UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF SYSTEM DYNAMIC MODEL TO EVALUATE THE IMPACT OF FEED - IN TARIFF FOR DIFFERENT ENERGY RESOURCES

MOHAMMAD SADEGH SHAHMOHAMMADI

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By

MOHAMMAD SADEGH SHAHMOHAMMADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

February 2015

DEDICATION

I dedicate my thesis to my loving wife, Sara, who has never left my side and did more than her share in our life to support me throughout my master studies.
I also dedicate this thesis to my loving parents whose words of encouragement always ring in my ears.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DEVELOPMENT OF SYSTEM DYNAMIC MODEL TO EVALUATE THE IMPACT OF FEED - IN TARIFF FOR DIFFERENT ENERGY RESOURCES

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MOHAMMAD SADEGH SHAHMOHAMMADI

February 2015

Chairman: Professor Rosnah bt. Mohd Yusuff, PhD

Faculty: Engineering

Malaysia has abundant potential of renewable energy resources and several renewable energy programs have been introduced by the government since the 1980s. However, comparing the real electricity generation capacity with the determined targets shows that results fell far short of the targets. Since 2001, more serious efforts were made in renewable energy development but the outputs were still not satisfactory by the end of the 9th Malaysia Plan in 2010. Therefore, the Feed-in Tariff mechanism which is known to be the most effective fiscal incentive for the expansion of renewable energy utilization was introduced in the Malaysia's National Renewable Energy Policy and Action Plan has been applied since 2011 for electricity generation from Solar, Small-Hydro, Biogas, Biomass and Municipal Solid Waste resources. Solar PV has the highest FiT rate with a range of 1.25-1.75 RM/kWh and Small-Hydro has the least rate with 0.23-0.24 RM/kWh. FiT duration for Solar PV, Municipal Solid Waste and Small-Hydro resources is 21 years while it is 16 years for Biomass and Biogas resources. Having said that, assigning inappropriate FiT rates or degression rates may result in a backfire. Hence, in this study, a broad range of data was gathered to develop a comprehensive system dynamics model to evaluate the impacts of Feed-in Tariff mechanism on the generation mix of Malaysia during a 20-year period between 2011 and 2030. The causal diagram was developed first to point out the causal relationships between the different variables of the model and to determine the system boundaries. Then ten subsystems were defined to establish the stock and flow diagram. High complexity of the system with several feedback loops and interrelationships between the variables was the main reason of applying system dynamics approach in this study. The model was ran in two different scenarios of "Business as Usual" and "Feed-in Tariff". Accordingly, the results of the model were extracted for each scenario and compared with each other. Outputs of the Feed-in Tariff scenario were also compared with the determined targets of Malaysia's national renewable energy policy and action plan in terms of environmental and economic factors. Results demonstrated that although the new policy may lead to a satisfactory level of target achievement, the Malaysian government may face an increasing shortage in its renewable energy fund budget starting around 2019; unless it increases its income sources by raising the surcharges on electricity bills and / or decreases its expenditures by optimizing the amount of Feed-in Tariffs in different periods. Sensitivity analysis illustrated that more funding will not lead to a more sustainable generation mix unless it is paid at the right time and in the right direction. Grid parity is also forecasted for different resources as an intermediate outcome of this study. 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 Feed-in Tariff to be paid for different renewable resources in different periods.

Abstrak Tesis dipersembahkan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan penganugerahan ijazah Master Sains

MEMBANGUN MODEL SISTEM DINAMIK UNTUK MENILAI IMPAK 'FEED - IN TARIFF' SUMBER TENAGA BERBEZA

Oleh

MOHAMMAD SADEGH SHAHMOHAMMADI

Februari 2015

Pengerusi: Professor Rosnah bt. Mohd Yusuff, PhD

Fakulti: Kejuruteraan

Malaysia mempunyai banyak potensi bagi sumber tenaga boleh diperbaharui kerana cuaca tropikalnya dan kaya dengan pertanian yang memberikan potensi yang besar dalam tenaga bio. Cuaca tropikal memberikan cahaya matahari yang cukup bagi penggunaan sistem solar. Beberapa program tenaga boleh diperbaharui telah diperkenalkan oleh kerajaan semenjak tahun 1980 an. Walaubagaimanapun dibandingkan kapasiti penjanaan elektrik sebenar dengan sasaran yang dikehendaki hasilnya adalah jauh rendah daripada sasaran. Sejak 2001, lebih banyak usaha yang serius telah diambil dalam pembangunan tenaga boleh diperbaharui tetapi outputnya masih lagi tidak memuaskan pada penghujung Rancangan Malaysia ke 9 dalam tahun 2010. Oleh yang sedemikian, mekanisma 'Feed-in Tariff' yang dikenal pasti sebagai mekanisma paling efektif bagi pengembangan penggunaan tenaga boleh diperbaharui telah diperkenalakn dalam Posisi Kebangsaan Tenaga Boleh Diperbaharui Malaysia dan Gerak Kerja dan telah diaplikasikan sejak 2011 kepada penjanaan tenaga elektrik daripada sumber Solar, Small-Hidro, Biogas, Biomass dan Sisa Pepejal Perbandaran. PV Tenaga Suria mempunyai kadar yang tertinggi FiT dengan jarak 1.25-1.75 RM/kWh dan Small-Hydro mempunyai kadar terendah dengan 0.23-0.24 RM/kWh. FiT berkadaran kepada PV tenaga solar, Bahan Pepejal Perbandaran dan sumber Small-Hydro adalah 21 tahun manakala ianya adalah 16 tahun bagi sumber Biomass dan Biogas. Sehubungan dengan itu, memadankan kadar FiT yang tidak bersesuaian atau kadar yang degressasi akan memberi impak yang negatif. Dalam kajian ini, satu data yang lengkap telah dikumpulkan bagi membangunkan satu model sistem dinamik komprehensif bagi menilai impak bagi mekanisma 'Feed-in Tariff' ke atas campuran penjanaan Malaysia semasa tempoh masa 20 tahun antara 2011 dan 2030. Rajah sebab dan akibat telah dibangunkan terlebih dahulu untuk menunjukkan hubungan sebab akibat antara pelbagai pembolehubah bagi model dan bagi mengenalpasti sempadan sistem. Kemudian, 10 sub sistem telah dikenalpasti bagi melaksanakan rajah saham dan aliran. Oleh yang sedemikian, dapatan kajian daripada model menggunakan data yang sepadan kepada perniagaan seperti senario yang biasa serta jangkaan output dalam mengaplikasikan mekanisma ‘Feed-in Tariff’ telah diperolehi daripada model secara berasingan dan dibandingkan dengan satu sama lain dari segi faktor persekitaran dan ekonomi. Dapatan kajian menunjukkan yang meskipun polisi baru telah menunjukkan tahap yang memuaskan bagi pencapaian sasaran, kerajaan Malaysia mungkin berhadapan dengan peningkatan bagi kekurangan dalam belanjawan perbiayaan tenaga boleh diperbaharui bermula sekitar 2019; melainkan ia dapat meningkatkan sumber pendapatan dengan menaikkan surcaj ke atai bil elektrik dan / atau mengurangkan perbelanjaannya dengan mengoptimumkan jumlah ‘Feed-in Tariff’ dalam pelbagai tempoh masa. Analisis sensitiviti menunjukkan lebih banyak pembiayaan tidak membawa kepada lebih campuran penjanaan boleh diperbaharui melainkan ianya dibayar pada masa yang tepat dan pada arah yang tepat. Grid pariti turut digunakan untuk meramal pelbagai sumber sebagai hasil pengantara bagi kajian ini. Menggunakan model ini, pembuat dasar boleh menjalankan analisi bagi mengenalpasti analisis untuk menentukan jumlah wang yang patut dikumpulkan daripada pengguna elektrik menerusi surcah ke atas bil elektrik dan juga jumlah ‘Feed-in Tariff’ perlu dibayar bagi berbeza sumber tenaga boleh diperbaharui dalam tempoh masa yang berbeza.

ACKNOWLEDGEMENTS

First of all I would like to thank the God for his perpetual assistance and I pray that he bless this work and make it useful for humanity.

Secondly, I would like to express my gratitude to Professor Dr. Rosnah bt. Mohd Yusuff, the chairman of my supervisory committee for her valuable advices, guidance, patience and encouragement.

Thirdly, I would like to thank Prof. Dr. Hamed Shakouri who gave me a better understanding of system dynamics concept.

Finally, I would like to express my appreciations to my friends Sina Keyhanian and Hojat Pakzad Moghadam who have contributed towards the success of this research in so many ways.

APPROVAL

I certify that a Thesis Examination Committee has met on 12 February 2015 to conduct the final examination of Mohammad Sadegh Shahmohammadi on his thesis entitled "Development of System Dynamic Model to Evaluate The Impacts of Feed-in Tariff for Different Energy Resources" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Norzima binti Zulkifli, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Faieza binti Abdul Aziz, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Nor Mariah bt Adam, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

A.N. Mustafizul Karim, PhD
Professor
International Islamic University Malaysia
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 17 June 2015

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Rosnah bt. Mohd Yusuff, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Kheirol Anuaz, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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Name of Member of Supervisory Committee: ______________________

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Signature: ______________________
Name of Member of Supervisory Committee: ______________________

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LIST OF ABBREVIATIONS

ACG	Accumulated Cost of GHG
ACJ	Accumulated Created Jobs
AFC	Annual Fixed Cost
AFU	Amount of fuel used to generate 1 kWh of electricity
AFuCon	Accumulated Fuel Consumption
BY	Base Year
BYC	Base Year Capacity
BYFC	Base Year Fixed Cost
CG	Cost of GHG (Annual)
CJ	Created Jobs
CRF	Capital Recovery Factor
DC	Displaced Cost
EC	Electricity Consumption
EG	Electricity Generation (Annual)
EGC	Electricity Generation Cost (Annual)
ER	Employment Rate
FC	Fixed Cost
FHC	Fuel Heat Content
FiA	Feed in Approval
FiT	Feed-in Tariff
FOC	Fixed Operating Cost
FuC	Fuel Cost
FuCon	Fuel Consumption (Annual)
FuS	Fuel Subsidy
GC	Generation Capacity
GCT	GHG emission Cost per Ton
GCU	GHG emission Cost per Unit of Electricity Generation
GE	GHG Emission (Annual)
GEF	GHG Emission Factor
GHG	Greenhouse Gas
HR	Heat Rate
IC	Increase in Capacity (Annual)
Inv	Investment
NT	Normal Electricity Tariff
OCC	Overnight Capital Cost
PDC	Prevailing Displaced Cost
PPP	Purchasing Power Parity
R	Revenue
RE	Renewable Energy
SD	System Dynamics
SEDA	Sustainable Energy Development Authority
SFuC	Subsidized Fuel Cost
SMART	Specific, Measurable, Attainable, Realistic and Time-specific
T&D	Transmission and Distribution Losses
TF	Tax Factor
TInv	Total Investment
TRR	Rate of Tariff Revision

TWI	Total Willingness for investment
UCEG	Unit Cost of Electricity Generation
UCEGG	Unit Cost of Electricity Generation including cost of GHG
UGP	Unit Gross Profit
USP	Unit Selling Price
VC	Variable Cost
VOC	Variable Operating Cost
WI	Willingness for Investment

CHAPTER 1

INTRODUCTION

Growing population, increasing energy demands, economic development, environmental problems, climate change and shrinking resource availability all points to the need for more effective approaches to energy systems planning (Li, Huang, & Chen, 2011). The outlook of non-renewable resource-based energy prices are expected to rise and their usage level is starting to exceed their threshold capacity (Keong, 2005). Hence, sustainable development and renewable energy have significantly attracted researchers' consideration during recent years. Utilization of new alternatives for fossil fuels seems to be a solution to survive the world from serious climate changes, pollutions and lack of energy. Therefore there is an urgent need for countries to establish and optimize their renewable energy sources. The growth in Malaysia's economy is dependent on an uninterrupted supply of energy, which implies that any conservation policies or disruptions to energy supply will have an adverse effect on economic growth.

Malaysia has good potential of renewable resources; nonetheless the share of these resources is less than one percent in its generation mix (TNB, 2012). Malaysia began its serious planning by considering renewal energy (RE) resources in the 8th Malaysia Plan (2001-2005) (Malaysia EPU, 2000) but only achieved 0.3 percent of the target
(Malek, 2010; Oh et.al, 2010). In the 9th Malaysia Plan (2006-2010) (Malaysia EPU, 2005) the achievements reached to 15% of the target (Malek, 2010; Sovacool & Drupady, 2011). The most recent policy considered by Malaysia is Feed-in Tariff Mechanism, which has been proven well for other countries facing problems with renewable resources planning (Campoccia et al., 2009).

FiT has been applied in several countries and has a number of benefits; however it may lead to some problems if it is not applied properly and there are some examples of failures caused by lack of proper and systematic planning (Dusonchet & Telaretti, 2010; Rüther & Zilles, 2011). A suitable planning is needed to reach a satisfying share of the targets in the 10th Malaysia Plan. Having knowledge about the outcomes of various decisions can be very vital. 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 & Telaretti, 2010) nonetheless small enough to avoid enforcing a big financial burden to the states (Rüther & Zilles, 2011). Assigning enormously high tariff rates for some resources may cause negative effects as it can attract more investment than anticipated. Malaysia has to be very careful and precise in determining the FiTs and their degression rates. On the other hand, since this policy imposes large costs to the government, determining proper amount of surcharge rates on electricity bills is another important issue. However, to the best knowledge of the author no systematic simulation has been carried out in Malaysia in this regard.

1.1 Problems statement

The literature showed that power generation modeling has not been well developed in Malaysia. Besides, previous experiences demonstrate that although Malaysia has ample amount of renewable resources, these resources have a very small share in its generation mix (TNB, 2012). To expand renewable energy utilization, the government has introduced new incentives, the most important of which is the Feed-in Tariff mechanism. This mechanism is applied in several countries with satisfying results; however, there are some examples of failures caused by lack of proper and systematic planning (Dusonchet & Telaretti, 2010; Rüther & Zilles, 2011). These failures arise from assigning either high or low FiT rates as well as determining insufficient budget for the incentives. Given that, applying a simulation method to thoroughly analyze the impacts of different policies on the power generation sector is essential and System Dynamics is a good choice because of having strong systematic analyzing tools like causal loop diagrams and stock and flow diagrams.
The system boundaries, variables that are affecting the system and their interrelationships are visualized in the causal diagrams. In fact, the structure of a system is established in its causal diagrams. Then to see the behavior of the system, mathematical relationships are included in the stock and flow diagrams. Data are entered in the stock and flow model and results are generated by software. Sensitivity analysis can be done by changing the amounts of some factors and measuring the changes in different variables. So, the impacts of applying different energy policies can be seen by changing the amount of FiTs for different resources in different periods and analyze the changes in the FiT budget, investment mix and all the consequent effects.

1.2 Objectives of the study

The aim of this study is to develop a comprehensive Decision Support System using System Dynamics simulation modeling to analyze the economic and environmental effects of applying different FiT policies on the power generation mix of Malaysia. The specific objectives are:

1. To develop the causal diagram of the power generation system in Malaysia.
2. To develop the stock and flow diagram for the different variables in the model.
3. To analyze the economic and environmental effects on the model by applying different FiT policies on the power generation system in Malaysia.

1.3 Scope and Limitations of the Study

The output model of the study will be a decision support system (DSS) that can be used by politicians, decision makers and researchers to have a deep and wide insight about the different energy mix conditions. They can foresee the estimated behavior of the energy system in terms of economic and environmental issues in case of applying different alternative polices before they make vital decisions and this can prevent wasting a lot of time and money and projects failures. This study will provide the researchers and decision makers with a holistic insight into the energy mix system and investigates the matter from different aspects by providing a general dynamic comprehensive tool that simulates the system and pictures the behavior of the system in presence of different scenarios. The result can be used to represent the level of sustainability of different policies if applied. The model is general and flexible and can be applied in different regions and countries with different potential energy resources and conditions. Specifically in Malaysia, the proposed model can be used by Energy Unit of Economic Planning Unit (EPU) of the Prime Minister's Office, Ministry of Energy, Green Technology and Water (KeTTHA), Sustainable Energy Development Authority Malaysia (SEDA), the Energy Commission (EC) and Pusat Tenaga Malaysia (PTM) or the Malaysia Energy Centre to assess the level of achievements to the SMART targets of national renewable energy policy and action plan by allowing them to adjust the Feed-in Tariff (FiT) rates and other fiscal incentives.

The effects of other fiscal incentives like loans and capital expenditures on the generation mix are not considered in this model.

1.4 Organization of the Thesis

The remainder of this study is structured as follows. In chapter 2 a comprehensive review have been provided on various related fields of energy problems in Malaysia and in the world such as: energy demand and generation, CO2 emission, renewable energy potentials and policies in Malaysia, feed-in tariff mechanism, system dynamics models and other energy models. At the end of this section, this study's designed model has been classified among various features of energy models in literature.

Chapter 3 provides the methodological details of the designed model. The first subsection provides information about the data gathering process which consists of the valid resources of the data used for model implementation such as cost of electricity, electricity tariff and employment rates. The last two subsections present the causal diagram and stock and flow diagram respectively providing sufficient explanation about the key causal relationships and main subsystems of the model.

Model implementation and simulation results have been gathered in chapter 4 for Business as Usual scenario (BAU) and the related scenario of utilizing Feed-in Tariff (FiT) mechanism as defined in Malaysia National Renewable Energy Policy and Action Plan. Important outcomes such as power generation from different resources, fuel consumption, CO2 emission, cost of emission and number of created jobs, have been evaluated and compared. Besides, achievements to the targets, grid parity and finally the required budget for Feed-in Tariff payment have been estimated and discussed. Also a novel sensitivity analysis has been implemented for providing better insight about various parameters effecting the model including the amount of Feed-in Tariff to be paid for solar resource and the surcharge rate that must be collected from electricity bills.

Eventually chapter 5 provides conclusions of the study and some research directions for future works.

The software by which simulation is performed in this study is Vensim PLE for windows version 6.0b.

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