CASE STUDY OF CARBON EMISSION INTENSITY FOR MELAKA STATE: ITS PLANNING IMPLICATION

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ABSTRACT

Integrating low-carbon-oriented urban planning into the world heritage site of Melaka State may challenge the objective of achieving its green technology state. The study's goal is to calculate the intensity of carbon emissions in Melaka State and identify the sectors that contribute the most to those emissions in order to differentiate the planning implications of climate mitigation action. Protocol for Community-Scale Greenhouse Gas Emissions framework of assessment, or GPC, was deployed to calculate various greenhouse gas emissions. Time series data from 2013 to 2017 was collected from various sectors that contribute to carbon emissions in relation to respective government agencies and stakeholders in Melaka state. The data was then computed using the BASIC+ software and analysed using the GPC framework. The result depicted a steady increase of carbon emission equivalence from 4,837,836 tCO_2e in 2014 to 6,295,918 tCO_2e in 2017, where the top three emitters; stationary energy, transportation, and waste, recorded 98.5% of the total carbon emission of 6,295,918 million tCO2e in the year of 2017. The carbon emission intensity increases in per-capita emissions from 6.19 tCO2e (2013) to 6.88 tCO_2e (2017), illustrating that each individual contributes to Melaka's increase in GHG emissions. Nevertheless, population growth records a decline in emission intensity of 0.189 tCO_2e (2013) to 0.176 tCO_2e (2017). With green technology intervention that reduces carbon emissions, the reduction indicates a U-shaped Kuznet curve for developed country status. Despite the constraints in the contemporary urban setting of Melaka's historic city centre as a world heritage site, the study suggests that numerous activities that promote green mobility, green technologies, and green initiatives have an impact on Melaka's overall carbon emission intensity at the individual level. Shifting from primary and secondary economic activity to tertiary economic activity and polycentric low carbon development will assist Melaka in meeting its goal of becoming a green technology city-state.

Keywords: Carbon Emission, Carbon Emission Intensity, Greenhouse Gas, Green Initiative, Climate Change Planning, Climate Mitigation

1.0 INTRODUCTION

Climate change is the biggest ever global environmental challenge with imperatives and massive impact. In 2020, CO_2 emissions per capita for Malaysia were recorded at 7.98 tons of CO_2 per capita, which is an increase from 1.33 tons of CO_2 per capita in 1971 to 7.98 tons of CO_2 per capita in 2020, growing at an average annual rate of 3.87% (Knoema, 2021). In response, Malaysia has made ambitious commitments to cut greenhouse gas and GHG emission intensity per unit of GDP by 45% by 2030 relative to 2005 (UNFCC, 2015). This is in line with the 2015 Paris climate agreement. Nevertheless, about 77.16 percent of Malaysians reside in metropolitan areas and cities by 2020 (Statistica, 2021), implying an increased demand for energy for power, mobility, and other purposes, which increased the quantity of carbon emitted. As a result, it increases the carbon emission intensity (CEI). Carbon emission intensity is defined as the rate of a certain pollutant's emission from fossil fuel use in relation to the intensity of a specific activity tied to economic development. It is produced by various activities, including fuel burning, energy use, garbage generation, and other activities (IPCC Climate Change, 2017). As the population grew, so did carbon emissions. Therefore, it is important to identify the source of pollutants to identify the mitigation action via low carbon development mode, which implicates low-carbon oriented urban planning (An et al., 2018). Several initiatives to lower carbon emission records in several cities in Malaysia Kuala Lumpur set an ambitious target of 70% carbon emissions reduction in the city by 2030, with the long-term aim of achieving carbon neutrality by 2050 (Ravindran, 2021). This aim was supported through a series of 10 action plans, 82 measures and 245 programmes in the coming years. In the year 2020, Kuala Lumpur has managed to reduce carbon emissions in the city by 54%. Iskandar Malaysia, which was estimated at 11.4 MtCO2eq of greenhouse gases, GHG emissions for Iskandar Malaysia in 2005, is projected to triple to 31.3 MtCO2eq in the year 2025 under a business as usual (BAU) scenario (Ho et al., 2013).

Melaka envisioned the Melaka Green Technology City State to contribute to the national goal of lowering carbon emissions. Melaka CO_2 levels increased by 18% between 2000 and 2015, resulting in an increase in the local tropospheric, the lowest layer of our atmosphere (Global Platform for Sustainable Cities, World Bank, 2019). As a result, the leveraging mission statements to translate that vision include the green city classification, which takes carbon emission reduction into account. Melaka's objective is to i. maintain its developed state status; ii. achieve city state status; and iii. achieve green city status (Krishnan et al., 2014). The following initiatives indicate the state's commitment to advancing the Green Technology City agenda: i. Melaka Green City Action Plan (GCAP) (22 April 2014); ii. National Smart Communities Program (6 July 2014); iii. Melaka as a member of ICLEI, or the global network of local governments for sustainability, which develops the official state of GHGs carbon inventory (11 November 2014); iv. International Green Training Centre (IGTC) (23 October 2014); and v. Melaka Green Seal as a State Green Building Rating Tools (16 October 2014). Despite the fact that numerous green initiatives are implemented to demonstrate support for green technology with the intention of reducing carbon emission intensity, the sectoral carbon emission intensity could not be detected. The ability to assess sectoral carbon intensity helps in strategising mitigation actions based on a selected carbon reduction or renewable technology.

Several local studies on carbon emissions in Melaka range from the development of mobile units for GHG emissions (Fam et al., 2017) and its guidelines (Fam et al. 2018), its relation to resilient city planning (Jamaliidin & Sulaiman 2018), climate adaptation governance (Zen et al., 2019), challenges in interpreting carbon emission governance at a sub-national level (Zen et al., 2021), defragmentation of city-scale GHG (Zen et al., 2020). However, none of the studies assesses carbon emission intensity by sector, which would aid in planning for future low-carbon development in Melaka. To assure the state's sustainability as a green technology state, GHG emissions must be measured. The Global Protocol for Community-scale Greenhouse Gas Emission Inventories (GPC), created by the World Resource Institute and the World Business Council for Sustainable Development (WBCSD), is one of the global measurements (WRI et al., 2014). The GPC's purpose is to promote consistent and transparent international GHG measurement and reporting between cities as a bottom-up method of responding to global climate change concerns. GPC has been tested in a variety of locations, and it must be supported by well-established, thorough, and trustworthy data sets or GHG inventories (GPC Protocol, 2012: WRI et al., 2014). Furthermore, GPC enables city-to-city comparisons for climate mitigation action, such as for Madrid and London (Andrade et al. 2018), and allows cities to plan action at the local authority level (Sununta et al., 2019; Wiedman et al., 2021).

Melaka has embraced the GPC framework, created a GHG inventory and keeps track of its C40 network involvement (ICLEI, 2015; Zen et al., 2019). However, little work is expanded in integrating the results of diverse economic activities' emissions for future planning and development. The current status of Melaka faces fragmented urban expansion and challenges associated with a low-density population, both of which result in greater transportation costs. Melaka State's current economic activities include services (46.3 percent), manufacturing (39.6 percent), construction (2.8 percent), agriculture (11.1 percent), mining and quart 0.1 percent, and duty import 0.1 percent (Melaka Structure Plan 2020 – 35). With a population of 821,110, tourists total 15.0 million, contributing to the state's GDP of USD 5,344 and GDP per capita of $9,148. There are 21,059 houses, 205 hectares of recreational area and a permanent forest reserve 5,137.62 hectares which are 3.09 percent of the total area of Melaka State (PLANMalaysia@Melaka, 2019).

Within this overall context, the following question emerges: for the growing population of Melaka, how is the impact of carbon emission as a predictor for the environment? How much carbon emits from various economic activities per GDP? How does the effect of various green technology initiatives exist in Melaka on the carbon emission intensity? All of these questions will be the central focus of this study.

2.0 LITERATURE REVIEW

The underlying theory of environmental pollution and population growth is explained by the environmental Kuznet curve (Kuznets, 1955). The hypothesised income-driven changes explain the condition in which pollution increases at low levels of income up to a turning point beyond which it decreases in: (1) the composition of production and/or consumption; (2) consumer preference for environmental quality; (3) institutions that are needed to internalise externalities; and/or (4) increasing returns to scale associated with pollution abatement. Therefore, U-shaped relationship of an environmental Kuznet curve (EKC) explains the green technology intervention over population growth and environmental pollution. This hypothesize explains the carbon emission intensity (CEI), which is related to a correlation of population increase and/ or urbanisation with its economic activity implication (Al-mulali et al., 2012; Zhu et al., 2012; Zhang and Lin, 2012). More tension is given to the environment due to increased carbon emissions which are influenced by an increase in energy consumption in buildings due to electricity, electronic product use, water consumption, trash generation, transportation, and so on. However, various factors of economic activity may affect the contribution towards carbon emission activity.

The emission rate of a certain pollutant in relation to the intensity of a specific activity, or an industrial production process, is known as emission intensity (also carbon intensity, C.I.). Grams of carbon dioxide emitted per megajoule of energy produced, or the ratio of GHG produced to gross domestic product, are examples of this (GDP). Emission intensities are used to calculate estimates of air pollutants or GHGs based on the amount of fuel burned, the number of animals in animal husbandry, industrial production levels, travel lengths, or other activity data. The environmental impact of various fuels or activities can also be compared using emission intensities. The phrases emission factor and carbon intensity are sometimes used interchangeably. Carbon emission reduction refers to the total amount of GHGs emitted, whereas carbon emission intensity compares the number of emissions to a unit of economic activity.

Besides the initiative to assess GHG emissions according to the sources of pollution to reduce or prevent further emissions, promoting the use of new technologies and renewable energies is also important (UNEP, 2021). This is a form of climate change mitigation action where the adoption of GPC method allows for the source of sectoral carbon emission and its related green technology. For that purpose, having inventory data on GHG emissions is part of the basic requirement for GPC framework assessment, a method of the Intergovernmental Panel on Climate Change (IPCC) (2006) (IPCC, 2006).

The significance of measuring carbon emission reduction and intensity is to capture the impact of numerous green programmes to reduce carbon emissions in Melaka state, as previously described. Meng et al., (2017) found a link between GHG emissions and socioeconomic development levels. With a greater per capita GDP, London produces more emissions than Madrid. The effect of industrial structure, energy intensity, energy structure, and carbon emission components was discovered using CEI calculations (Li & Ou, 2013). Studies that measure carbon emission equivalence by using GPC method in Nanchang, China resulted in a strategic direction for the city (Jia et al., 2018). The finding found that more than 74.41 percent of Nanchang's carbon emissions were related to coal. The connection between urbanisation and carbon emissions was explained in the positive correlation (Zhu et al., 2012). The GPC method specifies the expansion of urbanisation from the contribution of indirect carbon emission from embodied carbon of products brought into the city (Liu et al., 2011). The inverted U-shaped relationship between urbanisation and carbon emission in the city deployed green technology is captured (Martı´nez-Zarzoso & Maruotti, 2011). However, the effect of green technology on carbon emission per capita is difficult to capture.

City-to-city comparison on carbon emission and its urban set-up allows a co-learning platform to strategise efforts to reduce carbon emissions. One of the most popular tourist sites in northeastern Thailand, Dan Sai city, with a total administrative area of 7.3 km^2 has a total population of 3,679 people and 1,850 houses in 2016. As a medium-sized city with over 50,000 visitors every year, the locals and visitors generate increasing amounts of energy consumption and solid waste. The overall amount of GHG emissions from various activities in the Dan Sai city is 22,925.66 tCO_2eq, or 5.95 CO_2eq/person/year of GHG emissions per capita (Sununta et al., 2019). From the finding, the city designed a strategy to reduce emissions in three ways; first, increasing the number of solar rooftops, boosting the use of household light-emitting diodes, LED bulbs, and improving waste management with refuse-derived fuel, RDF technology. The municipality spent 175.48, 87.53, and 61.72 Baht/$kgCO_2eq$ for the three options. This project model represents a low-carbon city that has been transformed into a future sustainable metropolis. Therefore, provide justification for low-carbon-oriented urban planning (An et al., 2018).

Even though cities intend to deploy the GPC framework to calculate carbon emission and city-to-city comparison, difficulties in having data for a particular year as a base year and availability of data that fulfilled the calculation remain challenges in the implementation of the carbon emission accounting method. This challenge is spelt out by GHG inventories study for Helsinki, Stockholm, and Copenhagen (Dahal & Niemelä, 2017). A study on CEI helps in analysing the influence of economic expansion, industrial structure, and urbanisation. In China, for example, a cointegrating relationship between CEI and other parameters by using the historical data over a longer period, such as 30 to 40 years, has found tertiary industry's growth in economic GDP per capita had a substantial impact on reducing CEI (Zhang et al., 2014). Chinese government took the initiative to cut carbon emissions per unit of gross domestic product (GDP) (i.e., carbon emission intensity) by 40–45 % by 2020 compared with the level in 2005 (Yu et al., 2012).

Iskandar Malaysia has been tracking GHGs performance for 2015, 2016 and 2017 by using the GPC framework within the boundary. It was recorded that Iskandar Malaysia in 2017 emitted 16.20 million tCO_2e. An increase of 27 percent from 2010 in GHG emissions records 11.84 million tCO2e

(Iskandar Malaysia, 2017). Meanwhile, Penang is planning to produce GHG emission inventory based on GPC as reported in its future project planning development (Penang Green Council, 2020). Melaka's population density is 2,550 people per km^2 in the built-up area and 1,885 people per km^2 in the urban area (Global Platform for Sustainable Cities & World Bank, 2019). In 2017, it was half of East Asia's average built-up area population density of 5,800 persons per km^2 (Baker & Lee, 2015). This is the category for all cities with a population of more than 100,000 people. Melaka projected an increased population of 122,700 people from 2008 to 2020 to meet this issue, according to the National Physical Plan (NPP-2). The anticipated urban land area is 341 km^2, with each new resident receiving an additional 401 m^2 of land. Melaka is considered a state with fragmented population distribution that causes higher demand for travelling, which implies an increase of GHG from fuel combustion. A study in Norway with low population density in the five counties; Sogn og Fjordane, Finnmark, Nordland, Nord-Trøndelag and Troms implicates the five highest GHG emissions (Larsen & Hertwich, 2011).

3.0 METHODOLOGY

The GPC framework, which consists of three different scopes, is used in the study to assess the amount of municipal GHG emission activities (WRI et al., 2014). The framework determined the scope and sector to defragment various sources of carbon emissions in order to cover all relevant GHG emissions (WRI, 2014). Scope 1 is to cover GHG emissions from stationary energy, transportation, waste, industrial processes and product use (IPPU), and agriculture, forestry, and other land use (AFOLU) source physically situated within the city's perimeter. Scope 2 accounts for GHG emissions within the city limits caused by grid-supplied power, heat, steam, and/or cooling, whereas Scope 3 accounts for GHG emissions beyond the city's boundary caused by activities that occur within the area. Scope 1 is direct emission and removal caused by activities in the city subdivision. Scope 2 is indirect emission and removal caused by importing energy in various ways, both producing and supplying from outside the city, and scope 3 is another indirect emission and removal caused by activities beyond scope 1 and scope 2, such as the amount of waste produced within the city.

Table 1 GPC sector and scope

Sector	GHG	Scope
Energy	CO_2, CH_4 and N_2O	Scope1, Scope 2 & Scope 3
IPPU (Industrial Process and Product Use)	CO_2, N_2O, HFCs, PFCs and SF_6.	Scope 1
Waste	CO_2, CH_4 and N_2O	Scope 1
AFOLU (Agriculture, Forestry and Other Land Use)	CH_4 and N_2O	Scope 2 and Scope 3

(Source: WRI, C40, and ICLEI. (2014). https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf)

Cities can choose between two reporting levels under the GPC guidelines: BASIC or BASIC+. These levels cover specific scopes in many activity categories, with the BASIC+ level providing a more comprehensive study. The BASIC+ reporting level incorporates IPPU, AFOLU, and any other emissions occurring outside the geographic boundaries owing to urban activities, as well as the three BASIC categories (stationary energy, transportation, and waste) (WRI, 2014).

Table 2 GHG emission sources

IPCC Sectors	GPC Sectors
1. Energy	Stationary Energy Sources Transportation
2. IPPU	IPPU
3. Waste	Waste
4. AFOLU	AFOLU

(Source: WRI, C40, and ICLEI. (2014) https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf)

Table 3 GPC and source of emission

GPC	Source of Emission
1. Stationary	Residential, commercial & institutional, manufacturing, energy industries, agriculture, forestry and fishing-related activities.
2. Transportation	Road, railways, waterborne navigation, aviation, off-road
3. Waste	Solid waste disposal, biological treatment, incineration and burning, Wastewater treatment and discharge
4. IPPU	Industrial processes, product use
5. AFOLU	Livestock, land use and others.
6. Other Scope 3	-

(Source: WRI, C40, and ICLEI. (2014) https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf)

Based on GPC framework, the secondary data from linked government agencies at the state level covers four (4) key sectors: stationary energy, transportation, waste, agriculture, forestry, and other land use (AFOLU) (Table 3). For example, stationary energy data from residential buildings, commercial buildings, manufacturing facilities, and agriculture, three types of fuel consumption, three sources of transportation data, and the amount of municipal garbage and biowaste. The details of sectoral data collected and its source are depicted in Table 4.

Table 4 GPC Sectoral based and sources of emission data

Sector	Sub-sector	Sources	Data Carbon Emission (tCO_2e)
Stationary Energy	Residential Buildings	Grid Electricity	Tenaga Nasional Berhad (TNB), Suruhanjaya Tenaga (ST)
		Kerosene	Petron, PETRONAS, Shell
		LPG	Gas Malaysia Berhad
	Commercial And Institutional Buildings and Facilities	Grid Electricity	Tenaga Nasional Berhad (TNB), Suruhanjaya Tenaga (ST)
		Street Lighting (Grid Electricity)	Tenaga Nasional Berhad (TNB)
		Kerosene	Petron, PETRONAS, Shell
		LPG	NGC Energy, Gas Malaysia Berhad
	Manufacturing Industries and Construction	Grid Electricity	Tenaga Nasional Berhad (TNB), Suruhanjaya Tenaga (ST)
		PNG	Gas Malaysia Berhad
		Petrol	BH Petrol, Chevron
		Diesel	Petron, PETRONAS, Shell
		Furnace Oil	Petron, PETRONAS, Shell
	Energy Industries supplied to the grid	Diesel	Petron, PETRONAS, Shell
		Natural Gas	Gas Malaysia Berhad
	Agriculture, Forestry, And Fishing Activities	Grid Electricity	Tenaga Nasional Berhad (TNB), Suruhanjaya Tenaga (ST)
Mobile Transportation	On-Road Transportation	Petrol	Panorama Melaka Sdn Bhd, Lembaga Lebuhraya Malaysia (LLM)
		Diesel	Mara Liner Sdn Bhd
		CNG/NGV	Gas Malaysia Berhad
	Railway Transportation	Grid Electricity	Tenaga Nasional Berhad (TNB), Suruhanjaya Tenaga (ST)
		Diesel	Keretapi Tanah Melayu Berhad (KTMB)
	Civil Aviation	Landing And Take-Offs (LTO)	Malaysia Airlines Holdings Berhad (MAHB), Lembaga Penerbangan Awam Malaysia (CAAM)
Waste	Solid Waste Disposal		SW Corp
	Biological Treatment of Solid Waste		Indah Water Konsortium (IWK), Syarikat Air Melaka Berhad (SAMB)
AFOLU	Livestock Emission		Jabatan Perkhidmatan Veterinar Negeri Melaka (DVS), PLAN Malaysia, Jabatan Pertanian Negeri Melaka Jabatan Perhutanan Negeri Melaka

4.0 RESULTS

Fluctuation of GHG or carbon emissions records from 5,282,899 tCO_2e in year 2013, reduce to 4,837,836 tCO_2e in year 2014, an increase trend from 5,190,942 tCO_2e in year 2015 to 6,290,918 tCO_2e in year 2017 (Table 5, Figure 1). Sectoral GHG emission showed domination of stationary energy, followed by transport, waste and land use. First, stationary energy is contributed by energy use from industry and buildings for commercial and residential areas. The second top contributor is carbon emitted from transport and followed by waste. The results portray the three top sectors contributing to the total carbon emission. The top three of carbon dioxide equivalence are stationary energy, 3,333,435, transport 1,702,686 and waste 1,166,214 million tCO_2e were totaled up to 6,202,335 million tCO_2e in the year of 2017. This amount dominates 98.5% of the total carbon emission 6,295,918 million tCO_2e for Melaka state in the year 2017. The remaining 1.5% or 93,583 million tCO_2e is contributed from the waste sector.

Table 5 Carbon emission based on sector for Melaka State (year 2013 – 2017)

Sectoral GHG Emission (tCO_2e)	Year				
	2013	**2014**	**2015**	**2016**	**2017**
Stationary Energy	2,659,230	2,567,122	2,666,428	2,800,715	3,333,435
Transport	1,227,883	1,146,745	1,205,451	1,775,067	1,702,686
Waste	1,286,605	1,030,649	1,215,135	1,241,086	1,166,214
AFOLU	109,181	93,321	103,927	97,146	93,583
Total GHG emission	5,282,899	4,837,836	5,190,942	5,914,014	6,295,918

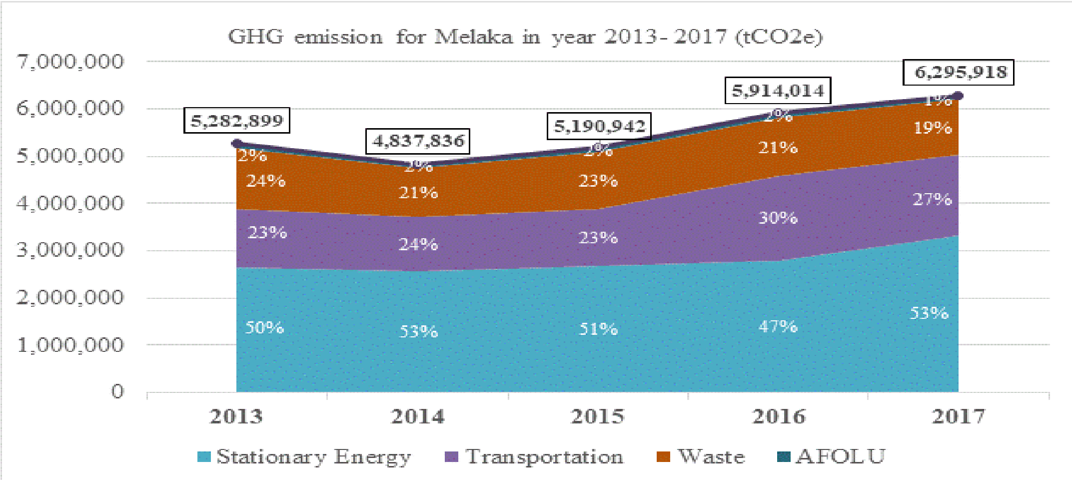

Fig. 1: GHG emission for Melaka in year 2013 – 2017
(Source: Performance of The Green House Gasses (GHG) Emissions for State of Melaka)

Nonetheless, there was an early reduction in carbon emission intensity capture from 6.19 tCO2e/capita in 2013 to 5.61 tCO2e/capita in 2014 (Figure 2, Table 6). The steady increase captured for the years 2014 to 2017 is captured in the orange dotted line. For population growth in the blue dotted line, an increasing trend shows that they overcame the carbon in the orange dotted line in the years 2016 to 2017. This indicates the slow pace of per capita carbon emission compared to the population growth of Melaka people. The flattening curve of the orange dotted line for carbon emission per capita may indicate the impact of the several carbon mitigation emission initiatives that existed in Melaka. The red dotted line for CEI per state GDP decreased from 0.189 kgCO2e/RM in 2016 to 0.176 kgCO2e/RM in 2017 (Figure 3, Table 6), indicating a stable decreasing trend of CE per GDP even though economic activity increased in those years. The results indicate some portion of the effect of the green technology initiatives such as solar farms, smart metering, green building, LED street lights, energy efficiency initiatives, waste separation at source, etc., on the city-wide CEI of Melaka state.

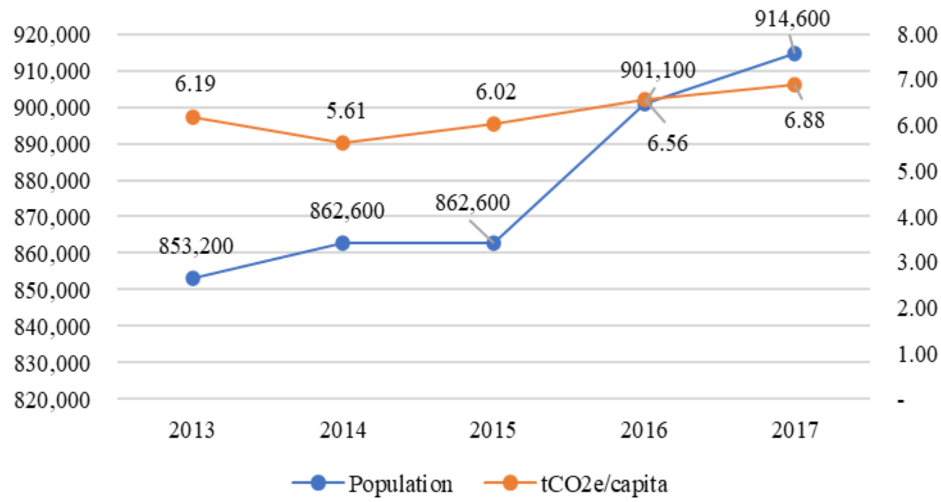

Fig. 2: GHG emission per capita for Melaka State, year 2013 to 2017
(Source: Performance of The Green House Gasses (GHG) Emissions for State of Melaka)

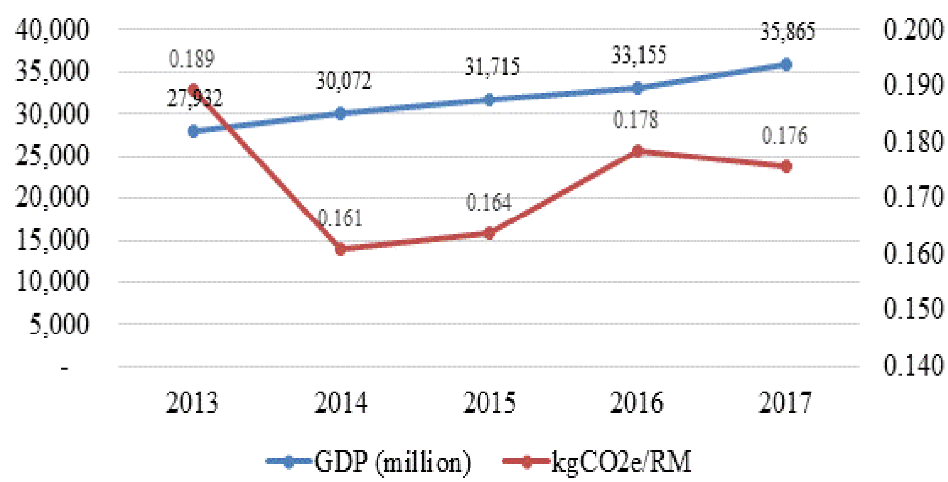

Fig. 3: Carbon emission intensity (CEI) for Melaka state year 2013 to 2017
(Source: Performance of The Green House Gasses (GHG) Emissions for State of Melaka)

Table 6: Carbon emission intensity (CEI) for Melaka State, year 2013 to 2017

	2013	2014	2015	2016	2017
Carbon Emission Equivalence million tCO_2e	5.283	4.838	5.191	5.914	6.296
Population	853,200	862,600	862,600	901,100	914,600
GDP (million)	27,932	30,072	31,715	33,155	35,865
Emission percapita (tCO_2e/capita)	6.19	5.61	6.02	6.56	6.88
Carbon Intensity ($kgCO_2e$/RM)	0.189	0.161	0.164	0.178	0.176

5.0 DISCUSSIONS

Manufacturing and industrial energy consumption contributed to the dominance of energy consumption by commercial and institutional building end users such as hotels, shopping centres, malls, educational institutions, private and public office buildings in Melaka from kerosene and liquid petroleum gas, LPG consumption and residential buildings. This finding describes the dynamic economic activity, which is still dominating the primary and secondary economies. In addition to that, the visitor records from the number of tourists contribute to an increase in carbon emissions per capita (Table 7). This statistic explains the high energy consumption recorded in the commercial and tourism sectors.

Table 7 Tourist number per year for Melaka State, year 2013 to 2017

	2013	2014	2015	2016	2017
Tourist Arrivals	14,312,717	15,032,030	15,736,859	16,282,081	16,794,468

(Source: Tourism Promotions Department, Melaka State Government)

The top second contribution from transport, 1,702,686 million tCO2e or 27% of the total carbon emission in Melaka, comes from the complex transportation sector, which covers land transport such as individual cars, buses, trucks, and air transport, which includes domestic traffic, internal traffic, and external traffic; traffic comes in and out of Melaka. The existing physical development structure and area setting due to Melaka's low population density cause high transportation expenses. This is one of the city's significant economic restraints for Melaka's ability to develop further (Global Platform for Sustainable Cities, 2019). Economic density is characterised as a major contributor to productivity in cities where the number of employment per square kilometre or gross domestic product (GDP) per square kilometre is measured. Hence, agglomeration economies and productivity gains for high economic density areas. In contrast, the economic density that lowers transportation costs makes it easier and less expensive to carry goods and people. Low carbon emissions result from efforts to boost economic density. On the other hand, economic growth is one of the most important factors influencing an increase in carbon emission intensity (Zhang et al., 2014).

As a comparison for the same year in 2014, the calculation of carbon emission intensity for Melaka recorded 5.61 tCO_2e per capita for a total of 853,200 population. A simple comparison with London city indicates the same amount of CEI, from 5.5 to 10e14.5 tCO_2e per capita, for an 8.478 million population (BSI, 2014). Although the two values have similarities, different modes of urban development may interpret the result differently. London city has a compact mixed-use urban development and dense population with various transportation modes resulting in high CEI. The Melaka city-state of fragmented urban development with high dependency on stationary energy and single-car transport causes high CEI. Contextualisation of carbon emision result is needed to interpret the CE result due to different modes of urban development to lower per capita emission.

Our results indicate that the GDP growth rate is higher than that of energy consumption from stationary energy and carbon emissions. Although carbon emission intensity shows a trend of decreasing, there may be an impact from green technology intervention. This finding could point to an inverted U-shaped relationship of an environmental Kuznet curve (EKC), which would explain the green technology intervention against population growth and pollution (Kuznets, 1955). This has mostly occurred in high-income countries where more clean technology is used to reduce environmental pollution in Europe (Rafaj et al., 2015). The trend has happened in China where the structural changes in the energy sector and the increasing trend in the growth rate of China's real GDP is higher than that of carbon emissions. This has affected the decrease of carbon emission intensity (Zhang et al., 2014).

Melaka plans to increase its population by 122,700 people between 2008 and 2020, according to the National Physical Plan (NPP-2). This design necessitates more urban land, which will stimulate greater city travel and interaction with the new residents. This would be contrary to the climate mitigation strategies advocated in this study to combat global warming. Over 40 years of data, there is a demonstrated research on one-way causality between the pace of urbanisation and economic growth to CEI in China's cities (Zhang et al., 2014). This is a result of tertiary economic activity includes both market and non-market sectors of the economy, such as trade, transportation, financial operations, business services, personal services, hotel and food service activities, real estate, and so on. In contrary, having a low-density population will challenge strategies to reduce carbon emissions from the transportation sector, such as in the five greatest CO_2 emitting countries in Norway (Sogn og Fjordane, Finnmark, Nordland, Nord-Trndelag, and Troms) (Larsen and Hertwich, 2011).

Another factor that contributes to emissions is urban sprawl as a result of population urbanisation. The proportion of the population living in urban areas as a percentage of the overall population may result in increased CEI. Due to that, the promotion of climate mitigation action, mixed-use development coupled with low carbon infrastructure was advocated (Wiedman et al., 2021). Under the State Structure Plan for Melaka (2020 – 2030), several strategic initiatives favour low-carbon-oriented urban planning covering township development for transit orientation development (TOD) on compact city and low carbon and green technology development. Hence, the focus on mitigating urban sprawl by having strategic direction will help to reduce the effect of carbon emissions from urbanisation. Suggestions for Melaka's land use and urban reform include incentivising higher density, mixed-use, green, and compact developments. An increased area for green helps to sequester carbon, especially in mixed and compact development. Promoting more green areas within Melaka's compact city centre, which must be considered within the heritage values and rules of the UNESCO World Heritage Site of Melaka, aids in reducing carbon emission effects on heritage buildings. To preserve the green area and permanent forest reserve, the framework of environmental sensitive area, or ESA, as development guidelines were adopted. This includes the aspects of the ESA (Phase 1, 2 & 3) and ESA management criteria.
It is suggested that Melaka construct a compact polycentric urban development form with well-established well-connected nodes. Polycentric urban forms are often regarded as ideal urban spatial layouts, capable of generating significant agglomeration externalities while also promoting social,

economic, and environmental objectives (Meichang & Bingbing, 2020). These recommendations increase population and economic density, resulting in lower transportation costs and carbon emissions. An improvement in economic density will reduce communication costs by enabling frequent face-to-face interactions that are important for the exchange of ideas and the creation of trust, which promote innovation and productivity. Density promotes the transfer of knowledge between workers and between firms. Economic density is essential for the transition to a knowledge-based service economy and tends to occur when cities move to a more mature phase of development. Service economies generally have higher economic densities than industrial economies for the following reasons: savings in services require less land per employee; given external economies, business services have greater potential for agglomeration, with businesses serving each other.

6.0 CONCLUSION

Finally, the effort to develop Melaka into a Green Technology City State has been recognised, which will necessitate a long-term commitment and initiatives from all government departments and communities. With the purpose of guaranteeing uniform and transparent international measurement and reporting of GHG emissions between cities, the GPC has emerged as the principal GHG emission calculator for cities. Carbon emission intensity (CEI), or carbon emissions per unit of GDP, is a metric for assessing regional carbon emission performance. The study found that carbon emission intensity as one of the tools in decomposing identified the effect of various green techno initiatives by the Melaka state government reflected in the slowdown of CEI value in 2015 green technology 2017. This will give confidence for a more aggressive approach in adopting green city programmes in a more strategic approach by considering the economic and physical planning for the state in lowering the country's carbon intensity. The focus of future research should be on the issues that the Melaka state government faces in reducing carbon emissions intensity, as the state government is working hard to achieve Green Technology City State designation.

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