# Long Term Policy Analysis of Malaysia's Renewable Energy Fund Budget: A System Dynamics Approach

M. Sadegh Shahmohammadi <sup>a,\*</sup>, Rosnah bt. Mohd. Yusuff <sup>a</sup>, Hamed Shakouri G.<sup>b</sup>, M. Mahmoud Sadat <sup>c</sup>, Sina Keyhanian <sup>d</sup>

<sup>a</sup> Department of Mechanical and Manufacturing Engineering, University of Putra Malaysia, Selangor, Malaysia

<sup>b</sup> Institute for Resource, Environment and Sustainability, The University of British Columbia, Vancouver, Canada

<sup>c</sup> Department of Operations Research, Faculty of Management, University of Tehran, Tehran, Iran

<sup>d</sup> Faculty of Mathematics and Natural Sciences, University of Groningen, Groningen, The Netherlands

#### Abstract

Malaysia has abundant potentials of renewable energy resources in bio-power, solar PV systems and small-scale hydropower. Feed in Tariff mechanism has been applied since 2011 in Malaysia to expand utilization of renewable energy for electricity generation. In this study a comprehensive system dynamics model is developed to simulate the impacts of assigning different Feed in Tariff rates for different potential renewable resources on the generation mix of Malaysia between 2011 and 2030. Results demonstrate that although the policy may lead to a satisfactory level of target achievement but the government may face an increasing shortage in its RE fund budget starting around 2019 unless it increases its income sources by rising the surcharges on electricity bills or decreases its expenditures by optimizing the amount of FiT payments in different periods. Sensitivity analysis illustrates that the more funding will not lead to a more sustainable generation mix unless it is paid in the right time and in the right direction. Using this model, policymakers can carry out analysis to determine the amount of money that must be collected from the electricity consumers as well as the amount of feed in tariff to be paid for different renewable resources in different periods.

#### **Keywords**

Renewable Energy, Feed In Tariff, Energy Policy, Decision Support System, Electricity Generation Modeling, System Dynamics

#### **1. Introduction**

Malaysia's energy supply policy is a high impact issue for its economy. With an annual growth rate of 8.1 percent it is projected by (Chua and Oh, 2011) that Malaysia's final energy demand in 2020 will reach 116 MTOE. Therefore due the rapid economic development, and the positive correlation of Malaysia's GDP with its energy consumption (Oh et al., 2010), the need for more energy resources in Malaysia's energy mix is vivid.

<sup>\*</sup> Mohammad Sadegh Shahmohammadi

Email: Sadegh Shahmohammadi@yahoo.com

The electricity generation of Malaysia has been strongly oil and natural gas dependent for many years. With oil and natural gas starting to run out and coal being a cheap resource, Malaysia shifted its perspective to utilizing from coal resource in order to generate remarkable part of its required electricity. This substitution first took place by decreasing share of oil and distillate, increasing of natural gas and a starting share of coal. Then in recent years, it went on by using more coal resource and lesser natural gas as in 2012 around 37% of Malaysia's electricity was generated from coal. Figure 1-1 shows the changes in power generation mix of Malaysia during the period between 1995 and 2012.



Figure 1-1. Generation mix of electricity in Malaysia, 1995-2012 (% of total) (TNB, 2012).

Starting to use a cheaper resource sounded good at first, but it highly increased the level of pollution and GHG emissions as in 2010 Malaysia had 57 percent higher per capita emissions than the world's average (Malaysia EPU, 2010, World Bank, 2014) and ranked as the 26th largest GHG emitter in the World (Muis et al., 2010). Figure 1-2 compares the trends for emission per capita in Malaysia and its neighboring countries as well as the world's average over the period between 1960 and 2010. As illustrated in the figure, Malaysia has the highest per capita emission level among its neighboring countries and in contrast with Singapore that has been successfully restraining its emissions the trend in Malaysia is still increasing.



Figure 1-2. Comparisons of emission per capita between Malaysia, its neighboring countries and world average.

Research shows that Malaysia has a promising potential for renewable energy resources (Oh et al., 2010). In order to resolve the high level of pollution, Malaysia authorities decided to bring renewable energy into the mix planning to increase their role in electricity generation. They began their planning by considering RE resources in the 8th Malaysia Plan (2001-2005)(Malaysia EPU, 2000) but the achievements were so poor leading to only 0.3 percent of the target, (Oh et al., 2010, Malek, 2010). The achievements in 9th Malaysia Plan (2006-2010) (MALAYSIA EPU, 2005) were higher but still not satisfying, which reached to 15% of the target (Sovacool and Drupady, 2011, Malek, 2010).

The main reasons that were avoiding the investors to switch to renewable electricity generation were technical, economic and institutional challenges (Sovacool and Drupady, 2011) as well as disappointment from previous achievements. In order to tackle these challenges, the Sustainable Energy Development Authority Malaysia (SEDA) developed a new plan called National Renewable Energy Policy and Action Plan (SEDA Malaysia, 2010) which focuses on green or so called SMART targets by defining fiscal incentives. In order to reach these targets. New policies were defined in this plan to stimulate investors to contribute in renewable electricity generation; the most important of which is the Feed in Tariff mechanism. The 10th Malaysia Plan (Malaysia EPU, 2010) which is in its final phases, has a target of 985 MW by 2015.

Feed in Tariff (FiT) refers to the regulatory minimum guaranteed price per kWh that a power utility has to pay to a renewable power producer (Sijm, 2002). Based on previous studies, FiT is the most beneficial policy for the expansion of RE utilization (Midttun and Gautesen, 2007, Hsu, 2012).

FiT provides RE investors with a long-term, minimum guaranteed price for the electricity they produce. Therefore, it increases their willingness for investment by providing a confident degree of financial reliability and reducing the risk of investment (Lesser and Su, 2008). For this reason, it has been the major mechanism for RE generation expansion in both Europe and the US in a way that 20 European countries were applying FiT mechanism in 2009 (Campoccia et al., 2009). Having said that, a huge budget is required for the governments to adopt the FiT mechanism.

Although FiT has a number of benefits, they may lead to some drawbacks if they are not applied properly as well. FiT rates, degression rates and the period in which FiT policy is applied are the most important factors in utilization of this policy. The FiT rates must be high enough to recover the investment cost within a reasonable timeframe (Dusonchet and Telaretti, 2010) nonetheless small enough to avoid enforcing a big financial burden to the states. (Rüther and Zilles, 2011).

The Renewable Energy Act was enforced in 2011 by SEDA Malaysia (IREA, 2013) establishing the FiT system. Costs of the system are transferred onto electricity consumers who pay an additional surcharge on top of their electricity bills collected by the distribution licensees, and then deposited into the RE Fund. Customers who consume less than 300 kWh/month will be exempted from contributing to the RE Fund. To benefit from tariffs, renewable developers need to secure a feed in approval from SEDA Malaysia and conclude a RE power purchase agreement with distribution levels (eg. TNB, SESB, public power utilities). FiT rates are ranging over a 21-

year period for solar PV, solid waste and mini-hydro and 16-year period for biomass and biogas (SEDA Malaysia, 2010).

The main objective of this study is to develop a virtual laboratory by which policy makers can assess the effects of assigning different amount of FiT rates for different technologies as well as determining different surcharge percentages on electricity bills on the RE fund budget to assist them to implement more efficient budget management systems toward sustainability in electricity generation. For this purpose, the qualitative concept of investors' willingness for investment (WI) is quantified by applying the idea that the more profit per unit of investment absorbs more capital. Capacity limits are also considered to estimate the willingness for investment in each of the resources. Clearly all of the factors affecting the profit, capital cost and capacities including fixed and variable costs, electricity tariff and FiT rates as well as capacity factors will affect the WI in each of the resources that will consequently lead to changes in the electricity mix. Then, sensitivity analysis is used to show the impact of FiT rates as well as the surcharge percentage on electricity bills on the RE fund budget and the total electricity generation from renewables.

Using this model, policymakers can carry out analysis to determine the amount of money that must be collected from the electricity consumers through the surcharges on electricity bills as well as the amount of FiTs to be paid for different renewable resources in different periods.

The remainder of this paper is as follows. Section 2 provides a review on previous studies that have investigated Malaysia's renewable energy potentials or developed energy models. Section three addresses the data gathering of this study and then introduces the casual diagrams as well as the designed subsystems for the proposed system dynamics model. Section 4 presents the experimental results in different points of view in order to validate and show the applicability of the proposed model.

#### 2. Literature Review

Various researches can be found in literature that have addressed energy issues by different techniques. The extent of this field shows the high level of importance that energy management carries in our world. In order to focus on Malaysia's comprehensive simulation and analysis of energy policies, in this paper we have benefited from reviewing similar models designed, developed and implemented for real world cases in order to capture novel ideas altogether and present a suitable and applicable model. Hereinafter energy models refer to models considering electricity generation issues.

Malaysia's electricity market is a regulated market meaning that the government sets the fuel price in each interval at a fixed level and the variation of the price is up to the government policies. Through suitable policies, the government provides various facilities for investors in order to contribute to the growth of the renewable energy industry in Malaysia. (Teufel et al., 2013) have categorized the models in electricity markets based on their thematic foundation in two main categories namely regulated and liberalized markets each having different types of structure. The model of this paper lies under the category of regulated markets and considers both aspects of resource policy and investment decisions and investment cycles.

To the best of our knowledge, there are rare electricity generation models developed for Malaysia and not any applications of SD in this field. This study is the first system dynamics approach used for power generation simulation modelling in Malaysia. Because of the insufficient energy models and policymaking tools, the country has several gaps that need to be investigated in the field of electricity generation planning and modelling. Most of the researcher's attention during the recent years has been focused on studying the past and current situation of power generation in Malaysia and investigating the potentials of different resources. Environmental issues such as greenhouse gas emission were addressed in several studies investigating power systems in Malaysia.

(Chua and Oh, 2010) have studied the main energy policies implemented between 1974 and 2009 in Malaysia and presented the role of key players and agencies in energy development as well as highlighting Malaysia's international participation towards reduction of greenhouse gas emissions. (Hashim and Ho, 2011) have addressed the key policies, schemes, funding and incentives for RE development that was introduces by Malaysia's government and discussed their progress and achievements during a 10 year period before 2011.

(Chua and Oh, 2011) have focused on Malaysia's green development by addressing National Green Technology Policy and Green Building Index that were introduced in 2009. (Ong et al., 2011) and (Shafie et al., 2011) have reviewed the current energy usage and scenarios in Malaysia as well as studying the potentials of different resources that can be used for power generation.

(Rahman Mohamed and Lee, 2006) investigated various energy policies and alternative energy mixes adopted in Malaysia for sustainable development. (Jafar et al., 2008) studied the environmental impact of implementing the Fuel Diversification Strategy by evaluating the changes in GHG emission caused by the changes in the fuel mix and concluded that the fuel mix proposed by the Five-fuel diversification strategy generates higher emissions. (Tang and Tan, 2013) examined the electricity-economic growth nexus in Malaysia and showed that enhanced technology innovation can result in electricity consumption reduction. In addition, they have emphasized on the positive impact of technology innovation on Malaysia's long-term economic growth.

(Oh et al., 2010) have addressed the issues and challenges with regard to sustainable growth by discussing the difficulty of implementing the new energy policies in Malaysia and focusing on adequacy, security and quality of energy supply. (Mahlia, 2002) estimated the potential emissions from power generation in Malaysia from 2002 to 2020. Pattern of electricity generation from different technologies applied in Malaysia during 1976 to 2008 as well as the emissions during the same period was investigated in detail by (Shekarchian et al., 2011).

As the two most potential renewable resources of energy, the current and prospective state of biomass and solar energy in Malaysia have been investigated in (Mekhilef et al., 2011) and (Mekhilef et al., 2012) respectively. (Ng et al., 2012) thoroughly investigated the palm biomass potentials in Malaysia. (Kathirvale et al., 2004) and (Johari et al., 2012) studied the potentials and benefits of converting municipal solid waste to energy in Malaysia. (Tye et al., 2011) have considered the potentials and future scenarios of using bio-ethanol in transportation sector. The potential of power generation from wave energy in Peninsular Malaysia was investigated in (Muzathik et al., 2010). (Muhammad-Sukki et al., 2011) carried out cost benefit analysis between the solar PV installation in residential sector in the United Kingdom (UK) and Malaysia. Besides, they compared between FiT mechanism and other investment schemes available in Malaysia.

Surveying the literature shows that there is not enough attention to energy modelling in Malaysia. Most of the studies have considered the situations and conditions rather than giving solutions and developing assessment and decision support models. The only two works

providing models (although not using system dynamics tools) were (Gan and Li, 2008) and (Muis et al., 2010). (Gan and Li, 2008) developed an econometric model to investigate the outlook of energy, economy and environment to 2030. (Muis et al., 2010) developed a mixed integer linear programming optimization model to reduce the CO2 emissions by 50% from the current level.

#### 3. Material and Methods

This study benefits from a vast range of data gathered from various valid references. All data used in this model are extracted from (Wei et al., 2010, IEA, 2013, OpenEI, 2013a, EIA, 2013, World Bank, 2013b, World Bank, 2013c, World Bank, 2013a, World Bank, 2014, World Energy Council, 2004, Muis et al., 2010, IEA, 2011, OpenEI, 2013b, Shekarchian et al., 2011, EPA, 2013, TNB, 2012, SEDA Malaysia, 2010, SEDA Malaysia, 2011, Malaysia Energy Commission, 2010, Ng et al., 2012, MEIH, 2014).

#### **3.1.** Causal Relationships

In the System Dynamics methodology, a problem or a system is first represented as a causal loop diagram (Sterman, 2000). A causal loop diagram is a simple map of a system with all its constituent components and their interactions. By capturing interactions and consequently the feedback loops a causal loop diagram reveals the structure of a system. By understanding the structure of a system, it becomes possible to ascertain a system's behavior over a certain time period (Meadows, 2008).Causal loop diagrams aid in visualizing a system's structure and behavior, and analyzing the system qualitatively. Figure 3-1 shows the entire causal diagram used in this model. Positive causal relationships are shown by thin arrows while negative relationships are represented by thick arrows with a negative mark on the handle.

The figure is divided to five parts for better presentation. Part one, shows the causal relationships affecting the cost of generation from each of the resources. Part two, represents the role of incentives in increasing the profitability and feasibility of resources. Parts three and four that are the focus areas of this study provide information on the causal relationships that lead to rise or fall in electricity generation from each of the resources. Finally, part five demonstrates how different factors can either smooth or worsen the way to sustainability.



Figure 3-1. Causal Diagram of the Proposed Model.

## 3.1.1. Key Causal Relationships

Fig 3-2 that is derived from parts 1 and 2 of the casual diagram provides causes trees in four levels. Starting from the right hand side, level 1 shows how different variables and factors can cause changes in willingness for investment. While potential capacity together with feasibility and profitability have positive relationships with WI, capital cost goes in another direction. It means increase\decrease in capital cost will lead to decrease\increase in WI. Level 2 shows the effects of technology development and marginal capacity on capital cost and potential capacity

respectively. It also includes a number of factors affecting resources' feasibility and profitability. At the third level the causal relationships between Cost of electricity generation, selling price and gross profit of electricity generation is demonstrated. Obviously, decrease in costs and increase in selling price will lead to increase in profit. The fourth level shows the effects of variable and fixed costs as well as the amount of electricity generation on cost of generation; in addition the role of FiT in increasing the selling price is considered in this level.



Figure 3-2. Main Causal Relationships Derived from the First Two Parts of the Causal Diagram

Figure 3-3 which is extracted from parts 3 and 4 of the causal diagram scrutinizes how assigning different FiT rates on different renewable resources can affect both RE generation and RE fund budget. Clearly, increasing the FiT rates for a resource increases the investors' willingness for investment in it. "Total willingness for investment" in electricity generation is obtained from the sum of willingness for investment in different resources. Willingness ratio for each resource is derived from dividing the willingness for investment in that resource by the total willingness for investment in electricity generation. An important point that must be considered here is that increase in willingness for investment in one resource, simultaneously increases its willingness ratio and decreases other resources' willingness ratio by raising the total willingness for investment. This outcome triggers a competition between different technologies as it happens for all of the resources.

Logically, the amount of investment in each resource is almost correlated with the willingness ratio of that resource. Assigning high FiT rates for a technology attracts a lot of investors to apply for FiT approval and invest in that technology; meanwhile the RE fund budget must have enough stock to let the government enter an agreement with them for paying FiTs in case they are eligible to get the approval. Hence, on one hand, more FiT rates leads to growth in RE capacity by increasing the investment in renewable resources and consequently rises the FiT payment indirectly and on the other hand increases the FiT payment directly.

The key point can be derived by poring over the two paragraphs above. Assigning high FiT rates for one resource can lead to deficit in RE fund budget without gaining commensurate amount of green electricity with the money spent. That is because different technologies have different capacity factors and excessive support of resources with low capacity factor avoids the investors to put their money in the projects with higher capacity factors. This fact is further analyzed in the result section of this study.

Another important variable is the surcharge rate on the bills of electricity customers who consume more than 300 kWh per month. This variable is the source of RE fund budget. On one hand increasing the surcharge rate surges the RE fund budget by collecting more money from the consumers who have high consumption, but on the other hand it encourages the consumers to reduce their consumption to a level below 300kwh/month.



Figure 3-3. Main Causal Relationships Extracted from Parts 3 and 4 of the Causal Diagram.

Figures 3-4 and 3-5 are presented to show some of the other important relationships that exist in the electricity generation systems. Figure 3-4 shows an exponential growth behaviour. Growth in gross domestic product rises the welfare level in the society that will lead to increase in energy consumption. Then higher amount of energy is required to meet the demand and this higher generation will lead to an upsurge in GDP.



Figure 3-4. Two Reinforcing Loops Affecting the Model.

Fig 3-5 pictures two causal loops affecting investment variable. On one hand since the maximum potential capacity for some of the resources is limited, the willingness for investment in them decreases as they are approaching their maximum capacity and the access to resources is getting harder. So more investment in them will lead to less willingness for investment in them that implies a balancing behaviour. The delay mark on this loop shows the required lead-time for construction and plant establishment. On the other hand, Increase in investment in RE increases the GDP and subsequently results in demand escalation that will lead to more willingness for investment. This loop suggests a reinforcing behaviour.



Figure 3-5. Two Loops Affecting the Investment Variable in Opposite Directions.

#### **3.2.** Designed subsystems

Ten main subsystems were modeled in order to shape the stock & flow diagram of Malaysia's electricity generation system. These subsystems employ several stocks accumulating the important outputs of the model for each year and consequently applying them to the next year.



Figure 3-6. RE fund budget subsystem.

Figure 3-7. Fixed cost subsystem.

The RE fund budget subsystem accumulates its corresponding stock by deducting annual FiT payment from annual RE budget income, see figure 3-6. Annual RE budget income is calculated by multiplication of annual electricity sales, surcharge and high consumption percentage. Annual FiT payment is the sum of FiT payments for each of the RE resources. Figure 3-7 shows the fixed cost calculation subsystem which includes tax and tax savings to calculate the fixed cost of each resource in terms of equivalent series of annual costs. The main variables of this subsystem are fixed costs (FC), fixed operating cost (FOC) and overnight capital cost (OCC).

Variable cost which is simply the sum of variable operating cost (VOC) and fuel cost (FuC), has been applied to the model by the subsystem shown in Figure 3-8. An important feature of this subsystem is considering the fuel consumption subsidy. Figure 3-9 shows the GHG emission subsystem which not only includes the amount of greenhouse gas emissions in the simulation but also the monetized environmental impacts. The cost of carbon used in this study is extracted from (U.S. EPA, 2013). Since the cost of carbon in Malaysia is definitely different from that of USA, the Purchasing Power Parity (PPP) conversion factor is used to make it more realistic for Malaysia.



Figure 3-8. Variable costs subsystem.

Figure 3-9. GHG emission subsystem.

Calculating the electricity generation cost becomes a little bit tricky. In spite of the fact that the fixed cost is accumulated in each year (since we are not eliminating any previous capacities), it can also decline or increase each year due to change of technology; that explains the necessity of defining the annual fixed cost (AFC) as a stock. Figure 3-10 represents the responsible subsystem for this procedure. By knowing the GHG emission cost (per kWh) we can calculate the resulting unit cost of electricity with its resulting GHG emission by adding it up to UCEG. This cost can be used later to find the real grid parity.



Figure 3-10. Unit cost of electricity subsystem.



The generation subsystem in figure 3-11 accumulates the generation capacity for each year and estimates the annual electricity generation. The selling price in the revenue subsystem (figure 3-12) is the sum of normal tariff rate and the related FiT for each technology in each year. The amount of electricity consumption in each year is calculated by deducting the transmission and distribution losses from the total electricity generated in that year. Once grid parity is achieved, feed-in approval holders will be paid based on the prevailing displaced cost<sup>1</sup> for the remaining effective period of the agreement.

<sup>&</sup>lt;sup>1</sup> "Displaced cost" refers to the average cost of generating and supplying one kWh of electricity from resources other than RE resources through the supply line up to the point of interconnection with the RE installation.



Figure 3-12. Revenue subsystem.

Figure 3-13. Fuel consumption subsystem.



Figure 3-15. Employment subsystem.

Figure 3-13 represents the fuel consumption subsystem which is considered to estimate the accumulated amount of required fossil fuels to generate electricity. A variable named "Willingness for Investment" (WI) is defined in investment subsystem (figure 3-14) for the purpose of estimating how much capital is going to be invested in different available resources to generate electricity if different policies are applied. In fact WI is used to quantify the qualitative concept that conducts the financiers to invest their money in a specific resource. Eventually the employment subsystem in figure 3-15 is considered to estimate the number of jobs created by applying different policies.

## 4. Results and discussion

#### 4.1. Model validation

To validate the accuracy of the proposed model, the results were compared to the real outputs of the National Renewable Energy Policy in Malaysia. (Malek, 2013) has provided the information on the approved capacities from renewables by November 2013 that will lead to 484.6 MW operational capacity by 2015. This capacity of RE is only 1.8% more than the estimated 475 MW capacity in 2015 by the proposed model of this study that shows the model results are reliable.

Furthermore, given that the main variable of the proposed model is WI, USA historical data were used to investigate the relationship between WI and marginal capacity in each resource in 2000s. A correlation coefficient of 0.92 was obtained by implementing the historical data to the proposed model of this study that implies its applicability in real world cases.

#### 4.2. Willingness for investment

One of the main outcomes of the model is the willingness for investment, which has been obtained by implementing Malaysia's National Renewable Energy Policy, see figure 4-1. The reason that WI has converged to zero for small-hydro and bio-power resources is that they have reached their maximum capacity. The results show increasing role of solar PV resource in Malaysia's generation mix that will be further investigated in FiT sensitivity analysis on solar resource in subsection 4.5. This increase is due to its fixed cost reduction and increase of its capacity factor. Its high share in the mix can be justified by the high level of FiT payments assigned for solar energy. The WI trend will lead to the generation mix showed in figure 4-2.



#### 4.3. Potential target achievements

Figure 4-3 shows the comparison of the proposed model's estimation for resulting share of RE capacity in future years, and the targets of Malaysia's National Renewable Energy Policy. The values look different at first but it seems a shift can almost adapt the trends. Reasons such as not considering lead times or delays between investments and successful utilization of resources in the targets can account for this shift. Also the beginning slope of the targets is considered strictly increasing but the model estimates a slower slope, since the FiT payments were started at 2011, with their resulting influence showing itself near 2015; not immediately in 2010. However the model shows that the capacity share reaches a higher level of 14.63% compared to the targeted 13% in 2030. But the models' estimated RE mix (see figure 4-4) reaches to 9.76%

which is slightly lower than the targeted 10%. This can be justified by the fact that the capacity factor considered in this study's proposed model might be lower than the capacity factor considered when providing the targets.



Figure 4-3. Share of RE Capacity (Estimation vs. Targets) Figure 4-4. RE Mix (Estimation vs. Targets)

### 4.4. **RE fund budget shortage**

Although implementing the RE policies show improvements in sustainability factors and result in an acceptable level of target achievements, but the models projections alert an increasing trend of shortage in the RE fund budget passing 2019.

Figure 4-5 shows that although the RE policies result in an increase in the government's net income at first, but follows with a decreasing trend starting in 2016 that is to say the governments FiT payments will be more than its income from surcharges on electricity bills. This implies that in order to achieve a satisfying level of targets the government has to assign higher surcharge rates to bills. Otherwise, the government will have to pay much less FiTs which may lead to lower willingness for investment in RE.

The sensitivity analysis on this issue in the next subsection provides a better insight on how altering the surcharges on electricity bills and FiT rates can affect the government's net income.



Figure 4-5. The RE fund budget stock

# 4.5. Sensitivity analysis

The accomplished sensitivity analysis in this study is twofold. First the impacts of changing the RE fund budget inflow (surcharges on electricity bills) has been investigated. Then sensitivity of RE fund budget to its outflow (FiT payments) has been discussed.

As mentioned in previous subsection, the government will face high shortage in its budget in case of assigning 2% surcharge to consumers using more than 300 kWh/month. To overcome this problem the government must either increase its income by increasing the consumers' contribution or decrease its outcome by lessening the amount of FiTs to be paid by decreasing the FiT rates or refusing to approve submissions from the investors who are willing to invest in RE projects. Obviously, the second option may not lead the government to its targets. Figure 4-6 provides different trends of RE fund budget for different surcharge rates.

It shows that choosing the first approach will require the consumers' contribution to be at least 4 percent to be able to provide sufficient funding for the RE projects until 2030. However these figures provide an estimation for the required income, and for more accuracy optimization methods must be applied to find the best contribution percentage in different periods. The numbers in other countries also show a higher percentage for consumers' contribution; for instance Australia, China, Germany, Italy and Japan use 2.4, 3, 19, 8 and 3 percent respectively, (Malek, 2013).



*Figure 4-6.* Government's RE fund budget for different consumer contribution rates.

Figure 4-7. RE fund budget for different percentages of predefined FiT rates on solar resource.

Clearly infinite states can be considered for FiT assignment on different resources in different periods and to reach the optimum rates for each of them, an optimization approach is required. However, since FiT rates for solar PV systems are much higher than other renewable resources in Malaysia, sensitivity analysis is carried out to achieve an overview of how RE fund budget will respond to the changes in the FiT rates. Figure 4-7 shows these response trends for different percentages of predefined FiT rates on solar resource by SEDA Malaysia.

The relationship between the percentage of FiT payment on solar power, total FiT payments on renewables and electricity generation from RE is shown in Figure 4-8. The horizontal axis indicates the total FiT payments on renewables where the vertical axis shows the generation electricity from all renewable resources. The trends have been obtained for zero percent (in which no FiT is paid for solar), 40%, 70% and 100% as well as a special state of starting 100% payments after 2020 in which no FiT is assigned before 2020. For instance, in case of 70%, 70% of the proposed FiT rates by SEDA Malaysia is paid in each year.



Figure 4-8. The relationship between the percentage of FiT payment on solar power, total FiT payments on renewables and electricity generation from RE

The two oscillations in the trajectories shown in figure 4-8 are due to the sharp reductions in other renewables' FiTs when grid parity happens and at the end of the FiT agreement respectively. Figure 4-8 shows that paying more FiTs on one renewable resource does not necessarily lead to more electricity generation from total renewables. It may even have an opposite effect in some periods. This can be explained by considering the fine point that although assigning high FiT rates on one resource can make it interesting for investors and absorb a lot of capital, but it may not result in higher electricity generation because of the low capacity factor of that resource.

That is to say, paying excessively high FiTs in a resource with low capacity factor in comparison with other renewable resources prevents the investors to invest in other renewables with higher capacity factor and this may lead to only a small increase or even a decrease in total electricity generation from renewables; while the government pays much funding on the total renewables. Therefore, as sensitivity analysis shows, even though the assigned FiT rates may lead to reaching a satisfying level of targets, they are nonetheless inefficient. Table 1 and Table 2 provide information on the estimated total amount of FiTs to be paid for all renewables in case of applying different policies in FiT payment for solar resource as well as the related electricity generation from all renewables.

In Table 1, comparing the two policies of paying 100% from the beginning and 100% from 2020 onwards indicates that although the first policy will lead to a total 1460 GWH of more power generation but it needs 4,656 million USD more funding by 2030 that means 3.19 USD per kWh. In addition, analyzing the numbers in Table 2 reveals that paying 100% of solar resource FiTs will charge the government more 837 million USD while the total power generation from renewables will be 407 GWH lesser by 2020 in comparison with paying no FiTs to solar resource.

<b>Table 1.</b> Effects of assigning different FiT rates on
solar resource on the Estimated FiT payment and
Electricity Generation from renewables by 2030

		2
Percentage	Accumulated	Accumulated
	FiT Payment	Electricity
	(Million	Generation from RE
	USD)	By 2030 (GWH)
0%	6,478	187,427
40%	7,255	194,144
70%	9,883	197,626
100%	14,896	203,590
100% 2020 Onwards	10,239	202,130

**Table 2.** Effects of assigning different FiT rates on solar resource on the Estimated FiT payment and Electricity Generation from renewables by 2020

Percentage	Accumulated FiT Payment (Million USD)	Accumulated Electricity Generation from RE By 2020 (GWH)
0%	2,440	31,372
40%	2,460	31,375
70%	2,673	31,421
100%	3,277	30,965
100% 2020 Onwards	2,454	31,372

## 5. Conclusion & future directions

Rapid growth in Malaysia's population and economy can cause serious challenges in terms of environmental, social and economic issues. As a developing country that is involved in key conventions regarding environment and sustainable development, Malaysia has utilized several policies promoting renewable energy. Application of Feed in Tariffs mechanism is the newest policy that was launched by SEDA Malaysia in 2011 in order to support RE technologies until the grid parity occurs. Apparently, the level of success in this policy is highly dependent on the RE fund budget management. Taking everything into account, results shows the Malaysian government will face an increasing shortage in its RE fund budget starting around 2019 unless it increases its income sources by rising the surcharges on electricity bills or decreasing its expenditures by optimizing the amount of FiT payments in different periods. Sensitivity analysis indicates if the government choose the first option, the contribution fee must be around 4% during this period to cover the expenses. It also reveals that the FiT rates assigned for solar resource are not efficient at all; that is to say, assigning high FiT rates for solar systems not only will not lead to a more sustainable generation mix but also can decrease the efficiency of FiT payments in some periods.



Figure 5-1. RE Fund Budget Stock if FiT Payment to Solar PV Starts from 2020.

As there are infinite states that can be considered for both surcharge percentage on electricity bills and the FiT rates in different time intervals for different resources; it is highly recommended to the researchers to apply optimization methods on this model to find the optimum amount of money that must be collected from the consumers as well as the optimum FiT rates that must be assigned to different resources in different periods. However, as an example that seems more efficient than the current policy, having everything unchanged, if the government does not pay FiT for solar energy by 2019 and starts giving FiT approval to the potential solar PV investors from 2020, 3 percent of surcharge rate will be enough to cover the FiT charges by 2030 (See figure 5-1); while the accumulated generation will be merely 0.71 per cent lesser than the condition in which FiT payment on solar PV starts from 2011.

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