Establishment of City Level Carbon Dioxide Emission Baseline Database and Carbon Budgets for Developing Countries with Data Constraints

Wee-Kean Fong*, Hiroshi Matsumoto2 and Yu-Fat Lun3

1 Civil Engineer, CTI Engineering International Co., Ltd., Japan
2 Professor, Department of Architecture and Civil Engineering, Toyohashi University of Technology, Japan
3 Assistant Professor, Department of Architecture and Building Science, Graduate School of Engineering, Tohoku University, Japan

Abstract

One of the major constraints of developing countries in controlling carbon dioxide emissions is the limited availability of an emission database. Since there is no city level emission database in Malaysia, the authors have made the first attempt in the country to establish city level carbon dioxide emission data for different sizes of city using the System Dynamics based FML Model. From the results, it was found that the carbon dioxide emission of a city has a positive correlation with population size and GDP value, and an increasing emission trend is taking place in Malaysia regardless of the size of city. Projections of emission trends up to 2050 showed that if no aggressive actions were taken to cap emissions from the cities, there would be an extreme increase of emissions by as much as more than seven times of the current level. Hence, the authors have proposed three alternative approaches to set a city level carbon budget, i.e. equal share, population and GDP approaches. The study also demonstrated the capability of the present model in estimating present and future city level carbon dioxide emissions. The model can be used for establishment of a city level carbon dioxide emission database for the whole of Malaysia and in future may be applied to other developing countries.

Keywords: carbon dioxide emissions; carbon budget; city level; FML model; developing country

1. Introduction

Climate change is different from other global problems as it has made us realize that all mankind is living as part of an ecologically interdependent human community, and challenges us to think differently on many levels. Although the world is divided into many levels, regions and nationalities, dealing with climate change issues requires close cooperation from all nations, and at all levels of society.

Climate change is evidence that mankind is overloading the carrying capacity of the Earth’s atmosphere. The anthropogenic driver of global warming is the increasing concentration of greenhouse gases (GHG) in the atmosphere, and among the GHGs, carbon dioxide (CO2) is the largest contributing gas to the greenhouse effect. It is now widely agreed that a temperature rise of more than 2°C from pre-industrial level is likely to have enormous impacts ecologically, socially and economically worldwide. In order to avoid this, it is vital to stabilize the global GHG concentration at around 450 ppm CO2e (IPCC, 2007; UNDP, 2007).

As a priority, the world needs a binding international agreement to cut GHG emissions across a long time horizon with stringent targets. Presently the primary international policy framework against climate change is the United Nations Framework Convention on Climate Change (UNFCCC), specifically the Kyoto Protocol (UN, 1998). However, it did not place any quantitative emission restrictions on developing countries. Due to the rapid increase of GHG emissions from developing countries, it is essential for the major developing countries to be party to international agreements and to make commitments to reduce emissions. As part of the Bali Roadmap, negotiations for post-Kyoto Protocol actions that include both developed and developing countries are underway, and are targeted to be concluded by 2009 (UNFCCC, 2007).

Toward stabilizing CO2 emissions from developing countries, the present authors are continuously carrying out studies to investigate the energy consumption and CO2 emission trends in Malaysia, one of the fastest growing and most industrialized developing countries in Asia, with particular focus on the Iskandar Development Region (IDR), one of the largest urban conurbations in Malaysia (Fong et al., 2007a, 2007b,
2. Methods
2.1 Scope of Study

**Energy related CO₂ emissions.** CO₂ is the largest contributing gas to the greenhouse effect (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) (2007) reported that emissions of CO₂ arise mainly from fossil fuel use, and according to the International Energy Outlook 2006 (EIA, 2007), world CO₂ emissions from the consumption of fossil fuels is expected to grow from about 25,000 billion tons in 2003, to more than 40,000 billion tons by 2030. Hence in stabilizing GHG concentration, it is vital to control CO₂ emissions. For this reason, the present study focused on CO₂ emissions from energy use (hereinafter referred to as 'CO₂ emissions').

**City level CO₂ emissions.** The most significant increase of energy consumption and CO₂ emission is taking place in cities, where rapidly expanding populations enjoy higher living standards and material affluence (Fong et al., 2007a, 2008c; IGES, 2004). Thus, in dealing with the issue of CO₂ emissions, it is vital to focus on the urban sector, and the present study focuses on city level CO₂ emissions.

2.2 Case Study

Malaysia, as one of the fastest growing developing countries in Asia, is experiencing rapid economic growth and economic transition. Real gross domestic product (GDP) grew at an average rate of 6.5% per annum over the last 40 years. The Malaysian population has also grown from 10.3 million in 1970 to 27.6 million in 2007, a growth rate of more than 260% over a 37-year period. In recent years, Malaysia has experienced a very rapid rate of urbanization, whereby the urban population has increased significantly from 50.7% in 1991 to 63.0% in 2005. (EPU, 2006)

Being a developing country, presently there is no clear commitment to cap CO₂ emissions in Malaysia. Nonetheless, Malaysia is one of the 16 countries that signed the Cebu Declaration on East Asian Energy Security in 2007 (ASEAN, 2007), in which the participating countries officially acknowledged the energy and climate change issues, and agreed to make concerted efforts to improve energy efficiency and to mitigate GHG emissions, although no clear target for emission reduction was set. As mentioned, it is vital for the world to act against global warming with a sense of urgency and it is generally recognized that the effectiveness of voluntary action is limited. Hence, it is necessary to investigate the future scenarios of this country toward stabilizing CO₂ emissions.

In previous studies by the present authors, the focus was mainly placed on the Iskandar Development Region (IDR) (cf. Fig.1.), one of the three major urban conurbations in Malaysia (Fong et al., 2007a, 2007b, 2008a, 2008b; Ho and Fong, 2007). In this study, in order to investigate the emission trends of cities of different sizes and levels of socio-economic development, apart from IDR, the case study areas also include Batu Pahat city and Mersing city with much smaller populations, lower GDP values and high shares of the agricultural sector in the total GDP (cf. Fig.1. and Table 1.).

2.3 Overall Study Framework

Toward stabilizing CO₂ emissions from developing countries, the present authors have been continuously...
carrying out studies to investigate the energy consumption and CO₂ emission trends in Malaysia, with particular focus on IDR, toward creating a Low Carbon City. Fig.2 illustrates the overall framework of the current research activities undertaken by the present authors.

![Fig.2. Overall Study Framework](Image)

As mentioned above, one of the main constraints of developing countries in combating climate change is the incomplete emission database (Fong et al., 2008a, 2008c; Ho and Fong, 2007). Hence, the present authors have developed a System Dynamics based FML Model (FML Model) capable of estimating local level CO₂ emission trends under limited availability of supporting data (Fong et al., 2007a, 2008a, 2008b; Ho and Fong, 2007). Using this model, a baseline emission database for IDR was established, and preliminary projections of future emission trends of IDR were undertaken (Fong et al., 2008a; Ho and Fong, 2007). Subsequently, further studies were carried out to investigate the feasibility of adopting the said model as a decision making tool in the urban planning process in Malaysia, toward realization of the Low Carbon City (Fong et al., 2007b, 2008b). Further, from the above works, the present study investigates CO₂ emission trends and possible methodologies for setting city level carbon budgets, for various cities of different sizes and levels of socio-economic development.

The other on-going studies currently under investigation by the present authors include the projections of long-term CO₂ emission trends of IDR in order to identify the requirements and optimum approaches to realize Low Carbon Cities. Besides, complementing the above studies, several investigations regarding international trends in energy consumption/conservation and CO₂ emissions/reductions have also been undertaken (Fong et al., 2007c–2007g, 2008c). It must also be noted that the scope of study as shown in Fig.2 is still expanding in line with the new findings and global trends in handling climate change issues.

### 2.4 FML Model

In the previous studies, the authors developed a System Dynamics based FML Model, for estimation and prediction of city level energy related CO₂ emissions based on the case of IDR. The said FML Model was elaborated in detail by Fong et al. (2008a, 2008b).

In developing countries, the availability of supporting data is one of the major constraints in calculating CO₂ emission, and the situation is worse in the case of city level CO₂ emissions. Hence, FML Model that is capable of estimating city level CO₂ emissions with limited supporting data has been developed based on the case of IDR. From the detailed verification of results, it was confirmed that the model is capable of providing reasonably accurate estimates of local level CO₂ emissions. Also, the model is capable of simulating future emission trends under various socio-economic growth scenarios.

The FML Model developed previously (Fong et al., 2007a, 2008a, 2008b; Ho and Fong, 2007), only dealt with the city context, hence it consisted of only four sub-models, namely the residential, commercial, industrial and transportation sub-models that represent each respective urban sector, which are the main sources of energy consumption and CO₂ emissions in cities. Subsequently, an additional sub-model i.e. carbon sequestration sub-model, was added in order to take into consideration the carbon dioxide sink factor (Fong et al., 2008b). Considering that most developing countries rely strongly on the agricultural sector, it is thought that the existing FML Model should be further improved to include the agricultural sector as well, in order to capture the real situation of CO₂ emission trends in developing countries, including rural-based cities in Malaysia. Also, the present study involves comparison of CO₂ emission trends for cities of different sizes and levels of socio-economic development, in which, besides IDR, another two rural-based small cities, i.e. Batu Pahat city and Mersing city, have been chosen as case study cities. Unlike IDR where agriculture is a very minor economic activity, agriculture constitutes a significant share of the GDP in both Batu Pahat and Mersing. As such, in this study, a new sub-model, i.e. agricultural sub-model, has been added to the existing FML Model (cf. Fig.3.).

Similarly to the other four sub-models, in order to calculate the CO₂ emissions, it is first necessary to estimate energy consumption by agricultural sector. Hence, energy consumption by the agricultural sector was estimated based on GDP values (cf. Equation (1)), in which energy consumption per unit of GDP of the agricultural sector was calculated from the available
data in the Ninth Malaysia Plan 2006-2010 (EPU, 2006). These energy consumption rates were then multiplied by the GDP values of the agricultural sector.

For the calculation of CO₂ emissions, similar to the other four sub-models, the total energy consumption was yielded from the consumption of each fuel type as reported in the I-O Table (MEWC, 2000). Then, CO₂ emissions from the consumption of each fuel type were estimated based on the standard conversion factor for each fuel type as applied in the other four sub-models (Defra, 2005; Azman et al., 2004) (cf. Equation (2)).

\[
E_{\text{Agr}} = GDP_{\text{total}} \times S.GDP_{\text{Agr}} \times ECR_{\text{Agr}}
\] (1)

where,

- \(E_{\text{Agr}}\) Energy consumption by agricultural sector
- \(GDP_{\text{total}}\) Total GDP
- \(S.GDP_{\text{Agr}}\) Share of agricultural sector GDP against total GDP
- \(ECR_{\text{Agr}}\) Energy consumption rate per unit of agricultural sector GDP

\[
CO_2_{\text{Agr}} = E_{\text{Agr}} \times \sum_{i=f1}^{fn} (SE \times EmR)_i
\] (2)

where,

- \(CO_2_{\text{Agr}}\) Agricultural sector CO₂ emissions
- \(E_{\text{Agr}}\) Energy consumption by agricultural sector
- \(SE\) Share of each fuel type against the total agricultural sector energy consumption
- \(EmR\) CO₂ emission rate
- \(f1...fn\) Fuel types

3. Results and Discussion
3.1 Baseline Emissions

As mentioned above, local level CO₂ emission data is completely missing in Malaysia, except that the present authors have established the baseline emission data for IDR (Fong et al., 2008a, 2008b). In this study, baseline data for Batu Pahat and Mersing have been established using the FML Model mentioned earlier, in order to compare the emission trends between cities of different sizes and levels of development. Table 2. below presents the baseline CO₂ emission data for the three case study cities.

|     | 1990 | 2005 |
|-----|------|------|
|     | Total | Per capita | Total | Per capita |
| IDR | 0.91  | 1.33 | 5.64  | 4.17 |
| Batu Pahat | -0.83 | n/a | -0.61 | n/a |
| Mersing | -1.40 | n/a | -1.36 | n/a |

n/a: not applicable

Note: Negative figures mean that the volume of emissions is less than the volume removed by carbon sequestration (negative emissions).

From these results, several emission trends can be seen:

1) Relationship of CO₂ emissions with population size and GDP value. From the results (cf. Table 2.), it can be seen that out of these three cities, only IDR produces net CO₂ emissions, while the total volumes of CO₂ emissions in Batu Pahat and Mersing are less than the volume of CO₂ removed by carbon sequestration. The difference of emissions among these three cities is closely related to population size and economic development. Comparing the information of these three cities as shown in Table 1., it is obvious that the CO₂ emission of a city has a positive correlation with the population size and GDP value. This is in line with the findings from the previous study by the present authors, that population size and GDP growth rate are among the main drivers of urban energy consumption and CO₂ emissions (Fong et al., 2007a).

2) Increasing emissions. Increasing volumes of emissions are obviously taking place in all the three cities. For IDR, in line with the rapid increase of population from 0.68 million in 1990 to 1.35 million in 2005, and GDP growth from less than US$4 billion in 1990 to about US$20 billion in 2005, CO₂ emissions from IDR have escalated from 0.91 tons in 1990 to 5.64 tons in 2005, an over 6-fold increase over the last 15 years (cf. Table 2.). For the cases of Batu Pahat and Mersing, although they still have 'negative
emissions', their role as carbon dioxide sinks for large cities is decreasing. The results show that the capacity of Batu Pahat as a carbon dioxide sink has reduced significantly in the last 15 years.

(3) Emission intensity. From the per capita emission data, it can also be seen that besides the increase of emissions due to population growth in IDR, emission intensity in terms of per capita emission is also increasing at a very high rate, from 1.33 tons per capita in 1990 to 4.17 tons per capita in 2005, a more than 300% growth over a 15-year period (cf. Table 2).

3.2 Future Emission Trends

In order to examine the possible future trends of emissions, simulations have been undertaken using the FML Model. In this respect, the adopted target year was 2050, which is being used by the IPCC in setting the long-term global target for stabilizing GHG emissions.

It is extremely difficult to accurately predict future socio-economic growth trends as far ahead as 45 years (2005~2050). For the case of Malaysia, the common period used for long-term planning such as Structure Plans, Local Plans and other master plans is 20 years. For the case of the present case study cities, the planning period of IDR under the Comprehensive Development Plan for the South Johor Economic Region 2006-2025 (CDP), which is the master plan to guide the development of IDR up to 2025 (Khazanah Nasional, 2006), CDP is 20 years, from 2005 to 2025 (Khazanah Nasional, 2006), while for Batu Pahat and Mersing, they are covered by the Johor Structure Plan with a planning period of 20 years as well, from 2001 to 2020 (JPBD, 2001). Hence, in this study, the 45-year span projection period was divided into two stages i.e. 2005~2025 and 2026~2050. Under the Vision 2020, the Malaysian Government is targeting to raise the country to developed nation status by the year 2020 (EPU, 2006), thus rapid socio-economic development is likely to prevail up to sometime around 2020~2025. In view of this, it was assumed that for the coming 45 years, there would be two stages of socio-economic development in these three cities, in which economic growth is expected to peak within the first half of the projection period (2005~2025), and then gradually slow down and stabilize (2026~2050). As mentioned above, the first half of the projections were based on various data such as population, GDP, etc. as adopted in the CDP and Johor Structure Plan. Whereas for the second half, the projections were based on the assumption that economic and population growth rates would gradually drop and stabilize after peaking sometime around 2020~2025.

As shown in Table 3., the projection results indicate that if the current 'business as usual' trend of socio-economic development without paying much attention to the control of CO₂ emissions continues, emissions from IDR will significantly increase to about 44 million tons by 2050, more than seven times the 2005 level, and more than 48 times the 1990 level. While in the case of Batu Pahat, from its present role as sink for carbon dioxide, the city will likely become a net CO₂ emitter by 2050, with over 7 million tons of emissions, about 126% of the current (2005) volume of emission in IDR. In the case of Mersing, due to its emphasis on an agricultural based economy, it is expected that by 2050, the city will still be serving as a reservoir for carbon sinks with negative emissions. From the projection results of Batu Pahat and Mersing, although the increase rates of these two rural based cities seem to be negligible compared to IDR, it should not be forgotten that their present role of reservoirs for carbon sinks to remove emissions from other major cities will be gradually decreasing due to internal increase of CO₂ emissions. For example, in the case of Mersing, although it will still have a negative emission by 2050, from the global perspective, the reduction of its capacity for carbon sequestration means an increase of global carbon concentration. Hence, in terms of stabilizing global CO₂ emissions, the function of these rural-based cities as reservoirs of carbon sinks must not be overlooked.

| Table 3. Projections of CO₂ Emissions |
|--------------------------------------|
| CO₂ emission, million tons | 2050/ | 2005/ |
|                             | 1990  | 2005 | 2050 | 1990  | 2005 |
| IDR                      | 0.91  | 5.64 | 43.99 | 4844% | 779% |
| Batu Pahat               | -0.83 | -0.61 | 7.14 | n/a | n/a |
| Mersing                   | -1.40 | -1.36 | -0.89 | n/a | n/a |
| n/a: not applicable       |

3.3 City Level Carbon Budgets

Fighting against global warming requires urgent actions from all countries, at all levels of society. Due to the force of inertia and cumulative outcomes of climate change, any delay in cutting emissions will entail additional GHG stocks in the atmosphere, locking the future into higher temperatures. People living at the start of the 22nd Century will definitely live with the consequences of our emissions, just as we are living with the consequences of emissions since the industrial revolution. In this respect, as voluntary action is proving ineffective (UNDP, 2007), stringent targets are necessary to ensure no delay in stabilizing global emissions, and to protect future generations from suffering further temperature rise. In the case of Malaysia, although presently there is still no international framework to cap emissions, it is extremely important for the Malaysian Government to set stringent targets for emission reduction and to make concerted efforts to achieve it within a stipulated timeframe, in order to contribute to global efforts in combating climate change.

To reduce CO₂ emissions, effort at the national government level alone is not sufficient. Close cooperation from all levels of society is vital. Since cities are the main source of emissions (Fong et al., 2007a, 2008c; IGES, 2004), besides setting the national carbon budget, it is essential for city governments to...
set their own carbon budgets in line with the national target. Presently, there are many mega cities/states worldwide which have taken initiatives to set their own long-term targets in cutting GHG/CO₂ emissions. For example, the State of California in the United States is aiming to cut emissions to 80% below the 1990 level, while Greater London has set a target of 60% emission reduction from the 2000 level, both with the target year of 2050 (EC, 2007; GLA, 2007).

Concerning city level carbon budget, it is important to work out a standard mechanism for carbon budgeting that is suitable and fair for application to cities of different size, population and economic condition. In setting a carbon budget, firstly it is necessary to decide the ‘base year’. As mentioned above, the base years used by the State of California and Greater London are 1990 and 2000 respectively. However, when considering the global target of 50% of 1990 emissions as recommended by IPCC, any change in the base year to later than 1990 should include adjustment in reduction targets in order to compensate for any increase in emissions from 1990, otherwise, it is impossible to achieve the global target by 2050. Hence, it is deemed that standardization should be made by defining 1990 as the base year for target setting.

Before setting the city level carbon budget, it is also necessary to look into the national target. Since presently Malaysia is not committed to any international framework for capping CO₂ emissions, and the Malaysian Government has so far never set any target for emission control, the recommendation by the United Nations has been adopted in this study. The United Nations has made recommendations that the developed countries should cut emissions to at least 80% below the 1990 level while developing countries should cut emissions to 20% below the 1990 level (UNDP, 2007) (cf. Table 4.).

From the above emission reduction target (20% below the 1990 level by 2050), in setting a carbon budget for Malaysia, it is necessary to know the volume of national emissions in 1990. From the literature review (Fong et al., 2008c), there are a number of sources of information on CO₂ emissions for Malaysia, however there are problems of inconsistency of data and base year. Among these data, Table 5. shows the two most reliable data with base years closest to 1990.

Table 4. Recommendations of Emission Reduction Targets by the United Nations

| Category of country | Emission reduction target |
|---------------------|--------------------------|
| World               | 50% below 1990 level by 2050, with a peak around 2020 |
| Developed countries | At least 80% below 1990 level by 2050, with a peak between 2012 and 2015 |
| Major emitters of developing countries | Peaks in 2020, and reduction to around 20% below 1990 level by 2050 |

Source: UNDP, 2007

Between these two sets of data, although the emission estimated by the United Nations was for 1990, which is the same as the base year adopted in this study, the estimated volume is very much higher than the Initial National Communication (INC) data for 1990. Hence, after due consideration, the INC data is believed to be the most complete and most reliable official CO₂ emission data for Malaysia, as it was accepted by the Malaysian Cabinet in 2000 and subsequently submitted to the UNFCCC in the same year. Hence, in this study, it was assumed that the 1990 national CO₂ emission for Malaysia was 43.8 million tons.

After decided the national carbon budget, the final step is to establish city level carbon budgets for the three case study cities. However, due to varying city sizes, populations and levels of development, it is very difficult to decide a standard mechanism of carbon budgeting that is fair to all cities. The situation is similar to the international negotiations in distributing national shares of CO₂ reduction toward achieving the global target. In order to ensure a fair distribution of emission reduction responsibilities among cities of different sizes and levels of socio-economic development, the authors proposed three approaches for setting a carbon budget: (1) Equal Share Approach, (2) Population Approach, and (3) GDP Approach (economic approach):

(1) Based on the concept of Equal Share, all cities have the same degree of responsibility in CO₂ reduction toward achieving the national target. In this study, since it was assumed that 20% below the 1990 level be adopted as a national target, all cities should be responsible for cutting emissions to 20% below the 1990 level by 2050.

(2) Under the Population Approach, the eligible emissions of each city are decided based on the proportion of the current population (2005) of the subject city against the national population, cf. Equation (3).

(3) Under the GDP Approach, the eligible emissions of each city are decided by the proportion of current GDP value (2005) of the subject city against the national GDP value, cf. Equation (4).

\[
CB_{city,P} = \frac{CB_{Malaysia}}{P_{Malaysia,2005}} \times P_{city,2005}
\]

where,

- \(CB_{city,P}\) Carbon budget for the subject city under the Population Approach
- \(CB_{Malaysia}\) Carbon budget for Malaysia
- \(P_{Malaysia,2005}\) Total population of Malaysia in 2005
- \(P_{city,2005}\) Total population of subject city in 2005
$P_{city\_2005}$ Population of the subject city in 2005

$$CB_{city\_GDP} = \frac{CB_{Malaysia}}{GDP_{Malaysia\_2005}} \times GDP_{city\_2005}$$  \hspace{1cm} (4)

where,

$CB_{city\_GDP}$ Carbon budget for the subject city under the GDP Approach

$CB_{Malaysia}$ Carbon budget for Malaysia

$GDP_{Malaysia\_2005}$ GDP of Malaysia in 2005

$GDP_{city\_2005}$ GDP of the subject city in 2005

From the above approaches, carbon budgets for the three case study cities in comparison with the 1990 and 2005 emissions are shown in Fig.4. From the results, it can be seen that carbon budgets under the Equal Share Approach are the lowest among the three alternative approaches, and all the cities are required to reduce their existing levels of emission. If the Population Approach or GDP Approach were applied, there would still be room for increases in CO$_2$ emissions in Batu Pahat and Mersing in line with the future developments of these cities; whereas in the case of IDR, under the Population Approach, it would be necessary to reduce the present 5.64 million tons of emissions to 1.81 million tons, while under the GDP Approach, the city is eligible to have additional emissions up to 9.09 million tons.

4. Conclusions

The stabilization of global CO$_2$ concentrations requires close cooperation from all countries, including both developed and developing countries. In the case of Malaysia, so far there is still no complete and updated national emission database, while city level data is completely lacking. In the previous studies, the present authors found that cities are the main source of CO$_2$ emissions, thus in order to stabilize national and global emissions, it is vital to cap emissions from the cities. Also, it is believed that emission reduction efforts will not be successful if we rely entirely on the national governments without close support from city governments.

The first step toward capping emissions from cities is to establish a baseline city level emission database. Prior to this study, the present authors made the first attempt in the country to establish a city level CO$_2$ emission data for the Iskandar Development Region (IDR) using the System Dynamics based FML Model. In this study, the authors upgraded the said FML Model and applied it to IDR as well as two other rural-based small cities i.e. Batu Pahat city and Mersing city, to investigate the emission trends of cities of different size and levels of development. The findings include (1) city level CO$_2$ emission has a positive correlation with population size and GDP value, (2) an increasing emission trend is taking place in all the three case study cities regardless of city size, and (3) emission intensity in terms of per capita emission is also at an increasing trend.

Further, from the above, projections of future emission trends up to 2050 have been undertaken for the three case study cities. From the projections, it is foreseen that the emissions of IDR will likely increase to 7 times the 2005 level if no aggressive measures are taken to control emissions. In the case of Batu Pahat, from the present status of negative emission, by 2050 the city will produce net emissions of more than the present emission level of IDR.

Besides the baseline emission database, another important aspect in controlling city level emissions is the necessity to set a carbon budget for each city. For this purpose, the authors proposed three alternative approaches to set a city level carbon budget that the Malaysian Government may consider, i.e. the Equal Share, Population and GDP Approaches. Each
approach entailed a different carbon budget. The pros and cons of these approaches were discussed. Apart from the findings and recommendations above, the present study also demonstrated the capability of the present FML Model in estimating the present and future city level CO\textsubscript{2} emissions. Although it may not produce the exact value of actual emissions, from the detailed verifications of results undertaken prior to this study, it was confirmed that the model is able to produce highly reliable results that are suitable for studies concerning city level emission trends. It is believed that the current model can be used for establishment of a city level CO\textsubscript{2} emission database for the whole of Malaysia, and in future, the model may be further improved and recalibrated for applications in other developing countries, as part of the efforts to stabilize global CO\textsubscript{2} emissions.

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