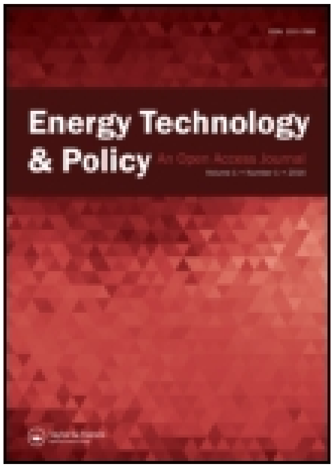

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Feedback-Rich Model for Assessing Feed-In Tariff Policy

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Abstract: The depletion of fossil fuels, environmental concerns, and security of supply risk has put an emphasis on renewable sources of electricity generation. However, the high cost of technology has compelled countries to develop support policies. Feed-in tariff (FIT), which has been successful in many countries, is one such policy. In this study, a qualitative model is presented. This model takes a holistic perspective in developing renewable power infrastructure. To do this, this model takes into account social, environmental, learning effect, and the FIT policy in scaling up the renewable energy capacity. The shortcomings of the FIT policy are highlighted along with improvements in policy structure. Developed from policy makers' perspective, this model also incorporates investors' perception of renewable market, in a Malaysian context. Modified structure suggests making the reduction in the FIT price a variable. An additional source of income—by introducing carbon tax on fossil fuel-based generation—is suggested. Furthermore, the government's policy target has to be made variable subject to support funds availability. The developed model's aim is to determine whether or not the goal of transforming electricity supply chain using FIT is achievable. This model also aims to show that the qualitative model would serve as a tool for future dialogue and policy improvements.

Keywords: Causal loop diagram, policy makers, renewable electricity, feed-in tariff

1. Introduction

At present, the electricity generation around the world is dominated by fossil fuels.[1] In fact, fossil fuels account for more than 67% of the total electricity generation, whereas in 2011 the electricity from renewable sources accounted for only 20.3% of the total production.[2] There are drawbacks in relying on fossil fuel usage. First, fossil fuel reserves are limited. Second, burning fossil fuels for electricity generation results in harmful emissions, known as greenhouse gases.[3] Besides these drawbacks, most of the fossil fuel reserves are located in geopolitically volatile areas. This situation elevates the security of supply risk of fossil fuel for electricity production in the long run. Seeing these challenges, countries around the world have been trying to augment their primary fuel mix with renewable sources for electricity generation. Enormous investments are needed to lessen the security of supply risk, as well as realizing the transition to low-carbon power generation. This aspiration requires significant innovations in the technical, social, and institutional context.[4] Focusing on the latter two, improved information dissemination and policy frameworks are required for bringing more renewable technologies to the electricity supply chain.

To stimulate the renewable technology infrastructure, investment policy targets have been set by several countries worldwide. Besides targets, over 80 countries have launched a variety of policies to boost investments in the renewable infrastructure.[5] The primary reason for introducing support mechanisms is to hedge uncertainty in the sector.[6] Uncertainty in the sector is due to high levels of complexity involved in the decision-making process. This complexity in decision making arises from investments being capital intensive, the requirement of large initial capital, irreversibility of decisions, delays in power plant construction, and last but not least, financial market uncertainty.[7,8] However, properly structured policies can play a fundamental role in reducing the risk during an investment decision.

At present, technologies for electricity generation using renewable sources are expensive, except for large hydro resources, compared to nonrenewable ones. To hedge the cost disadvantage of renewable technology investors, a robust support policy is required. One such policy is a feed-in tariff (FIT) scheme. This policy guarantees renewable power export to grid, at a price higher than market price, for a specific period of time.[9]

A number of researchers have used methodologies to assess the FIT policy. In this context, Jenner et al.[10] used the econometric approach to evaluate the success of the FIT policy in 26 European Union countries. To assess the effectiveness

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of Ontario's FIT policy, Kim and Lee[11] used the stochastic-optimization approach. Walter and Walsh,[12] on the other hand, employed static Monte Carlo simulation to assess the uptake of wind power. Furthermore, a dynamic simulation-based package, called Green-X, was used by Walker[13] to evaluate the effect of FIT in attaining 2% renewable energy share. Muhammad-Sukki et al.[14, 15] based their assessment on the accounting approach. Moreover, Verbruggen and Lauber[9] used a qualitative approach to asses FIT and Tradable Green Certificate scheme in renewable capacity deployment. Finally, as to the best knowledge of the authors of this article, only Hsu[16] and Aslani et al.[17] have presented FIT assessment models using the feedback approach.

The objective of this article is to present a feedback-rich model to assess the FIT policy structure. A feedback approach is needed to understand the interaction between various components of a system in which policy is to be implemented. Malaysia's FIT policy has been taken as a case study. It is hypothesized that without taking a holistic approach in identifying the policy structure and its linkages with other factors, the assessment of policy may not be a realistic approach. A holistic approach is defined as the condition in which social, economic, environmental, and technological factors have been taken into consideration while developing the feedback model. At this stage, we are proposing that for an effective policy development, it is imperative to consider interrelated factors and variables as opposed to developing a strict mathematical model. To justify our model, we have leveraged the system-thinking approach. This approach is most appropriate as it would start a dialogue on the sustainability of the FIT policy in a comprehensive context. Therefore, the aim of the model presented is to provide an instrument for future communication and dialogue on the FIT policy in general, and Malaysia's FIT policy in particular.

This article is structured as follows. Following the introduction, various policies that had been adopted in Malaysia's energy sector are discussed. Afterwards, the development and discussion on the feedback+rich model is presented. Finally, this article ends with a conclusion of the study.

2. Malaysian Government Initiatives for the Enhancement of Renewable Energy Infrastructure

The 1973 world oil crisis provoked the need for a comprehensive national-level energy policy for Malaysia. This impetus resulted in the National Petroleum Policy of 1975. With this policy, the planners aimed to regulate the oil and gas industries to achieve a balance between production and consumption juxtaposing to the country's economic development.[18] The National Energy Policy (1979), however, took a more holistic approach compared to the former one; it also emphasized the efficiency, security, and affordability of the energy supply. The reduction of waste and environmental impact, along with conservation of indigenous finite energy resources, were also a priority. The objective of the National Energy Policy was to reduce Malaysia's dependence on oil.[19] In order to diversify the fuel mix for power generation, the Malaysian government introduced the Fuel Diversification Policy. The first one in the series was the four-fuel strategy of 1981, which successfully diverted dependence from oil to natural gas. Under the 8th Malaysia Plan (2000–2005), a five-fuel policy was adopted in 1999. This policy introduced renewable sources as the fifth fuel, along with coal, hydro, natural gas, and oil. The success of the policies in diversifying the fuel mix for power generation can be seen in Figure 1. Furthermore, the 9th, and later, the 10th Malaysian Plan (2011–2015) have been targeted to have more than 5% of the renewable share in total electricity production. Despite the availability of abundant renewable resources, renewable technology share in electricity production is less than 1%. Therefore, to attract investments, policies ranging from renewable energy investment tax credits, known was investment tax allowances, to rebates, known as Pioneer Status, have been provided.[20] Most recently, feed-in tariff has been added to the list of support mechanisms.[21]

3. Feedback-Rich Model and Discussion

In the following subsections, a qualitative model for renewable capacity investments for Malaysia is discussed. This model adopts the system thinking approach, which is flexible and has no stringent numerical data requirements. Furthermore, the system thinking approach gives capability to model qualitative variables, which are inherent to the system but are rarely used in quantitative models; examples include cost reduction effect, social benefit effect, and others presented in the model. Hence, the proposed model is termed cost-effective.

The high-level model presents links between variables by means of an arrow depicting causal influences among the variables. In this way, this model presents a language to understand

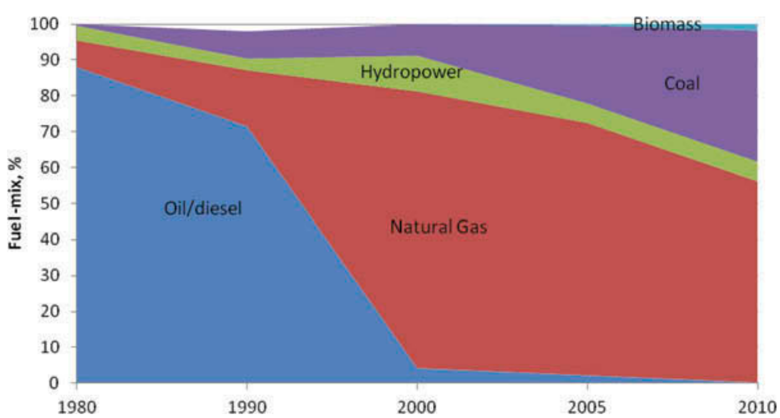

Fig. 1. Fuel-mix for electricity generation.

the feedback structure of the system under consideration. As Kim[22] stated, causal feedback loops can be considered as sentences, and by combining several loops together, a rational view of a particular problem can be created.

At this stage, we would like to restate the objective of this article: to present a conceptual model to help understand the structure responsible for the dynamic behavior of the renewable technology upscaling in general, and feed-in tariff policy in particular. The proposed model sought to holistically capture the logic of decision makers in planning process, as well as the possible interventions that can ensure system sustainability.

3.1 High-Level Model

The cost of electricity and environmental concerns are considered to be two main factors that concern long-term planning in the electricity sector.[23,24] The cost consideration is important as technology advancement reduces capital and operation costs, while the environmental concerns are in the context of global climate change. However, the model described in Figure 2, labeled Model 1, takes into account social, government policy, resource potential, and environmental links. These links show the interaction between these sectors, which are, at times, ignored in the planning process. In addition to the presentation of the links, the feedback effect is also highlighted. Furthermore, the structure of the model is developed so that it is equally applicable to regulated and deregulated electricity markets. This model has its lineage to the Ford,[25] Hasani-Marzoni and Hosseini,[26] and Ahmad and Tahar[27] models, all of which were developed using a feedback approach.

As seen in Figure 2, the main driver of *renewable capacity* is the *willingness to invest* variable. These two variables are linked to each other through seven loops. Each loop and its influence on the system will now be explained.

Loop 1, named the *social benefits* loop, primarily looks at the societal benefits coming from the construction of a renewable technology power plant. Loop 1 has a reinforcing effect on the system; for example, as the renewable capacity increases, so do the social benefits.

Fuel availability is a major factor in opting for any renewable technology. This factor is considered in loop 2, which is named the *resource potential* loop. The *resource potential* loop is concerned with the potential of renewable fuel available for electricity generation. Since resource potential is a limiting factor, the overall effect of this loop is to limit the *renewable capacity* to a certain fixed value.

Loop 3 presents a similar effect on the system as Loop 2. Loop 3, named *Target Discrepancy,* drives the system in achieving the target of renewable capacity share for the country.

A factor related to technology adoption, incorporated in this model, is *Industry learning* (Loop 4). This loop assumes that with more renewable capacity in the system, the cumulative experience of investors will reduce the cost of technology, thus increasing the *willingness to invest*. With more installed renewable capacity, the higher would be the investors' experience in dealing with the economic and technological aspects of a particular technology, and the cycle would continue perpetually, in theory. In reality, this loop would get impedance from other limiting factors in the system—for example, *resource potential*.

The environmental concerns regarding electricity production, modeled in Loop 5, are named *Environmental benefit.* The underlying logic of this loop is to save CO_2 emissions by generating electricity from renewable capacity. With more production from renewable sources, there would be an increase in saving, thus creating a continuous positive effect in the system.[28]

As mentioned in Section 2, renewable technologies at present are comparatively expensive; therefore, it is important to consider grid parity, which is modeled *in Loop 6,* named *Grid parity.* This

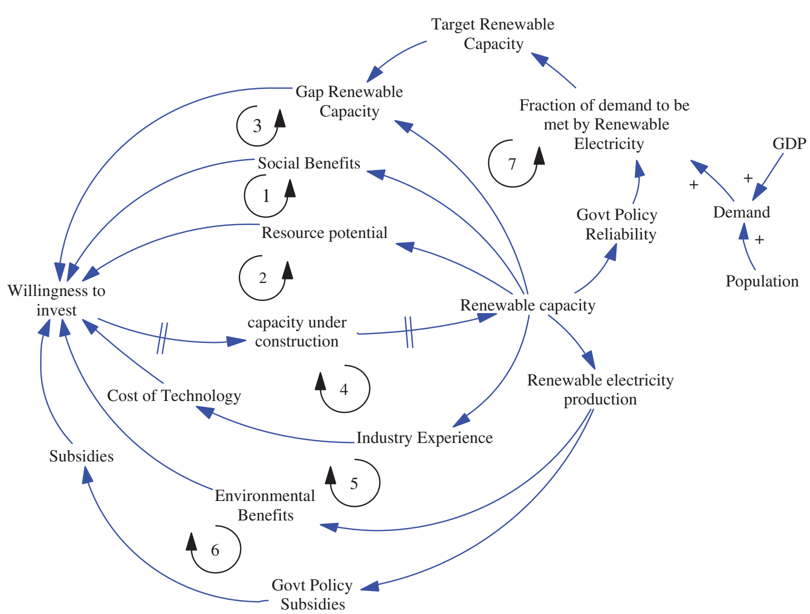

Fig. 2. Model 1: Feedback relationship between electricity generation from renewable sources and social, economic, and environmental aspects.

loop incorporates subsidies given to future investors in making investment decisions. In the model, the level of subsidy given is dependent on the total renewable capacity, such that the higher the capacity, the lower the level of subsidy given—a balancing effect. The *Grid parity* loop structure makes the grid parity issue to be handled endogenously in the system.

Finally, this model considers the government setting as the target for renewable capacity. This is named the *Reliability* (Loop 7) loop. The uniqueness of this loop is that it assists policy makers to endogenously set the target for renewable share, based on current levels of renewable capacity. This minimizes any chance of ambitiously setting the target, which results in the exploitation of the FIT policy. This was witnessed in Spain, and reported by Mediavilla et al.[29]

3.2 Model Enhancements

Model 1, presented in Figure 2, has been extended (now named Model 2), with the addition of more variables. This is shown in Figure 3. It is intended that the issues related to the FIT policy be highlighted by this model. This would help policy makers evaluate and further develop the intended policy in a holistic manner.

The loop structure is described below. Loop 8 is the extension of Loop 2; it incorporates planning and construction delays, along with renewable resource potential influencing *willingness to invest*. Two exogenous variables, *Average construction time* and *Unsuccessful planning rate,* control the loop characteristics. Loop 9 is the extension of Loop 1. A job created per kW of renewable capacity is a major index used for promoting technology (REN21).[5] Jobs have been created by renewable technology investments—for example, in Germany and Spain.[30] Loop 10 corresponds to Loop 4, where an increase in industry experience results in investment cost reduction of renewable technologies, not in the market price of electricity. The cost reduction structure is based on studies conducted by Shih and Tseng[31] and del Rio.[32] As technology cost reduction is not perpetual, as shown in model 2, this phenomenon has been factored in by considering the saturation to level of learning (see Loop 11). Besides these enhancements to the model, *Target Discrepancy* (Loop 3) and *Reliability* (Loop 7) have been merged to form Loop 12. The *demand* is now modeled in the *Government Target* variable as a stimulus to Loop 12. The *Environmental benefits* loop (Loop 5) has been extended by adding new variables such as the *CO_2 emissions avoided* and *environmental effect*. The reason for adding variables is to make explicit the role of environment in the system.

The bottom of Figure 3 shows the FIT policy causal structure. Note that there is no loop in this model as opposed to the subsidies loop in Model 1. The reason for this is that the model has been developed as a communication tool with the FIT policy developers of Malaysia. The initial intention is to show policy makers their current setting of the FIT policy in promoting renewable investments—an open loop. As per current structure, the finances required for the FIT operations is to be collected in a *renewable energy fund.* This fund is accumulated by taking 1% of profits from a national power company, known as Tenaga Nasional Berhad (TNB).[33] TNB is the monopoly distributor in Malaysia that handles the billing of electricity in the country.

The feedback effects of the subsidies, as shown in Model 1 (Figure 2), are not present in the current FIT policy structure (Figure 3). Improvements in the structure are proposed, taking feedback effect into account. These improvements, exhibiting Model 3, are shown in Figure 4.

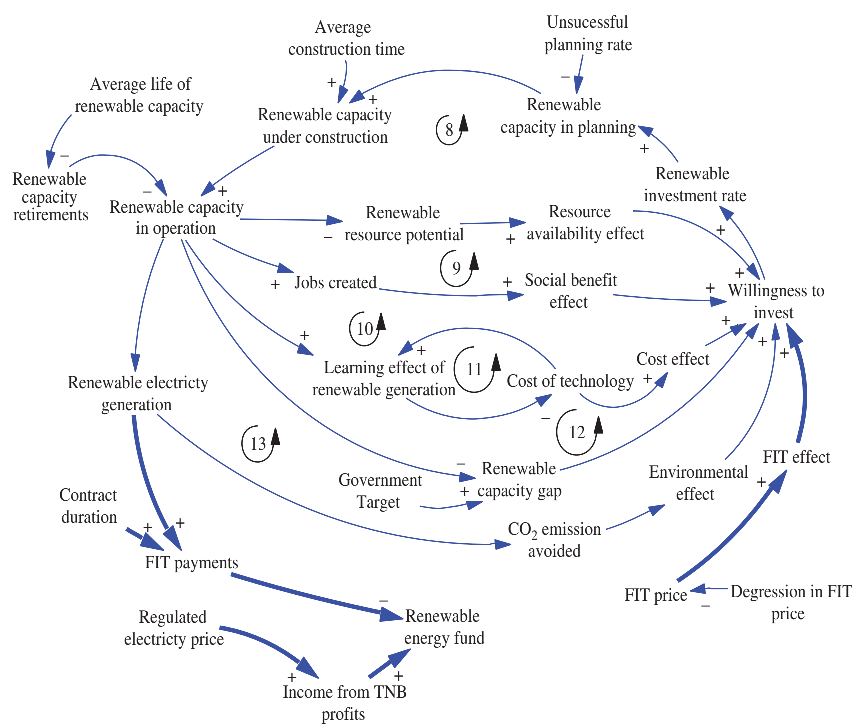

Fig. 3. Model 2: FIT policy structure causal diagram.

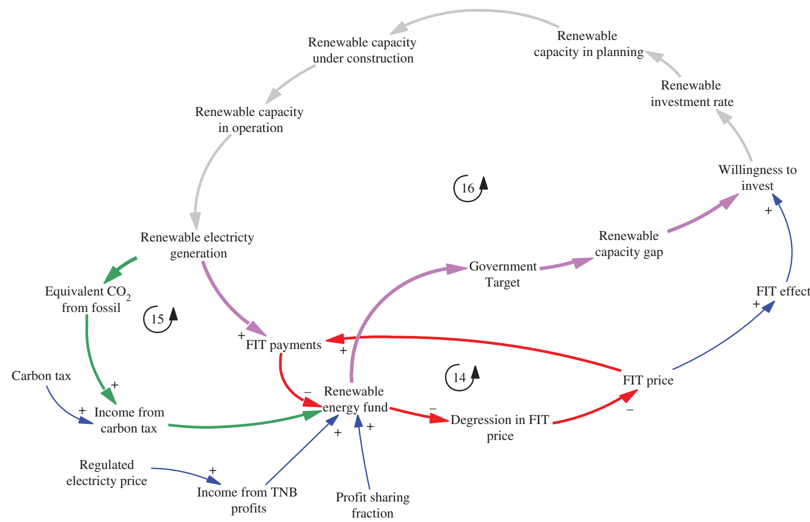

Fig. 4. Model 3: The FIT policy with new structures.

The potential problem with the current FIT policy is that there is an annual *degression in* the *FIT price* rate. This variable reduces the annual FIT price for new investments; thus, in the long run, it reduces investors' perception of benefitting from the FIT policy.[33] Also, this policy promotes an exploitative behavior of investors who want to get benefit from high FIT price at the beginning. This behavior is evident by the complete use of initial quota awarded for renewable technology within the one year of launch of this policy in Malaysia.[33] The reason for this behavior is the initial high FIT price for all renewable technologies. Within the renewable technologies, the majority of FIT applications are from only one technology—solar photovoltaic. The reason for this inclination toward photovoltaic is the most beneficial FIT contract parameters set by the government. If any one technology gets the most payment from *Renewable energy fund*, it would not only result in a technology lock-in, but it would also put significant stress on fund managers. In an extreme case, a complete collapse of the FIT policy may occur.

Therefore, an improved structure for the FIT policy is suggested. The new structure is presented in Model 3, as shown in Figure 4. Three different focal points of the structure are controlling the *degression* in the FIT price, *income from carbon tax,* and finally, *Government target* for renewable capacity. These three improvements are presented by Loop 14, Loop 15, and Loop 16, respectively. Loop 14 is primarily linked with the degression in the FIT price, while Loop 15 is concerned with generating extra income from imposing the carbon tax on fossil fuel-based generation technologies for the renewable energy fund. At present, the carbon tax has not been implemented as an extra source of income for the renewable energy fund. Likewise, Loop 16 sets the *government target* for renewable technologies. The feedback structure of these three loops is made dependent on one critical variable—the renewable energy fund. This is very important because the FIT policy has to satisfy two contradictory objectives. One objective is to hedge the financial risk of investors, while the other one is to maintain the expenditure of the policy within controllable limits.

3.3 Model Validation

Validation is a crucial aspect for building confidence in feedback-rich models.[34] For the purpose of validation, we adopted the process laid by Burns and Musa.[35] The proposed model was checked on three validation criterion: clarity, cause-effect reversal, and predicted-effect existence. Clarity test refers to the extent to which a model clearly communicates the implied causality. Similarly, cause-effect reversal explores the direction of cause and effect variables with an aim to avoid any wrong identification of a cause–effect link direction. However, if variables are in a loop, then both are cause variables; both are effect variables.[37] Finally, in the validation process, predicted effect existence tries to find any other effects variables that can be considered from a hypothesized cause, but within the scope of a model.

The validation process is summarized in Table 1.

4. Conclusion

A feedback-rich approach was used to evaluate the FIT policy. This approach helped to bring forth many crucial variables in feedback fashion. Also, this model showed the casual relationships between the variables that are a part of a renewable electricity generation sector. This article models the renewable capacity investments in a Malaysian context. The model presented incorporates the social, environmental, and technological learning effects, along with FIT policy from policy makers' perspective. The aim of the model is to shed light on the process of modeling investors' decision to invest in renewable capacity projects. Changes to the current policy that would increase the FIT fund besides controlling the investors' perception of FIT price reduction are suggested. This conceptual model established the basis for developing a simulation model, which may be used to highlight the dynamics of variables and structures discussed in this article.

Table 1. Validation tests performed on model.

Test	Model	Explanation	Test result
Clarity	Renewable capacity in operation → Renewable electricity generation	A clear distinction is made between renewable capacity, and amount of electricity that a renewable capacity can generate	Pass
Cause effect reversal	Jobs created → Social Benefit Effect	A job created is the cause variable while later one is its effect. Clearly the effect variable is not the cause	Pass
Predicted effect existence	Renewable electricity generation → Equivalent CO_2 from fossil fuel; Renewable electricity generation → FIT payments	With one cause variable there can be more than one effects	Pass

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