Technological advancement is crucial for achieving NZ goals (Ferdaus et al., 2024). However, barriers such as high investment costs, infrastructure gaps, and slow innovation adoption continue to impede progress (Lopes et al., 2016; Omrany et al., 2022). Additionally, the reliance on fossil fuel infrastructure and technological immaturity in low-carbon solutions further complicate transitions (Azevedo et al., 2021; Wang et al., 2023). Moreover, complexity in integrating decentralised energy systems and the challenges of adopting emerging digital technologies like AI, blockchain, and IoT also present significant hurdles (Ferdaus et al., 2024). On the other side, investment in grid modernization, smart infrastructure, and advanced energy management systems are critical enablers for overcoming these barriers (Su et al., 2022). Additionally, leveraging digital technologies and fostering innovation ecosystems can enhance energy efficiency and promote renewable integration (Pinkse, Demirel and Marino, 2023).

3.2.4. Data, Measurement, and Research

Accurate data measurement and research are essential for tracking progress toward NZ goals (Di Vaio et al., 2024; Azevedo et al., 2021; Sartori et al., 2012). However, inconsistencies in reporting standards, lack of comprehensive performance metrics, and fragmented research on NZ economies pose significant challenges (Riedel, 2024; Virmani et al., 2022). Additionally, limited adoption of life cycle assessment (LCA) and inadequate governance frameworks for measurement and verification further hinder effective policy implementation (Loveday, Morrison and Martin, 2022). However, enablers within this theme include the development of standardized reporting frameworks such as Integrated Reporting (IR), incorporation of dynamic LCA methodologies, and enhanced stakeholder collaboration on policy development (Di Vaio et al., 2024). Moreover, investment in research and development to improve AI algorithms for energy demand forecasting and system optimization also plays a pivotal role in overcoming data-related challenges (Ferdaus et al., 2024).

3.2.5. Organizational Challenges

Organizational challenges primarily stem from a lack of stakeholder engagement, insufficient corporate governance, and variations in companies' strategies (Riedel, 2024; Omrany et al., 2022). Additionally, the resistance to change, short-term profit focus, limited demand side management, and skill gaps within organizations further limit the effective implementation of

NZSs (Han et al., 2023; Di Vaio et al., 2024). Collaborative innovation networks, stakeholder engagement, and strategic partnerships are key enablers identified in the literature to address these challenges (Rahman et al., 2024). Moreover, the adoption of circular economy models and sustainability-focused business practices can enhance organizational adaptability and drive long-term sustainability (Hakovirta et al., 2022; Pinkse, Demirel and Marino, 2023).

3.2.6. Fossil Fuel Dependency and Energy Challenges

Fossil fuel dependency remains a major barrier, with challenges including integration with traditional power systems, inefficient resource utilisation, and over reliance on non-renewables with the exponential growth of energy demand (Ferdaus et al., 2024; Han et al., 2023). Additionally, the misalignment between energy efficiency and carbon reduction goals, coupled with the hidden carbon footprint of renewable energy manufacturing, complicates the transition (Rosenow and Eyre, 2022). Strategies to mitigate these challenges include renewable energy integration, scaling electrification across all sectors, and the deployment of smart grids and flexible energy systems (Azevedo et al., 2021; Tian et al., 2023). Additionally, energy efficiency technologies and advanced grid infrastructure are crucial for reducing fossil fuel reliance (Xu et al., 2023).

3.2.7. Market and Business Model Limitations

Market resistance, consumer awareness gaps, and high transition costs present significant challenges for sustainable business model transformation (Omrany et al., 2022; Lopes et al., 2016). Additionally, the volatility of climate investment markets, weak market demand, and a lack of standardised decision models for NZ further hinder progress (Bag, 2023; Hakovirta et al., 2022). Enablers in the literature include, business innovation accelerators, customer engagement strategies, and the scaling of circular economy models (Pinkse, Demirel and Marino, 2023; Asif et al., 2023). Additionally, integrating sustainable industrial policies and decoupling economic growth from carbon emissions are highlighted for achieving market readiness and overcoming business model limitations (Su et al., 2022).

3.2.8. Supply Chain and Circular Economy

Supply chain challenges include limited collaboration between suppliers and customers, high logistics costs, and the complexity of tracking emissions across supply chains, especially scope 3 emissions (Riedel, 2024; Asif et al., 2023; Virmani et al., 2022). Additionally, the slow

integration of circular economy principles, complexity of closed-loop supply chains, and resource dependency issues further complicate sustainability efforts (Agrawal et al., 2023). However, to address these challenges, the literature highlights developing and implementing sustainable supply chain business models, material recycling, and restructuring supply chains for circularity are vital enablers (Bonsu, 2021). Additionally, maximizing resource value retention and extending product life cycles are essential for fostering a circular economy (Rahman et al., 2024).

3.3. Discussion

3.3.1. Nexus between Net-Zero Strategies and Energy Efficiency

The interplay between NZSs and EE is a dynamic and multifaceted relationship, encompassing both complementary and conflicting perspectives. NZSs heavily rely on maximising EE to reduce energy demand while transitioning to renewable sources, as highlighted by the IPCC (2023), emphasising EE as a fundamental pathway to achieving emissions reductions and neutrality. Advocates of EE underscore its cost-effectiveness and feasibility in providing immediate GHG reductions (International Energy Agency, 2024; Ferdaus et al., 2024; Stern, 2021). Additionally, frameworks like "avoid-shift-improve" also advocate for demand-side solutions, highlighting retrofitting and reducing energy demand as critical measures (Creutzig et al., 2018; Rosenow et al., 2022). However, critics caution against over reliance on EE without systemic changes and advancements in clean energy technologies, such as carbon capture and storage (CCS) (Hepburn et al., 2019). Additionally, rebound effects where energy savings lead to increased consumption further complicate the narrative, with scholars including Pye et al. (2020) highlighting potential pitfalls. Meanwhile, others argue the effect is minimal and does not diminish EE's central role in sustainable NZSs (Gillingham et al., 2015). Moreover, EE improvements may also struggle to offset rising global energy demand driven by population and economic growth, necessitating additional measures (Pye et al., 2020). Hence, the broader perspective links NZS to the UN's SDGs, suggesting the need for holistic models that address inequality while supporting sustainability (Sartori et al., 2012; Johnson et al., 2023). Additionally, debates persist over prioritisation, as some studies argue that EE should precede renewable energy integration for on-site generation in NZ energy buildings (NZEBS) (Wang, 2014). While others suggest equal importance without clear hierarchy (Ahmed et al., 2022). Moreover, empirical evidence on how NZSs influence firms' energy efficiency and economic

outcomes, particularly for SMEs, remains limited, signalling a critical gap in the literature (Johnson et al., 2023).

3.3.2. Employing Net-Zero Strategies

The adoption of NZSs is driven by a range of factors, including technological innovation (TI), policy incentives, market dynamics, and societal awareness (Ahmed et al., 2022; Virmani et al., 2022). Illustrated in Table 1 and Figure 6, policy mechanisms, including carbon pricing, subsidies, and international agreements, are equally critical in addressing market inefficiencies and promoting competitiveness (UNFCCC, 2024; Xu et al., 2023). Additionally, societal drivers, such as growing climate awareness among consumers and investors, underscore the urgency for firms to adopt sustainable practices. Hence, advocates highlight the importance of collaborative strategic planning, international cooperation, and research and development to overcome challenges and accelerate the transition (Virmani et al., 2022).

Meanwhile, significant number of barriers hinder progress. High initial investment costs, regulatory uncertainties, and limited availability of clean technologies, disproportionately affect corporates and SMEs, especially that such policies may overburden SMEs with limited resources (British Chambers of Commerce, 2023; UNIDO, 2022). Additionally, systemic challenges, such as outdated grid infrastructure, lack of skilled workforce, and consumer resistance to adopting NZ aligned products, exacerbate these issues (Sartori et al., 2012; Virmani et al., 2022). Moreover, critics caution that delayed policy action and overly optimistic reliance on technological fixes, risk locking in high-emission infrastructure, making future transitions more costly and complex (Stern and Valero, 2021; Bistline et al., 2021). Moreover, TI enhances EE through advancements like AI-driven energy systems and smart grids poses challenges due to uneven accessibility and the rebound effects that may offset emissions reductions (Mealy et al., 2020; Khan et al., 2022). Furthermore, the social dimension also presents barriers, including the need to ensure equitable transitions that do not disproportionately burden vulnerable populations (Hepburn et al., 2019; Nyangchak, 2022). Addressing the previously highlighted drivers and barriers requires a comprehensive approach, since this holistic perspective remains collectively underexplored in the existing literature, highlighting a significant gap.

3.3.3. Key Performance Indicators (KPI) for Net-Zero Transition

KPIs play a crucial role in assessing progress toward NZ goals, encompassing metrics included in some frameworks such as environmental, social and governance (ESG) including

carbon intensity, EE, and renewable energy adoption rates. Proponents emphasise that well defined KPIs ensure accountability, enhance transparency, and drive stakeholder engagement, incentivizing firms to adopt sustainable practices (Ahmed et al., 2022). For instance, energy consumption, renewable energy share, and life-cycle assessments (LCAs) are commonly used metrics in NZ energy building evaluations (Sartori et al., 2012). Moreover, integrating KPIs with governance frameworks and economic considerations fosters alignment with broader sustainability objectives, such as supporting the UN SDGs (Pye et al., 2021). However, critics argue that over-reliance on KPIs can lead to greenwashing, where firms manipulate metrics without impactful actions (Hickel, 2020). Similarly, the lack of standardised definitions and system boundaries complicates cross-country and sectoral comparisons, limiting their effectiveness in promoting global coordination. Moreover, challenges such as the rebound effect, disparities between on-site and off-site energy solutions, and the absence of dynamic approaches further underscore the need for more comprehensive and adaptable KPIs (Ahmed et al., 2022; Sartori et al., 2012). To address these limitations, robust and dynamic measurement and verification frameworks are vital to ensure NZ targets are achieved effectively. This includes standardising data collection, integrating LCAs, and expanding KPIs, which are considered vital aspects and integral to the objectives outlined in this proposed research.

3.3.4. Impact of Net-Zero Strategies on Energy Efficiency and Economy

NZSs have significantly influenced EE improvements, driving innovation in technologies such as smart grids and energy management systems, causing not only a reduction of GHG emissions, but also lowering operational costs, creating economic incentives for firms. Additionally, EE plays a foundational role in achieving NZ targets by minimising energy demand. However, the impact of these strategies varies widely across sectors and regions. Energy-intensive industries face greater challenges in integrating efficiency measures, often requiring substantial capital investments (British Chambers of Commerce, 2023; Gillingham et al., 2015). Moreover, the economic implications of NZSs are both promising and challenging. Proponents argue that transitioning to a low-carbon economy creates opportunities for green jobs, fosters innovation, and enhances energy security (UNFCCC, 2024). Additionally, studies show that early adopters of sustainable practices often gain competitive advantages and long-term cost savings (Hepburn et al., 2019). Conversely, critics highlight the short-term economic disruptions associated with decarbonization, such as job losses in fossil fuel industries and high

transition costs for firms (International Energy Agency, 2024). Additionally, achieving NZ exacerbate inequalities if vulnerable firms are not adequately supported, necessitating careful policy design to balance economic growth with social equity.

4. Conclusion

This SLR provides a comprehensive exploration of the enablers and barriers of transitioning to a NZ economy within the framework of SDGs. By analysing 44 selected studies, the review identifies eight interconnected themes that shape the research landscape: policy and regulatory challenges, financial and economic constraints, technological and infrastructure barriers, data measurement and research, organizational challenges, fossil fuel dependency and energy challenges, market and business model limitations, and supply chain and circular economy. These themes reveal a total of 191 barriers and 101 enablers influencing the transition to NZ, highlighting the multifaceted challenges and opportunities for sustainable growth. The findings demonstrate that while NZSs offer a pivotal pathway for achieving SDGs, their implementation is hindered by several barriers. These include policy inconsistencies, financial constraints, technological immaturity, data gaps, organizational resistance, and fossil fuel dependency. Notably, policy and regulatory challenges were the most frequently identified barriers, emphasising the need for clear, consistent, and regionally customized policy frameworks. Furthermore, financial and economic constraints underscore the high initial capital expenditures and limited access to green finance, particularly affecting SMEs. Similarly, technological and infrastructure barriers highlight the immaturity of low-carbon solutions and the challenges of integrating decentralised energy systems, while organizational challenges reflect a lack of stakeholder engagement, resistance to change, and skill shortages.

Conversely, the study identifies several critical enablers necessary to overcome these barriers, including effective policy frameworks, financial incentives, technological innovation, stakeholder engagement, and international cooperation. The findings reveal that dynamic carbon pricing mechanisms, investment in digital technologies, public-private partnerships, and integrated circular economy principles are pivotal in facilitating NZ transitions. Additionally, the review underscores the necessity for standardised performance metrics, enhanced data analytics, and interdisciplinary collaboration to navigate the complexities of NZSs implementation. Moreover, the review highlights that the transition to NZ economy necessitates a paradigm shift in business models, organisational cultures, and societal behaviours to achieve holistic and

sustainable transformations. Additionally, the study calls for adaptive policies, innovative technologies, further empirical research on the nexus between NZ, EE, and economic growth, and collaborative ecosystems that integrate environmental sustainability with economic growth and social equity. Furthermore, the economic implications of NZSs are both promising and challenging, emphasising the need for well-designed policies that balance economic development, environmental sustainability, and social equity, tailored to firms' resources and capabilities.

It is acknowledged that the sample size of 44 studies represents an initial exploration of this broad field. While providing valuable insights, future research could benefit from expanding the search criteria or including additional databases to capture an even more comprehensive range of contemporary academic research and further enhance the depth of investigation into the identified barriers and enablers, especially with the rapidly growing publications. Lastly, this study bridges significant knowledge gaps by providing a nuanced understanding of the dynamic phase of implementing NZSs. It also offers strategic insights for policymakers, industry leaders, and researchers to enhance NZ adoption. By highlighting the fragmented yet interconnected nature of the research domain, this review establishes a robust foundation for future research and policy development.

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