The Relationship between Economic Growth, Carbon Dioxide Emission and Renewable Energy Development: Malaysian Evidence

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***Abstract*— The aim of this paper is to examine the relationship between country's economic growth record, CO_2 emission and renewable energy growth in Malaysia from the year 2012 until 2017. The annual data on GDP, CO_2 emission and renewable energy growth in Malaysia were collected from respective organizations, particularly, Bank Negara Malaysia, World Bank and SEDA Malaysia. The study makes an effort to quantitatively examine the relationship between economic growth, CO_2 emission and renewable energy development in Malaysia by running an Ordinary Least Squares (OLS) regression analysis to capture the relationship among these variables. The study finds that the GDP, CO_2 emission and renewable energy show a positive and strong correlation with each other. However, the OLS test indicates a bidirectional relationship between renewable energy growth and GDP, and directional relationship between GDP and CO_2 emission, but no relationship between CO_2 emissions and renewable energy growth. In conclusion, setting clear targets on renewable energy and effective enforcement by respective authority is important to ensure successful energy transition from fossil fuel to non-fossil fuel in the country. The effective government policies and supports also complement to ensure the conservation policy positively affects economic growth and reduces CO_2 emissions.**

Keywords*— *CO_2 emission; economic growth; renewable energy; regression; correlation

I. Introduction

Over the years, there has been an effort by many countries to review their energy policies especially regarding activities associated with electricity generation due to the continuous increase of greenhouse gas emission. As a result, many countries started to explore alternative sources of energy, such as renewable energy with the primary aims of reducing the greenhouse gas emission [1]. Most countries believed there will be an increase of investment in the area of renewable energy production, significantly to meet the national target of energy [2]. The development of renewable energy is believed to reduce air pollution and benefit a lot of people, particularly in the area of providing electricity and creation of job respectively [3]. It is believed that renewable energy can be a source of securing economic growth, maintain energy security and reduce the impact of climate change of a country [4].

Malaysia has been experiencing massive infrastructural development and increased in real estate sector demand that needs of high electricity consumption, since the last three decades [5]. The country's population size is also increasing rapidly, from 7.4 million in 1957 to 27.4 million people in 2010 [6]. The country's vision to become a higher income nation in the year 2020 should be allied with the continuous increase in population and energy demand. Based on this, the reliability of electricity supply is very crucial to ensure the country's economic growth. From 1990 to 2016, Peninsular Malaysia generated more than 90% of electricity consumption from fossil fuel, particularly from coal and natural gas [7]. This resulted in environmental burden arising from the burning of fossil fuels and excessive exploration of natural resources. Hence, forcing the country to introduce renewable energy such as biomass, biogas, municipal waste, solar and mini-hydro, in the Eight Malaysia Plan 2001-2005 [8] is an appropriate move. This strategic approach of energy mix has developed the country in terms of balancing the energy production and consumption, shifting from relying on fossil fuels and gradually expanding to renewable energy sources. To meet the objective of energy policy, the country introduced several incentives and programs related to renewable energy to increase effective supply of energy and minimize the negative impact of fossil fuels on the environment.

In recent years, there is various programs and incentives introduced by the Government of with the aim to reduce the greenhouse gas (GHG) emission, which resulted in the increased of renewable energy consumption. The current Eleventh Malaysia Plan 2016-2020 focuses to generate 2080 MW of renewable energy capacity by 2020 which is about 7.8% of the total installed capacity of the country's energy mix [9]. Following this, various stakeholders, such as, policymakers, policy analysts, industry players, users, and academician, have now shown their interest in renewable energy development [2][10][11]. Several studies have been carried out to investigate the relationship between renewable energy growth, carbon dioxide (CO_2) emissions and Gross Domestic Product (GDP), in order to support the country's energy policy objectives. In this regard, this study will examine the relationship between three variables, particularly country's economic growth record, CO_2 emission and renewable energy growth in Malaysia from the year 2012 until 2017 by running an Ordinary Least Squares (OLS) regression analysis to capture the relationship between these variables.

II. LITERATURE REVIEW

A. Previous studies

There are limited studies in recent research regarding renewable energy as a source of energy security. This situation arises due to the lack of focus towards exploring the advantages of renewable energy particularly in reducing CO_2 emissions [12]–[15]. The investigation of the relationship between renewable energy, CO_2 emissions and economic growth became noticeable since the year 2009. Various methodological approaches, such as OLS, Autoregressive Distributed Lag (ARDL), Granger Causality, Toda-Yamamoto (T-Y) and many others have been used to evaluate the relationship between these variables. Adewuyi and Awodumi found that the causal relationship among renewable energy consumption, economic growth, and carbon emissions remain indecisive either at single-country or multi-country levels depending on the various methodologies adopted and the specific nature of countries or regions analyzed by researchers [2]. Table 1 revealed that most of the previous studies shown the dominance of bidirectional causality between energy consumption and economic growth, and only a small number of them recorded neutrality or insignificant effect [2].

TABLE I. SUMMARY OF FINDINGS OF ALL STUDIES [2]

	Non-renewable energy	*Renewable energy*	*Renewable energy and non-renewable energy*
Renewable & non-renewable energy consumption and economic growth			
EN ↔Y	32	15	9
Y →EN	18	5	6
EN→ Y	19	10	5
Neutrality	10	6	1
Renewable & non-renewable energy consumption and carbon emission			
EN ↔CO_2	6	1	2
CO_2 →EN	0	4	2
EN →CO_2	3	5	4
Neutrality	2	2	0

NOTE: EN= ENERGY CONSUMPTION; Y= ECONOMIC GROWTH; CO_2= CARBON EMISSION; → = UNIDIRECTIONAL CAUSALITY; ↔ = BIDIRECTIONAL CAUSALITY

There have been efforts by researchers to evaluate and explore the relationship among GDP, energy and CO_2 emission using different approaches in Malaysia. Azlina et al. confirmed a relationship between GDP and renewable energy growth from 1975-2011 [16]. Herniza found a bidirectional relationship between economic growth and aggregate energy consumption from 1980 to 2011 [17]. Md. Saifur Rahman et al. used Toda-Yamamoto test to investigate the long-run effect of disaggregated energy consumption on economic growth in Malaysia from 1971-2014. They found that environmental pollution through spreading CO_2 emissions have a negative effect on economic growth [18].

Although there is rising interest in renewable energy growth and their relationships with GDP and CO_2 emission, there still a gap yet to be identified and addressed in this area. This includes passage of time series, where the previous study in Malaysia related to renewable energy growth only covers the period up to the year 2011. Due to very recent interest in renewable energy, current renewable energy policy adopted and aim of the United Nation Sustainable Development Goals (UNSDG), there is a need to reinvestigate the relationship between these variables, which it can contribute to the current body of knowledge in the literature.

B. An overview of Malaysia's economic development

In terms of economic development, Malaysia is classified as a newly industrialized nation due to the county's exporting activities of various commodities. The main products being exported by Malaysia include oil and palm oil [12]. Based on this, to achieve economic growth and socio-economic wellbeing within the country, adequate energy supply is of utmost important [19]. Since the discovery of oil in Sarawak in the year 1910, energy sector including oil and gas has been the mainstream of the country's economy [20]. Until now the economic growth of the country is raising vis a vis energy consumption especially since the country is in a rapid economic development. The relationship between economic growth, energy demand and CO_2 emission, as shown in Fig.1., exhibits a strong signal of the country's high dependency between economic growth and energy usage that lead to increase environmental burden through CO_2 emission.

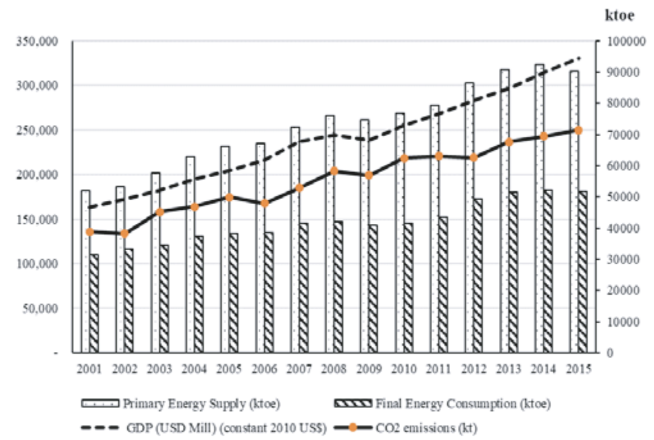

Fig. 1. Trends in GDP, Primary Energy Supply, Final Energy Consumption and CO_2 Emission [21]

C. Energy landscape in Malaysia

Malaysia is essentially blessed with various energy resources varying from conventional sources such as oil, natural gas, and coal, to clean and renewable resources, such as solar, hydropower and biomass [22], [23]. There have been several transformational programs which are targeted towards energy development and this has gradually progressed the county in aspects of efficiency, diversity and sustainability of energy [21]. The energy sector has also expanded considerably from purely relying on fossil fuels to diversifying to renewable sources. Also, a program such as the Eleventh Malaysia Plan clearly identified renewable sources as alternative energy for the economy and it is expected to continue gaining a positive momentum in the near future [9]. This strategy is very important to ensure energy security and reduce the dependency of energy from outside the country due to the fast depleting nature of Malaysia indigenous energy resources.

In 2015, Malaysia's total installed capacity was 30,439 MW, which is mainly fulfilled by natural gas and coal, as shown in Figure 2. Total installed capacity at present stands at around 30,439 gigawatts (GW), with most of the power stations located in the more densely populated and industrialized Peninsular Malaysia [24]. The electricity consumption in the year 2015 was 132,199 GWh, an increase of 3.0 percent from previous year, with the calculated reserve margin was 22.7 percent for Peninsular Malaysia, 66.0 percent for Sarawak and 47.8 percent for Sabah, respectively [21].

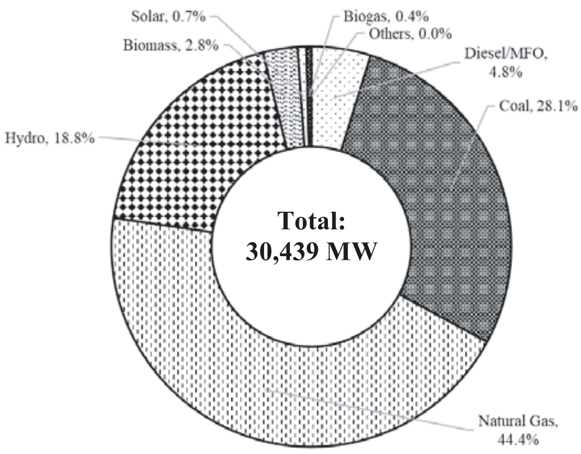

Fig. 2. Installed Capacity as of 31st December 2015 [21]

D. Renewable energy development in Malaysia

Recently, as a result of the depletion of fossil fuel and rise in petroleum prices, most countries including Malaysia have been forced to plan and strategize their energy sector, particularly on the development of renewable energy resources for a better source of power generation. Malaysia government is committed to reducing her GHG emissions intensity of GDP by 45 percent by 2030 relative to the emissions intensity of GDP in 2005 [21]. The government believes this decision will spur a new development of renewable energy in Malaysia. In this regard, the government is making serious efforts to ensure policies, program and incentives towards energy in others to promote and develop the use of renewable energy [25].

Malaysia since 2001 has made tremendous efforts towards renewable energy development. Several principles have been adopted by the county towards generation and delivery of energy based on market forces which have recorded tremendous outcomes. The Five-fuel Diversity Policy which was introduced in 2001 was the first renewable energy-related policy under the 8th Malaysia plan with the aim to supply 5% of the total electricity using renewable energy [8]. The implementation of this policy through various programs such as the Small Renewable Energy Power Program (SREP), the Biogen and the MBIPV projects, aimed to further develop renewable energy resources for utilization of power [26]. Even with this efforts, only 12MW or 1% electricity was generated from renewable energy at the end of 2005, compared to initial target that was anticipated to be 500 MW [8]. As a result of the slow rate of renewable energy growth, Malaysia Government decided to expand the policy to the 9th Malaysia Plan (2006-2010), with a reduced target that was set to generate 350 MW electricity at the end of 2010 but only 58.1 MW of renewable energy generation was achieved at the end of 2009 [22]. There are major implementation issues that lead to failure of the renewable energy development in the country, such as constrained by financial and technological factors, poor governance, the absence of regulatory framework and lack of institutional measures [27]. In order to achieve efficient energy generation of renewable energy, the government further established the National Green Technology Policy 2009, targeted towards increasing the share of renewable energy in power generation as well as to manufacture and accommodate the use of green products for diverse applications in the country [28]. A new Energy Policy was formulated under the 10th Malaysia Plan (2011-2015) to bring about economic efficiency, friendly environmental, and social considerations while enhancing energy security through alternative resources, and emphasizing again the importance of energy efficiency and conservation (EE&C) and use of renewable energy for power generation [29]. In 2011, the Renewable Energy Act 2011 was enacted to establish and implement the Feed-In Tariff (FiT) system that is expected to boost the renewable energy power generation within the country [30].

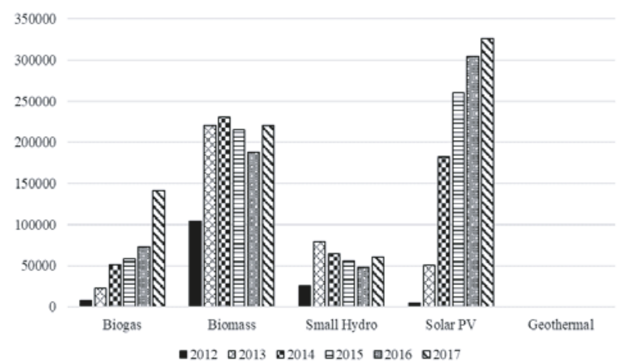

Fig. 3. Power Generation (MWh) of Commissioned RE Installations [31]

Since then up till today, Malaysia government continue to emphasize the importance of greenhouse and renewable energy by increasing contribution of alternative sources in energy mix through exploring new sources to generate power. This is why in the current eleventh Malaysia Plan (2016-2020) the government plan to enhance the capacity of renewable energy personnel and implement net energy metering [9]. Due to this tremendous effort made by the government, the generation of electricity from renewable energy such as solar, biomass, and biogas has expanded rapidly to a bigger scale, as shown in Fig.3, attaining about 1 percent in the energy generation mix in 2015 [21].

Based on this effort of encouraging the use of renewable energy in the country through various programs such as Feed-in Tariff (FiT), Large Scale Solar (LSS) and Net Energy Metering (NEM), more than 20% of the total installed capacity of energy is now from renewable energy including off-grid installation and cogeneration. The LSS and NEM programs which are generating up to 500MW and 1,000MW respectively, are expected to increase renewable energy share in future [7]. Under the National Renewable Energy Policy and Action Plan (NREPAP), introduced in 2009, electricity generated from renewable sources, such as, solar, biomass, biogas, mini hydro and solid wastes is expected to reach 11.227 GWh by the year 2020 [27]. Going forward, the percentage of renewable energy is expected to increase gradually to accommodate environmental and climate change issues, as shown in Fig.4. Looking at the massive support received from the Government of Malaysia, renewable energy will foreseeably play a major role in the country’s energy mix in the future.

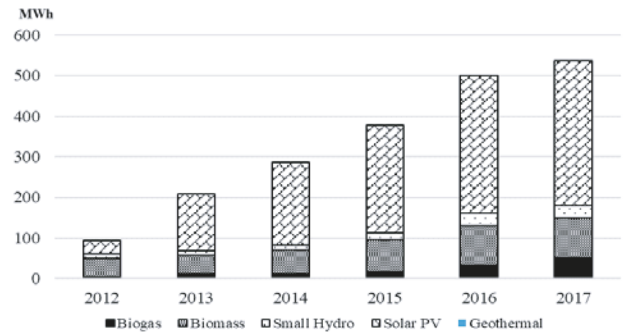

Fig. 4. Installed Capacity (MW) of Commissioned RE Installations [31]

III. Methodology

A. Data

The annual data on GDP, CO_2 emission and renewable energy growth in Malaysia were collected from respective organizations, particularly, Bank Negara Malaysia, World Bank, and Sustainable Energy Development Authority of Malaysia (SEDA Malaysia), as shown in Fig.5 [31]–[33]. These data will be analyzed using statistical tables and graphs.

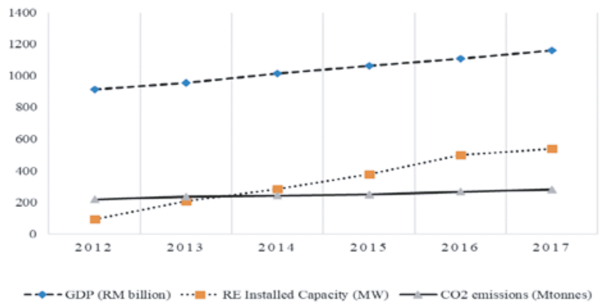

Fig. 5. GDP, CO_2 emission and renewable energy growth pattern in Malaysia

B. Model Presentation

This study applied the use OLS approach to examine the relationship between GDP, CO_2 emissions and renewable energy development using XLSTAT software [34]. The equation of OLS regression analysis is shown below with an assumption of a model p representing explanatory variables.

$$Y = \beta_0 + \Sigma_{j=1..p} \beta_j X_j + \varepsilon \quad (1)$$

where Y is the dependent variable, β_0, is the intercept of the model, X_j corresponds to the j^{th} explanatory variable of the model (j= 1 to p), and e is the random error with expectation 0 and variance σ^2.

In the case where there are n observations, the estimation of the predicted value of the dependent variable Y for the i^{th} observation is given by:

$$y_i = \beta_0 + \Sigma_{j=1..p} \beta_j X_{ij} \quad (2)$$

The OLS method minimizes the sum of square differences between the observed and predicted values, as shown in the model below:

$$[\beta = (X'DX)^{-1} X' Dy \ \sigma^2 = 1/(W - p^*) \ \Sigma_{i=1..n} w_i(y_i - y_i)] \quad (3)$$

where β is the vector of the estimators of the β_i parameters, X is the matrix of the explanatory variables preceded by a vector of 1s, y is the vector of the n observed values of the dependent variable, p* is the number of explanatory variables to which add 1 if the intercept is not fixed, w_i is the weight of the i^{th} observation, and W is the sum of the w_i weights, and D is a matrix with the w_i weights on its diagonal.

The vector of the predicted values can be written as follows:

$$y = X (X' DX)^{-1} X'Dy \quad (4)$$

Regression models help to investigate bivariate and multivariate relationships between variables [35]. It also enables to find average relationships and explicit the formulation of structural and random components of a hypothesized relationship between variables.

IV. Result and Discussion

Table II presents the statistical properties of the three variables. In order to test the distribution properties of these variables, skewness method was used to reflects the asymmetry of a distribution and Kurtosis to reflects the characteristics of the tails of a distribution. The results showed that a zero skewness is estimated for all variables, and in fact, the median of all variables also almost identical to the mean values. The normality of time series data tests using four tests, namely, Shapiro-Wilk test, Anderson-Darling test, Lilliefors test and Jarque-Bera test as an indicator, a significant level alpha=0.05 was also realized from the findings. All the normality tests indicate that all the p-value is greater than the alpha-value, that is why all the variables used in this study follows a normal distribution.

TABLE II. Statistical properties of variables

	GDP (RM Billion)	RE Installed Capacity (MW)	CO_2 emissions (Mtones)
Mean	1034.8580	333.6867	249.4656
Median	1037.6555	331.8750	246.3693
Standard Deviation	93.0084	170.9763	22.5255
Kurtosis	-1.3043	-1.3305	-0.2469
Skewness	-0.0220	-0.1692	0.2492
Shapiro-Wilk	0.936	0.815	0.982
Anderson-Darling	0.929	0.856	0.917
Lilliefors	0.977	0.860	0.907
Jarque-Bera	0.808	0.800	0.880

The correlation matrix of each explanatory variables is shown in Table III. The correlations between the renewable energy growth, CO_2 emission and economic growth are positive and strong, which is close to 1.

TABLE III. Correlation matrix of each variable

	RE Installed Capacity (MW)	CO_2 emissions (Mtonnes)	GDP (RM Billion)
RE Installed Capacity (MW)	1	0.978	0.992
CO2 emissions (Mtonnes)	0.978	1	0.982
GDP (RM billion)	0.992	0.982	1

Table IV presents the summary result of an OLS test for each variable. The F-statistic measures the joint significance of all regressors. These regressors are statistically significant if their probability is less than 5%. The economic growth of the country is influenced by the renewable energy development, and vice-versa, with both probability values is 0.001. The variable of CO_2 emission is not influenced to the growth of GDP and renewable energy since the probability values are more than 0.05. However, the CO_2 emission is influenced by the growth of economic activities or GDP in the country. In this regard, this study concludes that the GDP and renewable energy development in Malaysia has a bidirectional relationship each other, but no relationship between the development of renewable energy and CO_2 emission.

The result of this study can be supported by the study done by Cherni and Jouini [4] using Granger causality test, that indicated there is a bidirectional relationship between GDP and CO_2 emissions as well as between renewable energy growth and GDP but no relationship between CO_2 emissions and renewable energy growth. A study was done by Azlina et al. [16] using Malaysia's data on renewable energy, energy consumption, GDP and CO_2 emission from the year 1975 to 2011, also indicated that there is a relationship between GDP and renewable energy growth in Malaysia.

TABLE IV. Summary result of F-statistic and P-value of each variable

DV	*EV*	*F-stat*	*P value*	*Result*
GDP	RE	225.611	**0.001**	Variable RE is the most influential to variable GDP
	CO_2	0.646	0.480	
RE	GDP	192.917	**0.001**	Variable GDP is the most influential to variable RE
	CO_2	0.118	0.754	
CO_2	GDP	82.284	**0.003**	Variable GDP is the most influential to variable CO_2
	RE	0.118	0.754	

V. Conclusion

This study tried to explore the relationship between three variables, particularly, GDP, CO_2 emission and renewable energy growth for Malaysia from the year 2012 until 2017 using an OLS regression analysis to capture the relationship among these variables. Empirically, this study found that GDP, CO_2 emission and renewable energy show a positive and strong correlation among each other. However, the OLS test indicates a bidirectional relationship between renewable energy growth and GDP, and directional relationship between GDP and CO_2 emission, but no relationship between CO_2 emissions and renewable energy growth.

The energy supply and consumption trend in Malaysia showed signs of decoupling from the country's economic growth. Since 90% of energy supply in Malaysia comes from fossil fuel, which causes the main source for CO_2 emission, the reduction of fuel consumption based on fossil fuel will generate a problem to our economic growth. In this regard, one of the feasible solution to secure our energy supply and to reduce the CO2 emission, is through the massive development of our renewable energy sources to generate electricity. This can be explained by the directional relationship between renewable energy and economic growth. The result obtained from this study also proved that renewable energy sources are a strategic plan to secure the economic growth, maintain the energy security and mitigate the impact of climate change.

Findings from this study also revealed that, Malaysia is committed to reduce CO_2 emission particularly in the area of energy sector which has deemed to the highest CO_2 emitter under the national portfolio. This showed that, there is a need to have a balance of fuel mix which comprises of natural gas, coal, hydro and renewables, to ensure the country's development requirement are met, while also preserving energy security and the environment. This research realized that for Malaysia to achieve her developmental strides, it is vital to tap into non-fossil sources, particularly from renewable sources. Effective implementation of various programs such as FiT, LSS and NEM will increase the share of renewable energy in the energy mix in the future. In conclusion, setting clear targets on renewable energy and effective enforcement by respective authority is important to ensure successful energy transition from fossil fuel to non-fossil fuel in the country. The effective government policies and supports also complement to ensure the conservation policy positively affects economic growth and reduces CO_2 emissions.

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