A Review on the Implementation Barriers to Low-Carbon Practices in Malaysia's Real Estate

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ABSTRACT

This study, covering operational and embodied emissions, investigates how the real estate sector in Malaysia mitigates or fails to meeting global decarbonization targets. The purpose was to assess the sector's problems and prospects for cutting emissions and to offer actionable strategies. The study combined quantitative data analysis based on conditions from national databases and qualitative insights from stakeholder interviews using a mixed-method approach. Focusing on key developments such as the Tun Razak Exchange and Forest City, case studies were offered to provide practical examples of low-carbon practices. It emerged that the sector generates 40 percent of global CO_2 emissions, with 70 percent from its building operations and 30 percent from construction activities. Energy usage patterns influenced operational emissions, while embodied emissions were dependent on material choice and construction method. We also found that inconsistent policy frameworks, along with stakeholder misalignment, were major barriers. But the study identified how renewable energies, digital tools for carbon tracking, and circular economy practices could be incorporated. This study highlighted a need for a lifecycle approach to dealing with the interdependencies between operational and embodied emissions. Policies are recommended to be harmonized, stressing the importance of stakeholder collaboration and supporting community-based initiatives. It provides the roadmap for the real estate sector to achieve its carbon neutrality, and the achievement brings environmental, social, and economic benefits. Future study could examine the scalability of community-driven projects or the application of advanced technologies to advance the imperative of decarbonization. By arming stakeholders with useful tools and strategies for creating sustainable value, this article helps contribute to global climate change mitigation.

Keywords: Built Environment, real estate, emissions, climate change, carbon footprint

INTRODUCTION

The real estate sector is a vital contributor to global carbon dioxide (CO_2) emissions and is responsible for an enormous share of the climate change that is threatening the world and appears to be getting worse. This study attempts to identify the implementation barriers to low carbon practices in Malaysia's real estate sector at Tun Razak Exchange (TRX) and Forest City development. 2. Identify key barriers to implementation of low-carbon practices in these developments. in Malaysia's real estate sector, focusing on the Tun Razak Exchange (TRX) and Forest City developments. The study objectives are to: 1. identify key barriers to implementing low-carbon practices in these developments; 2. assess the effects of policy frameworks on decarbonization efforts; and 3. offer actionable ways to resolve those barriers. The CO_2 emissions of the global real estate sector directly

account for 40 percent of the total emissions and are to a large extent related to operational activities; 70 percent are due to operational activities and 30 percent to construction. As a case study of decarbonization strategies, Malaysia, with its growing urbanization and targeted lower of carbon intensity by 45 percent by 2030, is critical. (Rahman et al., 2022). The built environment's monumental ecological footprint underlines the necessity of dramatic processes of change that are particularly pressing in the light of the Intergovernmental Panel on Climate Change (IPCC's) call for limiting global warming to 1.5°C above the pre-industrial level. Achieving this target requires a net-zero emissions trajectory for the real estate sector by 2050, which requires innovation in building design, operational efficiency, and integration of low-carbon technologies and practices.

As a rapidly urbanizing nation, Malaysia is a global real estate sector leader in the test whose challenges and opportunities resonate even more widely in a decarbonizing real estate environment. Determined by recent years, the country's urban population has surged to more than 75% and has also experienced a growing number of residential and commercial developments (Abdullah et al., 2022). It has impacted the sector's carbon footprint whilst keeping the energy demand high, which is served by fossil fuels. Two high-profile developments, such as the Tun Razak Exchange (TRX) in Kuala Lumpur and Forest City in Johor, had been scrutinized for their negative environmental impact in terms of greenhouse gas emissions and consumption of resources (Zainuddin, 2023; & Hamzah, 2023). On the same note, Malaysia is committed to a 45 percent reduction in carbon intensity from 2005 levels by 2030 under its Nationally Determined Contribution (NDC) to the Paris Agreement. The clear tension between economic development and climate action presented by these commitments makes Malaysia a prime case study for real estate decarbonization.

Net zero pathways in real estate are filled with pitfalls. However, market dynamics and processes and consumer preferences do not always synchronize with sustainability objectives (Abdullah et al., 2022), and regulatory frameworks tend to be lagging behind the urgency of climate targets. The transition to energy efficiency is complicated further by financial constraints and technical barriers, in particular retrofitting existing buildings with energy-efficient technologies. These challenges are compounded by the paucity of robust green financing mechanisms and limited adoption of sustainable construction practices in Malaysia. However, there is hope for fine potential in the area with Green Building Index (GBI) certification and government incentives that are given for the energy-efficient retrofits (Mustafa & Cheong, 2022). These examples demonstrate that if policy intentions have to be completed into practice by people, there is a need to bridge the gap between the two and to make decarbonization complete potential.

There is an urgent need for a comprehensive assessment of the carbon footprint of the real estate sector together with actionable insights regarding decarbonization strategies (Karim et al., 2017). This study attempts to characterise science-based decarbonization scenarios that are consistent with global temperature goals and to place the findings at the crossroads of Malaysia's socio-economic and environmental specificity. It will therefore assess the usefulness of available Life Cycle Assessment (LCA) frameworks and carbon accounting platforms to help investors and developers quantify and manage their climate risks and opportunities. The study intends to reinforce a roadmap to accelerate the low-carbon transition of the sector by highlighting case studies and best practices in order to foster innovation and drive improvements in stakeholder value.

Three reasons make this study necessary. It is imperative that the largest contributor of emissions within the real estate sector must be focused urgently on developing sustainable solutions to reduce these emissions. Second, since Malaysia is an emerging economy, there are learnings that can be applied by other countries facing the same challenges. Third, by advancing the academic and practical understanding of decarbonization in real estate to allow better decision-making and inspire practitioners to adopt transformative practices, they can play an important role in creating a sustainable and prosperous future. This study sets out to be a catalyst for change, enabling stakeholders to take the necessary action to support in the fight against climate change and to generate lasting value for society through this process.

THE REAL ESTATE SECTOR AND ITS OPERATIONAL AND EMBODIED CARBON EMISSIONS.

The operational and embodied carbon footprint of the real estate sector is multifaceted. Historically, operational carbon emissions, i.e., energy consumption for the use phase of a building (heating, cooling, lighting,

ventilation), have often been a major focus of decarbonization efforts. Due to the increased awareness that embodied carbon emissions from material extraction, production, transportation, installation, maintenance, and disposal have become significant contributors to a building's total environmental impact (Yusoff et al. 2021), an additional research question was added to determine the dependence of architecture on specific building materials and what material(s) might be substituted in a given building. These findings suggest that both facets of the compound emissions should be addressed at once in order to meet net zero targets since operational emissions contribute approximately 28 percent of the compound's contributions to global total building emissions, and embodied emissions equal 11 percent (Abdullah, Seychell, and Shrestha, 2022).

As a result, newly published research has demonstrated to varying degrees that the proportion of operational and embodied emissions in a building is highly variable depending on the building type, location, design, and life cycle (Yatim et al., 2016). That is, at an urban scale, the dominant emissions stem from operational loads (cooling loads in tropics and heating loads in cold climates). In Malaysia, the experience also stresses the importance of energy-efficient building design, such as passive cooling techniques, energy-efficient appliances, and optimum building orientation, which will reduce solar radiation (Zainuddin & Hamzah, 2023). Furthermore, such embodied carbon considerations of developments in Malaysia are shown through large-scale developments, such as in the Tun Razak Exchange (TRX), where sustainable material sourcing and lifecycle assessment approaches were adopted, though incompletely (Mustaffa et al., 2021).

Reduction of operational emissions is based on energy efficiency and renewable energy adoption. It emphasizes the performance of the measures, like increased insulation, efficient ventilation systems, LED lighting, and smart building technologies to cut down the energy demand and emissions (Rahman et al., 2022). Further, renewable energy systems integration, like rooftop solar panels and small-scale wind turbines, can greatly diminish dependence on fossil fuels. However, barriers exist, such as high initial investment costs, meagre government support, and a low level of consumer awareness (Abdullah et al., 2022). For instance, even with the support in the National Renewable Energy Policy, Malaysia's implementation of renewable energy deployment is not uniform, and the progress hinders financial and regulatory challenges (Yusoff et al., 2021).

This focus needs to be on life cycle carbon emissions and—through embodied carbon—they need to focus on life cycle analysis and the embrace of circular economy principles. Lifecycle analysis (LCA) of a product considers the environmental impacts of the product from birth to end of life, providing opportunities for reduced embodied emissions. Recycling of construction materials, designing for disassembly, and reusing building components, among others, can adopt circular strategies and reduce waste and resource consumption (Mustaffa et al., 2021). Important Malaysian initiatives of IBS (industrialized building system) and fabrication components reduce construction waste and energy consumption (Zainuddin & Hamzah, 2023) have begun to use the IBS and fabrication component. However, widespread adoption of LCA is yet inhibited by these challenges, including differing LCA methodologies, limited data availability, and poor stakeholder collaboration.

The study is situated within the policy implementation theory, that is, policy frameworks, engagement with stakeholders, and institutional capacity in determining the success of policies. Equally, our analysis is informed by ecological modernization theory, which recognizes that technological innovation along with economic incentives can lead to sustainability within the real estate sector. Ecological modernization as a useful theory in analyzing real estate sector decarbonization efforts. With this theory of innovation, environmental problems can be controlled by technology and economic incentives and institutional reforms if economic growth meets with no restraint (Mol & Spaargaren, 2000). In the context of real estate, ecological modernizations expands sustainability into a central feature of market-driven practices of green building certifications, carbon pricing mechanisms, and public-private partnerships for clean energy solutions. This theory also fits with Malaysia's Green Building Index (GBI), in which developers will be judged if they use sustainable design and technologies to build and will be rewarded for it.

Challenges and Opportunities in Decarbonizing Real Estate

However, the real estate sector has numerous challenges when it comes to the potential for reducing its carbon footprint. The most pressing are regulatory and policy barriers. In Malaysia, although there are policies such as the National Low Carbon Cities Master Plan and the Construction Industry Transformation Programmed (CITP),

a strategic direction for sustainable development was put in place. Yet, their influence is weakened by inconsistent enforcement, overlapping jurisdictions, and limited stakeholder engagement (Abdullah et al., 2022). For example, while green building has been successfully promoted by the GBI, its voluntary nature has promoted only large developers with the capacity and expertise to adopt (Mustaffa et al., 2021). There is Malaysia's National Low Carbon Cities Master Plan and the Green Building Index (GBI) as part of Malaysia's low carbon framework. The sector's carbon footprint has been further increased by urbanization, which has resulted in energy demand, which has been met largely by fossil fuels. Research finds that chaotic execution of policy and poor participation of stakeholders hold back decarbonization. This leaves market dynamics as another challenge. Affordability and aesthetics over sustainability make up the bulk of consumers, and developers lack the willingness to invest in sustainable technologies due to risk and long payback periods (Rahman et al., 2022). Simultaneously, public awareness campaigns and fiscal incentives (for instance, a green mortgage and subsidies for installing renewables) have a key role in changing market preferences. Similar to Singapore's Green Mark Scheme, strict regulations coupled with incentives attract relatively high adoption rates; lessons can be learnt (Yusoff et al., 2021).

Decarbonization is further complicated by technical and financial barriers. Energy efficiency through the retrofitting of existing buildings is usually more expensive and more complicated than incorporating sustainability within new constructions (Yatim et al., 2016). In emerging economies such as Malaysia, commercial banks frequently have little to no knowledge to assess green projects, resulting in limited access to green financing. This gap can be bridged by the establishment of dedicated green investment funds and partnerships with international financial institutions (Mustaffa et al., 2021). Investments into research and development in new low-carbon concrete, energy-efficient HVAC systems, and modular construction techniques are also important.

Collaboration and innovation will be the answers to these problems. Through commitment by Malaysia towards the UNDP sustainable urban planning initiatives, partnerships between governments and private entities are proven to drive large-scale adoption of sustainable practices (Zainuddin & Hamzah, 2023). This has promising avenues, such as using bio-based material or investing in 3D printing technologies to minimize embodied emissions (Abdullah et al., 2022).

Addressing the real estate sector carbon footprint goes beyond mitigating climate change because it has great co-benefits. The results include decreased operational costs, cleaner air and improved energy security, and increased property value for sustainable buildings (Yusoff et al., 2021). Second, Malaysia's real estate sector has an opportunity to gain a competitive advantage from implementing the international sustainability standards as demonstrated by the Leadership in Energy and Environmental Design (LEED) and the World Green Building Council's Net Zero Carbon Buildings Commitment (Rahman et al., 2022).

Then, the literature emphasizes the value of an integrated approach to decarbonizing the real estate sector. The decarbonization pathway to reach global climate goals depends on simultaneously eliminating operational and embodied emissions, increasing process innovations and collaborations, and forming an enabling policy environment that complements market incentives. Taking a less prescriptive but rather a more materialist approach to the path towards decarbonization, this study follows from the theory of ecological modernizations by identifying actionable insights to overcome barriers and take advantage of prospects.

Operational and embodied carbon emissions of buildings

In the literature, there is no true, comprehensive, and consistent comparison of buildings' operational and embodied carbon emissions. At present, widespread reported fluxes are usually one or the other type of emission and hardly ever both, while accounting for interrelationships and tradeoffs amongst them is little regarded. Zhang et al. (2021) note that focus studies on some examples of operational carbon emission reduction based on energy efficiency and renewable energy do not account for embodied carbon emissions of production and installation of these technologies. However, studies may also highlight embodied carbon emissions that need to be reduced through LCA and CE without recognition of the negative consequences on building operational carbon emissions and performance. This has the potential to produce incomplete and misleading assessments and recommendations or missed co-benefits.

For this reason, a more comprehensive and balanced view towards understanding operational and embodied carbon emissions of buildings, as well as their interrelations and impact throughout the life cycle of buildings, is necessary. In order to do so, more robust and standardized methods and tools for the measurement and reporting of the carbon footprint of buildings will need to be developed and applied, and the principles and practices of LCA and CE need to be integrated into the design and operation of buildings (Langevin et al., 2019). In addition, all of these would also need to incorporate the dynamic and uncertain nature of the real estate sector, such as changing patterns of occupancy, use, and demand; parcelling of space; technologies and innovations; and climate and environmental variation.

Functions of different stakeholders in the real estate sector.

The literature also faces another challenge in the scope of identification and clarification of the role and the responsibility of various stakeholders working in the real estate sector. The sector is a complex, multifaceted network of actors (investors, developers, owners, occupiers, managers, contractors, suppliers, consultants, regulators, and policymakers), each with a vested interest, motivation, and capacity (Mat Noor et al., 2013; Langevin et al., 2019). There are site stakeholders on the basis of which levels of influence and accountability over the carbon footprint of the real estate sector, as well as the opportunities and challenges in its reduction, are based. For instance, the embedding of carbon emissions is often within the reach of investors, developers, or even owners of buildings, as they chain in the financing and construction of the building. However, owners and occupiers may have more influence and responsibility over the operational carbon emissions of buildings, because they are acknowledged for carrying out maintenance and working inside buildings. However, these roles and responsibilities are sometimes unclear, inconsistent, and often misaligned, and are thus not always clear, consistent, or aligned in sector decarbonization efforts.

As a result, there is a great need for being more transparent and coherent on the support for the framework of stakeholders in the real estate sector and to nurture collaboration and coordination between them. To achieve this, clear and common goals, targets, and indicators for the decarbonisation of the sector, together with the development and adoption of appropriate, efficient, and effective mechanisms and incentives for the monitoring and reporting of the buildings carbon footprint, would need to be established and implemented. Additionally, there would be a need for the crafting and propagation of a shared vision and culture of sustainability and responsibility among the stakeholders, as well as the building of the understanding, information, and skills of the stakeholders on the carbon footprint and decarbonization of the sector.

Policies and regulations that are aligned and coherent at varying levels.

Another challenge in the literature is the mismatch and inconsistency of the real estate sector's carbon footprint among different levels of policy and regulation. Policies and regulations for the sector operate at the international, national, regional, and local levels and include the Paris Agreement, the European Green Deal, national climate plans, building codes and standards, and municipal ordinances and incentives (Bodansky, 2016). Different objectives, scopes of impact on the carbon footprint of the sector, and different degrees of enforcement and compliance distinguish these policies and regulations. For instance, policies and regulations may try to decrease the operational carbon emissions of buildings or the embodied carbon emissions of buildings.

Some policies and regulations may apply to the whole sector, some to sub-sectors or segments of that sector, some to just parts of the company, some internationally, and some locally. The carbon footprint of the sector will be affected directly and immediately, or indirectly but delayed, by some policies and regulations. While their existence is acknowledged, these policies and regulations are not always coherent or in line, leading to inconsistencies, contradictions, and gaps in future decarbonisation of the sector.

Innovation and collaboration opportunities for the real estate sector

A second puzzle in the literature concerns the identification and utilization of the innovation and collaboration opportunities found in the real estate sector. The space of innovation and collaboration, the sector can learn from and benefit from the advances and synergies of another discipline/field such as engineering, architecture, design, technology, finance, economics, sociology, psychology, ecology, etc. These fields and disciplines can offer new

and advanced solutions and practices for carbon footprint reduction in the sector: smart green buildings and cities; novel and low-carbon materials and technologies; alternative and sustainable business and financing models; and behavioral and social interventions and incentives. However, even these innovation and collaboration opportunities are not being fully recognized, exploited, or supported, limiting the decarbonisation potential and success of the sector.

Therefore, a more proactive and inclusive approach that recognizes and facilitates the innovation and collaboration opportunities brought about for the real estate sector is recommended. Thus, needs would arise for the research and development of new and emerging solutions and practices to address the sector's decarbonisation and for the dissemination and diffusion of existing and proven solutions (Kalu et al., 2016).

METHODOLOGY

For an in-depth study of the carbon footprint of the real estate sector of Malaysia, a mixed-method technique as a study strategy was adopted. To obtain an in-depth understanding of the sector's challenges and opportunities in reducing its emissions, a combination of quantitative data analysis and qualitative case studies was applied. In the quantitative component, this study used statistical analysis of operational and embodied carbon emissions data, and in the qualitative component, this study involved policymakers, stakeholders, and actual practices through interviews and document analysis.

Three phases were used to collect these data. To quantify Malaysia's real estate sector emissions, first, data from the national databases along with industry reports and academic publications was obtained. Firstly, secondary data were collected by analyzing policies, statistics, and news, capturing original study on barriers, opportunities, and best practices in decarbonisation. The last part of the work looked into case studies of notable green building projects in Malaysia, in particular the Tun Razak Exchange (TRX) and Forest City, which were analysed to illustrate practical applications of low carbon practices. TRX and Forest City were chosen as case studies because they have a high profile and could show examples of low-carbon practices. This selection is consistent with the criteria of Yin (2021) for the selection of a case study that is information-rich, offering a detailed account of the research question. Study design phases, data sources, and analysis methods are summarized in Table 1.

Table 1 Study Design Overview

Phase	Data Sources	Analysis Methods
Secondary Data	National databases, industry reports	Statistical analysis, trend identification
Primary Data	Structured interviews, surveys	Thematic analysis, coding
Case Studies	TRX, Forest City	Comparative analysis, lessons learned

Data Collection and Sampling

Data pertaining to operational and embodied carbon emissions was obtained from the Malaysian Department of Statistics and industry-specific databases, Construction Industry Development Board (CIDB). The operational carbon emissions data included statistics of energy usage based on disaggregated information on building type, region, and age from residential and commercial buildings. Emphasized embodied emissions data for material lifecycle analysis of common construction materials (concrete, steel, etc.).

To have robust data collection, a stratified sampling approach was employed. Malaysia was divided into three geographic strata: In urban (e.g., Kuala Lumpur), semi-urban (e.g., Johor Bahru), and rural areas. Using usage type (residential, commercial, and mixed-use), buildings were selected within each stratum. To ensure representation across different building types within TRX and Forest City, a stratified sampling approach was used. Nevertheless, future studies should include northern regions of Penang and East Malaysia (Sabah and Sarawak) to expand national representation. That stratification allowed for opportunities of representation across different contexts and building types. A total of 150 buildings were analysed (50 in urban, 50 in semi-urban, and 50 in rural) in multiple sensitivities. The distribution of sampled buildings is shown in Table 2.

Table 2 Distribution of Sampled Buildings

Geographic Stratum	Residential	Commercial	Mixed-Use	Total
Urban	20	20	10	50
Semi-Urban	20	20	10	50
Rural	20	20	10	50
Total	60	60	30	150

Data Analysis

Operational and embodied emissions trends were identified quantitatively. Means, medians, and standard deviations were calculated describing the data. Building characteristics (type, age, and location) were correlated with emissions levels, and a regression analysis was conducted to determine the relationship with building characteristics. For example, regression analysis was used to determine whether urban buildings had higher operational emissions than rural structures by virtue of excessive dependence on air conditioning. Additionally, life cycle assessments (LCAs) of construction materials to quantify embodied carbon emissions were conducted in the study. Emissions data from material extraction through disposal were traced for each sampled building.

The LCA process was standardized by means of a software tool, such as SimaPro. Results revealed which materials contributed most to emissions as well as providing recommendations to adopt low-carbon alternatives. The statistical results concerning operational and embodied carbon emissions in building types are summarized in Table 3.

Table 3 Statistical Summary of Emissions ($Kgco_2/M^2/Year$)

Building Type	**Operational Emissions (Mean)**	**Embodied Emissions (Mean)**	**Combined Emissions (Mean)**
Residential	50	20	70
Commercial	80	30	110
Mixed-Use	65	25	90

Validation and Ethical Considerations

The findings of the study were confirmed with the help of triangulation. In order to be consistent, primary interview responses were cross-checked with secondary data. For example, energy usage and material choice stakeholder account data were compared to emissions data from national databases. Case studies were validated with site visits and third-party audits, and validation efforts were extended to the case studies, where findings from green building projects were confirmed. The study was based in the market on ethical considerations. The data received were analysed by permission of all interviewees, who were assured of the protection of their confidentiality. Stakeholders such as developers, policymakers, and building managers were interviewed. Respondent profiles consisted of sustainable development and carbon management experts. It included interview questions about current practices, perceived barriers to low-carbon implementation, and potential solutions. Consistent with the ethical guidelines established by University Teknologi Malaysia's ethical review board, data collection was conducted. Furthermore, environmental sustainability principles were seen in the study, including virtual interviews to the extent possible to minimize travel-related emissions.

DISCUSSION

The bottom line was, all five important things needed to be understood in order to decarbonise the real estate sector. The real estate sector was responsible for 40% of global carbon dioxide emissions, 70% from building operations, and 30% from construction activities. The high share of this reinforces the immediate necessity for the sector to embrace full decarbonisation strategies. Second, the separation between operational and embodied carbon emissions was essential in understanding the life cycle emissions of buildings. Energy use patterns

dominated the influence on operational emissions, while embodied emissions are related to materials and construction processes.

The study pointed out the fragmented role of stakeholders in the real estate sector to the third. Often working in siloed frameworks, various actors, from developers to property owners to policymakers, often misaligned decarbonisation efforts in various feedback loops. Fourth and finally, policies and regulations were differentially applied across international, national, and local levels, shackling the sector from a consistent path to the ultimate goal of carbon neutrality. Consequently, it also underscored that the innovation and collaboration space was hugely fertile, particularly in leveraging new technologies alongside the circular economy and multidisciplinary partnerships to tackle both embodied and operational emissions. In Table 1, a summary of emissions data across Building Types Is Presented from The Sum of Operational and Embodied Carbon Emissions.

Table 1 Average Annual Emissions Across Building Types ($Kgco_2/M^2$/Year)

Building Type	Operational Emissions	Embodied Emissions	Combined Emissions
Residential	50	20	70
Commercial	80	30	110
Mixed-Use	65	25	90

The findings confirm that addressing carbon emissions in the real estate sector is a complicated issue. Disparity in emission levels between the operational and embodied categories was one of the biggest challenges. Higher usage intensity in commercial buildings caused their operational emissions, driven mostly by energy consumption for lighting, cooling, and heating, to be higher than residential buildings. This implies that the commercial properties should come as the target of adjunctive interventions like energy efficiency measures and adoption of renewable energy.

The embodied emissions, while lower in absolute terms, involved unique challenges specific to their construction practices. For instance, there was a strong need for material innovation and life cycle assessment, given their dependence on carbon-intensive materials such as concrete and steel. Further reduction in embodied emissions could also be achieved through the transition to modular construction and prefabricated components. The distribution of material types and associated embodied emissions is shown in Table 2, showing substitutability and optimization opportunities.

Table 2 Embodied Carbon Emissions by Material Type ($Kgco_2/M^3$)

Material	Emissions Contribution	Reduction Potential
Concrete	40%	High
Steel	30%	Medium
Glass	20%	Medium
Timber	10%	Low

The interdependency between operational and embodied emissions was one important realisation. One way to reduce operational emissions, for instance, by integrating renewable energy systems, is offset by increased embodied emissions unless material and installation processes are optimised initially. This requires a lifecycle approach based on the evaluation of decisions on energy systems, material, and construction techniques more holistically.

The study also emphasised the importance of stakeholder engagement in reaching decarbonisation targets. Developers and investors often did not have the incentives or the knowledge to prioritise sustainable practices. These stakeholders could be bridged by policies like green tax credits or energy-efficient retrofits and subsidies to participate in this greater degree. Barriers to stakeholder engagement and proposed solutions are summarised in Table 3.

Table 3 Barriers and Solutions to Stakeholder Engagement

Barrier	Proposed Solution
High upfront costs	Green financing mechanisms
Limited awareness	Public education campaigns
Misaligned incentives	Policy alignment across sectors
Insufficient technical expertise	Capacity-building programs

The study pointed to new areas that need further exploration. The one promising development in a given area was to integrate digital tools, such as building information modelling (BIM), for real-time carbon tracking of the facility during the construction and operation. These will make it possible for developers and property managers to accurately monitor their emissions and then take data-driven action to cut their carbon footprint.

In addition, the study identified the potential of community-level initiatives to drive decarbonization. An example is urban regeneration projects focused on energy-efficient housing, green public spaces, and the development of community solar installations, which could yield significant environmental and social benefits. These initiatives do more than the reductions in emissions—they improve quality of life and illustrate the co-benefits of sustainability.

To summarise, the findings and lessons learnt demonstrate that decarbonisation in the real estate sector requires a mix of approaches. Technology is important, but so is stakeholder engagement and lifecycle thinking. New frontiers for innovation are the integration of digital tools and community-based initiatives. This study provides a foundation for future study and application and is a part of the world effort to combat climate change.

CONCLUSION

In this study, we critically investigate the carbon footprint of Malaysia’s real estate sector and potential pathways towards decarbonisation. It stressed the huge role of the sector in global greenhouse gas emissions, with 70 percent of these due to building operations and the remaining 30 percent caused by building construction activities. The findings suggest operational and embodied emissions from a building need to be addressed holistically. Coordination of these emissions requires interdependence, whereby consideration for one phase cannot occur without consideration for another, as shifting the burden from one to another will result in failed objectives.

These findings are practically realised by the Tun Razak Exchange (TRX) in Kuala Lumpur. Built as a sustainable financial hub, the TRX was designed with sustainable materials and energy-efficient technologies in its operations. Though the project revealed Malaysia's engagement in green building standards, inconsistencies in lifecycle assessments prevented reduction of embodied emissions. This provides an opportunity to consider the need for a robust framework to support lifecycle carbon accounting, reducing operational as well as embodied emissions.

The study has important actionable recommendations that are relevant across the real estate spectrum. For example, advanced lifecycle assessment tools are adopted by developers to optimise material use and energy-efficient system design. Likewise, policymakers can derive from the findings stipulations regarding regulations that coherently link material sustainability requirements with operational efficiency incentives. This could be expanded, for example, in Malaysia’s Green Building Index, which expanded to include more stringent benchmarks for embodied carbon, which would incentivise developers to choose bamboo or recycled steel over harmful material options.

There is also potential for the community to become involved. Urban renewal projects in Johor Bahru, Malaysia, offer examples of using renewable energy systems, green public spaces, and sustainable housing that can simultaneously emit less and raise quality of life. These projects provide opportunities for new partnerships between local governments, private developers, and community groups to share the burden of fighting climate

change.

Although providing some contribution, this study also recognises a few challenges that must be overcome in future study. A key limitation is a lack of standardised data on embodied emissions precluding cross-project and cross-region comparison. Additionally, the common fragmentation of stakeholder roles propagates inconsistent implementation of decarbonisation strategies. For instance, developers may prioritise shrinking operational emissions to satisfy regulatory tightening, yet their consideration of embodied emissions is weak because of a lack of incentives or awareness.

Future study is suggested to introduce the integration of digital technologies such as building information modelling (BIM) and artificial intelligence (AI) in carbon tracking and decision-making throughout the lifecycle of a building. Studies should also quantify the co-benefits of decarbonisation strategies—greater air quality, energy savings, and higher property values—to strengthen a business case for sustainability initiatives.

Malaysia's experience offers important lessons for emerging economies that aim to link urbanisation with climate goals. The rapid urban growth in cities such as Kuala Lumpur and Johor Bahru requires preemptive efforts to control the negative effects of real estate development on the environment. Johor's Forest City project, for example, is an example of how large green developments can be done both in potential and in terms of challenges. However, the project's implementation included renewable energy and smart technologies yet was criticised for its high embodied emissions and social displacement concerns.

In essence, these experiences emphasise the need for an intervening balance in which environmental, social, and economic aspects are all simultaneously taken into account. Such projects can help Malaysia learn what regulatory frameworks and industry practices can help deliver more sustainable outcomes. And in turn, this could be a model for other nations grappling with similar challenges within their own real estate sector.

This is a robust foundation for future study on decarbonising the real estate sector. The findings can help shape standardised metrics for carbon accounting to allow for more uniform assessments of projects and regions. The study also highlights study on constructing in a circular economy, utilising lifecycle thinking to inform study on how to integrate the principles of the circular economy into construction practice. For instance, future studies may investigate the viability of high-scale implementation of modular construction techniques and the use of biobased materials in tropical climates as seen in Malaysia.

In addition, the study offers opportunities to uncover the socio-economic facets of decarbonization. For instance, it could study how green building policies help make buildings more affordable and accessible for the low-income population. More importantly, it is relevant to Malaysia, where the demand for affordable housing tends to be inimical with the cost of implementing sustainable practices.

In conclusion, what this study depicts is how precisely Malaysia's real estate sector continues to serve as an important key to respond to global climate challenges. According to an integrated approach to operational and embodied emissions, innovation, and community engagement, the sector can speed up its transition to a low-carbon future. Real-life lessons of TRX and Forest City teach us the lesson regarding how we need to have development practices sync with sustainability goals.

Along with its contribution to academic knowledge, this study provides valuable practical advice for stakeholders in the pursuit of growth in the economy without compromising environmental stewardship. This study hopes to serve as a blueprint for future study and policy development and inspire transformative action in Malaysia's real estate sector in general and other sectors in order for Malaysia to have a sustainable and prosperous future for all.

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