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The driving factors of energy-related CO_2 emission growth in Malaysia: The LMDI decomposition method based on energy allocation analysis

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ABSTRACT

Malaysia is a typical Southeast Asian country that is a dynamic part of the global growth of energy-related CO_2 (carbon dioxide) emissions, but little research exists on the driving factors of its energy-related CO_2 emission growth. Most of the related publications have considered only the effect of the change of economic indicators using econometric methods, and seldom have they considered the technical driving factors from the perspective of energy systems. In this study, a methodology called the logarithmic mean Divisia index (LMDI) decomposition method based on energy allocation analysis was applied to define the contributions of technical driving factors related to the growth of CO_2 emissions in Malaysia during the periods 1978–1990, 1990–2002, and 2002–2014. The technical driving factors include end-use energy structure, electricity generation efficiency, and fuel-mix in electricity generation. The results indicate that, although the population, GDP per capita and energy intensity are still the main driving factors influencing the changes of energy-related CO_2 emissions in Malaysia, the influence of technical driving factors is increasing from in 1978–2014. The increasing ratio of electricity in the end-use stage and the structural changes of fuel-mix in electricity generation contribute to energy-related CO_2 emission growth. Meanwhile, the increasing end-use energy efficiency and electricity supply efficiency effectively slow down CO_2 emissions in Malaysia. Compared with previous publications, the technical driving factors considered in this study can provide a more detailed explanation for the interaction between energy, the economy, and CO_2 emissions. On the basis of an overview of Malaysia's existing policies, policy recommendations for further control of energy-related CO_2 emissions in Malaysia that mainly focus on these technical factors were proposed.

1. Introduction

As the impact of global climate change has become substantial, most countries have come to an agreement on the urgency of controlling energy-related carbon dioxide (CO_2) emissions [1]. One of the priorities for national policymakers in reducing energy-related CO_2 emissions is to understand the driving factors behind the growth of energy-related CO_2 emissions [2]. However, this problem is related to the specific circumstances of each country. Different economic development stages and energy system conditions lead to different driving factors behind energy-related CO_2 emission growth [3]. Therefore, scientific analysis on these driving factors in various countries is of great value and will

Abbreviations: AAGR, Average annual growth rate; CO_2, Carbon dioxide; GDP, Gross domestic product; IDA, Index decomposition analysis; INDC, Intended Nationally Determined Contribution; IPCC, Intergovernmental Panel on Climate Change; LMDI, Logarithmic mean Divisia index; LNG, Liquid natural gas; MEIH, Malaysia Energy Information Hub; NGCC, Natural gas combined cycle; PDA, Production theoretical decomposition analysis; PEQ, Primary energy quantity; PPP, Purchasing power parity; SQ, Standard quantity heat value quantity; SDA, Structural decomposition analysis; toe, Ton oil of equivalent; t, Ton

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not only help national policymakers, but also provide a basis for international organizations to set up policies to reduce energy-related CO_2 emissions.

Malaysia, a country of moderate population size and land area and a more developed economy relative to its neighbours, is a typical Southeast Asian country. As one an economic growth centre, Southeast Asia takes part in the global energy system in a dynamic manner and is on track to emit much more CO_2 in the future [4]. In addition, Malaysia is also representative of countries with an abundance of crude oil and natural gas resources and a lack of motivation to reduce energy-related CO_2 emissions. Therefore, conducting a case study of Malaysia is helpful for understanding the typical characteristics and mechanisms of energy-related CO_2 emission growth among these Southeast Asian countries as well as those with abundant crude oil and natural gas resources.

In the past 40 years, Malaysia has achieved rapid economic growth in the process of attempting to accomplish industrialization and urbanization [5]. This has resulted in the rapid growth of energy consumption and related CO_2 emissions. Between 1978 and 2014, the energy consumption and related CO_2 emissions increased from 6,426 ktoe and 18,687 kt to 68,594 ktoe and 196,332 kt, an average annual growth rate of 6.80% and 6.75% (see Section 4.2). Although as a developing country Malaysia has no quantitative commitments under the Kyoto Protocol, it has already announced its willingness to reduce emissions [6]. In 2009, the Malaysian government announced the National Policy on Climate Change [7] to ensure climate-resilient development to fulfil national aspirations for sustainability. Furthermore, according to the Intended Nationally Determined Contribution (IND Tables 1, 2, 3, 4, A1, A2, A3 and A4C) of the government of Malaysia [8], Malaysia intends to reduce its greenhouse gas emissions intensity of GDP by 45% by 2030, relative to the emissions intensity of GDP in 2005. At the same time, interestingly, while other countries are gradually stopping construction and beginning to close down coal-fired power plants, the proportion of coal-fired power in Malaysia is increasing [9], contributing to CO_2 emission growth. Therefore, there is a sufficient domestic policy background and an interesting background energy systems to support the study of the driving factors behind energy-related carbon emissions in Malaysia.

However, few studies have been published that provide an in-depth discussion of the driving factors behind energy-related CO_2 emission growth in Malaysia from the perspective of considering energy systems. According to the literature review (see Section 2.1), most previous studies have focused on the causality between energy-related CO_2 emissions and economic indicators from an economic point of view, while lacking in analysis of the causality between energy system characteristics and energy-related CO_2 emissions. Although the effect of the change of economic indicators are important, considering that the energy system is the bridge between economic development and energy-related CO_2 emissions, a thorough analysis of the energy system is useful for furthering the understanding of the technical driving factors of energy-related CO_2 emission growth. According to the previous studies [10], the authors found that these technical driving factors may include end-use energy structure which audited in standard quantity (heat value) form, primary energy quantity converted factor (K_{PEQ}) and primary carbon dioxide emission factor (K_C). K_{PEQ} is a key parameter for establishing the connection between end-use energy consumption which expressed in standard quantity form, also known as heat value form, and energy consumption which is expressed in primary energy quantity form. K_{PEQ} is defined as the total number of units of primary energy that are consumed to produce one unit of secondary energy. K_C is a key parameter for establishing the connection between energy consumption expressed in primary energy quantity form and CO_2 emissions, it is defined as the total number of units of CO_2 emissions when one unit of end-use energy expressed in primary energy quantity form is consumed. These technical driving factors can be used to extend the conventional Kaya identity (see section 2.4), so that we can build the bridge between economy development and energy system. To reveal the driving mechanism from the perspective of energy systems for energy-related CO_2 emission growth in Malaysia, a comprehensive study should be launched to systematically examine the impact of the technical driving factors on the energy-related CO_2 emissions from the energy perspective. Hence, this paper aims to apply a methodology called logarithmic mean Divisia index (LMDI) decomposition method based on energy allocation analysis [10] to further study the driving factors behind energy-related CO_2 emissions in Malaysia.

First, we conducted an energy allocation analysis for Malaysia. The technical driving indicators, including end-use energy structure, K_{PEQ} and K_C were obtained through energy allocation analysis, and the characteristics of the energy system were illustrated by mapping Sankey diagrams. Considering Malaysia's data availability and the purpose of this study, we simplified the method of energy allocation analysis (see Section 3.2), which only the K_{PEQ} of electricity and K_C of electricity were considered. These simplifications can also help us to focus more on the key changes of Malaysia's energy system on energy-related CO_2 emissions. The K_{PEQ} of electricity can reflect the electricity generation efficiency, while the K_C of electricity can reflect the energy mix in electricity generation. Then, the driving factors of energy-related CO_2 emission growth were analysed using the LMDI decomposition method. Although both the effect of the change of economic indicators and technical driving factors were considered in this study, we more emphasized at technical driving factors. The effect of the change of economic indicators included population, GDP per capita, and energy intensity, while the technical driving factors included end-use energy structure, electricity generation efficiency (K_{PEQ}), and fuel-mix in electricity generation (K_C). In addition, the influence of resource availability was also discussed. On the basis of the results of decomposition, after a review of Malaysia's historical statistics and existing policies, policy recommendations for reducing the energy-related CO_2 emissions in Malaysia were finally proposed.

The main contributions of this work are as follows: it applied the LMDI decomposition method based on energy allocation analysis to analyse driving factors of energy-related CO_2 emission growth in Malaysia, reveal the driving mechanism from the perspective of energy systems for energy-related CO_2 emission growth in Malaysia over the course of 36 years was presented according to three economic development stages (i.e., 1978–1990, 1990–2002, and 2002–2014). Compared with previous publications on driving factors of energy-related CO_2 emission growth in Malaysia, three technical factors were firstly introduced in this study, including end-use energy structure, electricity generation efficiency, and fuel-mix in electricity generation. These factors can provide a more detailed explanation for the interaction between energy, the economy, and CO_2 emissions, and also be helpful to propose policy recommendations for reduction of energy-related CO_2 emissions that focus more on key issues of energy systems.

The remaining sections are organized the following way. Section 2.1 is a literature review of the studies on the driving factors of energy-related CO_2 emission growth in Malaysia. Then, section 2.2, section 2.3 and section 2.4 present further literature reviews focused on index decomposition analysis and energy allocation analysis, respectively. Section 3 introduces the methodology, which includes an introduction of the analysis framework in section 3.1, energy allocation analysis in section 3.2, LMDI decomposition method in section 3.3, and data input in section 3.4. The results are presented in section 4 and further discussed in section 5. Policy implications are derived in section 6. Finally, section 7 finally presents the conclusion of this study.

2. Literature review

2.1. Driving factors of energy-related CO_2 emission growth in Malaysia

In the published literature, there were many studies on energy-related CO_2 emission growth in Malaysia. Most of them suggested a

Table 1
Studies concerning energy-related CO_2 emission growth in Malaysia based on econometric methods.

No.	Author	Economic indicators considered
1	Bekhet and Othman [14]	GDP
2	Yii and Geetha [15]	Technological innovation
3	Ali et al. [16]	GDP, energy consumption, financial development, and openness of trade
4	Begum [17]	GDP, energy consumption, and population
5	Lau et al. [18]	Foreign direct investment and trade openness
6	Lau et al. [19]	GDP, institutional quality, and exports
7	Saboori and Sulaiman [20]	GDP and energy consumption
8	Shahbaz et al. [21]	GDP, energy consumption, and financial development
9	Azliza et al. [22]	Energy consumption and income
10	Bekhet and Othman [23]	GDP, energy consumption, urbanization growth, domestic investment, and financial development

dynamic interaction between energy-related CO_2 emissions and economic indicators by applying an econometric methodology, as shown in Table 1. In addition, several studies focused on scenario analysis or the projection of future energy-related CO_2 emission in Malaysia [11–13].

Therefore, it can be concluded that most of the previous studies on energy-related CO_2 emissions in Malaysia focused only on the causality between energy-related CO_2 emissions and economic indicators from an economic perspective. Few studies discussed the energy-related CO_2 emission growth from a technical perspective. For example, electricity generation efficiency, fuel-mix in electricity generation, and the proportion of electricity in end-use energy structure were seldom considered as driving factors in case studies of Malaysia, even though these driving factors may contribute significantly to the energy-related CO_2 emissions changes.

In addition to the econometric methodology mentioned in this section, there are some decomposition methods which are often used to analyse the driving factors of energy-related CO_2 emissions changes. In the following section, we review the decomposition methods.

2.2. Decomposition analysis method of energy-related CO_2 emission changes

Generally, the decomposition analysis methods can be majorly divided into two categories. One is to explore the impact of commodity production on energy-related CO_2 emissions changes from the production side of commodities, which index decomposition analysis (IDA) method is the main method [24]. The other one is to explore the impact of final demand of commodity on energy-related CO_2 emissions changes from the consumption side of commodities, which the structural decomposition analysis (SDA) method is the main method [24,25].

In the IDA method, energy-related CO_2 emissions refer to CO_2 emissions of direct energy consumption consumed by economic sectors of the economy for the production of commodities, as well as CO_2 emissions of energy consumption in residential sector. From this perspective, scholars mainly focus on the impact of production structure, energy intensity and energy structure adjustment on energy-related CO_2 emissions. In SDA method, energy-related CO_2 emissions are characterized as all energy-related CO_2 emissions, including direct and indirect emissions, emitted for the production of final demand, after introducing input-output method from economics. From this perspective, scholars focus on the impact of the structural of final demand and the input-output efficiency of the entire economic system on energy-related CO_2 emissions. In addition, the SDA method also needs monetary input-output tables and matching energy balance tables as support.

IDA method and SDA method have specific advantages in solving specific problems. For example, the IDA method can better describe the process of energy supply, energy conversion and energy consumption physically, and can better analyse some technical driving factors, such as end-use energy structure, energy mix in electricity generation and electricity generation efficiency. In other words, the IDA method is closer to the energy system and pays more attention to technical details; while the SDA method can better reflect the economic development and the change of the final demand structure for the energy-related CO_2 emissions. Su and Ang [26] compared IDA method and SDA method, and presented a systematic review between these methods.

In 2007, Zhou et al. [27] proposed a method different from IDA and SDA based on production theory in economics, which is called production-theoretical decomposition analysis (PDA) method, in order to provide a better economic explanation for the changes of energy intensity. Specifically, based on Shepherd output distance function, Zhou et al. decomposed the change of energy intensity into industrial structure effect, energy structure effect, production technology effect, technology efficiency effect, capital-energy substitution effect and labor-energy substitution effect. PDA method not only provides a better economic explanation for the change of energy intensity, but also has more economic policy implications. According to Du and Lin [28], although PDA method has good economic explanatory ability, its main drawback is that it may give a contrary conclusion to reality in measuring economic structure effect and energy consumption structure effect. The main reason is that all structural components are symmetrical in the output distance function, so the PDA method cannot reflect the different attributes of different economic sectors or energy varieties. In order to overcome this shortcoming of PDA method, Du and Lin tried to combine IDA method and PDA method to form a comprehensive analysis framework, namely IDA + PDA method. Compared with IDA method, it provides a theoretical explanation for the change of energy intensity through production theory. Compared with PDA method, it overcomes the shortcomings of industrial structure effect and energy consumption structure effect, and makes the decomposition result more reasonable. Therefore, in the follow-up studies [29–33], the application of PDA method is mainly in the form of PDA + IDA. Compared with IDA and SDA methods, the application of PDA are relatively less.

In the authors' opinion, these methods have their own characteristics and advantages, the selection of method mainly depends on the research purpose. According to the research purpose of this study, which we would like to reveal the driving mechanism from the perspective of energy systems for energy-related CO_2 emission growth in Malaysia, and make recommendations for the low-carbon development of Malaysia's from perspective of energy system, IDA method was chosen as the method of this study. Index decomposition analysis of energy-related CO_2 emissions.

The index decomposition analysis (IDA) originated after the first global oil crisis and was initially used to analyse the driving factors influencing the aggregate energy intensity of the industrial sector [24]. However, there are unexplained residual terms in IDA results. To overcome this problem, Ang and Choi [34,35] proposed a new decomposition method, called LMDI, and proved that its decomposition results do not contain any residual terms. Ang [36] also presented a practical guide for LMDI decomposition method. Since then, LMDI has become the primary IDA method, widely used to analyse the driving factors behind energy consumption and its energy-related CO_2 emission growth in various countries and regions.

In the previous related studies, the LMDI decomposition method has not changed much at the methodological level. In most studies, scholars adopted conventional Kaya identity which as the expression of energy-related CO_2 emission. In Kaya identity, energy-related CO_2 emission are represented as the product of GDP (Q), energy intensity (E/Q) and carbon emission factor (C/E), as shown in equation (1). The scholars further used LMDI decomposition method to decompose the increment of the emissions into several effects.

$$C = Q\cdot\frac{E}{Q}\cdot\frac{C}{E} \tag{1}$$

with data availability guaranteed, scholars have expanded the conventional Kaya identity to increase the resolution of the economic sector from the economic side, and to increase the resolution of energy structure from the energy side, hence the effects of the change of economic sectors (Q_i/Q) and primary energy structure (E_{ij}/E_i) can be further considered in LMDI decomposition method, as shown in equation (2):

$$C = \sum_{ij} Q\cdot\frac{Q_i}{Q}\cdot\frac{Q_i}{Q_i}\cdot\frac{E_{ij}}{E_i}\cdot\frac{C_{ij}}{E_{ij}} \tag{2}$$

In the subsequent studies [10], scholars further expanded equation (1) or (2) from economic side or energy side, according to their research purposes and the advantages of their discipline, in order to provide more evidence for the designation of corresponding policies.

On the economic side, some scholars introduced production theory into Kaya identity to provide a deep mechanism analysis, such as Wang et al. [37] characterized GDP as Cobb-Douglas production function, and further considered the effect of capital and labor changes on energy consumption. In addition, the PDA + IDA method mentioned in the previous section also improved the resolution of energy intensity, and further characterized its effects on energy consumption (or its CO_2 emissions) as industrial structure effect, energy structure effect, production technology effect, technology efficiency effect, capital-energy substitution effect and labor-energy substitution effect [29–33].

On the energy side, Chong et al. [38] and Ma et al. [10] have summarized the application of the LMDI decomposition method in both energy consumption growth (10 cases) and energy-related CO_2 emission growth (52 cases). They found that the change of economic indicators, such as population, gross domestic production, economic structure and energy intensity, were always considered in the LMDI decomposition method. However, some technical driving factors, such as end-use energy structure, electricity generation efficiency, and fuel-mix in electricity generation, were seldom considered. Hence, they suggested utilizing energy allocation analysis (see Section 2.3) to obtain key technical driving factors, including end-use energy structure, K_{PEQ} and K_C, and then further analysing them using the LMDI decomposition method. After a series of case studies [10,38–40], they proposed a methodology for analysing the driving factors of energy consumption and its related CO_2 emission growth from the perspective of energy system, which they referred to as the LMDI decomposition method based on energy allocation analysis.

Although IDA + PDA method and IDA + Cobb-Douglas production function may provide some theoretical explanations from the economic perspective, it may face some difficulties in putting forward some policy proposals based on the actual energy development, for example the substitution between labor and energy. We will introduce IDA method in next section. According to the purpose of this study, LMDI decomposition method based energy allocation analysis which proposed by Chong et al. is suitable for the purpose of this paper.

2.3. LMDI decomposition method based on energy allocation analysis

In the LMDI decomposition method based on energy allocation analysis, the deduction of technical factors is the key. These factors mainly depended on the rigorous calculations of energy loss between primary energy resources, such as raw coal, and secondary energy carriers, such as electricity, which was consumed in the end-use sector. On the basis of these calculations, the researchers can obtain the energy efficiency of each secondary energy carrier from the perspective of the entire energy network. Although the actual quantity or heat value of various secondary energy carriers in each stage and the amount of energy loss in the energy conversion stage are generally listed in available national energy balance tables, the amount of energy loss in the whole energy system is not always given. As a visualization tool to present the energy balance and loss process of energy system to policymakers, a Sankey diagram provides a standardized method for data processing and loss calculation of energy balance tables. The energy balance calculation and illustration based on a Sankey diagram is expected to provide a standardized process for the deduction of technical factors. Although the amount of energy loss in the whole energy system can be derived from the energy balance, the calculation process will be very complex if the energy system contained complex energy conversion stage, like China [41].

A Sankey diagram is a specific type of flow diagram in which the width of the arrows is proportional to the flow quantity [42] and the colour of the flow distinguishes the flow type [10]. Sankey diagrams are named after Irish Captain Matthew Henry Phineas Riall Sankey, who used this type of diagram in 1898 in a classic figure showing the energy efficiency of a steam engine. Sankey diagrams have been used as an effective tool to focus on energy flow and its distribution across various energy systems for various purposes [43]. For example, Ma et al. [44] presented a Sankey diagram of China's oil flows to facilitate the analysis of historical and ongoing trends of China's oil development. Chong et al. [5] presented a Sankey diagram of Malaysia's energy flows together with a trend analysis of the main factors influencing the energy flows. Davis et al. [45] interpreted the energy flow from available primary fuel to end use in all of the provinces and territories in Canada using a Sankey diagram. Subramanyam et al. [46] developed Sankey diagrams that mapped energy flow for both the demand and supply sides for the province of Alberta, Canada. Li et al. [39] proposed a systematic analysis framework based on energy Sankey diagrams to understand the driving factors that influence the energy supply chain, including the energy supply, energy conversion, and end-use of the Beijing-Tianjin-Hebei regions in China. He et al. [47] mapped an energy Sankey diagram to present a complete picture of the status quo of residential energy consumption in rural regions in China. Some scholars have also focused on the development of the Sankey diagram [41,48,49]. In addition to its application in the field of energy, the Sankey diagram was also widely used in other fields, including land [50], waste [51], iron [52], Cereals [53], rare earth [54], and water resources [55,56].

In the process of the continuous publication of energy Sankey diagrams, Cullen and Allwood [57] were early scholars who proposed a systematic method of energy allocation analysis. They found that most energy efficiency analysis considered only the potential gains from known efficiency technologies in the end-use sector, while ignoring the complex flow of energy through the chains of energy conversion sectors. Hence, they suggested that energy losses in energy conversion sectors should be calculated into and compensated for in the end-use energy consumption, allowing for researchers to identify the primary energy consumption responsibility of each end-use energy consumer. Further that, they presented this type of energy flow in the form of Sankey diagram, so called an energy allocation Sankey diagram, and traced the global energy flows from energy sources to final services without showing any energy loss. Following their study, Ma et al. [58] further applied energy allocation analysis to a case study of China and mapped China's energy allocation Sankey diagram.

On the basis of these studies, Chong et al. [40] further introduced an input-output method to simplify the calculation and compensation process of energy losses. With this method, the original energy balance table was converted into a standardized energy input-output table, allowing the Leontief inverse matrix of the energy input-output table to be calculated. Finally, the primary energy quantity converted factor can be obtained by using the row vector of the inverse matrix, which can be used to simplify the calculation of energy loss compensation. Meanwhile, on the basis of this energy allocation analysis, the K_{PEQ} was first introduced into LMDI decomposition in the form of technical driving factors of energy consumption growth. Therefore, the three basic steps of the LMDI decomposition method based on energy allocation analysis were formed, including: 1) energy allocation analysis of the whole energy system to acquire technical factors; 2) mapping the energy allocation Sankey diagram to illustrate major features of the whole energy system; and 3) LMDI decomposition of energy consumption growth to reveal the effects of technical driving factors from energy system perspective.

After Chong et al.'s study, a series of case studies [10,38–40] in China were published using the LMDI decomposition method based on energy allocation analysis. The first application of this method in the driving factor decomposition of energy-related CO_2 emission growth [10] was also carried out in China, by further introducing the K_C into LMDI decomposition. However, this method has not been used in other countries.

3. Methodology and data input

3.1. Analysis procedure

In this study, we applied the methodology called the LMDI decomposition method based on energy allocation analysis to study energy-related CO_2 emission growth in Malaysia.

According to Ma et al. [10], we first conducted energy allocation analysis to understand the features of the energy system of Malaysia, and delivered three technical influencing factors, included end-use energy structure, K_{PEQ}, and K_C (see section 3.2). These three technical driving factors will be examined in the LMDI decomposition method, to reveal the driving mechanism from the perspective of energy systems for energy-related CO_2 emission growth in Malaysia (see section 3.3). Although the visualization of energy flows was not necessary in this study, we demonstrated the results of the energy allocation analysis in the form of a Sankey diagram, as it may help readers and policymakers better understand the results of the energy allocation analysis.

In order to determine the contributions of the driving factors quantitatively, an LMDI method was adopted to decompose their contributions to energy-related CO_2 emission growth in Malaysia. The driving factors under consideration included population, GDP per capita, energy intensity, end-use energy structure, K_{PEQ} and K_C. Moreover, we discussed the impact of resource availability through a literature review and statistical analysis.

The adjustment of the political goals of the parties and the strategic plans of the government can interfere with the development trends of all direct driving factors, such as energy demand, resource availability, and technology choice. The most powerful strategic plan in Malaysia is the five-year Malaysia plan, which focuses on the development of the people-based economy and the capital-based economy with the implementation of high impact projects. In its five-year plans, the government of Malaysia sets a series of targets to be fulfilled in the next five years. These targets include economic indicators, such as GDP growth rate, as well as some technical indicators, such as electricity generation efficiency and primary energy consumption structure. A series of policies and plans, and even legal acts (submitted to parliament), will be promoted by each department of the government to attempt to meet the targets of the five-year plan. Therefore, the main policies, plans, and acts will be taken as the indirect driving factors to help explain the policy background of the driving factors in the analysis.

3.2. Energy allocation analysis and energy allocation Sankey diagram

We conducted an energy allocation analysis on the energy system in Malaysia from 1978 to 2014. Detailed information about energy allocation analysis can be found in Chong et al.'s [38] and Ma et al.'s [10] studies, as well as earlier studies [57,58]. We then mapped the energy allocation Sankey diagram of Malaysia in 2014 to present the result of the energy allocation analysis.

The core idea of energy allocation analysis is that, energy losses in energy conversion sectors should be calculated into and compensated for in the end-use energy consumption. Similarly, when we introduce the energy allocation analysis into the calculation of energy-related CO_2 emissions, we can calculate emissions responsibility of the energy conversion stage (especially the thermal power plants) into the emissions responsibility of each end-use sectors. Following this principle, researchers can determine the boundary selection of energy allocation analysis according to their own research purposes, therefore, the process of energy allocation analysis and the selection of technical influencing factors are not unique.

For example, in order to understand the impact of boiler efficiency on coal consumption, Chong et al. [40] introduced boiler efficiency into the energy allocation analysis. Hence, the technical driving factors considered include not only the energy conversion efficiency, but also the end-use efficiency of energy. In addition, Chong et al. also suggests that, researchers can further consider the energy efficiency of various types of end-use energy consumption, such as the electricity efficiency of various electrical appliances, according to their own purposes and data availability. These can be referred to Cullen and Allowood [57], Ma et al. [58], and Sun et al. [59]. Based on this, by further expanding the boundary of energy allocation analysis, researchers can further refine more technical driving factors, such as engine efficiency of vehicles, stove thermal efficiency and so on. However, these data are difficult to obtain, especially for long time series data. Besides, when the process of energy allocation analysis becomes too complex, it will also lead to the ambiguity of the purpose of this study. Therefore, according to the research purpose in this study, only electricity generation efficiency and energy mix in electricity generation were considered as technical influencing factors.

3.3. LMDI decomposition method

The total energy-related CO_2 emissions for Malaysia can be expressed and calculated using equation (3), and can be further expanded with some major economic indicators and technical indicators, as shown in equation (4). Economic structure was not considered a driving factor because of the lack of official historical sectoral energy consumption data. Furthermore, only the K_{PEQ} and K_C of electricity are considered in LMDI decomposition method, as the change of K_{PEQ} and K_C of other secondary energy can be negligible compared with electricity. Hence, the effect of the change of K_{PEQ} can be understood as the effect of the change of electricity generation efficiency, while the effect of the change of K_C can be understood as the effect of the change of fuel-mix change in electricity generation. On the basis of Malaysia's economic development stages, the periods 1978–1990, 1990–2002, and 2002–2014 were selected for conducting the LMDI decomposition.

$$C = \sum_j E_{SQ,j} \cdot K_{PEQ,j} \cdot K_{C,j} \tag{3}$$

$$C = \sum_j P \cdot \frac{GDP}{P} \cdot \frac{E_{SQ}}{GDP} \cdot \frac{E_{SQ,j}}{E_{SQ}} \cdot K_{PEQ,j} \cdot K_{C,j} \tag{4}$$

The elements in equations (3) and (4) above are described in Table 2. Both additive LMDI decomposition and multiplicative LMDI decomposition were applied in this study. Additive LMDI decomposition contributes in the form of absolute values, whereas the multiplicative LMDI decomposition contributes in the form of relative values.

Table 2
Description of the elements in equations (3) and (4).

Elements	Description
Subscript j	End-use energy type, including 1) diesel, 2) fuel oil, 3) petrol, 4) LPG, 5) kerosene, 6) ATF and AV gas, 7) refinery gas, 8) natural gas, 9) coal and coke, 10) biodiesel, and 11) electricity.
C	Total CO_2 emissions
P	Population
GDP	Gross domestic production
E_{SQ}	Total end-use energy consumption expressed in Standard Quantity (SQ) form
$E_{SQ,j}$	Total consumption of energy j in the end-use sector expressed in SQ form
$K_{PEQ,j}$	Primary energy quantity converted factor of energy j
$K_{C,j}$	Primary carbon dioxide emission factor of energy j

Table 3
LMDI additive formulas for decomposing the energy-related CO_2 emission growth of Malaysia.

IDA identity		$C = \sum_j P \cdot \frac{GDP}{P} \cdot \frac{E_{SQ}}{GDP} \cdot \frac{E_{SQ,j}}{E_{SQ}} \cdot K_{PEQ,j} \cdot K_{C,j}$	
Driving factors	**Symbols**	**LMDI additive formulae**	**LMDI multiplicative formulae**
Change scheme	-	$\Delta C_{tot} = C^T - C^0 = \Delta C_{pop} + \Delta C_{gdp} + \Delta C_{int} + \Delta C_{mix} + \Delta C_{peq} + \Delta C_{emi}$	$D_{tot} = D^T/D^0 = D_{pop} D_{gdp} D_{int} D_{mix} D_{peq} D_{emi}$
Population	P	$\Delta C_{pop} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{P^T}{P^0}\right)$	$D_{pop} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{P^T}{P^0}\right)\right)$
GDP per capita	$Q = \frac{GDP}{P}$	$\Delta C_{gdp} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{Q^T}{Q^0}\right)$	$D_{gdp} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{Q^T}{Q^0}\right)\right)$
Energy intensity	$I_i = \frac{E_{SQ,i}}{GDP_i}$	$\Delta C_{int} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{I^T}{I^0}\right)$	$D_{int} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{I^T}{I^0}\right)\right)$
End-use energy structure	$M_j = \frac{E_{SQ,j}}{E_{SQ}}$	$\Delta C_{mix} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{M_j^T}{M_j^0}\right)$	$D_{mix} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{M_j^T}{M_j^0}\right)\right)$
Electricity generation efficiency	$K_{PEQ,j}$	$\Delta C_{peq} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{K_{PEQ,j}^T}{K_{PEQ,j}^0}\right)$	$D_{peq} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{K_{PEQ,j}^T}{K_{PEQ,j}^0}\right)\right)$
Fuel-mix in electricity generation	$K_{C,j}$	$\Delta C_{emi} = \sum_j \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0} \ln\left(\frac{K_{C,j}^T}{K_{C,j}^0}\right)$	$D_{emi} = \exp\left(\sum_j \left(\frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}\right) \cdot \left(\frac{\ln C^T - \ln C^0}{C^T - C^0}\right) \ln\left(\frac{K_{C,j}^T}{K_{C,j}^0}\right)\right)$

Note: The superscripts 0 and T specify the parameter value at time 0 and T, respectively.

The LMDI formulas for decomposing energy-related CO_2 emission growth in Malaysia are presented in Table 3.

3.4. Data input

The energy balance table [60] published by the Malaysia Energy Information Hub (MEIH) was the original data source for the energy flow. The series of end-use energy consumption data [61] and power generation structure data [9] were also obtained from the MEIH.

In addition, the economic data were obtained from The World Bank [62]. The data processing approach used to obtain K_{PEQ} and K_C for electricity can be found in Ref. [38]; the K_{PEQ} for other energy types was considered as 1.00.

The K_C for other energy types was taken from the Intergovernmental Panel on Climate Change (IPCC) [63]: diesel 3.10 t/toe, fuel oil 3.24 t/toe; gasoline 2.90 t/toe; LPG 2.64 t/toe; Kerosene and ATF 2.99 t/toe; Refinery gas 2.41 t/toe; natural gas 2.35 t/toe, coal 4.11 t/toe; hydraulic and biofuel 0 t/toe.

We presented these data in Appendix part: Table A1, end-use energy consumption data; Table A2, energy mix in thermal power plants, electricity generation in thermal power plants, and K_{PEQ} of electricity; Table A3, CO_2 emissions in thermal power plants, and K_C of electricity; Table A4, CO_2 emissions according to the energy type.

4. Results

4.1. Energy allocation Sankey diagram of Malaysia

The energy allocation Sankey diagram for Malaysia in 2014 is presented in Fig. 1. According to the diagram, the main features of Malaysia's energy system, including energy supply, energy conversion, and energy end-use, are as follows:

1. Natural gas and crude oil were the major domestic primary energy suppliers for Malaysia, accounting for 64.0% and 29.9% of the domestic primary energy supply in 2014, respectively, while hydraulic, coal, and other renewable energy contributed only 3.5%, 1.7%, and 0.9% of the domestic primary energy supply, respectively.
2. Malaysia is a net exporter of crude oil and natural gas, with 97% of the natural gas exported in LNG form. However, 89.0% of Malaysia's coal supply was imported.
3. Fire-power plants are the major electricity supplier in Malaysia. Natural gas (including LNG) fired-power plants and coal-fired power plants accounted for 44.1% and 43.4% of total electricity supply, respectively. Renewable energy, mainly from hydraulic, accounted for only 9.1%, and the rest of the renewable energy sources accounted for 0.5%. Oil products also contributed 2.9% of electricity generation.
4. The manufacturing sector, including the industrial (40.2%) and agriculture (1.5%) sectors, was the largest end-use energy sector in

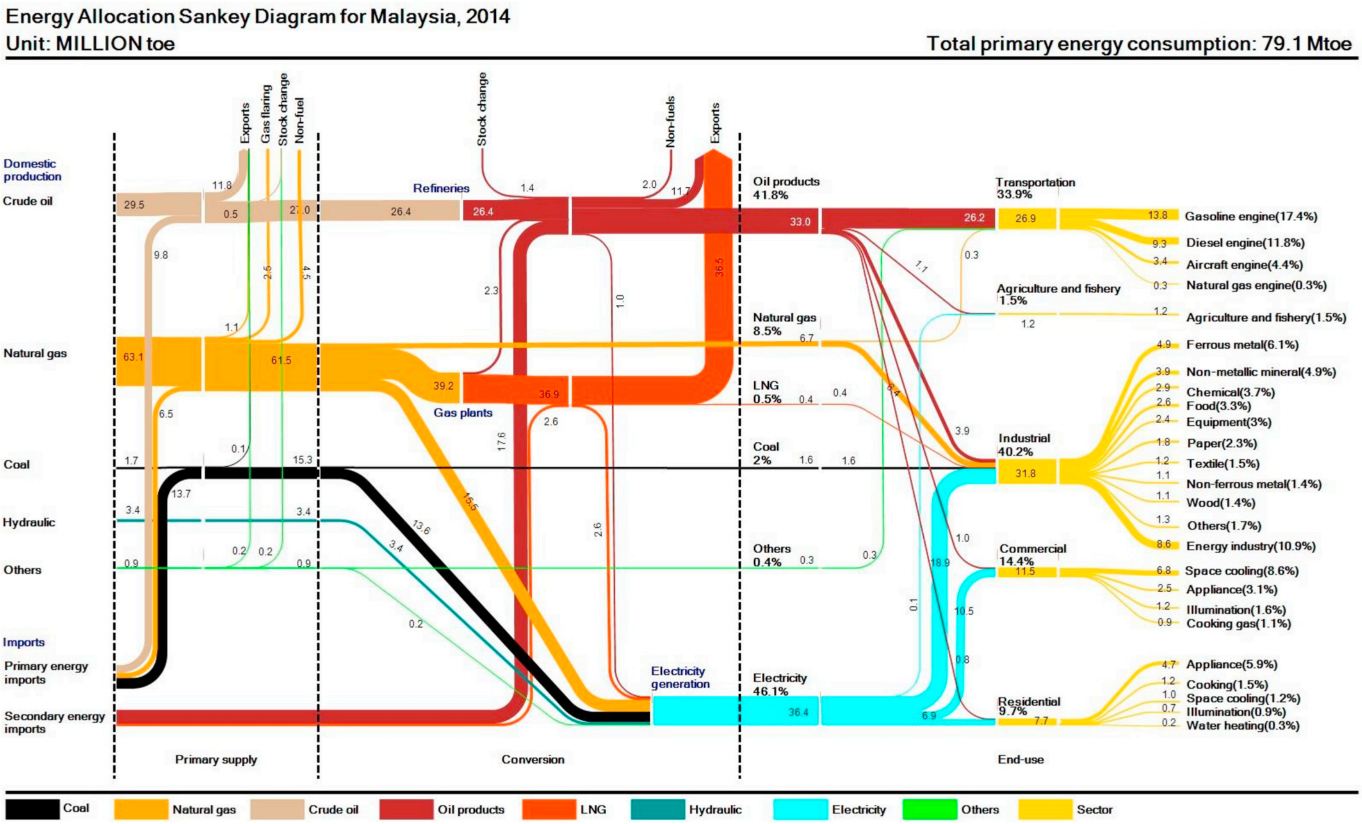

Fig. 1. Energy allocation Sankey diagram for Malaysia, 2014 (Note: the value of energy is expressed in primary energy quantity form).

Malaysia, accounting for 41.7% of the total primary energy consumption in 2014, whereas the transportation and commercial sector (11.6%) and the residential sector (7.7%) accounted for 34.0% and 24.3% of the total primary energy consumption, respectively. Electricity (46.1%), oil products (41.8%), and natural gas (8.5%) were the major energy types in the end-use stage.

4.2. Energy consumption and its CO_2 emissions in Malaysia

Before discussing the driving factors behind the energy-related CO_2 emission growth of Malaysia, the historical energy consumption and its related CO_2 emissions should be understood, as illustrated in Fig. 2. The calculation of energy-related CO_2 emissions can be seen in equation (3).

Referring to Fig. 2, the following can be seen:

- Over the entire time period of 1978–2014, end-use energy consumption grew from 5.04 to 53.50 Mtoe, with an average annual growth rate (AAGR) of 6.78%, while its related CO_2 emissions grew from 19.65 to 206.68 Mt, with an AAGR of 6.75%;
- In the first period, 1978–1990, end-use energy consumption grew from 5.04 to 13.18 Mtoe, with an AAGR of 8.34%, and its related CO_2 emissions grew from 19.65 to 49.80 Mt, with an AAGR of 8.06%;
- In the second period, 1990–2002, end-use energy consumption grew from 13.18 to 33.12 Mtoe, with an AAGR of 7.98%, and its related CO_2 emissions grew from 49.80 to 123.18 Mt, with an AAGR of 7.84%;
- In the third period, 2002–2014, end-use energy consumption grew from 33.12 to 53.50 Mtoe, with an AAGR of 4.08%, and its related CO_2 emissions grew from 123.18 to 206.68 Mt, with an AAGR of 4.41%.

By analysing historical trends, it was revealed that the growth rate of energy consumption and its related CO_2 emissions in Malaysia are quite similar throughout the period 1978–2014. Furthermore, comparing multifarious time periods shows that during the periods 1978–1990 and 1990–2002, the growth rate of energy-related CO_2 emissions was lower than the growth rate of energy consumption. However, during the period 2002–2014, the growth rate of energy-related CO_2 emissions and energy consumption reverse positions. This phenomenon illustrates the urgency of carrying out this research, because although the Malaysian government has announced the goal of reducing CO_2 emissions, the CO_2 emission factor of energy are still growing in recent years.

4.3. LMDI decomposition results of energy-related CO_2 emission growth

The additive and multiplicative LMDI decomposition results of energy-related CO_2 emission growth in Malaysia are presented in Figs. 3 and 4, respectively. The LMDI decomposition results show that:

- During the period 1978–1990, the continued growth of GDP per capita, population, energy intensity, and the proportion of electricity in the end-use energy structure were the main driving factors behind energy-related CO_2 emission growth. Although the increasing electricity generation efficiency and the change in fuel-mix in the electricity generation sector reduced energy-related CO_2 emission growth, the effect was not obvious.
- During 1990–2002, the continued growth of GDP per capita, population, and share of electricity in the end-use stage remained the main reasons for energy-related CO_2 emission growth, yet the growth of population and energy intensity gradually began to account for a small proportion of the cause of the growth of energy-related CO_2 emissions and the effects of GDP per capita intensified. The growth of electricity generation efficiency and the change in fuel-mix in the electricity generation still lowered energy-related

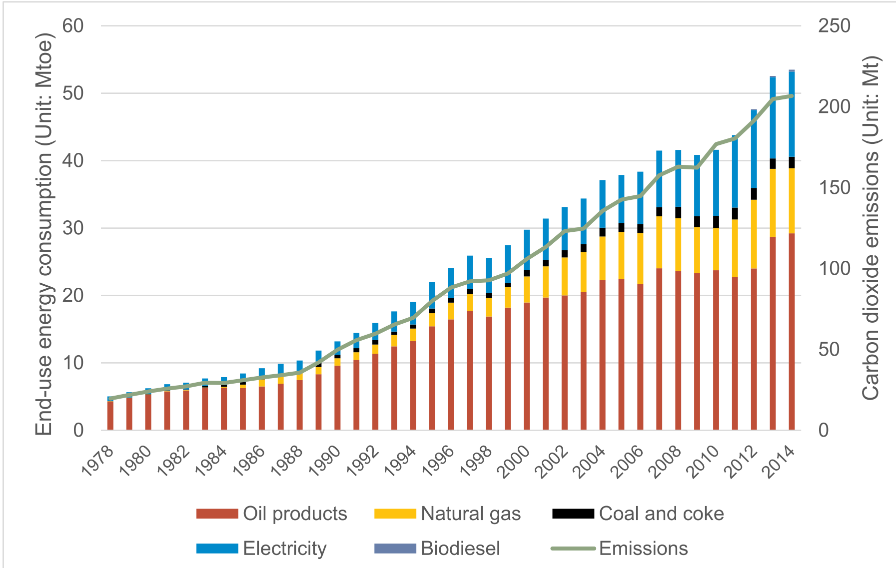

Fig. 2. End-use energy consumption in SQ form (heat value form) in Malaysia and their CO_2 emissions in 1978–2014, detailed data can be referred to Tables A1 and A4, in appendix part.

CO_2 emissions in comparison with the previous period, the mitigation effect of electricity generation efficiency grew, and the mitigation effect of the change in the fuel-mix in electricity generation decreased.

- During the period 2002–2014, the continued growth of GDP per capita, population, and share of electricity in the end-use stage persisted as the major reasons for energy-related CO_2 emission growth. However, the contribution of population was much lower than that during the previous two periods, and the contribution of GDP per capita was also lower than that during the previous period. During this period, energy intensity, which had been the cause of the growth of energy-related CO_2 emissions during the previous two periods, became the most important factor for decreasing the growth of energy-related CO_2 emissions. In addition, the growth of electricity generation efficiency contributed more to lowering energy-related CO_2 emissions than during the previous period. However, the change in the fuel-mix in electricity generation transformed from a factor decreasing energy-related CO_2 emissions to a factor increasing energy-related CO_2 emissions.

4.3.1. *The influence of population*

Malaysia's population growth had a significant influence on energy-related CO_2 emissions during the periods 1978–1990, 1990–2002, and 2002–2014, with each causing a 36.9% (10.19 Mt), 33.7% 23.53 Mt), and 22.3% (32.49 Mt) increase in energy-related CO_2 emissions.

From the data, it was found that, although energy-related CO_2 emissions caused by population growth were increasing, the relative emissions were decreasing year by year. The major reason was that the population in Malaysia increased beginning in 1978 with AAGR of 2.34%, which sped up population growth until 1988. In 1988, the

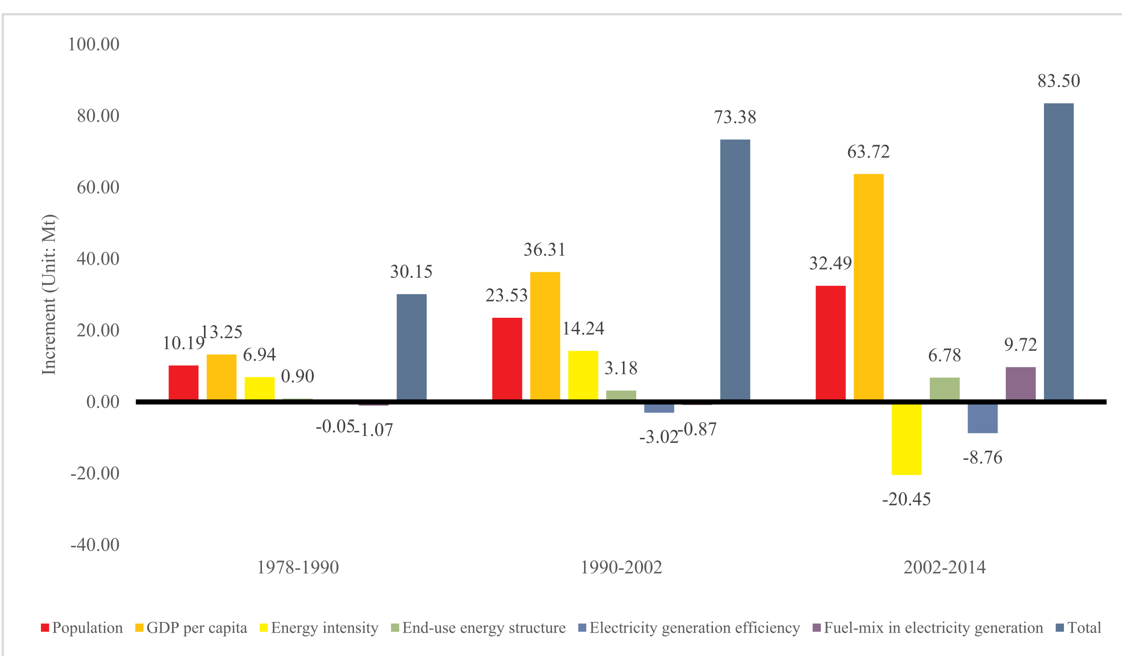

Fig. 3. LMDI decomposition results (additive) of energy-related CO_2 emissions increment in Malaysia (Units: Mt).

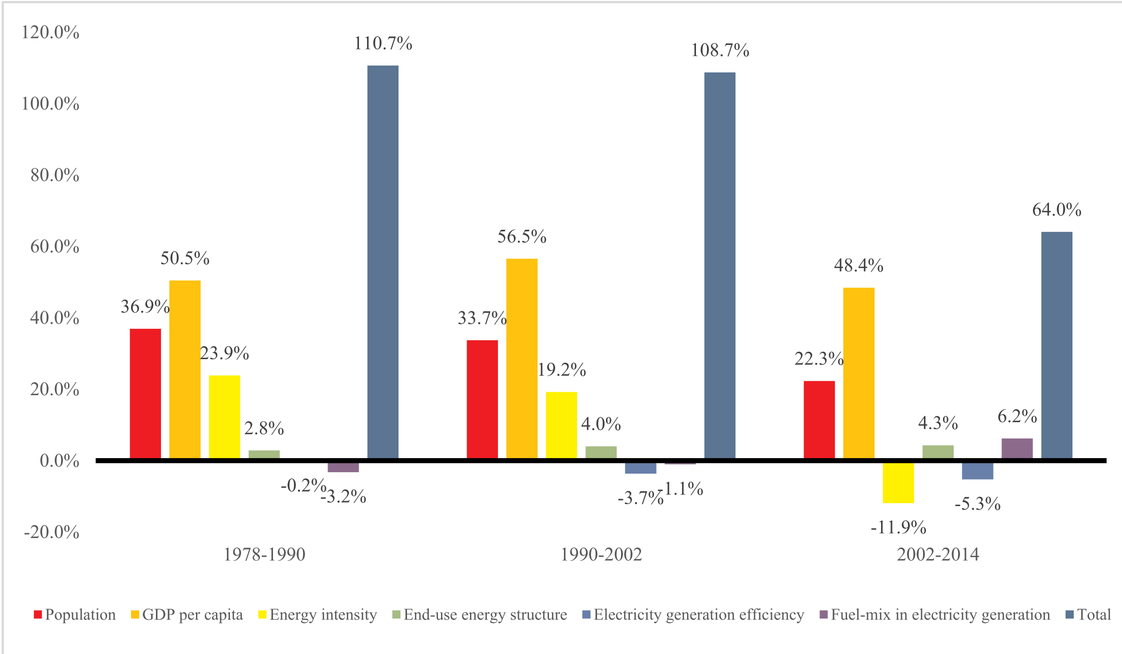

Fig. 4. LMDI decomposition results (multiplicative) of energy-related CO_2 emissions increment in Malaysia.

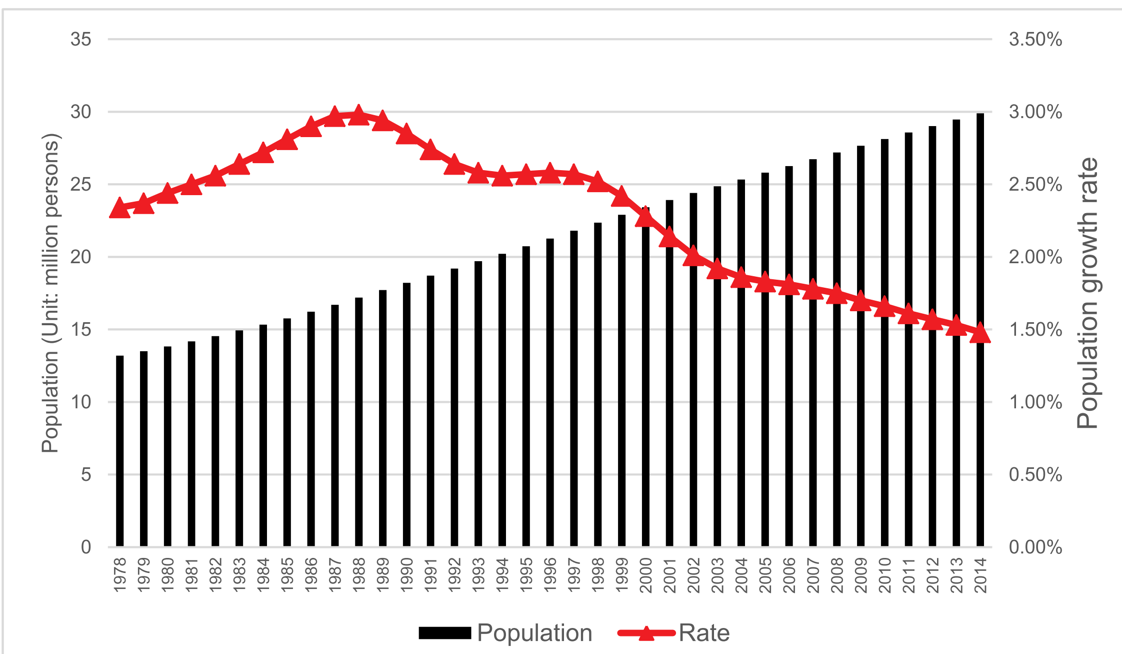

Fig. 5. Population and its growth rate in Malaysia, 1978–2014 [62].

population growth rate in Malaysia reached a peak of 2.98%, and then started to decrease until 2014 with AAGR of 1.48%. During the periods 1978–1990, 1990–2002, and 2002–2014 the average annual population growth rate in Malaysia was 2.72%, 2.47% and 1.71%, respectively, as shown in Fig. 5.

In the future, if Malaysia's population growth rate continues to decline, the impact of population factors on energy-related CO_2 emissions will lessen. The importance and necessity of population policies to influence energy-related CO_2 emissions is relatively small. However, the Malaysian government should consider the influence of immigration on population growth.

4.3.2. *The influence of GDP per capita*

The growth of GDP per capita in Malaysia was the major factor that drove energy-related CO_2 emission growth during the periods 1978–1990, 1990–2002, and 2002–2014, with contributions in each period being 50.5% (13.25 Mt), 56.5% (36.31 Mt), and 48.4% (63.72 Mt), respectively.

During the entire period from 1978 to 2014, GDP per capita in Malaysia showed the following trends: during 1978–1990, GDP grew from 2,953 to 4,492 USD, and the AAGR was 3.56%; during 1990–2002, GDP grew from 4,492 to 7,056 USD, and the AAGR was 3.83%; and during 2002–2014, GDP grew from 7,056 to 10,512 USD, and the AAGR was 3.38%. During the first and second periods, Malaysia

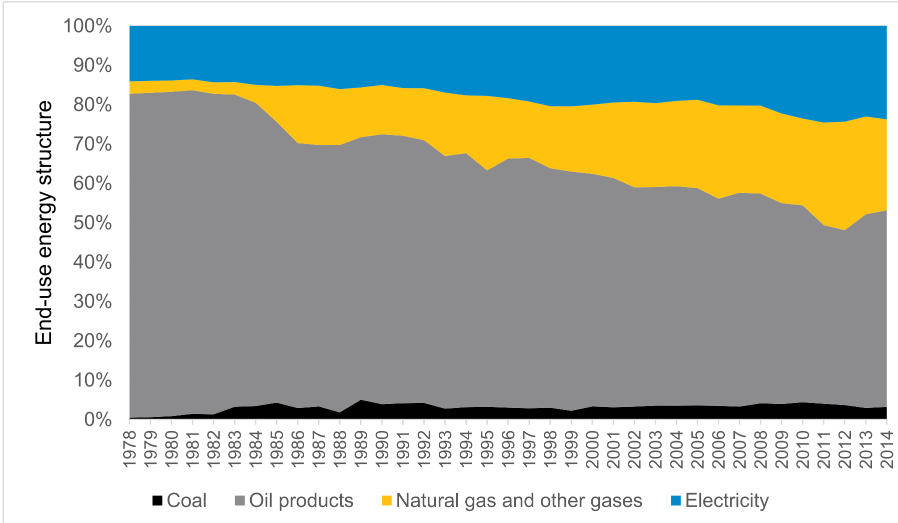

Fig. 6. Malaysia's end-use energy structure.

experienced rapid industrialization, urbanization, and motorization. During these two periods, the country faced a tremendous economic boom, especially during the second period, in which secondary industry was the primary focus. After 2002, the country stepped into the late industrialization period and was focused mainly on the tertiary sector. At this point, the growth of GDP per capita in Malaysia started to slow down. During the third period, Malaysia shifted its attention to the tertiary sector, which mainly focused on knowledge-intensive industries.

Although Malaysia has entered the late stage of industrialization, its GDP per capita is still far lower than developed countries. For example, in 2016, the GDP per capita of the United Kingdom was 3.8 times that of Malaysia [64]. On the basis of the trends of developed countries, the GDP per capita of Malaysia should continue to grow in the future, but its growth rate will be lower than that seen in the mid-industrialization stage. Therefore, the growth of the per capita GDP will remain the main driving factor for the growth of energy-related CO_2 emissions in Malaysia.

4.3.3. The influence of energy intensity

Malaysia's energy intensity increased energy-related CO_2 emission growth at a rate of 23.9% (6.94 Mt) and 19.2% (14.24 Mt) during the periods 1978–1990 and 1990–2002, respectively, and decreased growth at a rate of 11.9% (−20.45 Mt) during the period 2002–2014.

During the entire period of 1978–2014, the energy intensity in Malaysia showed the following trends: from 1978 to 1990, it increased from 0.1294 to 0.1611 toe/USD, with an AAGR of 1.84%; from 1990 to 2002, it increased from 0.1611 to 0.1924 toe/USD, with an AAGR of 1.49%; and from 2002 to 2014, it decreased from 0.1924 to 0.1693 toe/USD, with an AAGR of −1.06%. During the first period, Malaysia had higher energy intensity, as the country's industrial sector transformed from light to heavy industry and the country's infrastructure gradually matured. During this period, Malaysia primarily constructed infrastructure such as roads and factories to develop the country's industrial sector. During the second period, Malaysia still maintained a high rate of economic development, and energy intensity was also increasing gradually. However, the growth rate in energy intensity decreased compared with the first period, mainly because of increasing end-use energy efficiency and the introduction of energy-saving concepts. During the third period, the country had moved to the late industrialization period. That meant that Malaysia's industrial sector had tended to optimize and move to the tertiary sector, including aspects like financial and tourist services, which had lower energy intensity.

Although Malaysia's energy intensity has been declining rapidly in recent years, it is still far higher than that of developed countries. For example, in 2016, Malaysia's energy intensity was 3.4 times that of the United Kingdom [64,65]. Thus, compared to other driving factors, Malaysia's energy intensity decline will likely be the best way to mitigate energy-related CO_2 emissions in the near future. Therefore, the Malaysian government should continue to promote industrial upgrading, improving energy utilization efficiency in the end-use sector, in order to further reduce energy intensity.

4.3.4. The influence of end-use energy structure

The changes in Malaysia's end-use energy structure increased energy-related CO_2 emissions during the periods 1978–1990, 1990–2002, and 2002–2014, which contributed by 2.8% (0.90 Mt), 4.0% (3.18 Mt), and 4.3% (6.78 Mt), respectively. The increased proportion of electricity, coal, and natural gas in Malaysia's energy consumption significantly increased energy-related CO_2 emissions, whereas the decreased proportion of oil products reduced the total energy-related CO_2 emissions.

In the 1970s, Malaysia's economic development faced significant repercussions from two oil crises, which prompted the Malaysian government to devote attention to energy security. Through various efforts, the National Energy Policy was announced in 1979 [45].

In 1981, the Malaysian government further introduced the Four-Fuels Diversification Policy [66], which was aimed at reducing overdependence on crude oil and oil products, and also strove hard to replace those sources with natural gas, coal, and hydraulics. As a result of this policy, a portion of oil products' share in the end-use energy structure (from 82.3% in 1978 to 49.4% in 2014) was replaced by natural gas (from 3.2% in 1978 to 23.1% in 2014), which directly contributed to lowering energy-related CO_2 emissions. The end-use consumption of coal grew slowly compared with natural gas. The proportion of coal in the end-use energy structure increased from 0.5% in 1978 to 3.2% in 2014, which contributed a small amount of energy-related CO_2 emissions. Malaysia's end-use energy consumption structure can be seen in Fig. 6.

Additionally, because of improvements in lifestyle and the transformation of the economy, the proportion of electricity in the end-use energy structure increased from 14.1% in 1978 to 23.7% in 2014. Notably, The increasing proportion of electricity in the end-use energy structure significantly increased energy-related CO2 emissions. The major cause behind this is the fact that the production of electricity consumes more fossil fuels per unit. For example, in 2014, producing 1 toe of electricity consumed 2.48 toe of primary energy and emitted 7.24 t of energy-related CO_2 emissions.

Because generation of electricity still relies heavily on coal and natural gas, the proportion of non-fossil fuels is still small; the rapid growth of the proportion of electricity in the end-use energy structure will surely bring on more energy-related CO_2 emissions. Electricity generation efficiency and the electricity generation structure will be discussed in more detail in Sections 4.3.5 and 4.3.6. Obviously, the proportion of electricity in end-use energy consumption will continue to increase in the future in residential, commercial, and industrial sectors. Hence, the Malaysian government needs to limit unnecessary electricity consumption and promote electricity conservation awareness to the public. For example, according to the author's personal experience, although Malaysia is located in an equatorial region, the indoor temperature of most commercial buildings and government offices is so low that most staff and visitors need to wear jackets. According to the energy allocation Sankey diagrams, space cooling accounted for most of the energy consumption in both the commercial and residential sectors. Hence, controlling indoor temperature within an appropriate range will help to reduce electricity consumption and thus reduce energy-related CO_2 emissions.

4.3.5. The influence of electricity generation efficiency

Malaysia's electricity generation efficiency did not significantly influence the energy-related CO_2 emissions during the period 1978–1990, but it did decrease the energy-related CO_2 emissions during 1990–2002 and 2002–2014, with rates of 3.7% (−3.02 Mt) and 5.3% (−8.76 Mt).

During 1978–1990, oil-fired power plants and conventional gas-fired power plants with lower energy conversion efficiency contributed most of the electricity supply of Malaysia. During 1990–2002 and 2002–2014, more natural gas combined cycle (NGCC) thermal power plants and advanced coal-fired power plants with higher energy conversion efficiency were built, which improved the average electricity generation efficiency in Malaysia [67], as shown in Fig. 7.

Coal-fired power plants, NGCC power plants, gas turbine power plants, and conventional gas-fired (oil-fired) power plants are the major types of power plants in Malaysia (Fig. 8). In 2008, the electricity generation efficiency of these types of power plants were 35%, 44%, 29%, and 35%, respectively [67]. Compared to conventional gas-fired power plants and gas turbine power plants, NGCC power plants have higher electricity generation efficiency. Therefore, if Malaysia wants to reduce CO_2 emissions from the electricity generation sector, NGCC power plants should be preferred over the newly built gas-fired power plants, while the existing conventional gas-fired power plants and gas turbine power plants should be modified to function as NGCC power plants instead. The existing coal-fired power plants could also be upgraded and retrofitted to increase their electricity generation efficiency.

4.3.6. The influence of fuel-mix in electricity generation

The change of fuel-mix in Malaysia's electricity generation decreased the energy-related CO_2 emissions during both 1978–1990 and 1990–2002, with rates of 3.2% (−1.07 Mt) and 1.1% (−0.87 Mt), respectively, while it increased energy-related CO_2 emissions during 2002–2014, with a rate of 6.2% (9.72 Mt).

Since the Malaysian government started promoting the Four-Fuels Diversification Policy, gas-fired power plants have become the major electricity suppliers in Malaysia, as the proportion of electricity from gas-fired power plants increased from 0.9% in 1978 to 75.2% in 2000. However, out of consideration for natural gas depletion and national energy security, the government proposed reducing the proportion of natural gas in power generation. Since 1988, coal-fired power plants began contributing less to electricity supply. The proportion of coal-fired power reached its peak in 2012, at 48.6%, and then decreased to 43.4% in 2014. Although hydraulic power generation grew continuously, the proportion of hydraulic first increased from 10.8% in 1978 to 29.4% in 1988, only to decrease to 9.1% by 2014.

The fuel-mix in Malaysia's electricity generation is shown in Fig. 9. As a result of the fuel-mix adjustment in electricity generation, the CO_2 emissions factor for electricity first decreased from 2.87 in 1978 to 2.11 in 1988, then increased to 3.09 by 2011, and then decreased to 2.92 by 2014, as illustrated in Fig. 10.

Although Malaysia has abundant natural gas and renewable energy resources, the Malaysian government is promoting coal-fired power. As a result, the proportion of coal in the fuel-mix of electricity generation has increased significantly in recent years and has contributed to energy-related CO_2 emission growth. In addition, we also found that the proportion of non-fossil energy in the fuel-mix of electricity generation is still very small, accounting for only 10% in 2014. Although the Malaysian government has introduced many policies to promote renewable energy power generation, it has not achieved the desired results. At present, many researchers have offered different opinions on the development of renewable energy in Malaysia and provided corresponding policy suggestions [68–73]. However, we still recommend that the Malaysian government, even in the case of the slow development of renewable energy power generation, should control the development of coal-fired power and build more NGCC power plants with high energy-conversion efficiency to meet Malaysia's electricity demand. We also urge the Malaysian government to reconsider the development of nuclear power.

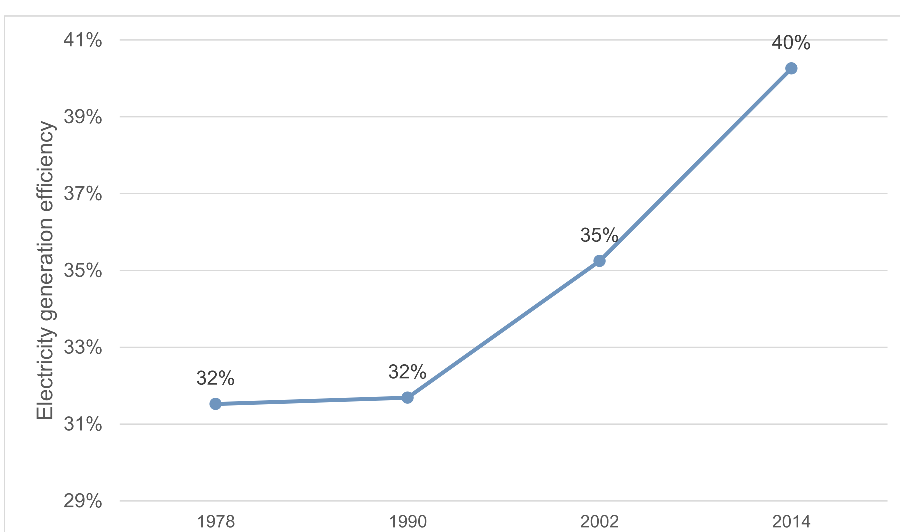

Fig. 7. Electricity generation efficiency in Malaysia.

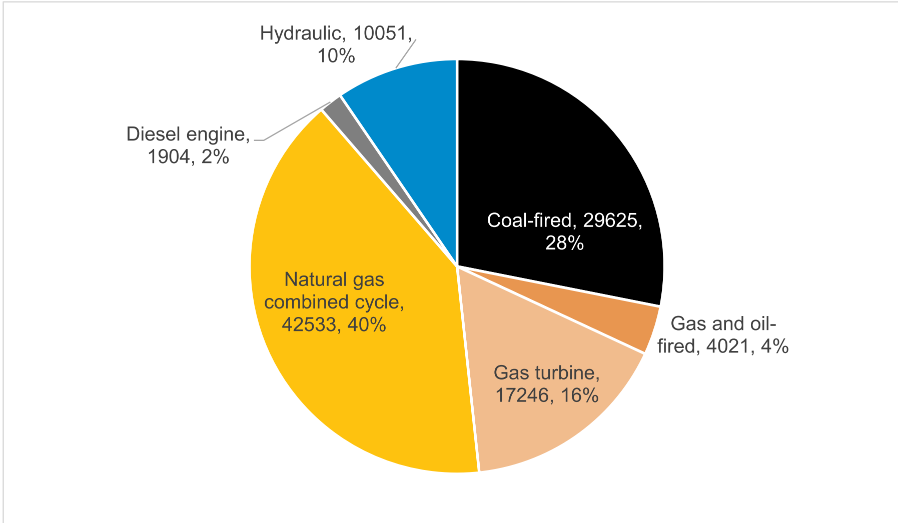

Fig. 8. Electricity generation for various types of power plants in Malaysia, 2008 (Unit: GWh).

4.4. The influence of resource availability

The fact that Malaysia is rich in resources has determined its end-use energy consumption structure and electricity generation structure. Malaysia has abundant crude oil and natural gas resources, their proven reserves of which were 3.6 billion barrels and 2.7 trillion cubic meters in 2017 [74].

It can be seen that, before 1980, countries in the region mostly relied on oil products, regardless of the end-use energy structure or fuel-mix in electricity generation. After the oil crisis, the government of Malaysia began to pay attention to a diversified development of energy and to actively increase the role of natural gas both in the end-use energy structure and in the fuel-mix in electricity generation. Although Malaysia has some coal reserves (about 2 billion tons [70]), they are difficult to acquire because of their remote geographical position. However, to achieve the target diversification of its energy consumption structure and to ensure a cheap supply of electricity, Malaysia has begun to build large-scale coal-fired power plants and to import coal from Indonesia and Australia [75].

Malaysia has several non-hydro renewable energy resources [76]. Since they were first officially promoted in Malaysia in 2000, their utilization has gradually increased through the efforts of the government [45]. However, the proportions of these energies in the energy supply structure are still low.

So far, there are no nuclear power plants in Malaysia.

5. Discussion of the results

Before discussing our findings, we would like to introduce the research contents and results of studies on similar issues from other scholars. As we mentioned in the literature review, most of these studies are based on econometric methods designed to test whether Malaysia's energy-related CO_2 emissions and economic development (represented by GDP per capita) conform to the Kuznets curve hypothesis or whether economic development will inhibit energy-related CO_2 emissions [20,77]. In other words, during the period from the early industrialization to the middle and late industrialization, Malaysia's energy-related CO_2 emissions would be expected to show an upward trend with economic development, while after the middle and late industrialization, Malaysia's energy-related CO_2 emissions would be expected to show a downward trend with economic development.

In this study, our results show that economic development (GDP per capita) is the most important factor in increasing the growth of energy-related CO_2 emissions, whether in 1978–1980, 1980–1992, or

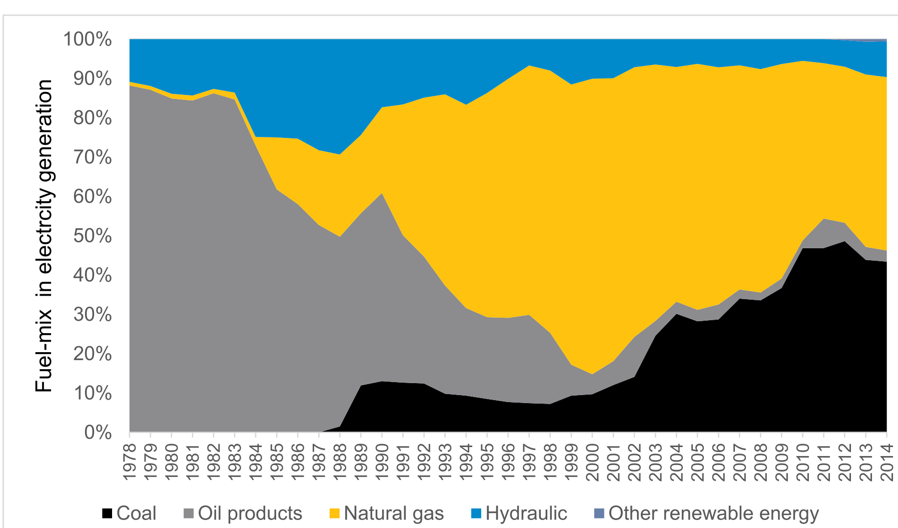

Fig. 9. Fuel-mix in electricity generation in Malaysia from 1978 to 2014.

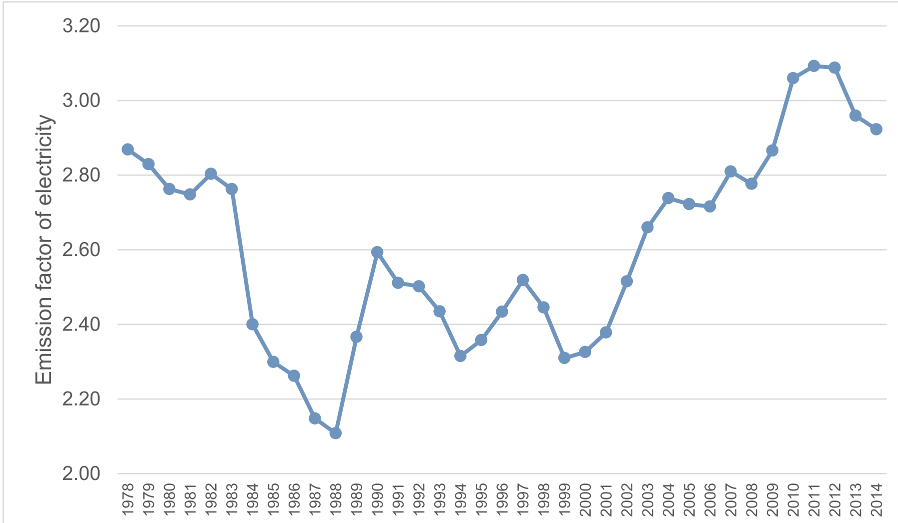

Fig. 10. CO_2 emission factor, not considering energy conversion efficiency and considering only the fuel-mix in electricity generation, in Malaysia, 1978–2014.

1992–2014. Moreover, considering the characteristics of the LMDI decomposition method adopted in this study, as long as the economy continues to develop, it will continue to contribute to the increase of energy-related CO_2 emissions. However, the overall results of this study are still consistent with those of previous studies. The main reason is that using the LMDI decomposition method, along with the impact of economic indicators such as population and GDP per capita on energy-related CO_2 emissions, the impact of technical indicators reflecting the characteristics of the energy system on energy-related CO_2 emissions can also be considered, and these technical indicators will likely inhibit the growth of energy-related CO_2 emissions. With the passage of time, which can otherwise be understood as economic development, these changes in technical indicators will begin to inhibit energy-related CO_2 emissions such that the growth rate of energy-related CO_2 emissions is lower than the economic growth rate. When the energy-related CO_2 emissions restrained by the changes of these technical indicators exceed the rate of increase of energy-related CO_2 emissions contributed by economic growth, the energy-related CO_2 emissions will reach their peak and show a downward trend. That is to say, because these technical indicators are tightly intertwined with economic indicators, there is a quantitative relationship between energy-related CO_2 emissions and economic development, which first increases and then decreases, as explained by the Kuznets curve hypothesis.

In the LMDI decomposition method adopted in this study, the technical indicators considered included energy intensity, end-use energy structure, electricity generation efficiency, and fuel-mix in electricity generation. It can be seen that, although energy intensity increased in 1978–1980 and 1980–1992, contributing to the increase in energy-related CO_2 emissions, it showed a downward trend in 1992–2014, thus inhibiting energy-related CO_2 emissions. The reasons for the decline in energy intensity included not only the improvement in end-use energy efficiency but also the transformation of the economic structure from heavy chemical industries with high energy intensity to advanced manufacturing and tertiary industries. In addition, in 1978–2014, the continuous improvement of electricity generation efficiency was also one of the main factors in restraining the growth of energy-related CO_2 emissions, while the increasing proportion of electricity in the end-use energy consumption continued to contribute to the increase in energy-related CO_2 emissions. The changes in Malaysia's fuel-mix in electricity generation restrained energy-related CO_2 emissions from 1978 to 2002, but in 2002–2014 they suddenly contributed more to the increase in energy-related CO_2 emissions, mainly due to the significant increase in the proportion of coal in the fuel-mix in electricity generation during this period. Therefore, observing these three factors separately can further explain the impact of technical factors on energy-related CO_2 emission growth in more detail, especially when combined with detailing changes in the energy system.

In summary, we can find that the change in energy-related CO_2 emissions rates is mainly the result of the interaction between economic factors and technical factors. When the mitigation of energy-related CO_2 emissions that were restrained by technical indicators exceeds the amount of energy-related CO_2 emissions contributed by economic indicators, energy-related CO_2 emissions will show a downward trend. Therefore, the results of the LMDI decomposition method are consistent with results based on econometrics methods. Compared with econometric methods, the LMDI decomposition method considers more technical factors—it can consider the driving factors more comprehensively from both economic and technical perspectives and provide policy makers with more policy recommendations related to the energy system. In addition, the results and discussions of the technical influencing factors considered in the LMDI decomposition method can provide support for the conclusions drawn from econometric methods and further explain the mitigation mechanism of energy-related CO_2 emissions.

6. Policy implications

Before we gave policy implications, we reviewed Malaysia's past energy-related policies and acts. We can see that since the founding of Malaysia, the country's energy-related policies and acts concerns have undergone changes in the following manner: 1) diversification of fossil energy and hydraulic consumption; 2) development of renewable energy; 3) improvement of energy efficiency and promotion of new technologies; 4) more and more emphasis on actively facing the challenge of global climate change. These changes are shown in Table 4.

Comparing these policy changes with our results, we find that (1) the energy diversification policy promoted by the Malaysian government before 2000 was successful; (2) the National Green Technology Policy played a role in improving energy efficiency after 2009; and (3) the effect of the Fifth Fuel Policy in 2000 and the National Renewable Energy Policy and Action Plan in 2010 had no significant effect.

It can also be seen that the political changes in Malaysia in May 2018 brought uncertainties to the country's energy development [78]. Because of the emerging new concept of governing, energy development in Malaysia faces uncertainty. For example, the dominant market position of Petronas, owned by the Malaysian government and vested with its entire store of oil and gas resources, has become controversial [79]. Furthermore, the serious ecological crisis due to large-scale

Table 4
A summary of energy-related acts and policies in Malaysia [5,7,8].

Acts/Policies	Year	Description
Petroleum Development Act	1974	Establish state-owned oil and gas company, Petronas.
National Petroleum Policy	1975	Regulate the oil and gas industries to achieve the country's economic needs.
National Energy Policy	1979	Ensure the stability of energy supplies, which is the guideline for energy policy in the future, based on three principal objectives: supply objectives, utilization objectives, and environment objectives.
National Depletion Policy	1980	Safeguard the country's finite and non-renewable petroleum resources from over-exploitation.
Four-Fuels Diversification Policy	1981	Reduce over-dependence on oil as the main energy source, and replace oil with natural gas, coal, and hydro.
Fifth Fuel Policy	2000	Introduce renewable energy as fifth fuel.
National Biofuel Policy	2006	Encourage the use of environmentally friendly, sustainable, and viable sources of biomass energy.
National Green Technology Policy	2009	Provide direction and motivation for Malaysians to continuously enjoy a good quality of life and a healthy environment, including improving energy efficiency.
National Renewable Energy Policy and Action Plan	2010	Promote renewable energy, including a comprehensive roadmap of Malaysian renewable energy development.
National Policy on Climate Change	2009	Ensure climate-resilient development to fulfil national aspirations for sustainability.
INDC	2015	Malaysia intends to reduce its greenhouse gas (GHG) emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005.

hydraulic development in Sarawak (which takes up more than 90% of Malaysian hydraulic resources) has also fostered controversy, particularly because blocking the rivers to build dams drowns a large area of tropical rain forest and also destroys the culture of local minorities [80,81]. At the same time, Malaysia's Ministry of Energy, Green Technology and Water announced that the government will reconsider Malaysia's nuclear power development plan and set it aside [82]. Thus, it can be seen that the current energy policy and carbon reduction road map still contain great uncertainty. Therefore, the government should combine its governing concept and the current economic and energy development to promote low-carbon development in Malaysia.

On the basis of the results in section 4 and discussions in section 5, through the comparison with the above review of existing policies and policy debates, the policy implications of this study can be summarized as follows:

- The Malaysian government must study and determine long-term control targets for total energy-related CO_2 emissions as soon as possible, and most crucially, they must develop predictions of the nation's peak of energy-related CO_2 emissions and actively guide society to reach that peak as soon as possible. By doing so, the government can strengthen the climate change awareness of society as a whole and promote the introduction and implementation of the following energy policy suggestions. As described in the introduction and the above policy review, Malaysian society still lacks sufficient willingness to rapidly transition the energy system and build a low-carbon society. Currently, Malaysia's energy-related CO_2 emissions continue to increase along with the growth of economy and, therefore, will face more and more pressure to reduce CO_2 emissions in the future.
- The Malaysian government must further strengthen the control of energy intensity in the near-term through increasing end-use energy efficiency and adjusting the economy structure. From the perspective of economic development, the government of Malaysia does not have any reason to lower energy-related CO_2 emissions by reducing population or limiting their economic growth. However, the GDP per capita will remain the main driving factor of energy-related CO_2 emission growth in the future. Therefore, this increased contribution may be offset through reducing energy intensity.
- The Malaysian government must focus on exploring and reflecting on the reasons for the slow development of renewable energy and should systematically plan a roadmap for renewable energy development in light of economic development, national income, and the formation mechanism of energy prices, so as to ensure that the roadmap is acceptable to all stakeholders.
- The Malaysian government must restrict the development of coal-fired power plants. Even if the development of renewable energy is still slow, the Malaysian government should give priority to building NGCC power plants, which have higher electricity generation efficiency and lower CO_2 emissions. This is mainly due to the fact that the rapidly increasing proportion of coal in the fuel-mix of electricity generation has become one of the main factors driving the growth of energy-related CO_2 emissions in Malaysia since 2000.
- The Malaysian government must instil energy-saving awareness in its citizens in order to reduce unnecessary electricity consumption. In particular, people need to understand that indoor temperatures should not be set too low as a means of reducing unnecessary space-cooling-related electricity consumption, which accounted for 59% and 13% of energy consumption in the commercial and residential sectors, respectively.

7. Conclusions

In this study, an LMDI decomposition method based on energy allocation analysis was used for the first time in Malaysia to provide a more comprehensive understanding of the contributions of technical factors to energy-related CO_2 emission growth. Technical driving factors, including energy intensity, end-use energy structure, the primary energy quantity converted factor, and the primary carbon dioxide emission factor were deduced for Malaysia for the first time. Furthermore, we mapped the results of an energy allocation analysis of Malaysian energy use in 2014 in the form of a Sankey diagram. Then, we applied the LMDI decomposition method to reveal the effects of the various driving factors of energy-related CO_2 emission growth in Malaysia during 1978–1990, 1990–2002, and 2002–2014.

The LMDI decomposition results indicate that GDP growth per capita, population, and proportion of electricity in end-use are the major driving factors of the growth of energy-related CO_2 emissions in Malaysia during the periods 1978–1990, 1990–2002, and 2002–2014. In addition, the increasing electricity supply efficiency restrained the energy-related CO_2 emissions in Malaysia during all three periods. The energy intensity first increased energy-related CO_2 emissions during the periods 1978–1990 and 1990–2002 and then reduced energy-related CO_2 emissions during 2002–2014. The change in fuel-mix in electricity generation did not influence energy-related CO_2 emissions significantly during the periods 1978–1990 and 1990–2002, but it increased energy-related CO_2 emissions during the period 2002–2014 because of the introduction of coal-fired power plants in Malaysia. Following these main findings, we provided several policy implications for the Malaysian government to enhance the control of CO_2 emissions from the perspective of the energy system, as discussed in Section 6.

In summary, our findings indicate that the change in energy-related CO_2 emissions is mainly the result of the interaction between economic factors and technical factors. When the mitigation of energy-related CO_2 emissions restrained by technical indicators exceeds the rate of increase of energy-related CO_2 emissions contributed by economic indicators, energy-related CO_2 emissions will show a downward trend. Therefore, the results of the LMDI decomposition method are consistent with those based on econometrics methods. Compared to econometric methods, the LMDI decomposition method considers more technical factors, so that the driving factors can be explored more comprehensively from both economic and technical perspectives, providing policy makers with more policy recommendations related to the energy system. In addition, the results and discussions of the technical influencing factors considered in the LMDI decomposition method can provide support for the conclusions drawn from econometric methods and explain the mitigation mechanism of energy-related CO_2 emissions.

In future research, we suggest using this method to study the driving factors of energy-related CO_2 emission growth in other Southeast Asian countries and in other regions as well.

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Appendix. detailed data input

Table A1
End-use energy consumption data of Malaysia which was expressed in SQ (heat value) form (Unit: Mtoe).

Year	Diesel	Fuel Oil	Gasoline	LPG	Kerosene	ATF	Refinery Gas	Natural gas	Coal and coke	Electricity generated	Biodiesel	Total
1978	**1.88**	**0.71**	**1.01**	**0.1**	**0.34**	**0.22**	**0.03**	**0.03**	**0.02**	**0.71**	**0**	**5.04**
1979	2.11	0.81	1.18	0.11	0.36	0.21	0.03	0.03	0.03	0.79	0	5.66
1980	2.37	0.85	1.32	0.12	0.35	0.26	0.02	0.04	0.05	0.86	0	6.23
1981	2.81	0.73	1.42	0.12	0.37	0.29	0.03	0.04	0.1	0.93	0	6.84
1982	3.09	0.42	1.53	0.14	0.36	0.35	0.02	0.05	0.09	1.01	0	7.07
1983	3.05	0.6	1.76	0.17	0.35	0.34	0.03	0.05	0.25	1.1	0	7.69
1984	2.9	0.53	1.93	0.19	0.36	0.37	0.04	0.13	0.27	1.18	0	7.89
1985	2.77	0.55	2.09	0.23	0.31	0.29	0.03	0.52	0.36	1.29	0	8.43
1986	2.8	0.49	2.18	0.27	0.3	0.43	0.03	1.06	0.27	1.39	0	9.21
1987	3.03	0.53	2.3	0.33	0.27	0.44	0.03	1.13	0.33	1.5	0	9.87
1988	3.28	0.6	2.45	0.38	0.26	0.46	0.03	1.06	0.19	1.66	0	10.36
1989	3.82	0.79	2.59	0.42	0.21	0.5	0.01	1.07	0.6	1.85	0	11.84
1990	**4.42**	**0.88**	**2.9**	**0.55**	**0.2**	**0.63**	**0.01**	**1.09**	**0.51**	**1.98**	**0**	**13.18**
1991	4.87	0.95	3.14	0.61	0.18	0.69	0.01	1.13	0.6	2.28	0	14.45
1992	5.29	1.09	3.33	0.73	0.16	0.76	0	1.37	0.67	2.52	0	15.92
1993	5.34	1.29	3.67	1.12	0.15	0.88	0.01	1.72	0.49	2.99	0	17.64
1994	5.64	1.39	4.14	0.93	0.15	0.98	0.01	1.86	0.6	3.36	0	19.06
1995	5.81	1.51	4.55	2.22	0.18	1.16	0.01	1.94	0.71	3.91	0	21.98
1996	6.74	1.77	5.21	1.22	0.2	1.34	0	2.47	0.73	4.42	0	24.08
1997	7.31	1.98	5.59	1.25	0.17	1.44	0	2.47	0.74	4.98	0	25.92
1998	6.25	1.68	5.85	1.3	0.17	1.62	0	2.73	0.77	5.22	0	25.59
1999	6.51	1.79	6.79	1.52	0.16	1.42	0	3.02	0.61	5.61	0	27.44
2000	7.63	1.88	6.39	1.36	0.13	1.57	0	3.86	0.99	5.96	0	29.77
2001	8.12	1.5	6.83	1.39	0.1	1.76	0	4.62	0.98	6.11	0	31.41
2002	**8.04**	**1.59**	**6.95**	**1.54**	**0.09**	**1.79**	**0.01**	**5.64**	**1.09**	**6.38**	**0**	**33.12**
2003	8.54	1.26	7.36	1.44	0.09	1.85	0.01	5.89	1.21	6.75	0	34.39
2004	9.26	1.46	7.84	1.54	0.09	2.06	0.01	6.49	1.31	7.08	0	37.13
2005	8.67	1.95	8.21	1.51	0.08	2.01	0.01	6.98	1.35	7.11	0	37.89
2006	8.54	1.9	7.52	1.52	0.08	2.15	0.01	7.56	1.34	7.74	0	38.36
2007	9.51	2.2	8.6	1.48	0.08	2.16	0.01	7.71	1.36	8.39	0	41.48
2008	9.17	1.96	8.84	1.48	0.08	2.11	0	7.82	1.71	8.42	0	41.59
2009	8.63	1.29	8.77	2.51	0.03	2.12	0	6.8	1.61	9.09	0	40.85
2010	8.39	0.48	9.56	2.92	0.02	2.38	0	6.25	1.83	9.79	0	41.62
2011	8.71	0.41	8.16	2.89	0.02	2.55	0	8.52	1.76	10.75	0.02	43.79
2012	8.76	0.77	8.92	2.89	0.04	2.52	0	10.21	1.74	11.56	0.12	47.52
2013	9.57	0.33	12.66	2.95	0.03	3	0	10.08	1.54	12.05	0.19	52.39
2014	**10.16**	**0.25**	**12.71**	**2.63**	**0.02**	**3.16**	**0**	**9.64**	**1.71**	**12.63**	**0.3**	**53.2**

Note: These end-use energy consumption data was acquired from the end-use energy consumption database of MEIH. However, we replaced the data of electricity with the data from the electricity generation database of MEIH, as the data from end-use energy consumption database did not include the electricity transmission loss.

Table A2
Fuel consumption in thermal power plants, electricity generation in thermal power plants, and K_{PEQ} of electricity.

Year	Fuel consumption in thermal power plants							Electricity generation in thermal power plants	K_{PEQ}
	Diesel	Fuel Oil	Natural Gas	Coal and Coke	Biomass	Biogas	Total		
Unit	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	–
1978	**0.15**	**1.84**	**0.02**	**0.00**	**0.00**	**0.00**	**2.01**	**0.63**	**3.17**
1979	0.25	1.93	0.02	0.00	0.00	0.00	2.20	0.70	3.17
1980	0.29	2.06	0.03	0.00	0.00	0.00	2.38	0.74	3.20
1981	0.27	2.10	0.04	0.00	0.00	0.00	2.41	0.80	3.03
1982	0.33	2.36	0.04	0.00	0.00	0.00	2.73	0.89	3.08
1983	0.46	2.37	0.06	0.00	0.00	0.00	2.89	0.95	3.05
1984	0.32	2.35	0.08	0.00	0.00	0.00	2.75	0.89	3.10
1985	0.35	2.17	0.54	0.00	0.00	0.00	3.06	0.96	3.17
1986	0.24	2.21	0.70	0.00	0.00	0.00	3.16	1.04	3.05
1987	0.18	2.09	0.82	0.00	0.00	0.00	3.09	1.08	2.87
1988	0.23	2.05	0.99	0.07	0.00	0.00	3.35	1.18	2.84
1989	0.32	1.89	1.00	0.60	0.00	0.00	3.81	1.40	2.73
1990	**0.12**	**2.87**	**1.36**	**0.81**	**0.00**	**0.00**	**5.16**	**1.64**	**3.16**
1991	0.16	2.69	2.53	0.96	0.00	0.00	6.35	1.90	3.33
1992	0.16	2.35	3.14	0.97	0.00	0.00	6.62	2.15	3.09
1993	0.09	2.39	4.37	0.88	0.00	0.00	7.73	2.57	3.01
1994	0.25	1.96	5.12	0.93	0.00	0.00	8.25	2.80	2.95
1995	0.27	2.07	6.41	0.96	0.00	0.00	9.71	3.37	2.88
1996	0.28	2.35	7.49	0.95	0.00	0.00	11.08	3.98	2.79
1997	0.19	2.48	7.53	0.88	0.00	0.00	11.08	4.64	2.39
1998	0.28	2.13	8.89	0.96	0.00	0.00	12.26	4.80	2.55
1999	0.17	0.95	10.16	1.33	0.00	0.00	12.62	4.96	2.54
2000	0.19	0.59	11.58	1.50	0.00	0.00	13.86	5.36	2.59
2001	0.28	0.73	11.92	1.99	0.00	0.00	14.92	5.51	2.71
2002	**0.48**	**1.36**	**12.42**	**2.56**	**0.00**	**0.00**	**16.82**	**5.93**	**2.84**
2003	0.34	0.29	10.89	4.10	0.00	0.00	15.63	6.31	2.48
2004	0.27	0.27	10.55	5.33	0.00	0.00	16.42	6.57	2.50
2005	0.30	0.28	12.27	5.54	0.00	0.00	18.39	6.66	2.76
2006	0.62	0.17	12.52	5.96	0.00	0.00	19.28	7.19	2.68
2007	0.31	0.20	12.55	7.49	0.00	0.00	20.55	7.83	2.63
2008	0.30	0.18	13.65	8.07	0.00	0.00	22.20	7.78	2.85
2009	0.38	0.21	13.39	9.01	0.00	0.00	22.99	8.52	2.70
2010	0.42	0.13	12.63	12.95	0.00	0.00	26.12	9.25	2.82
2011	0.98	1.10	10.98	13.01	0.00	0.00	26.07	10.09	2.58
2012	0.81	0.55	11.53	14.14	0.07	0.00	27.10	10.78	2.51
2013	0.62	0.39	13.52	13.53	0.16	0.01	28.23	11.05	2.55
2014	**0.62**	**0.27**	**13.86**	**13.65**	**0.10**	**0.01**	**28.51**	**11.48**	**2.48**

Note: K_{PEQ} of electricity is defined as the total number of units of primary energy that are consumed to produce one unit of electricity. In this case, K_{PEQ} = Total fuel consumption in thermal power plants/Electricity generation in thermal power plants.

Table A3
CO_2 emissions in thermal power plants and K_C of electricity.

Year	CO_2 emissions in thermal power plants							K_C
	Diesel	Fuel Oil	Natural Gas	Coal and Coke	Biomass	Biogas	Total	
Unit	Mt	Mt	Mt	Mt	Mt	Mt	Mt	t/toe
1978	**0.45**	**5.96**	**0.05**	**0.00**	**0.00**	**0.00**	**6.46**	**2.87**
1979	0.77	6.25	0.06	0.00	0.00	0.00	7.07	2.83
1980	0.89	6.67	0.08	0.00	0.00	0.00	7.63	2.76
1981	0.85	6.79	0.08	0.00	0.00	0.00	7.72	2.75
1982	1.03	7.63	0.08	0.00	0.00	0.00	8.75	2.80
1983	1.43	7.67	0.14	0.00	0.00	0.00	9.24	2.76
1984	0.99	7.61	0.19	0.00	0.00	0.00	8.80	2.40
1985	1.07	7.04	1.27	0.00	0.00	0.00	9.37	2.30
1986	0.74	7.16	1.65	0.00	0.00	0.00	9.55	2.26
1987	0.57	6.75	1.92	0.00	0.00	0.00	9.24	2.15
1988	0.72	6.64	2.32	0.29	0.00	0.00	9.98	2.11
1989	0.99	6.11	2.36	2.48	0.00	0.00	11.93	2.37
1990	**0.36**	**9.30**	**3.19**	**3.34**	**0.00**	**0.00**	**16.20**	**2.59**
1991	0.51	8.70	5.95	3.96	0.00	0.00	19.11	2.51
1992	0.50	7.61	7.38	3.98	0.00	0.00	19.47	2.50
1993	0.27	7.73	10.27	3.63	0.00	0.00	21.90	2.43
1994	0.77	6.33	12.02	3.80	0.00	0.00	22.93	2.32
1995	0.82	6.71	15.06	3.93	0.00	0.00	26.52	2.36

(continued on next page)

Table A3 (*continued*)

Year	CO_2 emissions in thermal power plants							K_C
	Diesel	Fuel Oil	Natural Gas	Coal and Coke	Biomass	Biogas	Total	
Unit	Mt	Mt	Mt	Mt	Mt	Mt	Mt	t/toe
1996	0.88	7.62	17.58	3.91	0.00	0.00	29.98	2.43
1997	0.57	8.03	17.68	3.63	0.00	0.00	29.91	2.52
1998	0.85	6.89	20.86	3.96	0.00	0.00	32.57	2.45
1999	0.53	3.08	23.85	5.48	0.00	0.00	32.94	2.31
2000	0.59	1.92	27.18	6.15	0.00	0.00	35.84	2.33
2001	0.86	2.36	27.98	8.20	0.00	0.00	39.41	2.38
2002	**1.48**	**4.41**	**29.16**	**10.51**	**0.00**	**0.00**	**45.56**	**2.52**
2003	1.05	0.94	25.57	16.87	0.00	0.00	44.43	2.66
2004	0.84	0.89	24.75	21.90	0.00	0.00	48.38	2.74
2005	0.92	0.89	28.80	22.78	0.00	0.00	53.40	2.72
2006	1.91	0.55	29.40	24.52	0.00	0.00	56.38	2.72
2007	0.97	0.64	29.46	30.78	0.00	0.00	61.85	2.81
2008	0.93	0.59	32.04	33.18	0.00	0.00	66.73	2.78
2009	1.19	0.66	31.43	37.04	0.00	0.00	70.33	2.87
2010	1.29	0.40	29.64	53.25	0.00	0.00	84.58	3.06
2011	3.04	3.57	25.77	53.50	0.00	0.00	85.88	3.09
2012	2.51	1.78	27.07	58.13	0.00	0.00	89.49	3.08
2013	1.93	1.27	31.73	55.62	0.00	0.00	90.55	2.94
2014	**1.93**	**0.87**	**32.53**	**56.11**	**0.00**	**0.00**	**91.44**	**2.92**

Note: K_C is a key parameter for establishing the connection between electricity consumption expressed in primary energy quantity form and CO_2 emissions, it is defined as the total number of units of CO_2 emissions when one unit of electricity expressed in primary energy quantity form is consumed.
K_C of electricity = Total CO_2 emissions in thermal power plants/total electricity generation expressed in PEQ form.

Table A4
Energy-related CO_2 emissions in Malaysia, according to the end-use energy type (Unit: Mtoe).

Year	Diesel	Fuel Oil	Gasoline	LPG	Kerosene	ATF	Refinery Gas	Natural gas	Coal and coke	Electricity generated	Biodiesel
1978	**5.82**	**2.30**	**2.93**	**0.27**	**1.01**	**0.64**	**0.07**	**0.07**	**0.09**	**6.46**	**19.65**
1979	6.54	2.61	3.42	0.30	1.07	0.62	0.06	0.08	0.14	7.07	21.91
1980	7.34	2.74	3.82	0.32	1.05	0.76	0.06	0.08	0.22	7.63	24.02
1981	8.71	2.38	4.13	0.33	1.10	0.85	0.06	0.09	0.41	7.72	25.77
1982	9.59	1.37	4.43	0.36	1.09	1.04	0.06	0.11	0.38	8.75	27.16
1983	9.45	1.96	5.09	0.46	1.05	1.01	0.06	0.11	1.02	9.24	29.46
1984	8.99	1.71	5.58	0.50	1.07	1.11	0.09	0.31	1.11	8.80	29.26
1985	8.59	1.79	6.05	0.60	0.93	0.86	0.07	1.21	1.49	9.37	30.97
1986	8.69	1.58	6.32	0.72	0.90	1.28	0.07	2.48	1.10	9.55	32.68
1987	9.38	1.71	6.66	0.87	0.80	1.30	0.07	2.66	1.34	9.24	34.03
1988	10.15	1.94	7.11	1.00	0.76	1.37	0.08	2.48	0.78	9.98	35.64
1989	11.83	2.54	7.50	1.10	0.63	1.49	0.03	2.51	2.45	11.93	42.00
1990	**13.70**	**2.86**	**8.41**	**1.45**	**0.61**	**1.88**	**0.02**	**2.57**	**2.11**	**16.20**	**49.80**
1991	15.10	3.06	9.09	1.61	0.54	2.06	0.03	2.64	2.46	19.11	55.71
1992	16.40	3.52	9.64	1.93	0.48	2.29	0.00	3.21	2.76	19.47	59.70
1993	16.55	4.19	10.63	2.95	0.44	2.62	0.02	4.03	2.00	21.90	65.33
1994	17.49	4.51	12.00	2.44	0.45	2.93	0.02	4.37	2.46	22.93	69.60
1995	18.00	4.87	13.19	5.84	0.53	3.47	0.02	4.54	2.93	26.52	79.92
1996	20.87	5.73	15.09	3.21	0.59	3.99	0.01	5.81	2.99	29.98	88.27
1997	22.67	6.40	16.20	3.29	0.51	4.30	0.01	5.79	3.04	29.91	92.11
1998	19.37	5.43	16.97	3.43	0.49	4.84	0.01	6.40	3.15	32.57	92.68
1999	20.16	5.80	19.70	4.02	0.48	4.26	0.01	7.10	2.50	32.94	96.96
2000	23.64	6.07	18.52	3.59	0.39	4.71	0.01	9.07	4.07	35.84	105.90
2001	25.15	4.85	19.79	3.67	0.30	5.27	0.01	10.85	4.02	39.41	113.31
2002	**24.92**	**5.15**	**20.15**	**4.07**	**0.28**	**5.34**	**0.01**	**13.25**	**4.47**	**45.56**	**123.18**
2003	26.46	4.07	21.34	3.79	0.28	5.54	0.02	13.82	4.98	44.43	124.72
2004	28.70	4.74	22.73	4.07	0.26	6.15	0.03	15.23	5.37	48.38	135.65
2005	26.87	6.33	23.81	3.98	0.25	6.01	0.02	16.39	5.54	53.40	142.60
2006	26.47	6.15	21.80	4.01	0.24	6.44	0.03	17.75	5.49	56.38	144.75
2007	29.48	7.13	24.94	3.89	0.23	6.45	0.02	18.09	5.60	61.85	157.67
2008	28.41	6.35	25.64	3.89	0.22	6.32	0.00	18.35	7.04	66.73	162.96
2009	26.76	4.18	25.42	6.61	0.09	6.34	0.00	15.96	6.63	70.33	162.32
2010	25.99	1.55	27.72	7.71	0.06	7.12	0.00	14.68	7.51	84.58	176.91
2011	27.00	1.34	23.65	7.63	0.06	7.64	0.00	19.99	7.23	85.88	180.41
2012	27.14	2.49	25.86	7.63	0.11	7.54	0.00	23.96	7.17	89.49	191.39
2013	29.65	1.06	36.70	7.77	0.09	8.97	0.00	23.65	6.33	90.55	204.78
2014	**31.49**	**0.80**	**36.84**	**6.95**	**0.07**	**9.45**	**0.00**	**22.63**	**7.03**	**91.44**	**206.68**

References

[1] Association WN. Climate change – the science. http://www.world-nuclear.org/information-library/energy-and-the-environment/climate-change-the-science.aspx; 2017.
[2] Eurostat. Climate change - driving forces. http://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces; 2017.
[3] Stern N. The economics of climate change: the stern review. Cambridge, United Kingdom: Cambridge University Press; 2007.
[4] International Energy Agency. Southeast Asia: a new heavyweight in global energy. http://www.iea.org/southeastasia/; 2017.
[5] Chong C, Ni W, Ma L, Liu P, Li Z. The use of energy in Malaysia: tracing energy flows from primary source to end use. Energies 2015;8(4):2828–66.
[6] United Nations Conference on Environment and Development (UNFCCC). Speech by minister of natural resources and environment Malaysia for joint high level segment of COP21/CMP11. https://unfccc.int/sites/default/files/cop21cmp11_hls_speech_malaysia.pdf; 2015.
[7] Ministry of Natural Resources and Environment, Malaysia. National policy on climate change of Malaysia. http://www.asialeds.org/sites/default/files/resource/file/NCCP_080710_for-web.pdf; 2009.
[8] United Nations Conference on Environment and Development (UNFCCC). Intended nationally determined contribution (INDC) of the government of Malaysia. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Malaysia/1/INDC%20Malaysia%20Final%2027%20November%202015%20Revised%20Final%20UNFCCC.pdf; 2015.
[9] Malaysia Energy Information Hub. Power generation structure in Malaysia. http://meih.st.gov.my/statistics?p_auth=KFBuQE83&p_p_id=Eng_Statistic_WAR_STOASPublicPortlet&p_p_lifecycle=1&p_p_state=maximized&p_p_mode=view&p_p_col_id=column-1&p_p_col_pos=1&p_p_col_count=2&_Eng_Statistic_WAR_STOASPublicPortlet_execution=e1s1&_Eng_Statistic_WAR_STOASPublicPortlet__eventId=ViewStatistic8&categoryId=8&flowId=20&showTotal=false; 2018.
[10] Ma L, Chong C, Zhang X, Liu P, Li W, Li Z, et al. LMDI decomposition of energy-related CO2 emissions based on energy and CO2 allocation Sankey diagrams: the method and an application to China. Sustainability 2018;10(2):344.
[11] Mustapa SI, Bekhet HA. Analysis of CO2 emissions reduction in the Malaysian transportation sector: an optimisation approach. Energy Policy 2016;89:171–83.
[12] Fairuz SMC, Sulaiman MY, Lim CH, Mat S, Ali B, Saadatian O, et al. Long term strategy for electricity generation in Peninsular Malaysia – analysis of cost and carbon footprint using MESSAGE. Energy Policy 2013;62:493–502.
[13] Gan PY, Komiyama R, Li Z. A low carbon society outlook for Malaysia to 2035. Renew Sustain Energy Rev 2013;21:432–43.
[14] Bekhet HA, Othman NS. The role of renewable energy to validate dynamic interaction between CO 2 emissions and GDP toward sustainable development in Malaysia. Energy Econ 2018;72:47–61.
[15] Yii K, Geetha C. The nexus between technology innovation and CO 2 emissions in Malaysia: evidence from granger causality test. Energy Procedia 2017;105:3118–24.
[16] Ali W, Abdullah A, Azam M. Re-visiting the environmental Kuznets curve hypothesis for Malaysia: fresh evidence from ARDL bounds testing approach. Renew Sustain Energy Rev 2017;77:990–1000.
[17] Begum RA, Sohag K, Abdullah SMS, Jaafar M. CO 2 emissions, energy consumption, economic and population growth in Malaysia. Renew Sustain Energy Rev 2015;41:594–601.
[18] Lau L, Choong C, Eng Y. Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter? Energy Policy 2014;68:490–7.
[19] Lau L, Choong C, Eng Y. Carbon dioxide emission, institutional quality, and economic growth: empirical evidence in Malaysia. Renew Energy 2014;68:276–81.
[20] Saboori B, Sulaiman J. Environmental degradation, economic growth and energy consumption: evidence of the environmental Kuznets curve in Malaysia. Energy Policy 2013;60:892–905.
[21] Shahbaz M, Solarin SA, Mahmood H, Arouri M. Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Econ Modell 2013;35:145–52.
[22] Azlina AA, Law SH, Nik Mustapha NH. Dynamic linkages among transport energy consumption, income and CO2 emission in Malaysia. Energy Policy 2014;73:598–606.
[23] Bekhet HA, Othman NS. Impact of urbanization growth on Malaysia CO 2 emissions: evidence from the dynamic relationship. J Clean Prod 2017;154:374–88.
[24] Ang BW, Zhang FQ. A survey of index decomposition analysis in energy and environmental studies. Energy 2000;25(12):1149–76.
[25] Miller RE, Blair PD. Input-output analysis: Foundations and extensions. New York: United States of America: Cambridge University Press; 2009.
[26] Su B, Ang BW. Structural decomposition analysis applied to energy and emissions: some methodological developments. Energy Econ 2012;34(1):177–88.
[27] Zhou P, Ang BW. Decomposition of aggregate CO2 emissions: a production-theoretical approach. Energy Econ 2008;30(3):1054–67.
[28] Lin B, Du K. Decomposing energy intensity change: a combination of index decomposition analysis and production-theoretical decomposition analysis. Appl Energy 2014;129:158–65.
[29] Chen J, Xu C, Cui L, Huang S, Song M. Driving factors of CO2 emissions and inequality characteristics in China: a combined decomposition approach. Energy Econ 2019;78:589–97.
[30] Hang Y, Wang Q, Zhou D, Zhang L. Factors influencing the progress in decoupling economic growth from carbon dioxide emissions in China's manufacturing industry. Resour Conserv Recycl 2019;146:77–88.
[31] Li A, Zhang A, Zhou Y, Yao X. Decomposition analysis of factors affecting carbon dioxide emissions across provinces in China. J Clean Prod 2017;141:1428–44.
[32] Liu X, Zhou D, Zhou P, Wang Q. Factors driving energy consumption in China: a joint decomposition approach. J Clean Prod 2018;172:724–34.
[33] Wang M, Feng C. Understanding China's industrial CO2 emissions: a comprehensive decomposition framework. J Clean Prod 2017;166:1335–46.
[34] Ang BW, Liu FL. A new energy decomposition method: perfect in decomposition and consistent in aggregation. Energy 2001;26(6):537–48.
[35] Ang BW. Decomposition analysis for policymaking in energy: which is the preferred method ? Energy Policy 2004;32(9):1131–9.
[36] Ang BW. The LMDI approach to decomposition analysis: a practical guide. Energy Policy 2005;33(7):867–71.
[37] Wang W, Liu X, Zhang M, Song X. Using a new generalized LMDI (logarithmic mean Divisia index) method to analyze China's energy consumption. Energy 2014;67:617–22.
[38] Chong C, Liu P, Ma L, Li Z, Ni W, Li X, et al. LMDI decomposition of energy consumption in Guangdong Province, China, based on an energy allocation diagram. Energy 2017;133:525–44.
[39] Li X, Chong C, Ma L, Liu P, Shen X, Jia Z, et al. Coordinating the dynamic development of energy and industry in composite regions: an I-SDOP analysis of the BTH region. Sustainability 2018;10(6):2093.
[40] Chong C, Ma L, Li Z, Ni W, Song S. Logarithmic mean Divisia index (LMDI) decomposition of coal consumption in China based on the energy allocation diagram of coal flows. Energy 2015;85:366–78.
[41] Chong C, Ma L, Li Z, Geng J, Zhang T. A programmed data-processing method for mapping energy allocation Sankey diagram of China. 2014. Shanghai, China.
[42] Wikipedia. Sankey diagram. https://en.wikipedia.org/wiki/Sankey_diagram; 2018.
[43] Soundararajan K, Ho HK, Su B. Sankey diagram framework for energy and exergy flows. Appl Energy 2014;136:1035–42.
[44] Ma L, Fu F, Li Z, Liu P. Oil development in China: current status and future trends. Energy Policy 2012;45:43–53.
[45] Davis M, Ahiduzzaman M, Kumar A. Mapping Canadian energy flow from primary fuel to end use. Energy Convers Manag 2018;156:178–91.
[46] Subramanyam V, Paramshivan D, Kumar A, Mondal MAH. Using Sankey diagrams to map energy flow from primary fuel to end use. Energy Convers Manag 2015;91:342–52.
[47] He M, Liu P, Ma L, Chong C, Li X, Song S, et al. A systems analysis of the development status and trends of rural household energy in China. Energies 2018;11(7):1741.
[48] Soundararajan K, Ho HK, Su B. Sankey diagram framework for energy and exergy flows. Appl Energy 2014;136:1035–42.
[49] Lupton RC, Allwood JM. Hybrid Sankey diagrams: visual analysis of multidimensional data for understanding resource use. Resour Conserv Recycl 2017;124:141–51.
[50] Cuba N. Research note: Sankey diagrams for visualizing land cover dynamics. Landsc Urban Plan 2015;139:163–7.
[51] Shuaib NA, Mativenga PT, Kazie J, Job S. Resource efficiency and composite waste in UK supply chain. Procedia CIRP 2015;29:662–7.
[52] Wu J, Yang J, Ma L, Li Z, Shen X. A system analysis of the development strategy of iron ore in China. Resour Policy 2016;48:32–40.
[53] Courtonne J, Alapetite J, Longaretti P, Dupré D, Prados E. Downscaling material flow analysis: the case of the cereal supply chain in France. Ecol Econ 2015;118:67–80.
[54] Du X, Graedel TE. Uncovering the end uses of the rare earth elements. Sci Total Environ 2013;461–462:781–4.
[55] Mukuve FM, Fenner RA. Scale variability of water, land, and energy resource interactions and their influence on the food system in Uganda. Sustain Prod Consum 2015;2:79–95.
[56] Mukuve FM, Fenner RA. The influence of water, land, energy and soil-nutrient resource interactions on the food system in Uganda. Food Policy 2015;51:24–37.
[57] Cullen JM, Allwood JM. The efficient use of energy: tracing the global flow of energy from fuel to service. Energy Policy 2010;38(1):75–81.
[58] Ma L, Allwood JM, Cullen JM, Li Z. The use of energy in China: tracing the flow of energy from primary source to demand drivers. Energy 2012;40(1):174–88.
[59] Sun J, Ma L, Ni W, Li Z. Presented at' ICMREE 2013. 2013.
[60] Malaysia Energy Information Hub. Malaysia energy balance, 2015. http://meih.st.gov.my/documents/10620/233145b9-0df3-4aa4-8fff-acd483ea5701; 2016.
[61] Malaysia Energy Information Hub. Final energy demand in Malaysia. http://meih.st.gov.my/statistics?p_auth=KFBuQE83&p_p_id=Eng_Statistic_WAR_STOASPublicPortlet&p_p_lifecycle=1&p_p_state=maximized&p_p_mode=view&p_p_col_id=column-1&p_p_col_pos=1&p_p_col_count=2&_Eng_Statistic_WAR_STOASPublicPortlet_execution=e2s1&_Eng_Statistic_WAR_STOASPublicPortlet__eventId=ViewStatistic9&categoryId=8&flowId=21&showTotal=false;2018.
[62] The World Bank. Statistic data of Malaysia. https://data.worldbank.org/country/malaysia; 2018.
[63] Intergovernmental Panel On Climate Change (IPCC). Emission factor database. http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_s1.php; 2006.
[64] The World Bank Group. World Bank national accounts data. https://data.worldbank.org; 2016.
[65] International Energy Agency. Sankey diagram. https://www.iea.org/Sankey/; 2016.
[66] Samsudin bin Hitam. Sustainable energy policy and strategies: a pre-requisite for the concerted development and promotion of the renewable energy in Malaysia. http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan003226.pdf; 1999.

[67] Shekarchian M, Moghavvemi M, Mahlia TMI, Mazandarani A. A review on the pattern of electricity generation and emission in Malaysia from 1976 to 2008. Renew Sustain Energy Rev 2011;15(6):2629–42.
[68] Kardooni R, Yusoff SB, Kari FB, Moeenizadeh L. Public opinion on renewable energy technologies and climate change in Peninsular Malaysia. Renew Energy 2018;116:659–68.
[69] Hannan MA, Begum RA, Abdolrasol MG, Hossain Lipu MS, Mohamed A, Rashid MM. Review of baseline studies on energy policies and indicators in Malaysia for future sustainable energy development. Renew Sustain Energy Rev 2018;94:551–64.
[70] Oh TH, Pang SY, Chua SC. Energy policy and alternative energy in Malaysia: issues and challenges for sustainable growth. Renew Sustain Energy Rev 2010;14(4):1241–52.
[71] Oh TH, Hasanuzzaman M, Selvaraj J, Teo SC, Chua SC. Energy policy and alternative energy in Malaysia: issues and challenges for sustainable growth – an update. Renew Sustain Energy Rev 2018;81:3021–31.
[72] Bujang AS, Bern CJ, Brumm TJ. Summary of energy demand and renewable energy policies in Malaysia. Renew Sustain Energy Rev 2016;53:1459–67.
[73] Wong SL, Ngadi N, Abdullah TAT, Inuwa IM. Recent advances of feed-in tariff in Malaysia. Renew Sustain Energy Rev 2015;41:42–52.
[74] BP. BP statistical review of World energy. https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf; 2018.
[75] United State Energy Information Administration. Overview of energy in Malaysia. https://www.eia.gov/beta/international/analysis.php?iso=MYS; 2017.
[76] Bujang AS, Bern CJ, Brumm TJ. Summary of energy demand and renewable energy policies in Malaysia. Renew Sustain Energy Rev 2016;53:1459–67.
[77] Saboori B, Sulaiman J, Mohd S. Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the Environmental Kuznets Curve. Energy Policy 2012;51:184–91.
[78] Wikipedia. Malaysian general election 2018; 2018 https://en.wikipedia.org/wiki/Malaysian_general_election; 2018.
[79] OilVoice. A new Malaysia, a new Petronas? https://oilvoice.com/Opinion/17502/A-new-Malaysia-a-new-Petronas; 2018.
[80] Swain Ashok, Chee Ang Ming. Political structure and dam conflicts: comparing cases in Southeast Asia. https://www.researchgate.net/publication/237602184_Political_Structure_and_'Dam'_Conflicts_Comparing_Cases_in/comments; 2002.
[81] The Edge Markets. Local scientist says Bakun dam water toxic. http://www.theedgemarkets.com/article/local-scientist-says-bakun-dam-water-toxic; 2015.
[82] Malaymail. Pakatan won't build nuke plants, says minister. https://www.malaymail.com/s/1654111/pakatan-wont-build-nuke-plants-says-minister; 2018.