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Time Series Patterns and Relationship of Energy Consumption and CO_2 Emissions in Malaysia

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Abstract: It is crucial to understand time series patterns of Malaysia's energy consumption and CO_2 emissions and their relationship for implementing strategies and policies to energy security and climate change mitigation. Data from 1980 to 2011 show that all types of fuel and sectors exhibited growth in energy consumption. Major fuel energy consumed are the electricity, diesel, natural gas and motor petrol while transport and industrial sectors are the main consumers of energy. Alike, electricity generation and transport sectors contribute a larger share of CO_2 emissions followed by manufacturing industries and construction sectors among others. In recent years, emissions from power generation rapidly increased due to the increasing coal share of energy input instead of natural gas. Moreover, the positive and linear relationship between CO_2 emission and energy consumption indicates that Malaysia's higher rate of energy consumption leads to the increased CO_2 emissions whereas a high growth of GDP and increasing population might cause increased energy consumption. However, implementation of Feed-in Tariff (FiT) mechanism would work as an incentive to reduce energy consumption and a motivation to consumers (individual or industry) to offset the incremental electricity cost by applying renewable energy and energy efficiency measures that ultimately would contribute to reduce emissions in Malaysia.

Key words: Energy consumption, emissions, mitigation, Malaysia.

Introduction

Malaysia is in the transition of its economy from developing to a developed country which caused one of the fastest economic growths in the world. As economic growth continues, it is expected to consume more energy. Development and economic growth continue to affect the growing demand of energy consumption in Malaysia (Ong et al., 2011). However, energy sector contributes about 20% of its gross domestic product (GDP) which is heavily dependent on non-renewable fuels such as fossil fuels and natural gas. Thus, extensive energy consumption also contributes to the emission of greenhouse gas. It is inevitable that the greenhouse gas emissions caused by fossil-fuel-based energy sources have significantly impacted global climate change (Milner et al., 2012).The increasing threat of climate change has called for more attention and discussion of global environmental issues (Saboori et al., 2012) such as higher average air and ocean temperatures, widespread melting of snow and ice, and rising average sea level. Intergovernmental Panel on Climate Change (IPCC) reported a possible increase from 1.1 to 6.4 °C in global temperatures and a rise from 16.5 to 53.8 cm

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in sea level by 2100 (IPCC, 2007). Major increase in greenhouse gas is attributed largely to carbon dioxide emissions (CO_2) as the principal gas leading to climate change (World Bank, 2007).

Studies reconnoitres mitigation options by which energy sector's emission can be reduced. Mitigation options that contribute significantly to the emission reduction including use of biomass for energy (Johansson, 2000), develop and use of energy efficient technology (Begum and Pereira, 2010; Pongthanaisawan and Sorapipatana, 2013; Huo et al., 2012), green technology (Oh et al., 2010), hydrogen and electric vehicles for passenger transportation and decarbonized electricity grid (Steenhof and McInnis, 2008; Pasaoglu et al., 2012). Malaysia also needs to increase its public transport services and to use alternative fuel like natural gas (Ong et al., 2011). Andress et al. (2011) suggested some strategies such as improve engine efficiency, introduce low carbon fuels and reduce vehicular miles travelled to reduce emissions from transportation sector. By using more cleaner fuel, renewable energy and introduction of eco-labeling technique can be useful for the emission reduction in Malaysia. Behavioural changes are also important for reducing energy consumption which can reduce GHG emission (Begum and Periera, 2015; Begum and Periera, 2010). As a consequence, it is crucial to understand time series patterns of Malaysia's energy consumption and CO_2 emissions and their relationship. The pattern and correlation analysis of energy consumption and CO_2 emissions would help to take actions for implementing strategies and policies to energy security and climate change mitigation. Thus, this article presents a detailed time series pattern of Malaysia's energy consumption and CO_2 emissions from 1980 to 2011 and shows their relationship analysis.

Data and Methods

Data used for the time series pattern and analysis are based on energy consumption by fuel type, sectoral and per capita; and CO_2 emissions of Malaysia from 1990 to 2010 which were collected and extracted from national and international data sources such as Malaysia Energy Information Hub, National Energy Balance (NEB) and World Development Indicators. However, according to the NEB (2011), energy consumption refers to energy demand or gross inland energy consumption which is calculated by the following formula:

Energy Demand = Gross inland consumption = Final energy consumption + Consumption of the energy transformation sector + Distribution losses + Non-energy consumption

Data on CO_2 emissions have been obtained from the World Development Indicators (World Bank, 2012, 2015) as limited availability of domestic sourced time series data of CO_2 emissions. Nevertheless, CO_2 emissions defined those stemming from burning of fossil fuels and manufacturing cement which include CO_2 produced during consumption of solid, liquid and gas fuels and gas flaring measured as metric tons per capita.

To find the relationship between energy consumption and CO_2 emission, analysis of Pearson's correlation coefficient was employed. The following formula has been used to obtain the correlation coefficient between two variables, X and Y.

$$r = \frac{\sum_{i=1}^{n}(X_i - X)(Y_i - Y)}{\sum_{i=1}^{n}(X_i - \bar{X})^2 \sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

where r = Pearson's correlation coefficient, X = energy consumption, Y = CO_2 emission; X_i = mean of X; Y_i = mean of Y and i = number of years. The value of correlation coefficient ranges between −1 (total negative correlation) and +1 (total positive correlation).

Malaysia's Energy Consumption: 1980-2011

The following sections present time series patterns and trends of energy consumption in Malaysia from the basis of fuel type, sectoral, total and per capita.

Energy Consumption by Fuel Type

Table 1 presents energy consumption by fuel types in Malaysia from the period of 1980 to 2011. Electricity, diesel, natural gas and motor petrol are the most consumed fuels while LPG, ATF & AV gas, coal & coke and non-energy fuel are comparatively less consumed fuels. The least consumed energy by fuel types are fuel oil, kerosene and refinery gas in which refinery gas is no longer used as fuels since 2008 until 2011. It is noticeable that total consumption for motor oil, electricity and natural gas has been linearly increased from 1980 to 2011 that might be due to increasing sales of motor vehicles, high growth in tourist travels and growth of automobile industry. Electricity is one of the highest energy consumption as fuel types with an increase of 2.9% from 2010 to 2011 whereas the total energy or fuel input to power stations increased by 30.3% in 2010 (32,068 ktoe) and by 0.8% in 2011 to 27,924 ktoe. The biggest drop for natural gas as fuel input to electricity generation was remarkable as

Table 1: Energy consumption by fuel types from 1980-2011 (ktoe)

Year	*Final Energy consumption by Fuel Type (ktoe)*										
	Diesel	*Fuel Oil*	*Motor Petrol*	*LPG*	*Kerosene*	*ATF & AV gas*	*Non-energy*	*Refinery gas*	*Natural gas*	*Coal & coke*	*Electricity*
1980	2368	846	1317	121	351	255	269	23	35	53	747
1981	2811	734	1423	124	368	285	270	26	39	99	800
1982	3094	422	1529	135	364	346	314	24	46	93	866
1983	3051	604	1756	174	352	338	320	26	45	249	935
1984	2901	528	1925	188	357	371	315	37	134	270	1019
1985	2773	554	2088	229	310	288	386	28	515	362	1079
1986	2803	489	2178	271	301	429	382	27	1056	268	1164
1987	3026	529	2297	330	269	435	358	27	1132	327	1253
1988	3275	598	2451	379	255	459	366	33	1058	189	1393
1989	3816	785	2585	415	211	499	313	11	1070	595	1548
1990	4421	883	2901	548	203	630	229	10	1093	513	1715
1991	4873	945	3135	612	180	690	467	12	1125	599	1925
1992	5291	1088	3326	733	160	764	565	0	1368	672	2218
1993	5339	1293	3666	1119	148	875	625	10	1716	487	2450
1994	5643	1392	4139	926	152	978	654	10	1863	598	2932
1995	5810	1506	4548	2215	177	1160	718	8	1935	712	3375
1996	6735	1770	5205	1215	197	1335	742	4	2474	727	3777
1997	7314	1978	5586	1245	169	1439	843	4	2465	740	4384
1998	6252	1678	5854	1301	165	1619	615	4	2726	767	4577
1999	6506	1792	6793	1523	162	1424	579	3	3023	608	4815
2000	7627	1875	6387	1362	131	1574	622	3	3863	991	5263
2001	8116	1497	6827	1392	99	1762	626	4	4621	977	5594
2002	8042	1590	6948	1542	92	1785	633	6	5644	1086	5922
2003	8539	1256	7360	1436	93	1852	632	7	5886	1212	6313
2004	9262	1463	7839	1542	86	2056	626	11	6490	1305	6642
2005	8672	1954	8211	1509	82	2010	564	10	6981	1348	6943
2006	8540	1901	7518	1520	79	2152	672	12	9317	1335	7272
2007	9512	2203	8600	1475	76	2155	823	9	10371	1361	7683
2008	9167	1963	8842	1475	75	2112	818	0	10750	1713	7986
2009	8634	1291	8766	2506	30	2120	799	0	6800	1613	8286
2010	8388	478	9560	2920	20	2380	657	0	6254	1826	8993
2011	8712	414	8155	2892	19	2553	1178	0	8515	1759	9235

Note: Non-energy use – the use of products resulting from the transformation process for non-energy purpose (i.e. bitumen/ lubricants, asphalt/greases) and use of energy products (such as natural gas) as industrial feed stocks.
Source: Energy Commission, 2012.

it decreased by 13.1% from 12,628 ktoe in 2010 to 10,977 ktoe in 2011 (NEB, 2011).

In order to meet the fuel demands, the power industry shifted to fuel oil and diesel. Therefore, fuel oil and diesel inputs in power station increased significantly by 782.4% and 136.4% respectively. In 2010, natural gas contributed as a main fuel input for electricity generation with a share of 53% followed by coal and coke, hydropower and diesel and fuel oil at 40.4%, 4.9% and 1.7% respectively where in 2011, coal and coke were the main fuel sources for electricity generation with 46.6% of the total fuel inputs, followed by natural

gas, hydropower, fuel oil and diesel at 39.3%, 6.6%, 4% and 3.5% respectively (NEB, 2010; NEB, 2011).The main consumer of electricity in 2011 was the industrial sector with its share of 43.9% of the total consumption in 2011 followed by the commercial sector at 34.3%, residential sector at 21.4%, agriculture sector at 0.3% and transport sector at 0.2%.

Overall, the total energy consumption by fuel types constituted mostly petroleum products at 55.1%, followed by electricity at 21.3%, natural gas at 19.6% and coal and coke at 4.0%. All types of fuel consumption have been increased in 2011, except for coal and coke and total petroleum products. Total consumption for coal and coke decreased by 3.7% to 1,759 ktoe where the total consumption for petroleum products also decreased by 1.9% to 23,946 ktoe.

Sectoral Energy Consumption

Figure 1 shows that energy consumption from all sectors has a fluctuation of growth over the years, compared to that of 1980. However, it has gone through ups and downs between years but overall shown an increasing trend with continuing its economic growth and development since 1980 to 2011. Increasing energy consumption was attributed to the high demand from the industrial, transport, residential and non-energy sectors. Transport and industrial sectors are the main consumer of energy with a share of 39.3% and 27.8% respectively in 2011. This was followed by the non-energy sector at 14.7%, commercial sector at 9.7%, residential sector at 6.4% and the agriculture sector at 2.1%. However, from 2008 to 2011, energy consumption for industrial sector showed decreasing trend due to improving energy efficiency. Malaysia's industrial energy intensity for 2011 was 61.3 toe/RM million, an increase of 6.7% from the intensity of 70 toe/RM million for 2010. This means that the final energy consumption for industrial sector slowed down in comparison to the GDP growth.

The energy consumption in Malaysia has been increasing with its economic growth and development since 1990 to 2005. Table 1 shows that the total demand of energy increased from 1,244 Petajoules (PJ) in 2000 to 1,631.7 PJ in 2005. The percentage of energy demand was highest for the transport sector at 40.5%, followed by the industrial sector at 38.6%, 13.1% from the residential and commercial sector, the non-energy sector at 7.3% and 0.5% from the agriculture sector. The Ninth Malaysia Plan (2006-2010) expected the overall national energy demand to increase at an average rate of 6.3% annually from 2006 to 2010. The transport and industrial sectors expected to continue to be major energy consumers with constituting 41.1% and 38.8% of the total energy demand in 2010, respectively. Commercial and residential buildings, alone, account for about 13% of total energy consumption and 48% of electricity consumption (EIB, 2008). For the industrial sector, energy-intensive industries (chemical, cement and ceramic, iron and steel, and food processing) are expected to remain major consumers (EPU, 2006). Unless this demand is provided by using renewable or alternative energy, coupled with energy efficiency efforts, GHG emissions will continue growing compared to the previous years.

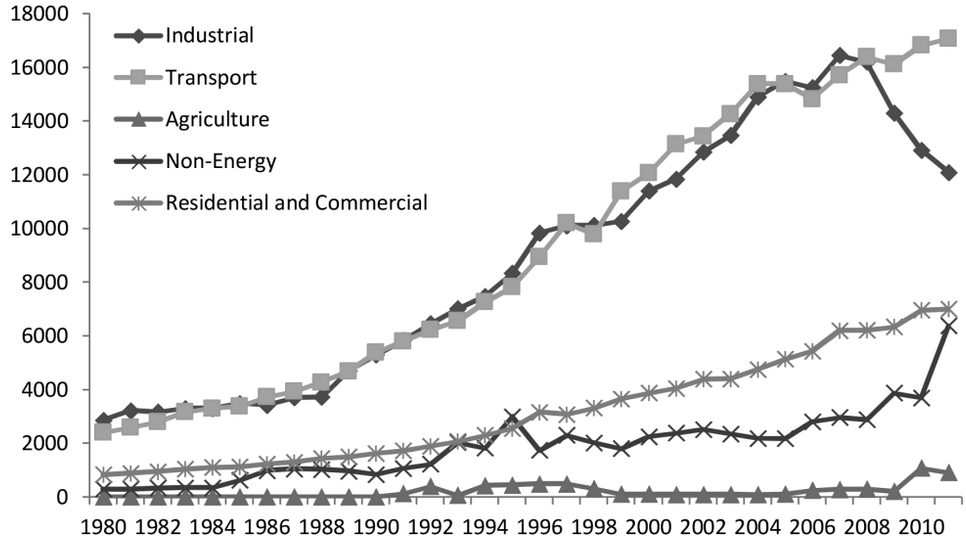

Figure 1: Sectoral energy consumption in Malaysia from 1980-2011 (Ktoe Tj) (Energy Commission, 2012).

Total and Per Capita Energy Consumption

Both total and per capita energy consumption demonstrate a linear and steadily pattern as shown in Figure 2. Over 30 years, the total energy consumption has rapidly increased from 6385 ktoe in 1980 to 43432 ktoe in 2011 with a growth rate of 18.72% per year. The trend of per capita energy consumption found similar to that of total energy consumption increased from 0.46 toe per person in 1980 to1.50 toe per person in 2011. The rapid increase of energy consumption might be due to major developments in all economic sectors including industrial with construction, residential, commercial and transport. As all economic sectors are expected to expand in near future, the energy consumption may experience the similar trend. Furthermore, total energy demand for industrial sector is expected to increase as new infrastructure projects scheduled to be implemented under the Economic Transformation Programme (ETP) which may provide the impetus for the sector (NEB, 2010).

Malaysia's CO_2 Emissions: 1980-2011

The time series patterns and trends of CO_2 emissions in Malaysia have been shown based on sectoral energy consumption and total and per capita emissions which are discussed below.

CO_2 Emissions from Sectoral Energy Consumption

Figure 3 shows Malaysia's CO_2 emissions from sectoral energy consumption from 1980 to 2011. In Malaysia, power generation sector is the largest CO_2 emitter

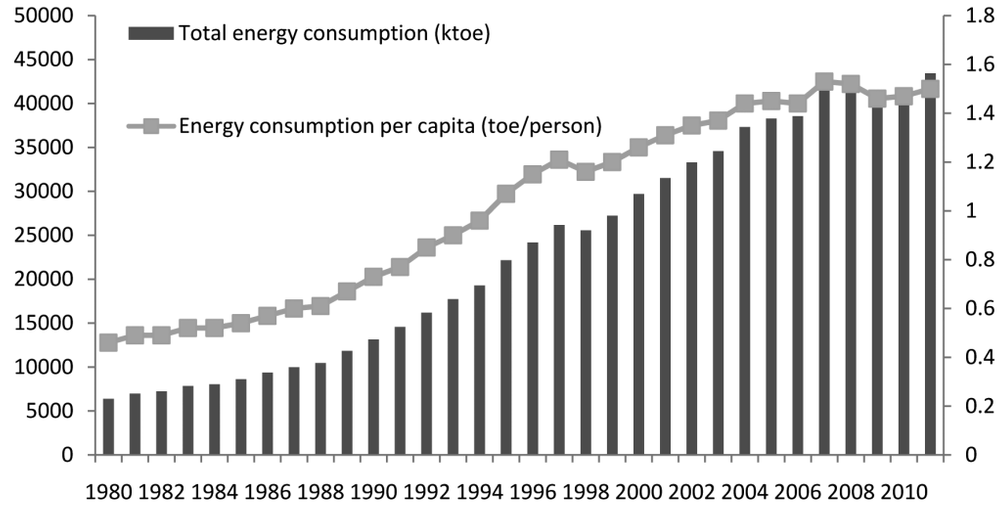

Figure 2: Total and per capita energy consumption (toe/person).

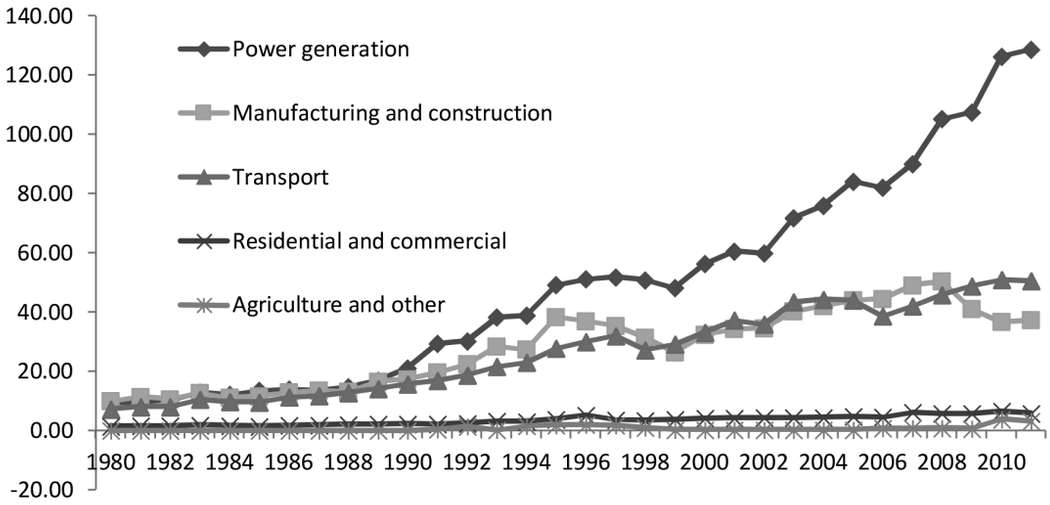

Figure 3: CO_2 emissions from sectoral energy consumption (million metric tonnes): 1980-2011.

whereas emissions from power generation energy consumption increased significantly since 1990 and rapidly increased in 2010 onwards. This might be the reason that, from 2009, there is a decrease of natural gas as energy input for electricity generation with an increase of coal share to 40.4% in 2010. As a result, coal overtook natural gas as its highest share of energy input for electricity generation at 46.6% of the total input of 27,924 ktoe in 2011. Nevertheless, Malaysia has a high demand of electricity especially for manufacturing and industrial sectors as well as tourism activities. Transport sector is the second largest contributor to CO_2 emissions based on sectoral energy consumption followed by manufacturing industries and construction sector; residential, commercial and public services; and agriculture and other sectors. It is important to note that the structure of sectoral energy consumption does not appear similar patterns to that of sectoral CO_2 emissions because the proportion of each energy type consumed differs from sector to sector. However, transport sector is found to be the highest contributor for both energy consumption and CO_2 emissions in Malaysia.

Total and Per Capita CO_2 Emissions

As presented in Figure 4, total CO_2 emissions from Malaysia's energy consumption experienced more than seven-fold increase of 225.69 million tonnes in 2011 compared to 28 million tonnes in 1980. It is also seen that the steady trend in per capita CO_2 emissions is similar to that of total CO_2 emissions. The per capita CO_2 emissions for Malaysia's energy consumption increased from 2.02 tonnes in 1980 to 7.90 tonnes in 2011, with a growth rate of 291%. However, due to the global economic crisis, CO_2 emissions found a decline in 2009, compared to 2008 but it tends to be increasing in 2010.

Relationship between Energy Consumption and CO_2 Emission

The relationship between energy consumption and CO_2 emission is measured by Pearson's correlation coefficient. The coefficient value of energy consumption and CO_2 emission or vice versa is found positive at 0.9 (Table 2). This means that most of the data points lying near to the linear and perfect line of equation which describes that CO_2 emission increases with an increase of energy consumption and vice versa. Furthermore, the value of correlation coefficient is found statistically significant at the 0.01 level ($P < 0.01$). The result reveals that Malaysia's higher rate of energy consumption leads to increase in CO_2 emissions whereas a high growth of GDP and increasing population might cause increased

Table 2: Correlation coefficient between energy consumption and CO_2 emission

Variables	*Pearson's correlation coefficient, r*	*Significant level (2- tailed); N = 21 (year)*
Energy consumption (ktoe) and CO_2 emission (million tonnes)/vice versa	0.956*	0.000

*Denotes significance at 0.01 level (2-tailed)

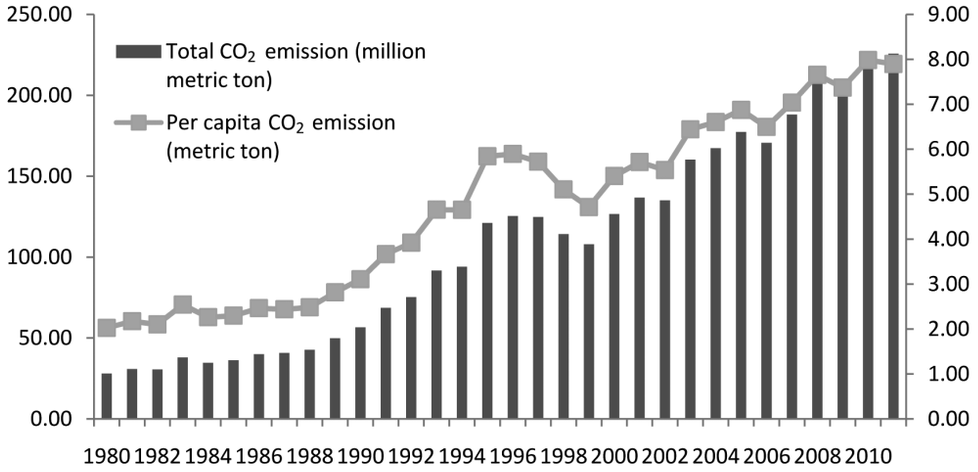

Figure 4: Total and per capita CO_2 emissions (unit: tCO_2e.): 1980-2011.

energy consumption. Figure 5 shows the data points and equation line for the relationship between energy consumption and CO_2 emission. The estimation of this relationship is based on measuring the degree of linear dependence between two variables.

Discussion and Conclusion

Malaysia is facing an increasing trend of all types of fuel energy consumption where electricity, diesel, natural gas and motor petrol are the major consumers. There is a significant change of main fuel input for electricity generation with a share of 47% of coal and coke in 2011 instead of 53% of natural gas in 2010. It shows that fossil fuel energy still holds absolute share of total energy consumption in Malaysia. According to the Malaysia second national communication (NC2), efforts to reduce dependency on petroleum products and environmental considerations are major objectives of more recent policies. In this context, renewable energy which is considered more environmental friendly has been made the fifth fuel after oil, gas, coal and hydro (MNRE, 2010). Recently, share of hydropower increases which contributed about 7% of total fuel sources for electricity generation in 2011. However, all the sectors exhibited growth in energy consumption while transport and industrial sectors are major consumers with about 67% of the total energy share in 2011. However, per capita energy consumption trends are similar to that of total energy consumption increased from 0.46 toe per person in 1980 to 1.50 toe per person in 2011.

Conversely, electricity/power generation and transport sectors contributed a larger share of CO_2 emissions followed by manufacturing industries and construction sectors among others. It is noteworthy that emissions from power generation rapidly increased in recent years. This might be due to the increasing coal share of energy input instead of natural gas for electricity generation. However, the Government of Malaysia in 2011 passed the Renewable Energy (RE) Act, and launched a roadmap to increase the contribution of RE to the electricity generation mix from less than 1% at present to 5.5% by 2015 (NEB, 2011). Under the Act, since December 2011, a Feed-in Tariff (FiT) mechanism is implemented to be paid by the contributions of additional 1% of total electricity bills into RE fund if any consumer used more than 300 kWh of electricity per month. This mechanism would work as an incentive to reduce energy consumption and a motivation to consumers (individual or industry) to offset the incremental electricity cost by applying renewable energy and energy efficiency measures that ultimately contribute to emission reduction in Malaysia. The government could provide indirect financial incentives through fiscal system of Enhanced Capital Allowance (ECA) scheme to encourage the take-up of cleaner technologies and activities aimed to reduce carbon emissions. Instead, carbon emission from transport sector has been more than doubled from 1995 to 2008 with annual growth of 8.4% which is relatively high among developing countries (Ong et al., 2012) because transportation sector in Malaysia is highly

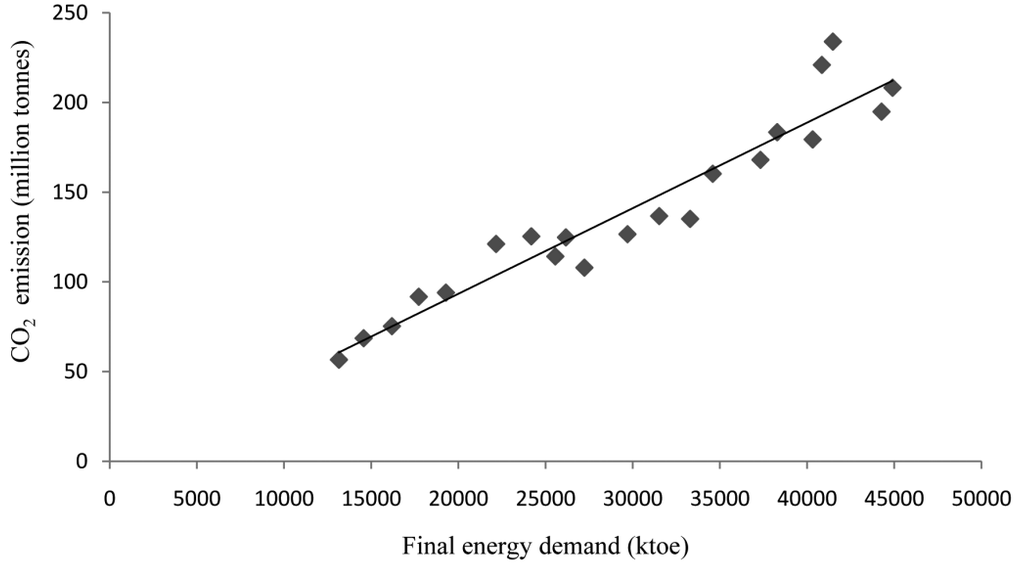

Figure 5: Data points and equation line for energy consumption and CO_2 emission.

dependent on petroleum products as energy source. Improved efficiency of energy use in all sectors and switching to alternative renewable fuels for electricity generation and transportation sectors could help to reduce energy related CO_2 emissions.

Furthermore, the correlation analysis found a positive and linear relationship between CO_2 emission and energy consumption. This indicates that Malaysia's higher rate of energy consumption leads to higher CO_2 emissions whereas a high growth of GDP and increasing population might cause further increase of energy consumption. In practical, it has to be conceded that Malaysia has experienced rapid transformation from agriculture-based economy to industrialisation and rapid growth of population and urbanisation accompanied by escalating energy demand and consumption that heavily relied on fossil fuels. These resulted in a significant rise in GHG emissions (Begum and Pereira, 2011). In near future, energy consumption is expected to continue growing which means increasing GHG emissions that may cause greater challenge to Malaysia's development and sustainability. Haug (2004) advised the main alternatives to reduce CO_2 emissions without hampering economic growth which are use of energy more efficiently thereby reducing energy consumption; change to the consumption of renewable energy sources; and burn fossil fuels while capturing and storing the CO_2 instead of releasing into the atmosphere. Carbon capture and storage (CCS) presents one of the most promising options for large-scale emission reductions from energy use (Zhu et al., 2015), and is forecasted to be competitive with other future carbon mitigation options (Othman et al., 2009). CCS can also be a great potential of mitigation option in Malaysia as coal is one of the main contributor to its energy consumption. However, effective measures and actions are necessary to implement energy conservation strategies and emission mitigation policies for addressing energy security and climate change. Finally, the trends, patterns and relationship of energy consumption and CO_2 emission might help to frame current energy and emission issues; and encourage to take measures for achieving low carbon economy in Malaysia. This article serves as a guide for further research in order to implement renewable energy and improve efficiency in energy conversion, transmission and utilisation.

Acknowledgement

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Calendar of Events

7th International Conference on Environment Science and Engineering (ICESE 2017)
11th to 13th April 2017
Seoul, Korea (south)
Website: http://www.icese.org/
Contact person: Ms. Iris Tang
Organized by: CBEES

Water: Operational Technology and Data—UK's only water engineering event
26th and 27th April 2017
Walton, United Kingdom
Website: http://go.evvnt.com/108140-1
Contact person: IET Event Services
Organized by: The IET

Decarbonised Energy and Water Resilience
3rd and 4th May 2017
London, United Kingdom
Website: http://www.ice-energyandwater.com
Contact person: ICE Events Team
Organized by: Institution of Civil Engineers

International Ecology Symposium 2017
11th to 13th May 2017
Kayseri, Turkey
Website: http://ecology2017.erciyes.edu.tr
Contact person: Fatih Duman

5th International Conference on Waste Management, Ecology and Biological Sciences (WMEBS-2017) Istanbul - Turkey
17th and 18th May 2017
Istanbul, Turkey
Website: http://wmebs.eacbee.org/
Contact person: Alissa Matthew
Organized by: Emirates Association of Chemical, Biological & Environment Engineers

4th International Conference on Geography, Environment and GIS, for students and young researchers
18th to 20th May 2017
Targoviste, Dambovita, Romania
Website: http://www.limnology.ro/GEG2017/abstract.html
Contact person: Petre Bretcan
Organized by: Department of Geography, Valahia University of Targoviste

3rd International Conference on Water Technology (ICWT 2017)
23rd to 25th May 2017
Beijing, China
Website: http://www.icwt.org/
Contact person: Ms. Iris Tang
Organized by: CBEES

3rd International Conference on Advances in Environment Research (ICAER 2017)
23rd to 25th May 2017
Beijing, China
Website: http://www.icaer.org/
Contact person: Ms. Lydia Liu
Organized by: CBEES

Water and Society 2017
5th to 7th June 2017
Seville, Spain
Website: http://www.wessex.ac.uk/conferences/2017/water-and-society-2017
Contact person: Irene Moreno Millan

8th International Conference on Environmental Science and Technology (ICEST 2017)
12th to 14th June 2017
Madrid, Spain
Website: http://www.icest.org/
Contact person: Ms. Iris Tang
Organized by: CBEES