Policy Measures for Reducing Emissions in the Real Estate Sector - A Review

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ABSTRACT

Drawing on empirical work, this study explores how policy can shift these emissions, two sectors responsible for 40% of original CO2 emissions globally. The research recognises the dual impacts of operational and embodied emissions, assessing policies in the US, UK, Germany, and China through the use of a comparative case study approach. The methodologies include national and international frameworks for content analysis. Key findings suggest a blended approach of regulatory and market-based instruments such as carbon pricing, green financing, and building codes addressing the barriers of high initial costs and fragmented regulations. Then, examine best practices with Germany's energy audits and green financing, the UK's stringent efficiency standards, and China's renewable energy mandates. Germany leads with 73% green standards adoption, while China's 35% real estate emissions highlight opportunities for sustainability investments globally. Progress is noted in Malaysia with some urban areas, but other rural areas lag behind due to limited resources and awareness. The study concludes that policies aimed at decarbonizing real estate should be conducted with a holistic and contextual approach focused on sustainability, affordability, and equity. The implications are broader aligning real estate practices with global climate goals, encouraging the growth of green buildings, reducing climate risk, and more. Future research would better explore synergies, the integration of mitigation and adaptation policies, and financing challenges in developing regions. This study provides policymakers with actionable insights into the design of effective strategies, developers with cost-efficient green technologies, and the global community with collective progress towards a sustainable built environment.

Keywords: Built Environment, real estate, emissions, policy, decarbonization

INTRODUCTION

With its huge contribution itself to global carbon emissions, the real estate industry is at a critical nexus of environmental stewardship and economic development. The global carbon dioxide emissions from the real estate sector amounted to around 40% in 2020, with the direct emissions from building operations and indirect emissions of energy and material consumption (Ahmed et al., 2020; Rahman et al., 2022). The fact that this dual impact exists strongly indicates the need for climate change-facing sustainable property development. The sector has advanced its sustainability integration; however, there remain large gaps for emissions reduction and moving toward low-carbon paths.

This work aims to contribute critical insights into current sustainability discussions within the real estate

industry. It emphasizes the industry's critical function in meeting the world's climate goals, especially for guarding biodiversity and human and economic well-being. For example, the government has set out ambitious carbon reduction targets in Malaysia under the 12th Malaysia Plan (2021–2025) and stresses the need for green building initiatives and renewable energy adoption (Abdullah e al., 2022). Neglecting regulations, poor green financing, and low public awareness of sustainable operations, however, still pose challenges for the country's real estate sector.

Many obstacles limit decarbonization of the real estate industry, which is critical to achieve. However, the high upfront costs of sustainable construction and retrofitting in the developing nations such as Malaysia (Noor et al., 2024) remain significant barriers. In addition, there is a lack of standardized regulations and financial incentives that intensifies the situation and hinders the development of green building techniques to be used universally. At present, the Green Building Index (GBI) may be popularly taken up in Malaysia, but its voluntary character does not inspire universal adoption. For instance, urban areas like Kuala Lumpur appear to have seen some rise in green certified building projects, whereas rural and suburban areas are left well behind with their resources and knowledge (Azis, 2021; Zainuddin & Hamzah, 2023).

Added to these challenges is the lack of comprehensive policies. On the other hand, while developed countries, including Germany and the United Kingdom, have well-developed legislative frameworks, in Malaysia, the policies are disjointed and more concerned with renewable energy generation instead of embedding sustainable practices throughout the real estate sector. Two of the reasons for slow progress are the lack of green finance access and the inability of stakeholders to gain technical expertise. Evidence-based policy measures to address these obstacles will need to be concerted to the unique socio-economic and environmental context of each of the regions.

REAL-WORLD CASES IN MALAYSIA

The Global Push for Sustainable Real Estate Practice gains a unique perspective from Malaysia. Uptake of the country's potential for green urban development is best illustrated by the Iskandar Malaysia project. This is a model for low-carbon city planning based on integrating energy-efficient buildings, renewable energy systems, and eco-friendly transportation (Abdullah e al., 2022). Just as the Penang Green Office program has seen local businesses take up green certification and save on energy and reduce carbon footprint (Abdullah e al., 2022).

However, challenges persist, although there have been these advancements. Due to cost constraints, the construction of affordable housing often neglects sustainability considerations. Additionally, the urban-to-rural divide in green adoption continues, with rural residents least likely to have access to green technologies or funding. These problems underscore the need for a comprehensive policy framework that corresponds to both the macro and neighborhood issues. Because the real estate industry contributes 40% of global emissions, this research is critical and relevant on the global and local scale. Effective policy measures are crucial to achieving international climate targets, for instance, the Paris Agreement. In addition, the study includes the integration of Malaysia-specific insights to ensure that the study findings are relevant to all global and regional stakeholders. Due to Malaysia's unique challenges, such as limited green financing and inconsistent regulatory enforcement, tailored solutions are needed to be suitable for local realities while meeting global sustainability goals (Zainuddin & Hamzah, 2023).

Finally, this research helps fill a crucial knowledge hole regarding sustainable real estate in the existing literature, with much of the focus around developed nations. The study should provide a comparative look at how Malaysia compares to leading economies like the United States and Germany and how that compares across different socio-economic and regulatory landscapes. Together with it, this analysis is not only a practical guide to policymakers to develop and implement strategies suitable to their specific local context; it also gives us best practices. The gains in insights are hoped to catalyze a diffusion of green practices—especially in emerging economies where such transitions are most needed (Zainuddin & Hamzah, 2023).

Climate Change and the Real Estate Sector

Emerging as a large emitter of greenhouse gas (GHG) in the real sector, the global carbon dioxide emission from

real estate is responsible for 40 percent of the overall GHG emissions of the globe in 2020 (Abidin et al. 2013; Rahman et al. 2022). This figure includes emissions from construction and construction material production as well as from energy use in the operation of buildings. Indeed, these emissions have far-reaching implications; they fuel rising global temperatures, biodiversity loss, and harmful impacts to human health and capacity for economic stability (Yusoff et al., 2021). Emissions from this sector are thus central to meeting global climate goals, notably those set in the Paris Agreement to keep global warming below 2°C above pre-industrial levels (Salleh et al., 2022).

The sector, however, continues to face a host of challenges, which impede its transition to low-carbon operations. One of the biggest challenges, however, is high initial costs for embracing sustainable practices in manufacturing or consuming, along with the lack of sufficient policy incentives and regulatory clarity that often dissuades stakeholders from taking concrete actions as in Table 1. Additionally, there are physical and transitional climate risks as well. Both physical climate risks (floods, heatwaves, sea level rise) and transitional climate risks (shifts in policy, technology, and market preferences for a low-carbon economy) are physical climate risks (Zhang et al., 2021). Together they become a tangled web of financial, operational, and regulatory headaches to get through for real estate stakeholders.

Table 1 Challenges and Opportunities in The Real Estate Sector

Category	**Challenges**	**Opportunities**
Economic	High upfront costs for green construction and retrofitting (Salleh et al., 2022).	Access to green financing programs such as Malaysia's Green Technology Financing Scheme (Abdullah e al., 2022).
Regulatory	Lack of standardized and enforceable green building regulations in some countries (Zainuddin & Hamzah, 2023).	Strengthened building codes and carbon pricing frameworks, as seen in Germany and the UK (Rahman et al., 2022).
Technical	Limited availability of expertise in sustainable design and technology (Tang, 2019).	Expansion of technical training programs and collaboration with international organizations.
Social	Low public awareness and adoption rates, particularly in rural areas (Zainuddin & Hamzah, 2023).	Public campaigns and incentive programs to raise awareness, such as the Penang Green Office initiative (Abdullah e al., 2022).

The literature on the real estate sector and climate change can be categorized into two primary streams: mitigation and adaptation. Mitigation-related research aims to reduce emissions through increasing energy efficiency, adopting renewable energy technologies, implementing green building certifications, including carbon pricing measures, and facilitating green financing (Tang, 2019). For example, similar to a yardstick for sustainable construction practices, standards like the Leadership in Energy and Environmental Design (LEED) and Malaysia's Green Building Index (GBI) define benchmarks for how much carbon footprint builders should reduce (Zainuddin & Hamzah, 2023). Adaptation research, however, is concerned with methodological studies aimed at understanding and dealing with climate-related risks for real estate assets. That includes climate risk modelling, scenario analysis, property valuation methods, and deploying mitigation measures such as flood-resistant designs (Yusoff et al., 2021).

Nevertheless, there seem to be significant gaps in the literature. Secondly, there is very limited comparative analysis on the policy measures taken by different countries to address emissions and climate risks to the real estate sector as in Table 2. As an example, unlike Germany and the United Kingdom, which have well-organized regulatory frameworks for green buildings, Malaysia's efforts have been voluntary and have not had enforcement mechanisms (Salleh et al., 2022). It does not provide enough examination of the mix of mitigation and adaptation strategies, including the mix's synergies and trade-offs. That's important for balancing goals because real estate sector achievement of a low-carbon and climate-resilient real estate sector demands an integrated approach.

Table 2 Comparative Analysis of Policy Measures in Real Estate

Country	Key Policies	Impact
Germany	Incentives for retrofitting through KfW loans; mandatory energy audits for large buildings (Zhang et al., 2021).	Significant reductions in energy consumption and emissions from residential properties.
United Kingdom	Building Regulations 2010 updated for stricter energy efficiency standards; adoption of Energy Performance Certificates (EPC) (Rahman et al., 2022).	Improved energy efficiency ratings and higher market value for compliant buildings.
United States	Tax credits for renewable energy installations (e.g., solar panels); LEED certification programs (Salleh et al., 2022).	Increased adoption of renewable energy in commercial and residential sectors.
Malaysia	Voluntary Green Building Index (GBI); limited financial incentives for green retrofitting (Zainuddin & Hamzah, 2023).	Modest progress in urban areas, with significant gaps in rural and suburban regions.

The Triple Bottom Line Theory

This research supports this work with a robust theoretical framework provided by the Triple Bottom Line (TBL) theory from Elkington (1997) (Zaharia & Zaharia, 2021). The TBL approach evaluates organizational and sectoral performance based on three interconnected dimensions: environmental sustainability, economic viability, and social equity. The theory of TBL in the real estate sector suggests that the environmental issues, for example, cutting GHG emissions, complement economic aspects (e.g., cost-effectiveness) and social objectives (e.g., fair access to sustainable housing) (Salleh et al., 2022).

When the TBL framework is used, the policy measures to reduce the real estate sector's carbon emissions can be holistically evaluated. For example, Malaysia's Green Technology Financing Scheme (GTFS), a green financing scheme, subsidises energy-efficient projects that meet environmental goals, so as to align these goals with economic incentives (Abdullah e al., 2022). Readily, policies of renewable energy adoption addressing environmental and social aspects minimize emissions and create job opportunities in clean energy sectors (Yusoff et al., 2021). This research combines the TBL framework and is effective overall in comprehensively assessing the effectivity of the policy measures in attaining sustainable outcomes.

Emission reduction mitigation strategies

Energy efficiency, renewable energy integration, and regulatory frameworks are usual mitigation policies integrated for reducing emissions in the real estate sector. When retrofitting older buildings with energy-saving technologies, operational emissions can be reduced. Germany's KfW Development Bank, for example, provides low-interest loans to retrofitting projects in residential and commercial properties that have significantly cut energy consumption (Zhang et al., 2021). Similar efforts are being initiated in Malaysia in the Building Sector Energy Efficiency Project (BSEEP) to promote energy-efficient building designs and technologies (Salleh et al., 2022).

Another important part of mitigation strategies is the renewable energy policies. Dramatically reducing the dependence on fuel derived from fossil sources can be achieved through building operations that incorporate solar and wind, as well as other renewable energy sources (Bekhet & Othman, 2016). Other countries are following China's example, as countries have mandated renewable energy installations in new construction projects. In Malaysia, solar energy adoption has been fuelled by programmer such as the Net Energy Metering (NEM) that, however, remain limited among the real estate industry by a relatively high cost of adoption (Abdullah e al., 2022).

Climate Risk Management: Adaptation Strategies

Adaptation policies are to minimize the vulnerabilities of real assets to physical and transitional climate risks.

As widely used tools for understanding the potential impacts of climate change on property values and locations, climate risk modelling and scenario analysis are. The Carbon Risk Real Estate Monitor (CRREM), for instance, creates a practical process for assessing transition risks and aligning real estate portfolios to decarbonization pathways (Rahman et al., 2022). Such tools are critical to facilitate stakeholders to acquire knowledge for asset management and investment strategy decisions (Khaeruman et al., 2024).

Adaptation efforts in Malaysia have largely been confined to urban areas where the Iskandar Malaysia Eco-City project includes flood-resistant designs along with the use of sustainable drainage systems. Nevertheless, rural and coastal areas have not been addressed with the same urgency in adaptation policies (Zainuddin & Hamzah, 2023). There must be an expansion in the scope of adaptation measures to cover vulnerable regions if the real estate sector as a whole is to be made more resilient.

Synergies and Tradeoffs in Policy

The real estate sector will need to be achieved through an integrated approach that balances mitigation and adaptation synergies and trade-offs. Interestingly, policies that encourage energy-efficient buildings have the potential to ease the uptake of adaptation measures by reducing operational emissions as well as increasing the resilience of buildings to climate risks (Yusoff et al., 2021). Nevertheless, in developing nations such as Malaysia, financial costs of implementing both strategies may constrain trade-offs.

The key message of this work is that policy design must capitalize on synergies while minimizing trade-offs. The example of integrating renewable energy systems into green building designs reduces emissions and improves energy security in conditions of extreme weather events. A holistic policy approach to addressing climate risks, such as reducing emissions and managing climate risks in the real estate sector, highlights how such sustainability goals cannot be achieved without a complexity in cases of emissions reduction and managing climate risks. Despite providing much-needed mitigation and adaptation strategies, gaps in comparative analysis and integrated approaches persist. This research aims to fill these gaps by applying the Triple Bottom Line framework to policy measures to assess their implications on the real estate sector's transition to a low-carbon and resilient market. The real estate industry has the potential to make an effective contribution to global climate goals through further research on the interactions between mitigation and adaptation policies.

Table 3 Selection Criteria and Key Characteristics of Case Study Countries

Criteria	**United States (U.S.)**	**United Kingdom (UK)**	**Germany**	**China**
Economic Development	Advanced	Advanced	Advanced	Developing
Real Estate Market Size	Largest global market	Large and mature	Robust, highly regulated	Rapidly expanding
Climate Risk Exposure	Hurricanes, wildfires	Flooding	Flooding	Urban air pollution, sea level rise
Climate Action Commitment	Moderate	High	High	Moderate

METHODOLOGY

This study adopted a comparative case study approach to examine the policy measures implemented in the real estate sectors of four countries: the United States (U.S.) the United Kingdom (UK) Germany and China. These countries were selected based on four key criteria: (b) through the key contributions made to their GDP and emissions profile, their varied real estate markets, and their differing exposure and vulnerability to climate risks; (a) from a broad perspective on policy dynamics; (c) through increased flooding in Germany and the UK, and wildfires and hurricanes in the U.S., and rising sea levels and urban air pollution in China; and (d) by varying levels of ambition and commitment to climate action represented by their admitted emissions targets and policies. Table 3 summarizes the overview of the selected criteria and key characteristics of selected countries is reported.

Data Collection and Sources

The primary data source for this study was secondary data which is more reliable and easily available. Academic articles, government reports, policy documents and statistical databases were used to collect data. Information found on these sources helped us see the design, implementation and outcomes of emissions reduction policies in each country. The Carbon Risk Real Estate Monitor Project (CRREM) was used as a benchmarking tool for considering the emissions as well as the risks of the real estate sector in each country for consistency and comparability. The CRREM tool provided a standardized methodology for assessing transition risks, and emission intensity benchmarks aligned with global climate targets. Data that was used in the study is the types of such listed in Table 4.

Data Analysis Methods

Quantitative and Qualitative methods were used in analysis to find out some meaningful insights from data. Systematic review of policy and reports on emissions reduction, risk mazement, and financial incentives was conducted. For numerical data (i.e. emission reduction rates and adoption rates of green building standards), descriptive statistics were used. The cross-country comparisons of these statistics helped in comparing the policy outcomes.

Table 4 Data Sources for Comparative Analysis

Type of Data Source	Examples	Purpose
Academic Articles	Peer-reviewed journals on real estate emissions policies	To establish theoretical and empirical foundations
Government Reports	Policy evaluations, national climate action plans	To identify key policy measures
Statistical Databases	CRREM, World Bank, United Nations (UN) statistics	To provide quantitative data on emissions and risks
Policy Documents	Building codes, tax incentives, renewable energy mandates	To understand the structure and implementation of measures

Further, we use discourse analysis to examine the language and framing in policy documents in order to discern how different governments have justified their policies of generating climate action. Table 5 gives some of the selected key statistics studied in this work.

Table 5 Selected Key Statistics from Case Study Countries

Statistic	United States (U.S.)	United Kingdom (UK)	Germany	China
Annual GHG Emissions from Real Estate (%)	30%	24%	18%	35%
Adoption Rate of Green Standards (%)	42%	68%	73%	30%
Energy Efficiency Investments (USD Billion)	25.3	12.7	15.4	21.6

Cross-Case Synthesis

The cross-case synthesis is used to compare and contrast the policy measures and results from the four countries. It facilitated similarities, differences, strengths and weakness identification across the case studies. It highlighted best practices, such as Germany's mandatory energy audits, Energy Performance Certificates in the UK, and large-scale investments in renewable energy in China. The weaknesses of the U.S. were based on its voluntary measures and without effective enforcement mechanisms in China.

It also revealed common themes - financial incentives and regulatory frameworks - and unique challenges - the

U.S.'s susceptibility to extreme weather events and China's urbanization pressures. The study systematically synthesized data to provide actionable insights to policymakers in developed and developing countries.

Although the comparative case study approach proved to be a valuable source of insights, it did so with some constraints. Because some policy outcomes could not be verified independently in light of reliance on secondary data and data availability between countries, this represents a constraint. Furthermore, the absence of the regional and local variation in focus of the study might have missed the regional and the local variations that could impact the outcome. Future work should make use of primary data, including interview with policymakers and stakeholders to validate findings and to get a more nuanced understanding of policy impacts. Further generalizability is obtained by expanding the scope to include the Global South, including other countries or regions.

The United State of America (U.S)

Overall, the real estate sector is the second largest emitter of greenhouse gases in the world, after the U.S. alone, emitting 40 percent of all U.S. greenhouse gas emissions. Significant physical and transitional climate risks to the U.S. include hurricanes, floods, wildfires, droughts, heat waves, sea level rise, and regulatory and market change. In recent times, the U.S. had rejoined the Paris Agreement and promised to decrease its emissions by 50–52% by 2030 and achieve net zero by 2050 (Bodansky, 2016).

Policy measures that would reduce emissions in the real estate sector in the US are principally driven by the state and local governments and the private and non-governmental sectors, such as investors, tenants, developers, and rating agencies. The responsible regulatory boundary of the real estate sector is very limited, and the federal government provides some form of incentives and guidance on green building practices.

The USA has used many policy steps to lower the emissions in the real estate sector, including carbon pricing, building standards, renewable energy mandates, and green financing schemes. Cap and trade programs and carbon taxes in California, New York, and Massachusetts, for example, create a financial incentive to cut emissions. These policies increase energy costs and operating costs for buildings and reinforce investments in low-carbon technologies and innovations. The most important measures are building standards, such as New York City's Local Law 97, which requires buildings above 25,000 square feet to reduce emissions by 40 percent by 2030 and 80 percent by 2050. These standards enable energy efficiency and competitiveness without penalties and liabilities for noncompliance.

Apart from this, renewable energy mandates contribute a good deal to decarbonising the real estate sector. California's Senate Bill 100, for example, mandates 100% carbon-free electricity by 2045, cutting energy costs and emissions and driving up renewable energy demand and infrastructure construction. The Property Assessed Clean Energy (PACE) program and other green financing schemes permit property owners to finance green building projects via property tax assessments. The reduction of upfront costs and financial risks becomes more appealing to investors making sustainability-related projects. Combined, these measures show how public and private sources can jointly steer real estate toward a low-carbon future through a number of measures.

The United States has put climate risk management measures in place for the real estate sector, such as climate risk disclosure, climate risk modelling, and climate risk mitigation strategies. Speaking to the AP from The Hague, Rob Govers, CEO of an international think tank on sustainable blue economy and finance, said American officials could learn from their counterparts in the EU, which is home to the world's first sweeping climate strategy for businesses. The idea is to help the investors be better informed by data to aid in their decision-making. Such disclosures create confidence among the rest of the stakeholders in whom the companies have invested, and so the companies to adopt the sustainable operations.

In recent years, the use of a climate risk modelling tool, such as the Carbon Risk Real Estate Monitor Project (CRREM), has become increasingly recognised for physical and transitional risk assessment. In developing efforts, CRREM has been created in partnership with the European Union to quantify transition risks and real estate assets' alignment with science-based greenhouse gas reduction pathways. The tool provides detailed emission benchmarks at the property and company level so investors can identify stranded assets and take

strategic low-carbon actions. Such models help integrate the real estate sector to understand the sector's exposure to climate-related vulnerabilities, enable the development of targeted risk management strategies, and unlock opportunities for building resilience and adaptation.

Property owners and investors are taking proactive measures to mitigate climate risks, preparing assets so they do not suffer, and optimising portfolios. Resilient updates—putting in flood barriers, storm shutters, and cool roofs—safeguard buildings from extreme weather events as well as temperatures. But investors are also diversifying their portfolios, pouring money into green bonds, low-carbon funds, or climate-resilient assets to dampen exposure to financial losses from the low-carbon transition. Thus, these mitigation strategies not only improve the durability and revaluedness of real estate assets but also reduce liability and reputational risks to provide the emerging market a sustainable and competitive edge.

In terms of ambition and action, the U.S. real estate sector has made incremental progress in decarbonisation but is lagging other nations; however, decisive action can make a difference. The Carbon Risk Real Estate Monitor (CRREM) notes that to meet the 1.5-degree climate target, the sector has to reduce emissions by 4.5% per annum but is in fact on a reduction of just 1.7% per annum. This represents the lagging performance of the sector and reinforces its lack of performance by its low ranking on the Global Real Estate Sustainability Benchmark (GRESB), an assessment of environmental, social, and governance (ESG) performance of real estate portfolios. The gaps will be crucial for the sector to meet international climate goals and for the sector to improve its competitiveness.

The U.S. real estate sector faces large and growing climate risks, physical and transitional, which threaten its value and performance. The Urban Land Institute and Heitman's 2016 report estimates that physical risks—such as flooding, heat stress, and water scarcity—could eat up to 15 percent of value from the sector by 2050. By 2050, CRREM estimates that such transitional risks, such as carbon pricing, stricter energy efficiency standards, and greater green preferences of investors, could depress the value by an additional 14 percent. These risks show the importance of resolving to protect assets and stabilisation in the long term for the sector by adopting resilience and mitigation strategies. However, the U.S. real estate sector has plenty of potential to take its green transition further and boost its resilience. Having a large and diverse market sector provides the great opportunities to innovate and to cooperate. Both the U.S. entrepreneurial culture and the country's leadership in green real estate practices have spawned pioneering efforts, which have the potential to be followed by broader adoption of sustainable practices. Additionally, the resilience and decarbonisation efforts of the sector are enhanced by strong policy support and momentum from the Biden administration's renewed focus on climate action, including rejoining the Paris Agreement and setting ambitious national climate goals.

The United Kingdom (UK)

For example, the world's sixth-largest emitter of greenhouse gases, the United Kingdom, has no shortage of challenges and opportunities to deal with emissions produced by their real estate sector, which in total represents approximately 40 percent of the country's emissions. The risks are relatively moderate, but physical risks include storms, floods, heatwaves, and droughts, and transitional risks such as policies, markets, and investor preferences. But though we've faced all these challenges, the UK has stood out as a global leader on climate action. And it has legally promised to slash its emissions by 68 percent by 2030 and eliminate them entirely by 2050. This ambitious agenda indicates that the UK is determined to bring its real estate sector into line with global climate targets and also to mitigate its own risks.

There is a range of government policy measures taken at the national and devolved administration, local authority, and industry association levels to decarbonize the real estate sector. Where they do, carbon pricing is critical, with the Carbon Price Support (CPS) setting a minimum of £18 per tonne of carbon dioxide emissions for fossil fuel power plants. This pricing mechanism complements the EU Emissions Trading System (ETS) and opens the way for a domestic ETS or carbon tax post Brexit. In addition, there are strong building standards: The Future Homes Standard, requiring low carbon heating and energy efficiency in new homes from 2025, and the Minimum Energy Efficiency Standards (MEES), which promote steadily increasing building performance. The purpose of these is to reduce emissions while keeping a focus on innovation and competitiveness in the real estate sector.

Alongside renewable energy mandates and green financing schemes, the UK is also pushing a low carbon real estate strategy. Renewable energy production is now being incentivized by policies such as the Renewable Obligation (RO) and the Contracts for Difference (CfD), which reduce emissions and reduce energy costs in order to expand renewable energy infrastructure. There are green financing initiatives, including the Green Homes Grant and the Green Finance Institute, which mobilise resources for energy-efficient building retrofits and new green developments. Importantly, these measures not only reduce the financial risks to owners and investors in both the public and private markets, but they also generate a tremendous level of private sector engagement in decarbonization efforts.

The UK has considerable work to do in terms of risk disclosure and modelling in managing climate risks. It is a sign of the government's leadership in transparency and accountability that its commitment to mandate large companies and financial institutions to make climate-related financial disclosures by 2025. The UK Climate Projections (UKCP) puts out detailed data and scenarios to assess the physical risk of flooding and sea level rise so property owners and investors can prepare for what is to come. Furthermore, the sector has utilized risk mitigation, including resilience outlays like flood defences and green roof, as well as portfolio diversification via to green bonds and climate resilient assets. The initiatives serve to protect the sector value and facilitate its ability to adapt in a fast-changing environment.

It shows the progress made by the UK in decarbonizing its real estate sector and what remains to be done. Yet, CRREM says that with 4.9% annual emissions reduction, the UK has already surpassed the 4.8% annual required to meet the 1.5˚C scenario. The UK also sits at the top of the Global Real Estate Sustainability Benchmark (GRESB), representing good environmental, social, and governance (ESG) performance. While there are still moderate climate risks, physical risks could reduce sector value by 10 percent and transitional risks by 11 percent by 2050. However, given these risks, the UK has a mature and engaged market, an effective policy framework, and a development vehicle such as the Green Finance Institute and UKCP, which together put it in good shape to deliver a sustainable and resilient real estate sector.

Germany

One-third of our total emissions comes from the real estate sector in Germany—one of the world's largest real estate markets—and managing those emissions will be challenging, to say the least. Moderate physical climate risks (storms, floods, heat waves, droughts), transitional risks (changing policies, market dynamics), and minimal technology and transition risks characterize the sector. Still, Germany is one of the biggest supporters of climate action in the European Union, having promised to cut its emissions by 65 percent by 2030 and reach a net zero target by 2045. The country is serious about its ambitious climate goals, as it strives to cut down on its carbon footprint while hedging against risk to its real estate sector.

In order to achieve these aims, Germany has put in place a range of policy measures that aim to reduce emissions and manage climate risks of the real estate sector. The federal government leads with these initiatives, with state and municipal governments and industry associations. Green building practices and standards have also been inspired by the private sector. The Fuel Emissions Trading Act is an important policy, the directives of which require all companies operating within the heating oil, natural gas, petrol, and diesel markets to participate in the national emissions trading system (nETS). The proposed system fixes the price of carbon at €25 per unit of CO2 CO2 tonne from 2021 to €55 in 2025. It seeks to decrease emissions from transport and building sectors and to stimulate opportunities for low-carbon investments.

Germany has, in addition to carbon pricing, stringent building standards that promote energy efficiency to reduce emissions. The Energy Saving Ordinance (EnEV) requires primary energy consumption, heat loss, and insulation levels. In terms of heating, the Renewable Energies Heat Act (EEWärmeG) obliges new buildings to substitute their heat demand from renewable sources like solar, biomass, or geothermal energy within limits. These building codes and standards are intended to increase the performance of the real estate sector by reducing emissions, both by new and existing buildings, and by making them more competitive on the market.

In Germany, they have had renewable energy mandates designed to lower emissions and energy costs. The Renewables Sources Act (EEG) offers feed-in tariffs and market premia for the production of renewable energy.

Germany's wider strategy is to raise renewable energy in the electricity mix to 65 percent by 2030 and 80 percent by 2050, and the EEG is part of that. They help increase renewable energy infrastructure and lower the energy cost to real estate owners and tenants while reducing the sector's carbon footprint.

From a financing point of view, Germany has set up green financing schemes to help facilitate the transition towards a low-carbon real estate sector. For example, the KfW Energy Efficient Construction and Renovation programme provides low-interest loans and grants for energy-saving construction and renovation of residential and commercial buildings. The Federal Ministry for Economic Affairs and Energy (BMWi) also contributes funds to energy-efficient buildings research and innovation projects. Green financing initiatives help to lower financial burdens in real estate ownership and further investment in sustainable buildings, which tends to reduce financial risks in the long term for the sector.

In order to minimise climate risks, Germany has used policies to promote policy transparency and enhance risk management. The country supports the EU Directive on the disclosure of non-financial and diversity information that large companies must report on those climate-related risks and opportunities. The recommendations of the Task Force on Climate-related Financial Disclosures (TCFD)—a comprehensive framework for climate-related disclosures—have also been endorsed by Germany. Moreover, a property owner can assess physical climate risks such as flooding, temperature changes, and water scarcity using available tools (e.g., DWD and C3S). The real estate sector learns how vulnerable it is in these and uses these risk management tools to develop adaptive practices that aid in resilience.

Germany has already reduced emissions from its real estate sector largely through the implementation of policy measures. CRREM shows that the German real estate sector must reduce emissions by 5.1 percent per year to reach the 1.5˚C scenario and is now set to overshoot this target with a reduction of 5.2 percent per year. Germany is also further up than is in the Global Real State Sustainability Benchmark (GRESB), indicating strong environmental, social, and governance (ESG) performance. Nevertheless, the sector is subject to moderate climate risks, which may result in a 10% reduction of the property value by 2050 and up to 11% due to transitional risks. Even in the face of these risks, Germany's mature real estate market, high regulatory bar, and robust financial mechanisms make it well placed to reduce risks and achieve its climate goals and strengthen the sector.

China

For China, the world's largest emitting country, its real estate sector alone could make up as much as 40% of total greenhouse gas emissions, and much less than this is less, but challenging to manage. Physical and transitional climate risks, including typhoons, floods, droughts, heat waves, and the impacts of policy and market change, are highly vulnerable to the country. To tackle these, China has declared its commitment to peak carbon emissions this century and reach carbon neutrality no later than 2060. These ambitious goals serve as a yardstick for transformation; however, the real estate sector is pivotal to how the country reduces its emissions overall.

Central government policy measures to reduce emissions and control risks in the Chinese real estate sector adopted are mainly driven by the central government, with support from provincial governments and municipalities and industry associations. Moreover, the private sector has been involved more and more in promoting and using these green building practices and standards. The third and one of the key policies is the introduction of a national carbon market, which initially covers the power sector but is broadened to cover the building sector. This market limits total emissions in covered sectors and sets a cap of emission allowances. Carbon pricing will attempt to provide financial incentives to reduce emissions through a market-driven approach to emission reductions.

By building standards, China has developed a variety of regulations to meet energy efficiency and emissions reductions targets for both new and existing buildings. Green Building Evaluation Standard (GBES) establishes criteria for evaluating the green performance of buildings by not only energy and water consumption but also material use and indoor environmental quality. Furthermore, the Green Building Action Plan requires that all new public buildings and large-scale housing buildings satisfy green building standards by 2020. Improving the energy performance of buildings could reduce emissions while making the real estate sector more competitive, and these policies are critical.

Supporting emission reductions and also reducing current energy costs, China too has mandated renewable energies. Under the Renewable Energy Law, grid operators are obligated to purchase all renewable source electricity while subsidising and offering preferential tariffs for the renewable energy projects. Specific quotas and targets are defined in the Renewable Energy Consumption Action Plan on the percentage of renewable energy to be used in the electricity consumption of provinces and regions. The real estate sector is enabled to reduce its dependence on fossil fuels, reducing emissions and energy costs and helping to develop renewable energy infrastructure across the country.

To mitigate the financial barriers with green building projects in China, green financing schemes have been developed. With policy support and financial incentives, the China Green Building Label certifies green buildings, while the China Green Bond Catalogue defines eligible green projects, including those on energy efficiency and green building. These schemes address financial risks of green building efforts and enhance the overall financial viability of green building initiatives with the purpose of encouraging investment in sustainable real estate development and hastening the transition to a low-carbon real estate market.

Policies on climate risk disclosure and mitigation have been formulated by China in terms of managing climate risks. It's required by the China Securities Regulatory Commission (CSRC) that the guidelines on environmental impacts, risks, and opportunities be disclosed voluntarily. For example, the Green Finance Guidelines promoted by the People's Bank of China (PBOC) have encouraged financial institutions to disclose environmental and social information. The China Meteorological Administration (CMA) and other platforms offer climate risk modelling tools that help real estate owners model physical climate risks like flooding, heat stress, and water scarcity. These risk management tools are critical for real estate stakeholders to consider for vulnerabilities and gain increasing resiliency.

Some of the climate risk mitigation practices in the Chinese real estate sector are already taking place. However, property owners are betting on resilience upgrades, including flood control measures, green walls, heat recovery systems, and smart grids, to save their buildings from extreme weather events or temperature fluctuations. Additionally, investors are spreading out their own portfolios—including investments in green bonds, low-carbon funds, and climate-resilient assets—to offset any possible financial losses from the low-carbon transition. Mitigation strategies such as these will lower liability and reputation risk and increase the overall resilience and profitability of the real estate assets in the context of climate-related challenges.

China's progress towards decarbonizing buildings in China is mixed but full of challenges. To achieve the 1.5˚C scenario, CRREM calculates that the Chinese real estate sector must cut down its emissions by 5.4 percent per annum compared to current emissions reductions of just 2.9 percent per annum. Furthermore, China lags behind in the Global Real Estate Sustainability Benchmark (GRESB), a survey of real estate portfolios based on their environmental, social, and governance (ESG) performance. With strong central government policy support, China's large and dynamic real estate market remains a market with significant growth and development potential and also of potential for innovative and sustainable building practices.

In addition, China's real estate sector also has important climate risks, both in their physical and transitional form, which have possible negative implications on its quantity and quality of value and performance in the coming decades. But according to a report prepared by the Urban Land Institute and Heitman, the Chinese real estate sector could potentially lose up to 20 percent of its value by 2050 due to physical climate risk, like flooding, heat stress, and water scarcity. Further, according to CRREM, greenhouse risks of the kind included carbon pricing, energy efficiency standards, and strong green preferences could wipe up to 18 percent in valuation by 2050. While China's integrated and centralized policy structure, complemented with a national carbon market and the China Green Building Label, are strong assets to fasten the green transition and increase real estate sector resilience.

FINDINGS AND IMPLICATIONS

This study's findings offer important suggestions for understanding the intricacies and obstacles of mitigating emissions and coping with climate risk in the real estate sector. The first of the primary conclusions of this paper is that policy measures to ultimately decrease emissions and manage associated risks in the real estate sector rely

very much on how countries approach policy measures in general. The reasons for these variations rest on differences in economic development, political systems, cultural environments, exposure to climate, and climate ambition. This study indicates, however, that there is no single universal solution to decarbonising and adapting the real estate sector. Instead, a more context-specific, situation-specific, planned approach is necessary, in which the special local conditions, political environment, as well as eco-environmental constraints and predicaments as they pertain to each country are adopted into consideration. Let's take the example of how different countries might have a different course of action: they may push for aggressive carbon pricing and renewable energy mandates, while another may push for energy efficiency standards and green building certifications. What is important for meaningful climate outcomes in the sector is the adaptability of policy measures to local context.

The findings of the study also underscore that there are many interrelations (synergies, trade-offs) among the policy measures for emissions reduction and climate risk management in the real estate sector and their impacts. Further examination will show that although in many ways these policies are good, at the same time they can present unpredictable difficulties. Carbon pricing is an example of a financial incentive (for example, energy efficiency improvements or adoption of renewable energy) that also increases energy costs and thus also increases operational expenses of buildings. It can reduce the profitability of green buildings and prevent private sector investment. And similarly, building standards can even become stricter, pushing for better performance, but that will come at a steeper cost to the developer, which can then be charged on to the consumer. Such tradeoffs imply that policymakers need to think about the broader economic context and that policies should not inadvertently derail those who play the key role in that. A more reasonable policy requires that the costs and benefits for developers, consumers, and investors are reflected in the equation.

The Synergies and Trade-offs of Policy Measures

Another critical finding from the present study is the analysis of synergies and tradeoffs of different policy measures. Policies such as a renewable energy mandate can lead to governments requiring buildings to depend on cleaner energy sources and therefore reduce emissions. However, the leveraging of these mandates depends on significant commitment of investments in generation capacity and in transmission systems. However, in many regions, the existing infrastructure is not capable of handling the rise of renewable energy demand, which could result in difficulty in achieving renewable energy targets. Therefore, their implementation depends significantly on proper alignment of renewable energy policies with needed infrastructure investments. Similarly, green financing schemes are intended to alleviate any financial barriers to developer investors in sustainable building projects, provided watershares capital and terms of financing are forthcoming. For instance, demand for green buildings may be low when the cost of capital is too high or when the cost of financing is too high for some types of projects.

This also shows that the overall climate risk strategy within real estate is incomplete without climate risk disclosure and climate risk modelling. It would provide transparency and accountability in the sector, strengthening investors and other stakeholders' ability to make informed decisions. However, there is a potential downside to this policy: Disclosure also exposes the sector to reputational risks and litigation when companies don't follow disclosure standards or are not effective in taking action on disclosed risks. Policymakers therefore have to create an environment of mandatory disclosure where, at the same time, incentives are given to take positive actions and raise performance. Without such incentives, climate risk disclosure can be more a compliance manoeuvre than a mechanism to encourage real climate risk mitigation.

The Design and Effectiveness of Policy Measures (for National Policy Organisation)

The study also reveals that certain policy measures are more effective than others based both on their design and their implementation. For instance, capitalist carbon pricing, a theoretically powerful tool to cut emissions, may not do the work if the carbon price is too low or the network is too small. Setting a carbon price that amounts to the real cost of carbon and extends to the broad range of sectors is important, the study says, including the real estate sector. Likewise, the degree of success in building standards depends on the relative stringency, flexibility, and efficiency of enforcement mechanisms. Improvements in energy efficiency and reductions in emissions will be contingent on stricter building standards, but the actual reductions will be negated if inspection and monitoring

are insufficient. Consequently, policies must be designed with sufficiently clear, enforceable rules for their service and with sufficient resources to be able to comply.

Renewable energy mandates can also fail if renewable energy generation is not reliable enough or if the grid infrastructure cannot absorb the new energy sources. Green financing mechanisms, however, will have little or no impact if they only serve the developers of large, complex projects on tailored terms and conditions. The implications from this study show that policymakers need to carefully develop and implement policies if they are to drive real, lasting change. Finally, the study shows how these measures will succeed, or not, and to what extent, depending on how they evolve and react over time to new challenges and market dynamics.

Dynamic and adaptive policy frameworks are utilised.

Further, the study finds that real estate sector climate risk management requires flexible and adaptive policy regimes. Policy solutions to climate change and the lived impacts on the real estate sector are complex and therefore must change over time as well. Especially in light of climate risk modelling, in which data quality, availability, and comparability are likely to vary as new research and technology emerge. The study finds that while climate risk models are useful, they still have a long way to go and there are issues with data accuracy and calibration to real conditions. Therefore, policymakers should develop a flexible conduct of risk modelling by constantly refreshing and revising its forecasts as new data becomes available as in Table 6.

Table 6 Policy Measures in The Real Estate Sector

Policy Measure	Key Features and Implications
Carbon Pricing	Financial incentive for emissions reductions, but requires high carbon prices to be effective.
Green Building Standards	Improved energy efficiency and building performance, but may increase costs for developers.
Renewable Energy Mandates	Reduces emissions but requires large infrastructure investments for generation and transmission.
Green Financing Schemes	Provides capital for green projects, but depends on availability and accessibility of funding.

Like climate risk mitigation measures, our work should be improved continuously. The task of identifying and prioritizing climate hazards is a complex process that involves ongoing risk assessment with many stakeholder inputs. The study argues, however, that several foundational long-term strategies are necessary for implementing successful climate risk mitigation in real estate. In the short term, immediate measures, for example, bringing the building to a better level of energy efficiency, attenuate vulnerabilities. Building and neighborhood resilience to future climate impacts should be a long-term strategy in the form of developing climate-resilient infrastructure.

The study also provides a number of new insights and lessons for policymakers and industry stakeholders. The financial models and investment decisions need to incorporate climate risks. In this real estate sector, environmental and social aspects of sustainability are realised by more and more investors, but financial returns remain the main priority and are neglected for the risks related to climate change. Second, the study suggests that climate risk assessments are an important component of investment decisions to prevent unanticipated losses as a result of either climate-related events or policy shifts. The realization of these objectives will involve a rebalancing of traditional financial models, which may eventually set a foundation for more sustainable investment practices as in Table 7.

Table 7 Policy Synergies and Trade-Offs

Policy Measure	**Synergies**	**Trade-offs**
Carbon Pricing	Encourages low-carbon investment, drives energy efficiency.	Increases operational costs for buildings.

Renewable Energy Mandates	Reduces emissions, lowers energy costs long-term.	Requires substantial investments in infrastructure.
Building Standards	Improves competitiveness and performance of buildings.	Increases construction costs for developers.

In addition, the present study also witnesses a lack of dependable, consistent data on climate issues for the real estate sector. While some tools and platforms for climate risk modelling are being developed, there is still a dearth of comprehensive and high-quality data to base decision-making on. The urgency of having stronger data governance and collaboration between governments, private sector actors, and research institutions to strengthen the data ecosystem that provides reliable climate-relevant data is underscored. Without such data, it will be practically impossible to accurately characterise climate risks and to implement effective mitigation strategies.

Strengthening the Sector—Policy Recommendations

As a result of the findings of the study, a number of policy recommendations can be made to enhance the resilience of the real estate sector to climate change. The first step, however, is for policymakers to set a strong example by funding the development of a complete carbon pricing framework, encompassing all major emitting sectors, like real estate. Such behaviour would encourage the real estate sector to use carbon-low technology and curb emissions. Second, building standards must be continuously developed, and mechanisms of enforcement must be strengthened to account for the technology and science.

Third, we should complement renewable energy mandates with investments in grid infrastructure to integrate renewable energy into the building sector under reliable conditions. Fourth, green financing schemes should be further expanded to enable more widespread availability to the developers and projects and favorable terms and conditions for investment in sustainable buildings. Policymakers should at last mandate climate risk disclosure for real estate companies and incentives for proactive climate risk mitigation. It will make sure that the sector is better ready in addressing the challenges of climate change and availing of the opportunity of resilience and adaptation mentioned in Table 8.

Table 8 Challenges and Opportunities in Real Estate Climate Policies

Challenge	**Impact on Policy Effectiveness**	**Opportunities**
Insufficient Carbon Pricing	Limits effectiveness in reducing emissions.	Stronger pricing mechanisms could drive large-scale change.
Data and Climate Risk Modelling	Inconsistent data quality limits modelling accuracy.	Improved data and modelling tools can guide policy.
Financial Barriers for Green Projects	Limits green building adoption.	Expansion of green financing can drive further investment.

CONCLUSION

The global challenge of climate change, Malaysia has shown their efforts by means of the policy of the Green Building Index (GBI) and initiatives such as the Iskandar Malaysia Eco-City project. The results of this study are mirrored in these endeavours, indicating the need to take a customized, localized view of decarbonization. For instance, low-carbon urban planning, exemplified by Iskandar Malaysia's integration of energy-efficient buildings, renewable energy systems, and sustainable transportation, is also used as a case study. But their challenges—an urban-rural divide in participation in the green and a dearth of green financing, as well as a lack of uniform enforcement—merely echo trends highlighted in the paper, urging an inclusive, integrated policy approach.

This research is expected to provide information for future strategies in Malaysia and other economies similar to it. A comprehensive approach that integrates both regulatory and market-based tools can assist Malaysia in

tackling both operational and embodied emissions, in the absence of geoengineering capabilities, while also taking into consideration a wide range of the stakeholders. For example, expansion of financial schemes such as Malaysia's Green Technology Financing Scheme (GTFS) can help remove the entry barrier for the private developers to invest in the sustainable infrastructure. In addition, mandatory green certification standards, similar to Germany's energy audits or the UK's Energy Performance Certificates (EPC), can greatly enhance energy efficiency in the sector without impacting competitiveness on the market.

This paper provides critical ground for future research, especially in examining mitigation and adaptation strategies and their interactions. Further guidance can the application of frameworks such as the Triple Bottom Line (TBL) aid the application of policy measures achieving environmental, economic, and social objectives in balance. The roots from the global case studies can be used to provide a contextualized view of what the Malaysian context could enable regarding the formulation of robust policies to enhance the sustainability, resilience, and equity of the real estate sector.

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