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The financial impact of adopting carbon-tax as policy on electricity generation system: A case study of Malaysia's power generation mix

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Abstract

It has been acknowledged that increasing amount of carbon in the atmosphere is being responsible for climate change and seasonal variation. The burning of fossil fuel for electricity generation has been among the key factor for increased CO_2 production. However, the biggest concern of the policymakers around the world is to minimize the rate of carbon emission by implementing effective and efficient policies. Considering the catastrophic impact of carbon 192 countries of the world have signed an agreement under the umbrella of United Nations Conventional framework on climate change (UNFCCC) to restrict the emission by a significant value. Malaysia has also committed to reducing the carbon emission rate 45% by the end of 2030.Among the several measures, carbon-tax is advocated most effective tool and has high possibility to be implemented as Malaysia's future low carbon development. The main objective of this study is to highlights the global carbon taxing trend and to estimate the energy price equivalence of carbon taxes in Malaysia's energy market. To evaluate the financial impact of adopting a carbon-tax policy on current power generation mix of Malaysia the system was examined by three different carbon pricing rate. The study is set to compliance with the five fuel diversity strategy as per 11th energy action plan for electricity generation in Malaysia.

Keywords: Energy Policy; Carbon-Tax; Global Warming; Carbon Pricing Trend

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1. Introduction

US Environmental Protection Agency (EPA) has declared that atmospheric concentration of GHG has tremendously increased in last fifty years from 312 parts per million (ppm) in 1950 to 401 parts per million (ppm) in 2015 (EPA, 2016) which is responsible to raise global temperature, sea level, patterns of rainfall, plants growth and productivity, intensity of storms, marine life and chemistry of oceans (Marron et al., 2015). After the release of fifth assessment report of intergovernmental panel of carbon emission (AR5) policymakers are reviewing their long-term strategy to minimize the rate of carbon emission in the atmosphere. However, the fossil fuel burning is the biggest contributor of carbon emission and contributes 67% of entire emission globally (Fernando and Hor, 2017) among which power sector contributes 54.8% of total emission (World Bank, 2017). A significant reduction in utilization of fossil fuel is the only option to restrict the changing global temperature below 2C (IPCC, 2014). Following the natural phenomena partial amount of CO_2 has been absorbed by the oceans, but as emission increased, the consequential acidification of those oceans leads to the climate change and global warming (Cubasch et al., 2013). Among the GHG CO_2 is the most abundant gas produced by human activities (IPCC, 2005) released as a by-product in the combustion process of fossil fuels namely coal, natural gas,and petroleum products (Thollander et al., 2007). However in US power plant is the largest standalone source of GHG emission which contributes approximately 29% of total US carbon emission (Contreras et al., 2016). Similarly in Malaysia over 55% of emission is due to the electricity generation industry (World Bank, 2017). Energy consumption, economic growth,and environmental degradation are interrelated to each another. It has been acknowledged that constant economic growth is highly dependent upon uninterrupted supplies of electricity (Chandran et al., 2010; Lean and Smyth, 2010a, 2010b; Tang, 2008; Tang and Tan, 2013; Yoo, 2006). Malaysia is an emerging economy and the demand for electricity has been increased tremendously in last few years. Since 1995 to 2015 the demand for electricity has been increased from 38,820 GWh to 146,221 GWh and is expected to increase 30 % more by 2020 (MES, 2017). Malaysia is also third largest carbon dioxide (CO_2) emitter in Southeast Asia followed by Indonesia and Thailand (World Bank, 2017). Malaysia Fossil fuel reservoirs are gradually depleting. It is estimated that Malaysia's oil reserve will last 18 to 20 more years, natural gas 30 to 35 more years and coal is imported for electricity generation (Oh et al., 2010; Chua and Oh, 2010). In the long term, this situation will result in jeopardizing the security and affordability of electricity in the country. Hence, the social and economic well being of the people will also be affected.

The consumption of fossil fuel as an energy resource in a population is one of the huge challenges to global environmental sustainability and economic stability."Greenhouse Gas" and chemicals that evolved during the combustion of fossil fuels are also responsible for many health issues. Donohue and Cogdell (2006) argued that government, private sectors,and scientific community have been united on a single platform to seek such alternative energy sources which can be developed an adopted to decrease the consumption of fossil fuels and simultaneously reduced GHG emissions. The crucial challenges of Malaysia power sector are the sustainability, security,and reliability of energy supply, which is a mix of non-renewable and renewable energy for long-term development. Today, the world is more circumspect, and renewable energy has been put in the limelight in upgrading the efficiency of the existing power resources. Numerous sound energy policies and significant measures have been formulated to prepare the country for its

transition to being a developed nation on a sustainable basis (Chong and lam, 2013). Various efforts were undertaken to embark on the utilization of renewable energy resources, biomass, biogas, solar, nuclear, hydro-power and municipal waste for energy generation. In tandem with the government's initiatives, a number of renewable energy policies, strategies,and program were launched and enforced to ensure the reliance on the energy supply (Hossein and Wahid, 2012).

2. Overview of Malaysia's power generation sector

The electricity supply industry in Malaysia is mostly monopolistic with the regionalized vertical integration of the generation, transmission, and distribution of electric power. At present, there are three main players; Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd (SESB) and Sarawak Electricity Supply Corp (SESCO), each covering the region of the Peninsula Malaysia, Sarawak, and Sabah respectively. More than 80% of electricity in Malaysia is generated through fossil-fuels (natural gas and coal) which is continued to expand rapidly over the years. Total installed capacity at present stands at around 30 Gigawatt (GW), among which most of the power generation stations are situated in the densely industrial and densely populated Peninsular Malaysia. Meanwhile, the states of Sabah and Sarawak which are located in the Borneo archipelago are mostly powered up by hydropower due to their favorable geographical terrains. A few of these thermal power generation plants are based on co-fuel generation technology, which can the run on two different fuel hence this advancement allow greater flexibility for plant operation at an optimal level. Malaysia's total installed power generation capacity by the end of 2010 was 24,361 MW (NEB, 2010); However, it has significantly increased in last five years and reached to 30,440 MW.Peninsular Malaysia has got the largest share of 75% of the installed capacity, followed by Sarawak and Sabah at 16.7% and 8.3%, respectively. The reserve margin of the system stands around 43.7%; the long-term objective of Suruhanjaya Tenaga (ST) is to cut it to 20% level; thus reducing unused electricity generation capacity resulting in operational cost savings. The national grid serves all the urban population, while 98% of the rural population has access to electricity network (Bakhtyar et al., 2013). Table 1 shows the state wise share for the total installed capacity of Malaysia's electricity generation mix.

Table 1. Distribution of installed capacity in Malaysia

Installed Power Generation Capacity of Malaysia 31st December2015					
Generation Type	**Sabah**	**Sarawak**	**Peninsular**	**Total**	**% Share**
Coal	0	480	8,066	8,546	28.1
Natural Gas	1,231.4	903.6	11,370.6	13,505.6	44.4
Hydropower	82.5	3,458.8	2,174.8	5,716.1	18.8
Diesel	897	169.9	399	1,465.9	4.8
Biomass	3,01.5	74.1	486.9	862.5	2.8
Solar Power	18.3	0.3	207.7	226.3	0.7
Biogas	6.1	6.6	104.7	117.4	0.4
Total Units Generated	2,536.8	5,093.3	22,809.7	30,439.8	100%

Source: NEB (2015)

It can be concluded from the above table that the 2015 power generation mix has been comparatively diversified as compared to the year 2010 that is 91% fossil fuel, renewable 0.2% and hydro 8%. This scenario leads Malaysia towards sustainable and environment-friendly future of buildings. Since, it has almost reduced its dependency on fossil fuel by 10%, besides almost doubled its hydroelectric and solar resources and added the use of biomass and biogas as renewable resources.

2.1. Malaysia fuel policies

A policy of four-fuel diversification has been guided by Malaysia energy sector since 1980. The International oil crisis of 1978-79 not only increased the oil prices but also disrupt the supplies. This was the time when policy-makers proposed a diversified fuel plan which includes coal, natural gas and hydropower as an alternative energy sources. At the time Malaysian land had large gas reservoirs and unexploited hydropower. The coal occupied the central position in the policy due to its easy native availability, technological feasibility and stable prices. The four fuel policy pushed the country towards an enormous balance of fuel mix in energy consumption. The great outcome of this policy was reflected from the fact that during 1980 Malaysia energy sector was 90% dependent on oil which noticeably declined to 64% in 1997. Natural gas and coal, in 1997, accounted for 30% and 5% respectively of the total energy mix.

The fifth fuel policy was launched during the 8th Malaysian plan (2001-2005), and the government set itself a target of obtaining 5% of its energy from renewable sources by 2005. However, this policy ended up reaching only 0.3% of the target by the year 2005 (Sukki et al., 2011). The same target of 5% renewable energy was again set in the 9th plan (2006-2010). Under the 8th and 9th Malaysian Plans, the Malaysian government took several steps to explore and promote the use of renewable energy as an alternative fuel source. In this regard, more than 800 million USD was invested in new renewable energy production (Olz and Beerpoot, 2010). However the policy was ended by only achieving8.3% of the set target and only 41.5 MW was successfully connected to the grid(Maulud and Saidi, 2012; Rehman and Lee, 2006).

As part of the 10th Malaysia Plan in 2010, the National Renewable Energy Policy and Action Plan were launched. This policy has been launched to provide a secure and sustainable national electricity supply for socio-economic development (Malek, 2010). To increase the public awareness, a “Feed-in Tariff” was introduced. According to the 10th Malaysia plan, a total electricity generation of 985 MW should be achieved during 2010 to 2015, which is almost 23 times the 41.5 MW of previously installed capacity (EPU, 2010). The policy ends up by adding 243 MW in national grid (Kettha, 2015).Once again the 11th action plan has been launched with seeking to raise the contribution of renewable energy to electricity generation mix to 11% by the end of 2020.Uptillnow, the capacity has been increased 3.9 % of the total generation mix (NEB, 2015).Figure 1 summarizes the main energy policies of Malaysia energy sector.

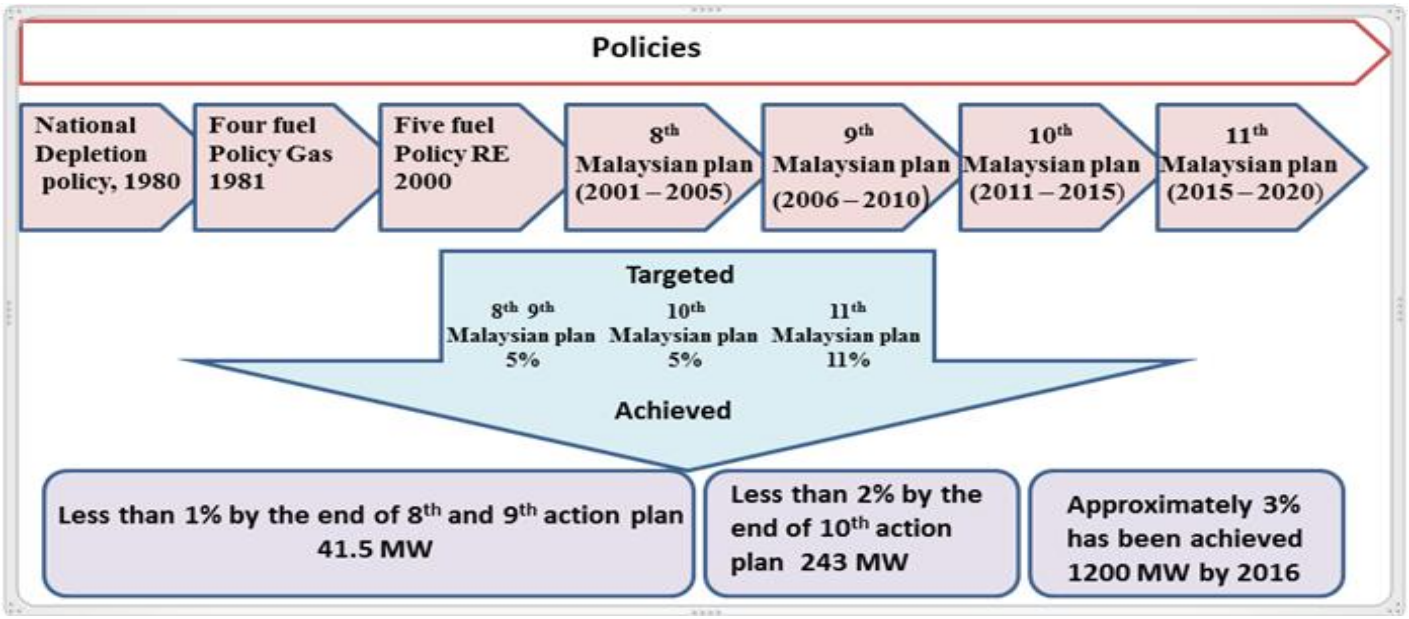

Figure 1. Policy development and achievement towards renewable power

3. Carbon-tax and emission factor

Increasing energy demand, depleting reservoirs and carbon emission climatic impact has put a pressure on policymakers for implementing efficient long terms policy. However, Malaysia has implemented five fuel diversification strategies to cope with the continuous depletion of indigenous resources. On the other hand in France agreement IPPC Malaysia has also committed to reducing up to 45% of carbon emission by 2030, in which 35% reduction is on unconditional terms and 10 percent was based upon the receipt of climate finance, technology innovation and capacity enhancement by developed countries, up till now no initiative has been taken of policy front regarding carbon emission control. There is a growing consensus among policy-makers – that has long been accepted among economists – that putting a price on GHG pollution is the most effective means of reducing our carbon footprint (Stern, 2007). A carbon-tax is considered as an environmental tax which is implemented on production and service activities that pollute environmental commodities. Some countries in Europe, such as the Netherlands, Sweden, Finland, and Norway, have implemented carbon taxes for years (Baranzini et al., 2000). China has also introduced carbon capping scheme in its 13th national action plan which is expected to be implemented during (2016-2020) in the form of carbon-tax (Liu et al., 2015). Malaysia is trying to become a developed country by 2020.Hence there is a critical need for Malaysia to review its energy policy and adopt carbon pricing mechanism for power generation industry as it is the largest contributor which approximately contributes 54.8% of entire emission (World Bank,2017). Sovacool (2008) has presented the carbon emission rate of different fuels used to generate 1 KW of electricity as shown in Table 2.

Table 2. Technology and fuel type with carbon emission intensity

Technology	Capacity/Configuration/Fuel	gCO_2e/KWh
Conventional Power Generation Technologies		
Coal	Various generator types without scrubbing	1050
Coal	Various generator types with scrubbing	960
Heavy oil	various generators and turbine types	778
Diesel	various generators and turbine types	778
Fuel cell	hydrogen from the gas reforming	664
Natural Gas	various combined cycle turbines	443
Nuclear	various reactor types	66
Renewable Power Generation Technologies		
Wind	2.5 MW offshore	9
Hydroelectric	3.1 MW, reservoirs	10
Wind	1.5 MW, onshore	10
Biogas	Anaerobic digestion	11
Hydroelectric	300KW, run on the river	13
Solar thermal	80 MW parabolic trough	13
Biomass	Forest wood co-combustion with hard coal	14
Biomass	Forest wood steam turbine	22
Biomass	short rotation forestry co-combustion with hard coal	23
Biomass	Forest wood reciprocating engine	27
Biomass	waste wood steam turbine	31
Solar PV	polycrystalline silicone	32
Biomass	short rotational forest steam turbine	35
Geothermal	80 MW hot dry rock	38
Biomass	short rotation forestry steam turbine	41

Source: Sovacool (2008)

From the above table, it can be observed that the coal is the most hazardous fossil fuel containing 1050 gCo_2e/KWh followed by oil and gas. Unfortunately, more than 80% of electricity has been generated from fossil fuels in Malaysia's power generation mix. Adopting carbon-tax as policy tool will not only reduce the emission rate but also encourage the utilization of renewable resources for power generation process.

3.1. Trend of carbon pricing and taxation

A carbon tax is often presented as the most economically efficient approach to limit these emissions (Newcomer et al., 2008). It has recently started to gain support from unanticipated sectors like the oil and gas industry (Rosenberg, 2017) and 12 countries including the Canadian province of British Columbia have implemented carbon taxes with values ranging from $1/tonCO2e in Mexico to $130/tonCO2e in Sweden (World Bank, 2015). A carbon tax has been taken as a cost-effective scheme to reduce GHG emissions in a number of countries. As a typical example, British Columbia (B.C.) implemented the carbon tax on July 1, 2008, at a rate of $10 per metric ton of CO2. In July 2014, the B.C. carbon tax was increased to $25 per metric ton of CO2 (Carbon Tax Center, 2015).

Recently in Europe two of the coal-fired plant has been shut down due to the carbon taxation. The latest blow is the closure of the Britain's biggest power station, at Ferrybridge in West Yorkshire, shuts down seven years earlier than its expected time. The plant has a capacity to generate 2000 MW of electricity and half of the plant stopped operating in 2014 because of not been updated to meet strict new European Union emission rate. British carbon prices some of the highest in the developed countries. Today the price of power station across the EU is just 5.30 pounds per tons of carbon dioxide emitted but British coal plant pays 23.38 pounds per tons emitted (Tony, 2015).Similarly, in order to meet the green goal, Scotland power plant of 2400 MW capacity was shut down after 50 years of successful operation (Andrew, 2015).Excluding Japan, the china, India and rest of the Asian countries are not paying carbon emission taxes. Malaysia is planning to become a developed country by 2020 and it is a huge concern of policymakers to bring sustainability in the electric sector. In a recent study conducted by Australian National University (ANU) mentioned that Malaysia and Indonesia are heavily dependent upon the thermal resources for electricity generation. It proposed to implement a carbon tax on heavy industries i.e. starts from the minimal amount of $10 per ton of carbon emission (Saiful, 2014). It has been mentioned in 2011, TNB and IPP generated 5000MW of electricity from their combined 7000 MW of coal power station and emitted 40.6 million tons of carbon dioxide in the process (Assuming that every MWh emits 0.9 tons of CO_2). Imposing a carbon tax of RM 72 per ton on emission using Australian benchmark of AUD $ 23/ tones, The government would collect RM 2.85 billion annually to fund renewable energy projects. However in 6th national energy forum hosted by the energy commission, the ministry of environment, green technology and water raised the question for the carbon tax in Malaysia.It is expected that tax may be implemented after the extension of MRT line 1 extension project (Hafidz, 2015).

Researchers and policymakers around the globe are continuously reviewing their policies to reduce the carbon footprint. Most of the studies in past focused on the transportation and industrial sector. However particularly Power generation sector is not focused in many studies and there is no standard tool to calculate carbon emission only for power generation process. In this study, we develop a simple equation to calculate the cost of carbon emission in power generation process.In this study standard equation is proposed for the calculation of carbon emission in power generation process based on the carbon contents of a fuel and the proposed rated of per matric ton of carbon emission.

Carbon price for the generation of 1 KWh of electricity can be calculated as:

$$C_i = C_a C_b \sum n_x$$

C_i Cost of carbon released during generation of electricity
C_a Tons of carbon released by *X* type of technology in KWh
C_b Price of per metric ton of carbon released.
n Number of units generated
x Type of fuel (Coal, gas, Hydropower, Biomass, Solar)

where,

n =Power Generation (MWh) = Installed Capacity (MW) x Plant capacity (%) X Plant Operational time in Year.

4. Evaluation of carbon emission in Malaysia power generation process

The push toward a cleaner and more sustainable environment is resulting in new pressures on the electric power industry. The numerous fossil-fired power plants that operate today make the industry one of the largest man-made carbon dioxide emitters. There are many climate change initiatives in various stages of development and implementation that will strongly influence the future course of the industry. In the 11th national action plan, the government has set the target to reduce the total emission to 40% by the end of the year 2030.However up till now no serious major has been taken to achieve the target.The total estimated amount of carbon released in Malaysia's power generation process is shown in Table 3.

Table 3. Total Amount of carbon Emission in Malaysia Power Generation Process

Fuel Type	Capacity in MW	Capacity in KWh	(gCO2e/KWh)	Carbon Emission MT
Coal	8,546	73,110,960,000	1005	73,476,514.80
Natural Gas	13,505.6	118,309,056,000	443	52,410,911.81
Hydropower	5,716.1	50,073,036,000	13	650,949.47
Diesel	1,465.9	12,841,284,000	778	9,990,518.95
Biomass	862.5	7,555,500,000	27	203,998.50
Solar Power	226.3	1,982,388,000	22	43,612.54
Biogas	117.7	1,031,052,000	11	11,341.57
Total	30,440.1	264,903,276,000		136,787,847.64

Current Malaysia power generation sector is responsible to contribute 136 million metric tonnes of carbon emission per year. Fossil fuel combustion is the biggest contributor to carbon emission in power sector. In 2011 the estimated amount of global carbon emission from fossil fuel is around 34.8 billion tonnes. Among fossil fuels, coal is the most concentrated material and alone contributes 43% of total emission globally (Le et al., 2013).Due to the strong policy formulation, a significant decrease in coal generation has been observed in last five years in Malaysia's power generation mix. The total installed capacity of the coal-fired power plant has been decreased from 38% to 28% from the year 2010 to 2015 (NEB, 2015), however, the actual generation sharesstill stands at 34%. Due to the heavy dependence on fossil fuel Malaysia has becomes the third largest carbon emitter among ASEAN countries. Implementing carbon tax may divert the attention of investors to reduce the share of fossilfuel and to increase the investment in the renewable energy sector for sustainable power generation process.

5. Price equivalence of carbon tax

Malaysia's current generation mix consists of two conventional and three renewable resources, however, more than 80 percent of generation shared is occupied by conventional resources. Currently share of renewable (solar and biomass) is less than 5 percent. According to 11th Malaysia, energy action plan at least 11 percent of electricity should be generated through solar and biomass for sustainability by the end of the year 2020. On the other side increasing environmental concern increases pressure on policymakers for the immediate reduction in conventional generation resources and induced policy of carbon taxation on carbon emission. France, Denmark, Ireland, Iceland, Japan, Mexico and even South Africa have already implemented a carbon tax on carbon emission. Australia has taken 27$ USD on per metric ton of carbon emission. In this subsection, we examine the experiences of Malaysia current generation mix in levying a carbon tax to hypothesize three possible regimes ranging from 10 US$, 20 US$ and 30 US$ per metric ton of CO_2 emission.

Table 4. Estimated Cost of carbon Tax for Malaysia's Power generation mix

States	Installed Capacity	Carbon Emission MT	10$	20$	30$
Sabah	2,537	10,976,796	109,767,960	219,535,920	329,303,880
Sarawak	5,093	9,302,430	93,024,300	186,048,600	279,072,900
Peninsular	22,810	118,269,352	1,182,693,520	2,365,387,040	3,548,080,560
Total	**30,440**	**138,548,578**	**1,385,485,780**	**2,770,971,560**	**4,156,457,340**

Table 4 illustrates the comparison of cost at three different taxation rates for per metric ton of carbon emission during power generation process. It shows that approximately 4,156,457,340 USD per year should be paid in the account of carbon emission in power generation process at the rate of 30$ per metric ton. Although the amount is seems to be very low with respect to its consequences still a good initiative to restrict the investment in conventional power generation technologies. In future, this amount can be increased for safer and sustainable environment.

6. Conclusion

Global warming has become the most critical issue in the world due to increasing greenhouse gas (GHG) emissions. The report compiled by an Intergovernmental panel of climate change IPCC (2007) has mentioned that global temperature has increased by 0.56 to 0.92 C in last 100 years and expected to be increased by 2C by 2100. Therefore considering this fact 192 countries have signed the agreement to reduce the GHG

emission as shown in the United Nations Conventional framework on climate change (UNFCCC). Malaysia has also committed to reducing its emission to 45% by the end of 2030. However Implementing any new strategy for environmental and energy policy requires a detailed assessment of economic, technological and operational parameters. Implementing a carbon-Tax is no different. The carbon tax is useful and prospective policy measure to mitigate Malaysia's carbon emission. In order to examine its effect on Malaysia power generation industry, this study proposed three different carbon emission taxation rates and quantify the total amount of carbon emission in current power generation process. The study shows that the current Malaysia generation mix is responsible to contribute 136 million metric tons of carbon and at the rate for 30 USD it can manage to collect 4,156,457,340 USD which can be implemented on secure and sustainable future generation mix and also help to archive the 45% reduction deadlock before the time.

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