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THE PERFORMANCE OF KUALA LUMPUR'S CARBON EMISSIONS IN THE CONTEXT OF URBAN PLANNING

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Abstract

Cities are responsible for 70% of greenhouse gas (GHG) emissions on a global scale, and cities play an important role in reducing GHG emissions. It is essential for Kuala Lumpur to consider reducing the city's GHG emissions. The city's GHG emission inventory can track and monitor the effectiveness of the climate action plans that has been implemented. The aim of this study is to identify the performance level of GHG emissions in Kuala Lumpur between 2010 and 2019. It is also to identify the performance of Kuala Lumpur's GHG emissions in 2019 in comparison to the global and Malaysian level. Data is calculated using the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventory (GPC), which is recognised and utilised globally. Secondary data for the years 2010 and 2019 was analysed as well as the performance of the Kuala Lumpur GHG emission profile in 2019. With three (3) identified sources of emissions, Kuala Lumpur managed to reduce its GHG emission intensity from 2010 by 74.07% in 2019. The city's GHG emission was recorded at 15,675 ktCO2eq in 2019. The stationary energy sector contributes higher GHG emission than other sector, with 12,043 ktCO2eq (76.83%), followed by the transportation sector with 3,180 ktCO2eq (20.29%) and the waste sector with 452 ktCO2eq (2.88%). As of 2019, Kuala Lumpur's absolute carbon contribution to the global average is 0.03%, whereas Malaysia's absolute carbon contribution is 4.74%. Additionally, the city contributes just 0.07 kgCO2eq/RM (30.17%) to Malaysia's total GHG emission intensity.

Keywords: Carbon Emission, Greenhouse Gas Emission, Gross Domestic Product, Greenhouse Gas Intensity, Kuala Lumpur

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INTRODUCTION

Global warming and climate change are mostly caused by GHG emissions. The estimated amount of net anthropogenic GHG globally in 2019 is 59 $\pm$ 6.6 $GtCO_2eq$, resulting from a variety of gas types, according to Climate Change 2022 Mitigation of Climate Change Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2022).

Table 1: Global Average Annual Emission for Year 2019

Gases Type	Average Annual Emissions ($GtCO_2eq$)
CO_2 FFI	38 ± 3.0
CO_2 LULUCF	6.6 ± 4.6
CH_4	11 ± 3.2
N_2O	2.7 ± 1.6
Fluorinated gases	1.4 ± 0.41
GHG	**59 ± 6.6**

Source: Climate Change 2022 Mitigation of Climate Change Working Group III Contribution to the Sixth Assessment Report of the IPCC

Approximately 34% (20 $GtCO_2eq$) of net globally GHG emissions come from the energy sector, 24% (14 $GtCO_2eq$) from industry, 22% (13 $GtCO_2eq$) from AFOLU, 15% (8.7 $GtCO_2eq$) from transport, and 6% (3.3 $GtCO_2eq$) from buildings (IPCC, 2022).

In 2019, Malaysia recorded total GHG emissions of 330,358.21 Gg CO_2eq, excluding LULUCF. LULUCF activities have the potential for carbon stocks to be reversible and non-permanent. The CO_2 stored in soil and vegetation can be reversed by human activity, natural disturbances, or both. It is also exposed to the effects of climate change. Based on the Malaysia Fourth Biennial Update Report Under the United Nations Framework Convention on Climate Change (BUR4, 2022), the overall GHG emissions, excluding LULUCF, are 259,326.11 Gg CO_2eq from the energy sector, 32,853.80 Gg CO_2eq from the IPPU sector, 28,256.59 Gg CO_2eq from the waste sector and 9,921.71 Gg CO_2eq from the agriculture sector. The total GHG emissions, including LULUCF, were 115,643.68 Gg CO_2eq, with the LULUCF sector contributing -214,714.54 Gg CO_2eq. Hence, the Malaysia's GHG intensity against GDP (0.2320 $kgCO_2eq$/RM) in 2019 reduced by 35.90% compared to 2005 values (BUR4, 2022). Malaysia is a very dynamic country where land use is rapidly changing as the country's economy grows. As a result, land has frequently been changed within and between land-use categories multiple times throughout the course of a 20-year transition period.

Table 2 Malaysia's GHG emission

Sector	Emissions/Removals (Gg CO_2eq)
Energy	259,326.11
IPPU	32,853.80
Agriculture	9,921.71
LULUCF	-214,714.54
Waste	28,256.59
Total (Excluding LULUCF)	**330,358.21**
Total (Including LULUCF)	115,643.68

Source: Malaysia Fourth Biennial Update Report Under the United Nations Framework Convention on Climate Change

Kuala Lumpur, the capital of Malaysia, has developed to be one of the biggest cities in the country and is experiencing the effects of climate change as a result of increasing carbon emissions. It had seen extraordinary amounts of rain, frequent flash floods, and rising temperatures. In line with that, Kuala Lumpur has set a target of reducing GHG emissions intensity by 70% by 2030 (Kuala Lumpur Low Carbon Society Blueprint 2030, 2018) in order to achieve carbon neutrality (Kuala Lumpur Climate Action Plan, 2021) and become a net zero carbon emission city by 2050 (2020 Kuala Lumpur City-Wide Greenhouse Gas Inventory, 2022). At the 2021 United Nations Climate Change Conference of Parties (COP26), in Glasgow, Scotland, Kuala Lumpur pledged to achieving Carbon Neutrality by 2050 in order to make sure the city might withstand these challenges. This pledge demonstrates Kuala Lumpur commitment to mainstreaming climate action into the city's long-term planning. Hence, Kuala Lumpur City Hall has developed several of master plans and blueprints, including the Kuala Lumpur Structure Plan 2040 (2023), Kuala Lumpur Local Plan 2040 (Draft) (2024), Kuala Lumpur Low Carbon Society Blueprint 2030 (2018) and Kuala Lumpur Climate Action Plan 2050 (2021) that aim to achieve the vision. The Kuala Lumpur Low Carbon Society Blueprint 2030 (2018) established an ambitious interim target of reducing carbon emission intensity by 70% by 2030, which was expanded to the Kuala Lumpur Climate Action Plan 2050 (2021) to incorporate adaptation measures and prioritise inclusive and wider benefits to residents. The mitigation and adaptation programmes of climate action have been integrated into all of these masterplans and blueprints, and the initiatives are currently being mainstreamed into the Kuala Lumpur Local Plan 2040 (2023), which is being prepared in accordance with the Federal Territory (Planning) Act 1982 (Act 267, 1982) and will serve as the main tool for development control in the city.

Kuala Lumpur was recorded that rapid urbanization process impacted trends on land use (Norzailawati Mohd Noor, et al., 2013). Since climate change is here to stay, Kuala Lumpur is entitled to a proactive role in handling it. Kuala Lumpur City Hall began implementing city hall-focused initiatives through the

Kuala Lumpur City Hall's Carbon Management Plan (2017), using the approach to lead by example strategy. Programmes at the city level under the Kuala Lumpur Low Carbon Society Blueprint 2030 (2018) followed subsequently. This Blueprint is focused on 245 green programmes, 10 actions, and 3 major thrusts. The outcome of these programmes showed how urgently city-scale programmes were needed to address Kuala Lumpur's unexpected climate hazards. More significantly, it is necessary to make sure that the comprehensive plans and initiatives to make the city more resilient, vibrant, and inclusive are in line with the climate action. To address the next phase of the climate action journey, the Kuala Lumpur Climate Action Plan 2050 (2021) was developed. Together with the involvement of numerous government agencies, residents associations, professional associations, and non-profit organisations, all of these plans and masterplans were developed.

The importance of gathering information and data is crucial for the success of programmes because there is a lack of data quality and inventory to measure GHG emissions. According to Grafakos et al. (2016a), one of the challenging tasks of integrated climate change policy is monitoring actions. As a result, the Kuala Lumpur City Hall has a comprehensive 2020 Kuala Lumpur City-Wide Greenhouse Gas Inventory (2022). Nonetheless, Kuala Lumpur didn't publish any GHG emissions report in 2019, making comparisons of Kuala Lumpur GHG emissions to the rest of the global and Malaysia level were not practicable. However, the number of GHG emissions in 2010 will be utilised as the baseline, which is 22,852 ktCO_2eq with a 0.27 emission intensity of GDP. Some analysis will be conducted to describe Kuala Lumpur's GHG emissions for the year 2019 using the GPC approach in accordance with global and Malaysian regulations in order to determine the percentage of Kuala Lumpur's GHG emission contribution. In addition, several cities in Malaysia had documented their GHG emissions to support in the reduction of carbon emissions. Putrajaya had measured 1,459 ktCO_2eq in 2021. In the meantime, Seberang Perai's GHG emissions in 2019 were 6,620.38 ktCO_2eq.

LITERATURE REVIEW

The earth's surface temperature rises by 1.1°C between 2011-2020 compared to 1850-1900, showing clearly that human activity caused global warming (IPCC, 2023). This was primarily due to GHG emissions. Unsustainable energy use, changes in land use, patterns of consumption and production within and between countries, and individual behaviours have all contributed historically and currently to the continual rise in GHG emissions worldwide. From Wagg (2015), human activities or anthropogenic can produces GHG emissions that serve as a blanket around the planet, trapping heat from the sun and increasing temperatures (Wagg, 2023). Before the industrial age began in Europe, the atmospheric CO_2 concentration was 180 ppm (Kyle Whittinghill, 2023) and in 2019, the atmospheric CO_2 concentration has increased to 410 ppm (IPCC, 2023). Reducing the urban heat island effect, improving air quality, increasing resource efficiency in the built environment and energy systems, and enhancing carbon storage related to land use and urban forestry are all strategies to help reduce GHG emissions while enhancing a city's resilience. These strategies can be better understood in order to identify greater opportunities for their integration in urban areas (Grafakos, et al., 2018). According to the United Nations, the world's population will increase from 7.7 billion in 2019 to 8.5 billion in 2030, 9.7 billion in 2050 and 10.9 billion in 2100 (Population Division, 2019). In 2019, approximately 48% of the global population lives in urban area (IPCC, 2023) and accounted for 70% of global GHG emissions (KASA, 2021).

Due to their dense populations, cities are not only major contributors to global GHG emissions but also extremely prone to the effects of climate change, including heat waves, floods, severe storms, and droughts (Lucon et al., 2014; Revi et al., 2014; Balaban & de Oliveira, 2013; Fischedick et al., 2012). In the process of spatial planning, development plans such as Structure Plan are essential for demonstrating how policies should be implemented. Delivering the comprehensive urban GHG emission requirement requires a comprehensive approach (Wee-Kean Fong et al., 2008).

The GPC (GPC, 2014) was developed in 2014 by the World Resource Institute (WRI), Climate C40 Cities Leadership Group and ICLEI-Local Government for Sustainability (ICLEI) as a method for preparing a GHG inventory to enable reliable measurement and uniform GHG reporting. Cities all across the world, including Malaysian cities, have begun to submit their own GHG readings using GPC. The importance of GPC method was:

i. To assists the authorities on how to calculate and report local GHG emissions in compliance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2016).
ii. GHG emissions are calculated consistently, transparently, and internationally recognised throughout all cities.

Picture 1: GPC Guideline for Accounting and Reporting
Source: Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

The GPC is designed to take into consideration the city's GHG emissions for one reporting year. The GHG emissions from cities are categorised into five (5) main sectors, as well as stationary energy, transportation, waste, industrial processes and product use (IPPU) and agriculture, forestry and other land use (AFOLU). The stationary energy sector is involved with energy usage, the transportation sector is focused with transport types use, the waste sector is concerned with waste generation, the IPPU sector is involved with industrial activities, and the AFOLU sector is concerned with agriculture and forestry activity.

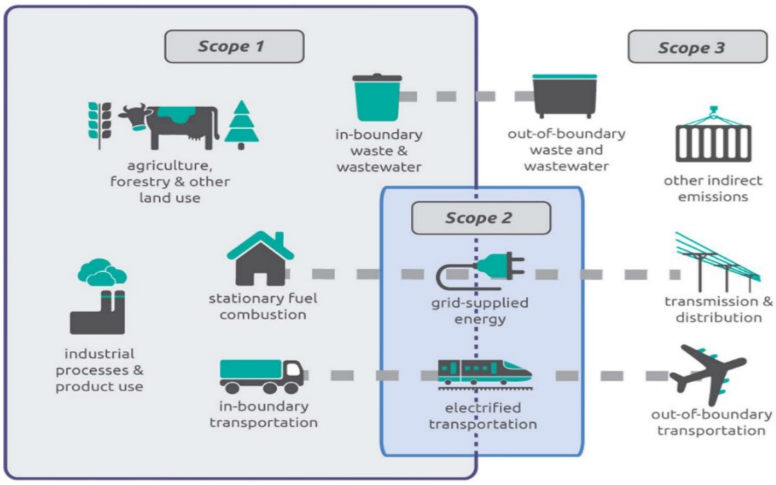
Table 3: GHG Emissions by Sectoral

Sector	Details
Stationary Energy	For most cities, stationary energy is the main source of emissions. This relates to the use of energy of various types in the building sector.
Transportation	The resulting GHG emissions from private and public vehicles on land, sea, and air.
Waste	Emissions from organic material decomposition when waste is disposed to a landfill, composted/digested anaerobically, or burned.
Industrial Processes and Product Use (IPPU)	This industry refers to industrial operations and has two parts, process industrialization and product utilisation.
Agriculture, Forestry and Other Land Use (AFOLU)	This sector must be captured for cities that have agricultural and forestry areas with sufficient data.

Source: The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventory

In order to reconcile the variances among all operations, the source of GHG emissions released into the atmosphere has been divided into three (3) scopes, namely Scope 1, Scope 2, and Scope 3. By referring to 2006 IPCC Guidelines for National Greenhouse Gas Inventories, the GHG values relative to CO_2 sources is:

i. Scope 1: GHG emissions occurring within area boundaries including the transportation, electricity generation and open burning.
ii. Scope 2: Only for electrical grid purchases from outside the border.
iii. Scope 3: GHG emissions that occur outside the border; activities within the border such as waste disposal and intercity transport.



Picture 2 Scope-Based Emission Estimation
Source: Garis Panduan Perancangan Bandar Rendah Karbon dan Berdaya Tahan Perubahan Iklim (PLANMalaysia, 2023)

The GPC provides a clear GHG reporting system for the entire city. In the GHG reporting system, cities can report GHG emissions using two approaches, BASIC or BASIC +. BASIC reporting includes emissions from stationary energy, transportation (in-boundary), and waste. Meanwhile, BASIC + reporting includes emissions from stationary energy, transportation (including in-boubdary and transboundary), waste, IPPU, and AFOLU.

Table 4: Types of Reporting

Types of Reporting	Details
BASIC	BASIC reporting covers emission sources that occur in most cities (stationary energy, in-boundary transportation, and in-boundary generated waste), and methodology estimates and data are more easily accessible.
BASIC +	BASIC+ covers a broader range of GHG emission sources (source BASIC add IPPU, AFOLU, and transboundary transportation). However, more difficult data collecting and calculation is required.

Source: The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventory

The IPCC states that there is a hierarchy of tiers for calculating greenhouse gas emissions. The levels of hierarchy are:

Tier 1: Globally available data with simplifying assumptions
Tier 2: Substituting country-specific value for disaggregated activity data character
Tier 3: Detailed modelling or inventory measurement system

Hence, the formula for calculating GHG emissions (GPC, 2014).

GHG emissions = Activity data x Emission Factor factor

Activity Data is a quantitative measure of GHG emissions from activities within a city over a specific time period

Emission Factor is the unit used to convert volume to GHG release mass

GHG emissions are measured in two types as well as absolute carbon reduction and intensity carbon reduction. The absolute carbon reduction is the actual amount of GHG emission, which is easy to detect but difficult to achieve in accordance with national plan. Meanwhile, intensity carbon reductions are amount targets on a specific scale, difficult to monitor, and consistent with national strategy.

Table 5 Types of GHG Emissions Measure

Absolute Carbon Reduction	Intensity Carbon Reduction
The actual amount of GHGs released	Target compared to a certain parameter/scale, such as GDP
Easy to monitor or detect	More information and more difficult monitoring
Difficult to tie to the national strategy	Parallel to the national strategy

Source: Garis Panduan Perancangan Bandar Rendah Karbon dan Berdaya Tahan Perubahan Iklim (PLANMalaysia, 2023)

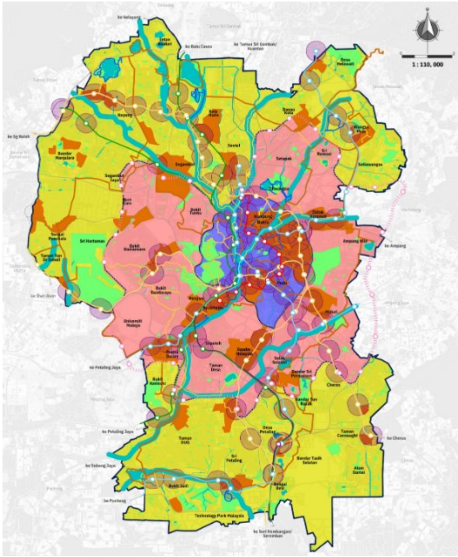
METHODS AND DATA

The GPC framework will be used in calculating Kuala Lumpur's 2019 GHG emissions. The GPC method for calculating carbon footprints is in line with the IPCC 2006 standards. There are three (3) sectors that are included in this calculation which is the stationary energy, transportation and waste sectors. Emissions from Agricultural, Forestry, and Other Land Use (AFOLU) and Industrial Processes and Product Use (IPPU) are not included in this calculation due to their minimal impact on GHG emissions in Kuala Lumpur. These exclusions are allowed by IPCC 2006 standards since these emissions have been identified to be less conducive to mitigation measures, hence their exclusion from the emission reduction action plan is unlikely to have a significant impact. Emission scope 1, 2, and 3 includes emission sources such as electric use, fuel use, and decomposition.

Table 6: Kuala Lumpur GHG Emissions Scope and Sources

Sector	Emission Scope	Emission Source
Stationary Energy	2	Electricity use
Transportation	1	Fuel use
Waste	3	Decomposition

All activities data occurring within the Kuala Lumpur boundary, which has a geographical area of 243km^2 and a population of 1.78 million people with GDP RM233,794 million, between January until December 2019, are included in the GHG emission calculation.



Picture 3 Map of the Kuala Lumpur City Boundary
Source: Kuala Lumpur City Hall

The capacity to calculate Kuala Lumpur's GHG emissions is strongly dependent on the quality of data obtained from various data providers. The Department of Statistics Malaysia was the source of the population, GDP, and area size data required for the city-wide category. Quantity of power used is the data type for the stationary energy category, and it comes from Performance & Statistical Information on the Malaysian power Supply Industry 2019. The data for the transportation category is available from Kementerian Perdagangan Dalam Negeri dan Kos Sara Hidup. The data type is the volume of diesel sold at petrol stations. The data type for the waste sector is waste tonnage in landfills, which is provided by Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam.

Table 7: Kuala Lumpur GHG Emissions Data Sources

Category	**Types of Data**	**Source**
City-Wide	Population, GDP, Area Size	Department of Statistic Malaysia (DOSM, 2023)
Stationary Energy	Quantity of electricity used (kWh/year)	Performance & Statistical Information on the Malaysian Electricity Supply Industry 2019 (Energy Commission, 2022)
Transportation	Volume of diesel sold at petrol stations (litres of fuel)	Kementerian Perdagangan Dalam Negeri dan Kos Sara Hidup (KPDN, 2023)

Category	Types of Data	Source
Waste	Tonnage of waste treated in landfills (tonnes)	Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam (SWCorp, 2023)

There are several emission factors involved in calculating GHG emissions. The emission factor for stationary energy is based on the Malaysian Green Technology Corporation (MGTC) Grid Emission Factor (GEF), whereas the emission factor for transport and waste is based on a report published by the Department for Environment, Food and Rural Affairs (DEFRA) 2019.

Table 8: GHG Emissions Factor Sources

Sector	Emission Factor Source	Emissions Factors
Stationary Energy	Malaysian Green Technology Corporation (MGTC); Grid Emission Factor (GEF)	Tonnes of CO_2 produced per kWh of electricity consumed
Transportation	Department for Environment, Food & Rural Affairs (DEFRA) 2019	Kilograms of CO_2 produced per litre of diesel consumed
Waste		Tonnes of CO_2 produced per kilometre travelled

ANALYSIS AND RESULT

Kuala Lumpur's GHG emissions in 2019 were approximately 15,675 $ktCO_2eq$, with the stationary energy sector accounting for 12,043 $ktCO_2eq$ (76.83%). It was followed by the transportation sector, which produced 3,180 $ktCO_2eq$ (20.29%), and the waste sector, which produced 452 $ktCO_2eq$ (2.88%).

Table 9: Kuala Lumpur GHG Emission for Year 2019

Sector	GHG Emission	%
Stationary Energy	12,043 $ktCO_2eq$	76.83
Transportation	3,180 $ktCO_2eq$	20.29
Waste	452 $ktCO_2eq$	2.88
Total ($ktCO_2eq$)	**15,675 $ktCO_2eq$**	**100.00**

Kuala Lumpur's 2019 calculation were used Tier 1 and Tier 2 approach that in line with 2010 baseline method. As a result, in 2019, while the overall population grew by 6.44%, total GHG emissions decreased by 31.41%. Kuala Lumpur also managed to reduce GHG emission intensity by 74.07% when compared to the level in 2010. In 2019, the GHG intensity per capita is also going to decrease to 35.60%.

Table 10: Kuala Lumpur GHG Emission Performance in Year 2019

Description	Details	
	2010	**2019**
Population Kuala Lumpur (persons)	1,674,621	1,782,500 (+6.44%)
Total GHG Emission ($ktCO_2eq$)	22,852	15,675 (-31.41%)
GDP at constant 2015 price (RM Million)	84,852	233,794
Emission Intensity of GDP ($kgCO_2e$/RM)	0.27	0.07 (-74.07%)
Emission Intensity Per Capita (tCO_2e/capita)	13.65	8.79 (-35.60%)

Based on overall GHG emission performance in Kuala Lumpur compared to the rest of globally and Malaysia level in 2019, Kuala Lumpur contributes only 0.03% absolute carbon to the rest of the global and 4.74% absolute carbon to Malaysia. Meanwhile, Kuala Lumpur's GHG emission intensity contributed only 0.07 $kgCO_2eq$/RM (30.17%) to Malaysia's total GHG emission intensity.

Table 11: Overall Kuala Lumpur's GHG Emission Performance

Item	Global	Malaysia	Kuala Lumpur	% KL's Carbon
Absolute Carbon	59 ± 6.6 $GtCO_2$-eq (59,000,000 $ktCO_2eq$)	330,358.21 Gg CO_2eq (330,358.21 $ktCO_2eq$)	15,675 $ktCO_2eq$	Global - 0.03% Malaysia - 4.74%
Emission Intensity of GDP	-	0.2320 $kgCO_2eq$/RM	0.07 $kgCO_2eq$/RM	30.17%

DISCUSSION

The right GHG emission calculation method is necessary to utilise as a tool in doing check and balance for justifying the climate effects in reducing emissions and removals of different GHG sectors, such as for city GHG emission reporting between the development of mitigation plans for the city. Carbon footprints are different each country, due to differences in development levels, economic structure, economic cycle, public infrastructure availability, climate, and residential lifestyles (Bruckner et al., 2021). It is also possible that different countries and regions within countries will have different emission patterns as a result of differences in income, lifestyle, geography, infrastructure, political and economic status (O'Neill, B.C., 2010). Urban area contributes more emissions than rural area (Liu et al, 2011). As Malaysia's capital city, Kuala Lumpur generates a lot of activity, which pattern of results in increased GHG emissions. However, higher density of population is related with lower per capita emissions

(Liddle et al, 2014) (Liu et al, 2017). Beyond from international reporting and accounting, countries or cities might consider other GHG emission strategies to assist in achieving of specific policy objectives. A clear calculation assessment might assist decision-makers in determining the consistency between policy targets and performance in order to avoid possibly unexpected implications of alternative strategies. Significant reductions in emissions from all sectors will necessitate a shift from the pevious priority on important but incremental gains, such as in the energy sector, to revolutionary changes in energy and feedstock supply, materials efficiency, and more circular material flows.

CONCLUSION

To combat climate change, immediate actions must be carried out to cut GHG emissions. Everyone has a role to play to support Kuala Lumpur achieve its targets for reducing GHG emissions intensity. It is essential to evaluate any target changes that have occurred since the start of the goal duration to establish whether the changes are the results of mitigating activities or other reasons, like air pollution from adjacent borders. Goal achievement will ultimately be measured using inventory data in the target year. Any difference in emissions must be tracked in order to determine if Kuala Lumpur is on track to achieve the target goal. Kuala Lumpur must also work with industry players that have pledged to reduce carbon intensity by 70% by 2030 and achieve net zero emissions by 2050. Kuala Lumpur needs to reduce more absolute carbon to support Malaysia achieve a 45% reduction in GHG emission intensity by 2030. As a result, the barriers to a low-carbon transition are not limited to a single category; it includes both technological and behavioural concerns. Taking on the various components of the challenges to low-carbon efforts might require a variety of approaches. Kuala Lumpur will remain a sustainable, vibrant, and liveable city for current and future generations as a result of carbon reduction initiatives and steps taken to adapt to the effects of climate change.

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