www.rericjournal.ait.ac.th

# Can Kuala Lumpur Achieve Carbon Neutrality by 2050?

Sing Yee Toh*, [1], Gabriel Hoh Teck Ling*, Loon Wai Chau*, Rohayu Abdullah* Chin Siong Ho*, Siti Hajar Misnan*, Ak Mohd Rafiq Ak Matusin*, and Nurzuliza Jamirsah*

**ARTICLE INFO**

*Article history:*
Received 11 November 2024
Received in revised form
09 April 2025
Accepted 15 May 2025

*Keywords:*
Carbon neutrality
Climate change
ExSS modeling
Kuala Lumpur
Malaysia

**ABSTRACT**

*Malaysia has committed to reducing the GHG emissions intensity of GDP by 45% by 2030 compared to 2005 levels and has announced the ambitious goal of achieving carbon neutrality by 2050 in the Twelfth Malaysia Plan. Kuala Lumpur, the capital city and economic hub of Malaysia, is leading efforts to mitigate climate change amidst rapid economic growth. Kuala Lumpur City Hall (KLCH) has set a target to reduce GHG emission intensity by up to 70% by 2030. This paper aims to extrapolate GHG emissions projections until 2050, considering current initiatives, and concurrently explore alternative decarbonization pathways using the Extended Snapshot (ExSS) modelling approach. Two scenarios were formulated: Scenario 1 (S1) represents Business-as-Usual (BAU), while Scenario 2 (S2) depicts Counter Measure (CM). The modelling results indicate Kuala Lumpur has the potential to significantly reduce its GHG emission intensity compared to the 2010 levels by up to 92% by 2050 (equivalent to an absolute reduction of 57,594 ktCO₂eq from the 2050 BAU scenario). The commercial sector demonstrates the most substantial decrease in absolute GHG emissions in the 2050 CM scenario compared to 2050 BAU projection. This upward trend in emission reductions aligns well with both national and city-level goals, as Kuala Lumpur is on track to become a low-carbon city by 2030, aiming to be carbon-neutral ready by 2040 and achieve carbon neutrality by 2050.*

## 1. INTRODUCTION

Climate change is an urgent global issue that requires immediate action to reduce greenhouse gas (GHG) emissions worldwide. The Intergovernmental Panel on Climate Change (IPCC) stresses that the opportunity to limit global warming to 1.5 °C— an aspirational limit first codified in Article 2 of the 2015 Paris Agreement, where 196 Parties pledged to "pursue efforts" to keep warming below this level - is rapidly diminishing [1]. According to the IPCC's Sixth Assessment Synthesis Report (AR6), the remaining global carbon budget compatible with a ≥50 % probability of meeting the 1.5 °C goal is approximately 500 $GtCO_2eq$, equivalent to less than a decade of emissions at the 2019 rate [2]. To stay within this budget, global GHG emissions must peak before 2025, decline by around 43% by 2030, and reach net-zero $CO_2$ emissions by the early 2050s [2]. The report further underscores the pivotal role of cities, which are responsible for an estimated 67–72% of global $CO_2eq$ emissions [2]. As such, the implementation of effective urban decarbonization strategies will be critical in determining whether international climate goals are attainable.

In 2020, Malaysia contributed approximately 0.67% of global GHG emissions, equivalent to 302 $MtCO_2eq$. This represents a significant increase since 1990, with a compound annual growth rate (CAGR) of 4.6% over the 30-year period [11]. As Malaysia's largest and fastest-growing metropolitan area, Kuala Lumpur plays a crucial role in determining the nation's trajectory toward the IPCC-aligned 1.5°C pathway and its carbon neutrality target for 2050. In support of the Paris Agreement, Malaysia has pledged to reduce its GHG emissions intensity of GDP by 45% by 2030 (relative to 2005 levels), and the Twelfth Malaysia Plan further outlines the goal of national carbon neutrality by mid-century. Since 2006, Kuala Lumpur has been at the forefront of low-carbon development, initiating a range of climate strategies and mitigation efforts. By 2017, Kuala Lumpur launched its first Low Carbon Society Blueprint 2030, consisting of 245 programs and actions aimed at achieving a 70% reduction in carbon emissions per unit of GDP by 2030. In 2022, KLCH, in collaboration with Universiti Teknologi Malaysia (UTM), established the KL Carbon Neutral Climate Action Plan 2050, which aims to achieve full carbon neutrality by mid-century. A core component of this initiative is the need for robust scientific analysis to assess current emissions, forecast future trends, and identify viable decarbonization strategies.

This paper addresses the need by estimating GHG emissions by end-use sector in Kuala Lumpur, using 2010 as the baseline year. Emissions are projected under

* Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

[1]Corresponding author:
Email: singyeetoh@graduate.utm.my

both Business-as-Usual (BAU) and Counter Measure (CM) scenarios for 2030, 2040, and 2050 using the Extended Snapshot (ExSS) model. Beyond quantifying emissions, this study offers a concrete and data-driven decarbonization roadmap for Kuala Lumpur by identifying sector-specific mitigation potentials and actionable strategies. The findings aim to provide valuable insights into feasible pathways for achieving carbon neutrality, serving as a practical framework for guiding urban climate action planning. This contribution is particularly relevant not only for policymakers and stakeholders in Malaysia but also for other rapidly urbanizing cities across Asia seeking to operationalize low-carbon development and resilience goals.

While the global carbon budget defines the urgency, most decarbonization efforts are operationalized at the city level, where tailored pathways are aligned to sector-specific emissions profiles and long-term neutrality targets. For instance, Copenhagen aims to become the world's first carbon-neutral capital by 2025, focusing on sustainable biomass-powered district heating and electrified transport [7]. In the United States, Boston targets 2050 for carbon neutrality, prioritizing the building sector, which accounts for over 70% of citywide emissions, through deep energy retrofits, electrification, and renewable power adoption [3]. In Asia, both Singapore and Yokohama have pledged net-zero by 2050. Singapore focuses on decarbonizing its electricity mix through hydrogen, solar, and regional renewable imports [8], [13], while Yokohama combines energy demand reduction, clean transport, and building efficiency improvements to transition fully to renewables [4]. These examples underscore the importance of city-level planning and sector-specific strategies in achieving carbon neutrality. However, no study has been conducted in Malaysia to assess this potential. This paper addresses this critical research gap by presenting the first empirical analysis exploring the feasibility of carbon neutrality in Kuala Lumpur, with the central hypothesis that the city can achieve carbon neutrality by 2050 through targeted, sector-based strategies.

## 2. KUALA LUMPUR DEVELOPMENT

### *2.1 Population*

**Table 1. Population of Kuala Lumpur.**

| 2010 | 2030 | 2050 |
|---|---|---|
| 1,674,621 | 1,980,000 | 2,457,581 |

Based on Table 1, Kuala Lumpur's population is projected to experience substantial growth from 2010 to 2050. In 2010, the city's population was 1,674,621. By 2030, it is expected to rise to 1,980,000, indicating an 18.3% increase over two decades. Looking ahead to 2050, the population is projected to reach 2,457,581, marking a 24.1% increase from 2030 and an overall growth of 46.8% from the 2010 baseline. This steady growth reflects the city's expanding urbanization and increasing economic activities.

### *2.2 Gross Domestic Product (GDP)*

**Table 2. GDP of Kuala Lumpur.**

| 2010 | 2030 | 2050 |
|---|---|---|
| USD 19,464 mil. | USD 82,225 mil. | USD 141,667 mil. |

Table 2 shows that Kuala Lumpur's GDP is projected to grow significantly from USD 19,464 million in 2010 to USD 82,225 million by 2030, a 322.4% increase. By 2050, the GDP is expected to reach USD 141,667 million, marking a 72.3% rise from 2030 and a 627.8% increase from 2010. To sustain this growth, Kuala Lumpur will need to implement sustainable practices and ensure effective policies that align with its carbon neutrality goals.

### *2.3 Economy Structure*

**Table 3. Economy structure of Kuala Lumpur.**

| Year | 2010 | 2030 | 2050 |
|---|---|---|---|
| Primary | USD 13 mil. 0.06% | USD 52 mil 0.06% | USD 90 mil. 0.06% |
| Secondary | USD 1,836 mil. 9.21% | USD 1,817 mil. 2.21% | USD 2,848 mil. 2.01% |
| Tertiary | USD 18,085 mil. 90.73% | USD 138,729 mil. 97.73% | USD 80,356 mil. 97.93% |

Table 3 illustrates the projected economic structure of Kuala Lumpur, highlighting the contributions of primary (agriculture, mining, quarrying), secondary (manufacturing, construction), and tertiary (commercial, services) sectors for 2010, 2030, and 2050. In 2010, the primary sector contributed USD 13 million (0.06%), the secondary sector USD 1,836 million (9.21%), and the tertiary sector USD 18,085 million (90.73%). By 2030, the primary sector's contribution is projected to increase slightly to USD 52 million (0.06%), while the secondary sector's contribution decreases to USD 1,817 million (2.21%). The tertiary sector is expected to dominate the economy with USD 80,356 million (97.73%). In 2050, the primary sector is projected to contribute USD 90 million (0.06%), and the secondary sector USD 2,848 million (2.01%). The tertiary sector will further solidify its dominance with a projected contribution of USD 138,729 million (97.93%). This trend highlights Kuala Lumpur's transition towards a service-oriented economy, with a significant emphasis on commercial and service sectors.

## 3. RESEARCH METHOD

To scientifically project Kuala Lumpur's potential for reducing GHG emission intensity under various scenarios, the internationally recognized Asia-Pacific Integrated Model (AIM) was employed. Developed by Kyoto University and Japan's National Institute for Environmental Studies (NIES), AIM is an Extended Snapshot Tool (ExSS) designed to create low-carbon

scenarios [5]. This model incorporates predetermined socioeconomic, industrial, and demographic scenarios to evaluate future energy consumption, power generation, technology diffusion, transportation, industrial outputs, residential and commercial activities, waste generation, and GHG emissions for a specific future or target year.

It is structured into four (4) modules: 1) driving variables such as population and GDP growth, 2) energy service demand, 3) primary energy supply analysis, and 4) GHG emissions, which are calculated using the Kaya Identity in Equation (1). In this equation, $F$ is GHG emissions from human activity, $P$ is population, $G$ is GDP, and $E$ is energy consumption [12].

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \quad (1)$$

In this study, the ExSS tool was employed alongside a solid waste model and a carbon sink model to quantify emissions in Kuala Lumpur. Data were collected from secondary sources such as official published documents and validated through a Focus Group Discussion (FGD). To estimate the total GHG emissions for the city, three (3) primary sources were considered: 1) energy, 2) waste, and 3) carbon sinks. The ExSS tool was specifically used to estimate GHG emissions from the energy sector, covering both energy demand and supply. For energy demand, data on population, number of households, GDP, transportation, as well as residential, commercial, and industrial activities were required. For energy supply, information on electricity generation and secondary energy sources was necessary.

To quantify GHG emissions from the waste sector, the study used data on waste generation volumes, waste composition, recycling and composting rates, and waste treatment technologies. For carbon sinks, the CO2 equivalents were calculated from forests and urban parks. Using the basic Kaya Identity equation, the study established baseline results based on the driving forces. The AIM tool was used to generate GHG emissions for the base year 2010 and to project Business-as-Usual (BAU) and Counter Measure (CM) scenarios for 2030, 2040, and 2050. These projections provide critical insights into Kuala Lumpur's potential pathways towards achieving carbon neutrality.

## 4. RESULT AND DISCUSSION

### *4.1 Absolute GHG Emission of Kuala Lumpur*

Figure 1 illustrates the absolute GHG emissions of Kuala Lumpur for the years 2010, 2020, 2030, 2040, and 2050, with projections for both Business-as-Usual (BAU) and Counter Measure (CM) scenarios. In 2010, the total emissions were 23,909 $ktCO_2eq$, with carbon sinks reducing this by 1,056 $ktCO_2eq$. The primary contributors were the commercial and industrial sectors, followed by passenger and freight transport.

By 2020, under the BAU scenario, emissions increased to 38,766 $ktCO_2eq$, a 62% rise from 2010. However, under the CM scenario, emissions were reduced to 28,440 $ktCO_2eq$, demonstrating a 27% decrease due to mitigation measures. In 2030, the BAU scenario projects emissions to reach 54,616 $ktCO_2eq$, a 128% increase from 2010, while the CM scenario shows a significant reduction to 28,498 $ktCO_2eq$, 48% lower than BAU. In 2040, BAU emissions are projected to peak at 63,896 $ktCO_2eq$, a 167% increase from 2010, whereas the CM scenario shows a substantial decrease to 24,766 $ktCO_2eq$, 61% lower than BAU. By 2050, BAU emissions are expected to reach 74,134 $ktCO_2eq$, a 210% increase from 2010, while the CM scenario reduces emissions to 16,540 $ktCO_2eq$, 78% lower than BAU.

Throughout these years, the primary sources of GHG emissions remain the commercial, industrial, and transport sectors, with municipal waste also contributing significantly. Carbon sinks consistently help offset a portion of the emissions, though their impact is relatively modest compared to the total emissions. The CM scenarios clearly demonstrate the effectiveness of mitigation measures, significantly lowering emissions compared to BAU projections at each future interval. This highlights the critical importance of implementing and enhancing countermeasures to effectively manage and reduce GHG emissions in Kuala Lumpur to achieve carbon neutrality goals by 2050.

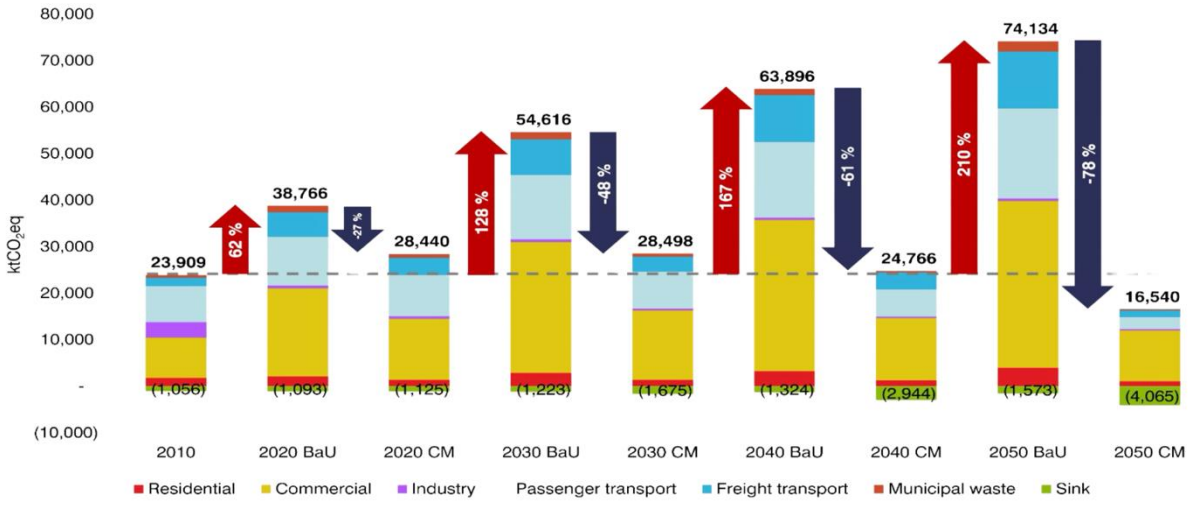


**Fig. 1. Absolute GHG emission of Kuala Lumpur for 2010, 2020, 2030, 2040, and 2050.**

### *4.2 Kuala Lumpur Carbon Neutrality Pathways*

Figure 2 illustrates the GHG emission intensity of GDP for Kuala Lumpur from 2010 to 2050, highlighting potential reductions under various pathways. In 2010, the baseline GHG emission intensity was 0.27 $ktCO_2eq$/RM Million. By 2020, under the carbon neutral pathway, this intensity dropped to 0.11 $ktCO_2eq$/RM Million, representing a 58% reduction. In 2030, the emission intensity is projected to decrease further to 0.08 $ktCO_2eq$/RM Million, achieving a 70% reduction. By 2040, it is expected to reduce to 0.05 $ktCO_2eq$/RM Million, marking an 82% reduction. Finally, by 2050, the emission intensity is projected to reach 0.02 $ktCO_2eq$/RM Million, a significant 92% reduction from the 2010 baseline. These reductions reflect the implementation of measures to transition Kuala Lumpur into a low-carbon society by 2030, become carbon-neutral ready by 2040, and achieving full carbon neutrality by 2050.

Figure 3 shows the absolute GHG emissions reduction pathways for Kuala Lumpur from 2010 to 2050 under both BAU and CM scenarios, including the contributions of carbon sinks. In 2010, total emissions were 23,909 $ktCO_2eq$. By 2020, emissions under the BAU scenario had increased to 38,766 $ktCO_2eq$, while under the CM scenario, they were reduced to 28,440 $ktCO_2eq$. By 2030, BAU emissions are projected to rise to 54,616 $ktCO_2eq$, but under the CM scenario, they are expected to reduce to 28,498 $ktCO_2eq$, achieving an absolute reduction of 26,119 $ktCO_2eq$. By 2040, BAU emissions peak at 63,896 $ktCO_2eq$, whereas CM scenario emissions significantly reduce to 24,766 $ktCO_2eq$, an absolute reduction of 39,130 $ktCO_2eq$. By 2050, BAU emissions reach 74,134 $ktCO_2eq$, while CM scenario emissions drop to 16,540 $ktCO_2eq$, indicating an absolute reduction of 57,594 $ktCO_2eq$.

These figures suggest that Kuala Lumpur can achieve substantial reductions in GHG emissions through effective mitigation strategies. By 2030, emissions can be reduced by 70% compared to 2010 levels, equivalent to an absolute reduction of 26,119 $ktCO_2eq$. By 2040, this reduction could reach 82%, equivalent to 39,130 $ktCO_2eq$, and by 2050, the city could achieve a 92% reduction, equating to 57,594 $ktCO_2eq$ from the BAU scenario. These trends align with the carbon neutrality trajectory, emphasizing the need for robust climate policies and sustainable practices to achieve the goal of becoming a carbon-neutral city by 2050.

To significantly reduce GHG emissions, Kuala Lumpur can implement several key measures. Enhancing feeder bus routes and promoting electric buses will help reduce the city's dependency on fossil fuels and decrease emissions from the transportation sector. Expanding urban greenery through green roofs and vertical gardens contributes to carbon sequestration and mitigates the urban heat island effect. The adoption of renewable energy technologies, particularly solar, alongside improvements in building and industrial energy efficiency, can further decrease overall energy consumption. In addition, integrating material efficiency and circular economy strategies such as resource reuse, sustainable construction, and waste reduction can complement existing mitigation efforts. As noted in [9], these approaches are especially important in developing countries to bridge the emissions gap and advance net-zero transitions. Collectively, these interventions support Kuala Lumpur's decarbonization trajectory, while stakeholder engagement remains essential to ensure inclusive and effective implementation.

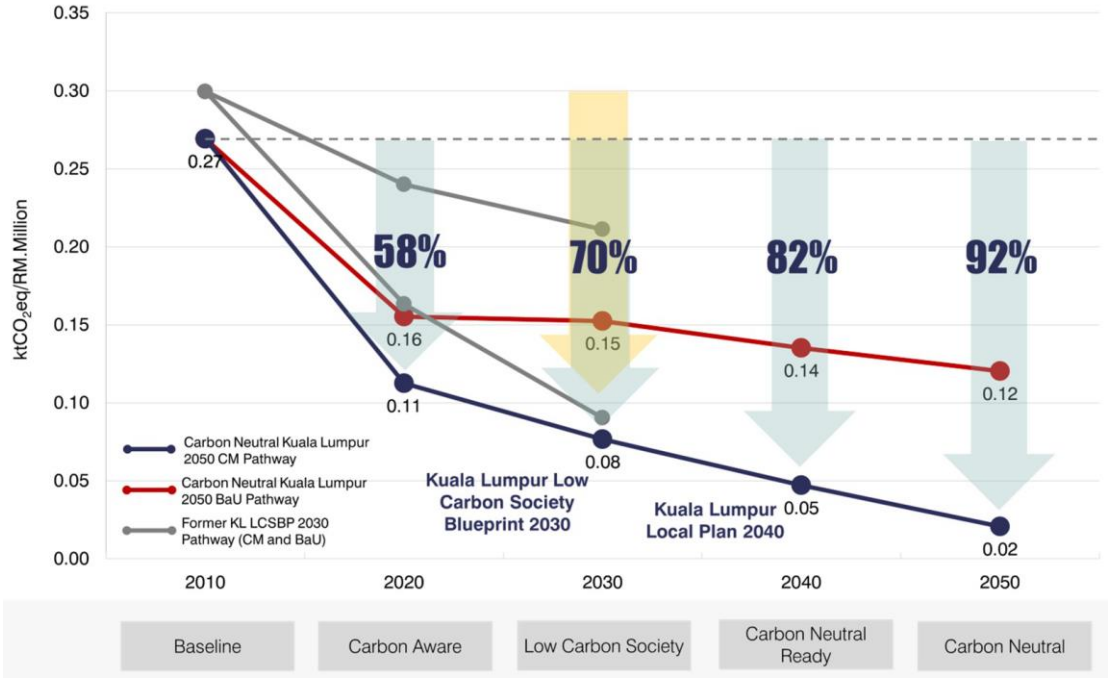


**Fig. 2. GHG emission intensity of GDP and potential reduction for 2010, 2020, 2030, 2040 and 2050.**

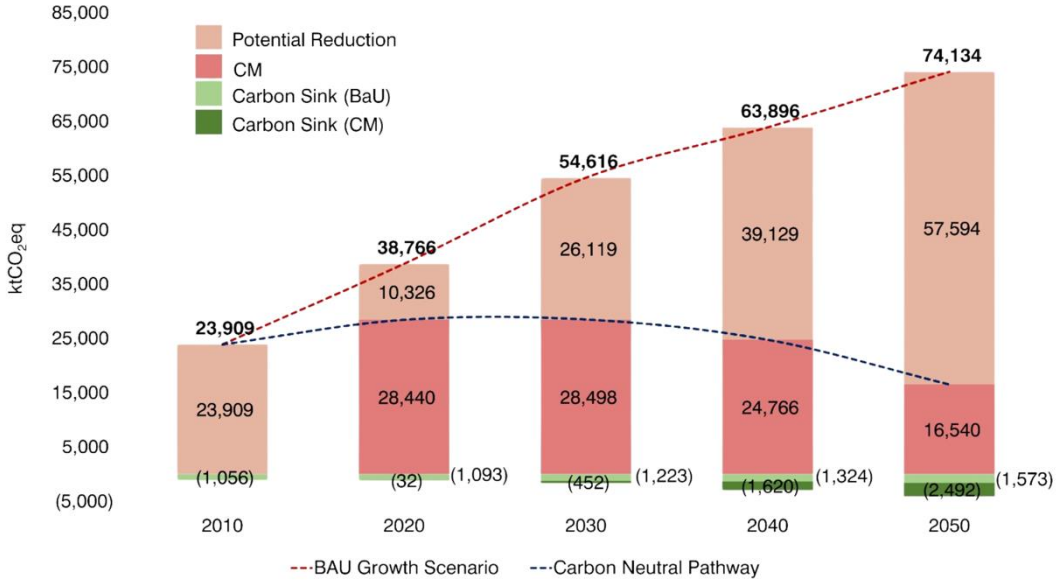


**Fig. 3. Kuala Lumpur carbon neutrality pathways.**

## 5. CONCLUSION

This study assesses the feasibility of Kuala Lumpur achieving carbon neutrality by 2050 by projecting GHG emissions under various scenarios using the ExSS modelling tool. It identifies sector-specific mitigation potentials and proposes strategic pathways to support the city's long-term climate ambitions. The findings highlight that the commercial, industrial, and transport sectors offer the highest potential for emission reductions, underscoring the need for tangible and actionable strategies tailored to the city's development context. Under the CM scenario, a 70% reduction in GHG intensity of GDP by 2030 compared to 2010 levels is achievable, setting the stage for a Low-Carbon Scenario (LCS). This trajectory leads to an 82% reduction by 2040 and a 92% reduction by 2050, paving the way towards carbon neutrality. To achieve net-zero emissions, the residual emissions of 16,540 $ktCO_2eq$ must be addressed through effective carbon offset mechanisms.

To guide these efforts, the study draws on the C40 Focused Acceleration framework, which supports cities in prioritizing and fast-tracking high-impact, feasible actions aligned with the 1.5 °C target [6]. For Kuala Lumpur, this translates into targeted strategies such as enhancing energy efficiency (EE) and expanding renewable energy (RE) installations in the commercial and industrial sectors. In the transport sector, decarbonization can be achieved through the electrification of public and freight transport, as well as by promoting mode shift via the expansion of transit-oriented development (TOD). In addition, behavioural change campaigns will be essential to influence public attitudes and encourage low-carbon choices in everyday life. Active stakeholder engagement across government, industry, and civil society is also critical to ensure coordinated implementation, public buy-in, and long-term success.

By applying the C40-informed framework and aligning with global best practices, this paper offers practical, sector-specific recommendations that can help Kuala Lumpur operationalize its carbon neutrality ambition. As the first empirical study assessing carbon neutrality pathways in a Malaysian city, it provides a valuable foundation for data-driven climate action and serves as a model for other rapidly urbanizing cities across the region.

This study has several limitations. The findings are derived solely from scenario-based modelling, with considerable assumptions introduced due to the downscaling of input data from national to city levels. Although the ExSS tool supports the development of low-carbon scenarios and aligns with IPCC emissions estimation methodologies, it primarily focuses on carbon emissions and does not account for intersectoral feedbacks. In contrast, tools such as the Global Change Assessment Model (GCAM) simulate integrated interactions across energy, land, water, economy, and climate systems over time [10]. Future research should incorporate empirical inventory validation to improve the accuracy of projections and reduce uncertainty in city-level scenario analysis.

## REFERENCES

[1] United Nations Framework Convention on Climate Change, "Paris Agreement," FCCC/CP/2015/L.9/Rev.1, 12 Dec. 2015. [Online]. Available at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[2] IPCC, *Climate Change 2023: Synthesis Report – Longer Report*. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Core Writing Team, H. Lee and J. Romero, Eds.

Geneva, Switzerland: IPCC, 2023. doi:10.59327/IPCC/AR6-9789291691647.

[3] Hatchadorian R., Best R., Wholey K., Calven A., Levine E., Tepfer S., Swett B., Walsh M.J., Pollack A., Perez T., Castigliego J.R., and Cleveland C.J., 2019. *Carbon Free Boston: Buildings Technical Report*, Boston University Institute for Sustainable Energy and Arup Group Ltd., Boston, MA, USA, 2019. [Online]. Available: https://sites.bu.edu/cfb/technical-reports/

[4] City of Yokohama, *Yokohama City Strategy on the Use of Renewable Energy: Outline*, Jul. 2020. [Online]. Available at: https://carbonneutralcities.org/wp-content/uploads/2020/07/Yokohama-City-Strategy-on-the-Use-of-Renewable-Energy-Outline.pdf

[5] Abdul-Azeez A., 2016. Measuring and Monitoring Carbon Emission to Promote Low-Carbon Development in Johor Bahru. *Working Paper Series*, 2016.

[6] C40 Cities and McKinsey and Company, *Focused Acceleration: A Strategic Approach to Climate Action in Cities to 2030*, 2017. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sususstainabili/our%20insights/a%20strategic%20approach%20to%20climacl%20action%20in%20cities%20focused%20acceleration/focused-acceleration.pdf

[7] Hansen K.B. and A. Agger. 2022. Copenhagen $CO_2$ neutrality in 2025? A polycentric analysis of urban climate governance in Copenhagen 2006–2020. *Environmental Policy and Governance* 33(3): 288–300. doi: 10.1002/eet.2030

[8] Loh J.R. and S. Bellam2024. Towards net zero: Evaluating energy security in Singapore using system dynamics modelling. *Applied Energy* 358: 122537 [Online]. Available: https://doi.org/10.1016/j.apenergy.2023.122537

[9] Sofuoğlu E. and D. Kirikkaleli. 2022. Towards achieving net zero emission targets and sustainable development goals, can long-term material footprint strategies be a useful tool? *Environmental Science and Pollution Research* 30: 26636–26649, Nov. 2022. [Online]. Available: https://doi.org/10.1007/s11356-022-24078-2

[10] Calvin K., Patel P., Clarke L., Asrar G., Bond-Lamberty B., Cui R.Y., Di Vittorio A., Dorheim K., Edmonds J., Hartin C., Hejazi M., Horowitz R., Iyer G., Kyle P., Kim S., Link R., McJeon H., Smith S.J., Snyder A., Waldhoff S., and Wise M., 2019. GCAM v5.1: representing the linkages between energy, water, land, climate, and economic systems. *Geoscientific Model Development* 12: 677–698. [Online]. Available: https://doi.org/10.5194/gmd-12-677-2019

[11] Emission Index. 2024. Greenhouse gas emissions in Malaysia, 2024. [Online]. Available: http://www.emission-index.com/countries/Malaysia. Accessed: May 30, 2024.

[12] Penn State Department of Meteorology. 2015. The Kaya Identity, meteo 469, from Meteorology to Mitigation: Understanding Global Warming," 2015. [Online]. Available: https://e-education.psu.edu/meteo469/node/213

[13] Wong L., 2022. Speech by Deputy Prime Minister and Minister for Finance Lawrence Wong at the Singapore International Energy Week. *Prime Minister's Office Singapore*, Oct. 25, 2022. [Online]. Available: https://www.pmo.gov.sg/Newsroom/DPM-Wong-at-Singapore-International-Energy-Week