Energy 84 (2015) 808–815

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Role of feed-in tariff policy in promoting solar photovoltaic investments in Malaysia: A system dynamics approach

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ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form
15 March 2015
Accepted 18 March 2015
Available online 7 April 2015

Keywords:
Feed-in tariff
System dynamics
Solar PV
Malaysia

ABSTRACT

Solar photovoltaic has shown a significant rise in terms of worldwide installation. One of the main reason is due to the introduction of the FiT (feed-in tariff) policy by the governments. This paper aims to evaluate FiT policy in promoting solar PV (photovoltaic) investments in Malaysia by using a dynamic systems approach. The assessment model captures the complexities arising from the interaction of FiT rate dynamics, construction delays, and investors' and technology learning dynamics in an integrated framework. The model provides total operational PV capacity, amount of finances needed to support the policy, and the cost of environmental savings, as output. Computer simulations, based on twelve scenarios, were used as a means to study the model behaviour. For the most favourable scenario, a total capacity of about 16 GW PV by 2050 can be expected, while for the least favourable scenario, expectations would be only about 10 GW. On the expenditure side, the most favourable scenario can cost up to MYR (Malaysia Ringgit) 15 billion, whereas, for the least favourable ones, the cost can be as low as MYR2 billion. The maximum cost of CO_2 abatement can vary from MYR 0.05 per kg-CO_2 to the lowest value of MYR 0.02 per kg-CO_2.

1. Introduction

The global demand for electricity is on a rise. In 2001, electricity generation was 15,640.7 TW h, which grew to 22,668 TWh in 2012 [1,2]. A rise in population and economic prosperity are attributed to be the main drivers behind the increase in demand [3]. According to the IEA (International Energy Agency), around 68% of the world's electricity production is from fossil fuels. Coal is the most widely used fossil fuel for power generation, followed by hydropower; supplying around 40.4% and 16.2% of the world's electricity needs in 2012, respectively [2]. There are two major concerns over the use of fossil fuels for electricity generation: finite resources and environmental degradation. It is estimated that coal will last 164 more years, oil 200 years, natural gas 65 years, and not fossil, but non-renewable, nuclear resources will be available for the coming 70 years [4]. The second concern regards harmful emissions like CO_x, NO_x and SO_x from using fossil fuels based electricity generation. These emissions are also believed to be contributing to global climatic change [5]. Therefore, one of the top priorities of countries around the world is to divert their electricity generation from non-renewable to renewable sources. This diversification will achieve sustainability in production as well as combat climate change.

Likewise, the GoM (Government of Malaysia) is keen to diversify the fuel-mix for power generation. Various steps had been taken in the past to promote renewable sources for electricity production. The 10th Malaysia Plan (2011–2015), being the most recent, targeted 985 MW of renewable generation capacity [6]. According to this plan, the solar PV (photovoltaic) capacity is targeted to be raised to 65 MW [7]. This seems to be an arduous task, as the solar PV technology is expensive and is still treated as novice technology

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http://dx.doi.org/10.1016/j.energy.2015.03.047
0360-5442/

in comparison to other commercially available technologies for electricity generation [8].

To overcome the financial barrier for a large scale adoption of the solar PV technology, GoM opted for FiT (feed-in tariff) policy, saying, " FiT is the most effective RE (renewable energy) policy mechanism in promoting and sustaining renewable energy growth" [9]. However, FiT subsidies place a financial burden on governments, which may restrict policy continuance under difficult economic conditions. This situation can thus adversely affect public confidence in these support mechanisms. Therefore, it becomes imperative for policy-makers to fully assess the consequences of their intended policies before implementing them. Thus, the objective of this study is to develop a simulation model which will evaluate the FiT policy for the solar PV systems deployment in Malaysia.

2. An overview of FiT policy

In an anticipation to increase the renewable capacity investments, around 72 countries and states around the world have introduced the FiT support scheme, including Kazakhstan and Ecuador being the latest ones [10]. This list includes Germany, Spain, and Ontario (Canada), from the developed world, to Taiwan and Turkey, from the developing world [11–15]. The aim of the FiT policy is to offset the high investment cost of renewable energy technologies. FiT is believed to be a more effective support mechanism as compared to renewable portfolio standard [16].

The risk mitigation, either financial or technical, or both, is an important feature for any policy design for renewable technology deployment [15]. The FiT policy fulfills both requirements; it guarantees fixed prices and long contractual periods, along with grid access to any technology using renewable fuel for electricity generation. The FiT prices are characterized per kWh of electricity (energy) produced, which has to be paid to an independent power producer by a system operator, or a utility company, to whose grid energy is exported. These prices vary for different technologies, range of capacities and length of contracts [17] hence, ensuring financial reliability [18]. On the technical side, FiT policy mandates the utility companies to provide grid access to independent producers. Consequently, FiT policy effectively lowers the perceived risk for investors; ensuring rapid and sustainable scaling up of renewable technology for electricity production [19]. However, some drawbacks have also been identified. The foremost reservation concerns FiT inhibiting a healthy market competition by giving preferential treatment to certain technologies; other reservations include, financial burden on taxpayers and propensity to lock–in to a specific technology [20,21]. To overcome these impediments policy-makers are compelled to limit the time and size of FiT policy; enabling local markets to flourish as well as embracing no extra financial burden [22].

Prior research suggests that the FiT policy can have varied outcomes in different countries in terms of installed PV capacities [18]. The reason for this variation is attributed to the unique design characteristics of the FiT policy in a particular country [12]. To evaluate the FiT policy, a number of researchers have adopted various methodological approaches in developing their assessment models. For example, Jenner et al. [12] used the econometric approach to evaluate the success of the FiT policy in 26 European Union countries, whereas Kim and Lee [23] used the stochastic-optimization approach to assess the effectiveness of Ontario's FiT policy. The static Monte Carlo simulation was employed to assess the uptake of wind power by Walters and Walsh [24], while a dynamic simulation package called, Green-X, was used by Walker [25] to evaluate the effect of FiT in attaining 2% of renewable technology share in UK. On the other hand, Muhammad-Sukki et al. [26] used an accounting approach to assess the impact of revised FiT rates for solar PV deployment in UK. Along with quantitative approaches, Verbruggen and Lauber [27] used a qualitative approach to asses FiT and Tradable Green Certificate scheme for renewable technology deployment. Furthermore, on the methodological side, models using a dynamic, nonlinear, feedback approach of system dynamics; similar modelling approach used in this study, focussed on modelling renewable target capacity [28,29], and assessing the renewable technology cost development [30]. However, only one model by Hsu [31] presented a combined FiT and subsidies assessment using system dynamics approach for solar PV. Finally, Shahmohammdi et al. [32] presented another system dynamics model assessing FiT considers a short time horizon for simulation. One of the drawbacks of considering shorter time horizon, in this case, can result in masking of valuable dynamics that can be exhibited once FiT contract period and life span of a particular technology is exhausted.

3. Malaysian electricity sector

Being a fast developing country, with an aspiration to be in a higher income group of countries, Malaysia's electricity demand is sharply increasing. The peak demand in 2000 was 10,639 MW, which rose to 17,883 MW in 2012 [33]; this corresponds to an annual rise of peak demand of 5.2%. This shows that large generation capacity expansions were made in order to meet the growing peak demand. In 2000, the total electricity demanded was 61,168 GWh, which jumped to 116,353 GWh in 2012, corresponding to an annual growth rate of 6.9% [33]. It is estimated that Malaysia would require 234 TWh by 2030 [10] while in short run, by 2022, 151 TWh [34,35], which seems to be a great challenge for the country. The development of peak demand and average electricity consumption, for the period 1997–2012 is shown in Fig. 1.

The Malaysian electricity generation is dependent on five main types of fuels: oil, coal, natural gas, hydro and others (biomass, biogas and solar). This fuel-mix for electricity generation presented in Fig. 2 shows that the share of oil/diesel for power production is decreasing, while the gap created is being filled-up by natural gas; currently, gas based production dominates the share of fuel-mix. Nevertheless, since 2000 the share of coal in fuel-mix is also on the rise.

On the renewable side, hydropower share is decreasing, as opposed to biomass share, which is rising sluggishly. In 2010, 94% of electricity was produced from fossil fuels, whereas hydropower plants provided only 5.6% of the total electricity produced [7]. It is estimated that the Malaysian oil reserves would only last for 18–20 years, while natural gas production can only be sustained for the coming 35–36 years [6]. The supply for coal, on the other hand, is maintained by imports from Indonesia, Australia, and South Africa [36]. Thus, in order to meet the rising power demand, whilst cutting the reliance on the fossil fuels, Malaysia needs to changeover to

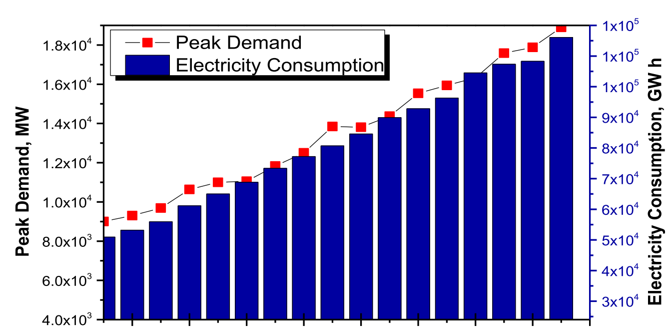

Fig. 1. Annual peak demand and electricity consumption [33].