



# Thailand's feed-in tariff for residential rooftop solar PV systems: Progress so far



Sopitsuda Tongsopit

Energy Research Institute, Chulalongkorn University, 12th Floor, Institute Building III, Phayathai Road, Pratumwan, Bangkok 10330, Thailand

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## ABSTRACT

This paper reviews Thailand's feed-in tariff framework for the support of solar power production and provides a feasibility analysis of residential-scale rooftop solar PV investment in Thailand under three scenarios. The initial phase of feed-in tariff support for solar power in the form of "Adder" gave rise to the dominance of solar farms, contributing currently to 99% of Thailand's solar power capacity. Since 2013, the government has begun to give a more focused support to rooftop solar power investment in the form of fixed feed-in tariff. However, the response to the government's feed-in tariff support for residential rooftop solar has been slow. Among many reasons, this paper argues that the lack of feasibility of residential rooftop solar power investment remains a key barrier. Under current market conditions, such investment could potentially be stimulated with the presence of a tax incentive and more attractive financing options.

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## Introduction

The growth of Thailand's grid-connected solar power capacity has been phenomenal, averaging 211% per year between 2007 and 2013. Ninety-nine percent of this growth comes from large-scale solar installations with installed capacity greater than 1 MW, while the market for rooftop solar PV systems remains underdeveloped. In July 2013, the Thai Cabinet approved a feed-in tariff measure to support rooftop solar power investment. This paper provides a review of two types of feed-in tariffs for solar power in Thailand and their outcomes in terms of driving capacity growth. Premium-price feed-in tariff, or Adder, was offered for solar power between 2007 and 2010, resulting in 782 MW of solar power by the end of 2013. Fixed feed-in tariffs were offered for rooftop solar systems for a brief period in 2013 and resulted in modest growth, especially in the residential rooftop solar sector. This paper then uses a discounted cash flow model to perform a feasibility analysis of residential-scale solar PV systems under three scenarios. The results show that investment in residential-scale rooftop solar systems is not feasible under the market conditions following the launch of the program unless additional incentives are provided by the government.

## International experiences of feed-in tariff designs

Feed-in tariff (FiT) has been the most popular type of renewable energy support worldwide. Experiences of solar FiT support for

renewables in many countries have shown that long-term, stable support of FiT appears to be a very important condition for market expansion (Lüthi, 2010; Antonelli & Desideri, 2014). Continuous and stable feed-in tariff support has driven solar PV market expansion in Italy (Antonelli & Desideri, 2014), Germany (Mabee et al., 2012), and for a period, in Spain (del Rio & Mir-Artigues, 2012), allowing these PV markets to reach a certain level of maturity. The effectiveness of these countries' FiT programs depends not only on the tariff rates but also on the design and implementation – how the implementation details are crafted and how the program is updated to meet changing circumstances.

Germany's continuous renewable energy market growth can be attributable to what Deutsche Bank calls "best-in-class" national feed-in tariff policy, characterized by transparency, longevity, and certainty (Fulton & Mellquist, 2011). In the early stage of FiT implementation, the German government gave high initial rates to reward early adopters. This strategy was then accompanied by a degression model in which the published tariffs declined by a fixed percentage each year in anticipation of technological learning.<sup>1</sup> For residential rooftop solar systems in Germany (0–30 kW), the initial FiT rate offered in 2000<sup>2</sup> was very high but a degression rate of 5% was scheduled to be applied to plants installed as of 2002 (Hoppmann et al., 2014). The degression rate has been updated many times in response to declining PV module prices and a growing market volume. In retrospect, the rate declined

<sup>1</sup> Technological learning can be defined as the condition under which more efficient technologies are developed in response to market incentives.

<sup>2</sup> 51 EUR cents/kWh (nominal term).

E-mail address: tongsopit@gmail.com.

rapidly so that today's residential solar tariff rate is around 73% lower than 2000 rate when it began.<sup>3</sup> Germany's degression model has been shown to incentivize ever more efficient and cheaper technologies and hence resulting in a reduction in the costs of the technologies (García-Alvarez & Mariz-Pérez, 2012). In addition, there was no cap in the capacity to receive FiT since the FiT was enshrined in the German Renewable Energy Sources Act, which obligates the utilities to prioritize the purchase of power from renewable resources. In 2012, in response to the rapid decreases in the price of solar electricity, Germany tied the degression schedule to the actual amount of solar installed in the preceding year. If installations of solar electricity exceeded targets then tariffs fall faster for new projects. If less than expected solar capacity is installed, tariffs fall more slowly than planned.

It should be noted that the market for residential-scale solar systems in Germany was supported by several measures in its early stage of formation. The government-funded 100,000-roof program pre-dated the feed-in tariffs. Implemented between 1999 and 2003, the program provided no-interest loans to PV installation sized 1 kW or greater.<sup>4</sup> In addition to the federally funded program, rooftop solar PV in Germany also receives support from other sources, including tax credits from local fiscal authorities and low-interest loans from state-owned banks and private banks (Spertino et al., 2013).

Italy is another country that has experienced an impressive growth in solar power. This growth has been attributable to attractive FiT rates given continuously with a yearly degression rate of 2% between 2008 and 2010. No cap or quota was placed on the overall amount of installations in the first three years after the FiT was introduced. The resulting annual growth rate of solar PV in Italy was impressive: +382% in 2008, +112% in 2009, and +192% in 2010 (Spertino et al., 2013). This approach “transformed Italy from a country with no significant PV production into one of the world's leading countries in terms of installed PV power and generated electricity” (Antonelli & Desideri, 2014). Other support measures that supplement FiT for solar power includes a reduction of 10% on the value-added tax (l'aliquota agevolata del 10 per cento) and the reduction of property tax given to buildings equipped with solar power (RESLEGAL, 2014).

Similar to Germany, Spain's feed-in tariffs framework was enshrined in the law and has been designed to increase the participation in RE generation in the electricity market (González, 2008). The case of solar power support in Spain shows that the design elements of feed-in tariffs matter, as has been expressed in del Rio & Mir-Artigues (2012); Schallenberg-Rodriguez & Hass (2012). FiT has been in place since 1998 in Spain. Its design elements went through several rounds of modifications in 2004, 2007, 2008, and 2010 in order to increase the effectiveness and reduce impacts on the electricity rates (see, e.g., del Rio & Mir-Artigues, 2012). The transition from the 2007 to 2008 regulation induced a boom in capacity growth since there was the expectation of a substantial reduction to the support level (del Rio & Mir-Artigues, 2012). In an attempt to contain the rising cost of support, policymakers responded by putting in place a capacity quota and a degression mechanism that was tied to the level of capacity reached in the previous year. This change in regulation, in combination with delayed and lengthy administrative procedures and the 2008 economic crisis, resulted in a drop in new solar capacity. The 2010 regulation went further to retroactively reduce the support level of the existing solar contracts, and the government abolished the FiT scheme entirely in 2013 (Diaz, 2013).

In those countries' context, FiT is seen as a tool to meet the national goals of carbon emission reduction, economic stimulation, and the positioning of the countries as a technology leader. Germany has achieved those goals (García-Alvarez & Mariz-Pérez, 2012; Barua et al., 2012;

<sup>3</sup> The comparison is done in nominal term. The feed-in tariff rate for residential-scale solar installation (<10 kW) was 51 Euro cents/kWh in 2000; by January 2014, this rate was reduced to 13.68 Euro cents/kWh in January 2014 (RESLEGAL, 2014).

<sup>4</sup> Details on the 100,000-Roof Solar Programme can be found from (Erge et al., 2001).

Sovacool, 2009; IEA – International Energy Agency, 2013), and many other European countries are on track. In developing countries, FiT can also offer opportunities for local economic development, stimulating innovation, but policymakers must first be convinced and design a set of associated policies to reach these goals. Using the examples of India, China, Brazil, Philippines, and Bangladesh, Timilsina et al. (2012) find that developing countries are more sensitive to the costs of solar energy support, and a common approach to solar energy promotion has been to “rationalize development and deployment strategy” (Timilsina et al., 2012).

Thailand is an interesting case study in which the benefits of solar PV power expansion are being doubted by some policymakers and utility experts due to the experiences arising from solar farms. Solar farms, or utility-scale solar systems (sized greater than 1 MW), are typically owned by “absentee owners” who are not members of the communities around the solar farm areas. The income earned from FiT is not retained in the community and communities have little participation in its operation and management. In addition, because so far there has been no policy or program specifically designed to stimulate innovation in solar PV, the expansion of solar PV installed capacity in Thailand is seen as contributing little to domestic industry development. Therefore, solar FiT is viewed by some as paid to expensive imported technologies with little prospect to stimulate domestic technological capability.

Furthermore, unlike the continuous support seen in the countries cited above, Thailand's rooftop solar FiT support has been different. The detailed designs include a presence of quota, a narrow application period, no degression rate, and no revision timeline. The policy came out for a brief period with uncertainties on future support. The short period of market opening reduces the opportunities to achieve economies of scale required for cost reduction, hence resulting in relatively high investment costs for rooftop owners.

### Backgrounds on Thai renewable energy policy and feed-in tariffs

Thailand's demand for power is constantly increasing at an average growth rate of 5% per year between 2002 and 2013 (EPPO – Energy Policy and Planning Office, 2014a). The total power consumption in 2013 was 164,341 GWh and the peak power demand was at 27,285 MW in 2013 (EPPO – Energy Policy and Planning Office, 2014b). Around 70% of the installed capacity is natural gas-based, while the rest comes from coal (20%), hydro (3%), and other sources combined (7%) (EPPO – Energy Policy and Planning Office, 2014c). The Thai government recognizes the need to reduce dependence on natural gas and therefore has set targets for energy efficiency and renewable power production. According to the Alternative Energy Development Plan (AEDP 2012–2021), Thailand aims to achieve 25% of final energy consumption using renewable energy sources by 2021. Under this plan, a solar power target of 3000 MW has been set. Feed-in tariff is the mechanism that has been designed to drive the growth of solar power in Thailand so far. Since 2007, two feed-in tariff schemes have been put in place to support the growth of solar power.

#### *Premium-price feed-in tariffs (adder) and its outcome*

In 2007, Thailand implemented a premium-price feed-in tariff, or the Adder measure. A premium-price feed-in tariff consists of a normal tariff that is usually the utility's avoided cost of purchasing power plus a premium that is paid on top of the normal tariff. For solar power, the Adder rate of 8 Thai Baht/kWh is paid on top of the avoided wholesale electricity cost, which varies from month to month and ranged from 3.06–3.17 Thai Baht/kWh<sup>5</sup> (9.4–9.8 US cents/kWh<sup>6</sup>) in 2014. The total tariff paid was between 34.05 and 34.38 US cents/kWh for solar

<sup>5</sup> The utility's avoided cost of purchasing power from renewable energy projects can be found from the Metropolitan Electricity Authority's web site: <http://www.meo.or.th/profile/index.php?l=th&tid=3&mid=2998&pid=2995>.

<sup>6</sup> Using an average exchange rate of 32.49 THB/USD in 2014.

power projects that received Adder in 2014. As shown in Table 1, the Adder measure in Thailand is provided for six types of renewable energy technologies. The Adder rates are distinguished by the technology type, installed capacity, and location. Adder rates are paid for 10 years for solar and wind power and 7 years for other types of renewables. The Adder program has been successful in stimulating RE investment, resulting in continuous growth of renewable power as shown in Fig. 1.

An exception is the discontinuous support for solar power that resulted from the oversubscription to the solar Adder and policymakers' and regulators' concerns on the impact of electricity pass-through costs to ratepayers (Tongsopit & Greacen, 2013). The support for solar power through the Adder program was paused since 2010. However, because of the large backlog of approved solar Adder applications, the growth of solar power continues today with 945 MW of solar power on-line and receiving adder and 479 MW of solar power in the pipeline that will receive adder once they come online (data as of May 2014) (ERC – Energy Regulatory Commission, 2014). 99% of solar power investment that has come online has been utility-scale solar installations (with installed capacity larger than 1 MW), as shown in Fig. 2.

#### Fixed-price feed-in tariffs and its outcome

After the pause of solar power support between 2010 and 2013, the Thai government launched a new feed-in tariff scheme for rooftop solar systems in July 2013. The new scheme has a fixed-price structure that is paid for 25 years. There are three tariff rates for three scales of installations as shown in Table 2. The tariffs are paid based on the amount of energy generated from the solar PV systems (as opposed to the amount left to be fed to the grid after consumption).

For this fixed-price feed-in tariff scheme, the government set a total target of 200 MW with 100 MW allocated to residential-scale (0–10 kW) installations and another 100 MW allocated to commercial- and industrial-scale installations (>10 kW–1 MW). In addition, the government allowed a short period of application submission between October and November 2013. The response from the private investors was overwhelming for commercial- and industrial-scale investment. However, residential-scale applications did not reach the target of 100 MW. After the closing of the application process, residential applications amounted to around 55% of the residential target and about half of these applications were approved. The comparison of applications and approval rates for different scales of rooftop solar installations are shown in Fig. 3. Early adopters to residential PV systems came mainly from the high-income segment of the population—those who are financially ready to invest in the technology. About half of the residential applications were accepted, and the major reason for rejection was incomplete applications.

Fig. 4 distinguishes between the rooftop solar capacity vs. utility-scale installations that came online between 2006 and 2013. Rooftop solar capacities include those of residential, commercial, and industrial scales. Rooftop solar capacity growth in this period was slow and the new FiT measure that was launched in 2013 could potentially induce a boom in the residential market. By the end of 2013, the growth in rooftop solar capacity that was caused by the FiT scheme was not yet visible since the application process for the FiT was open in late 2013 (October–November 2013).

There are numerous barriers that have been causing rooftop solar projects at all scales to experience delays in their implementation, including the unavailability of meters and complicated permitting processes. In addition to those barriers, the next section discusses the lack of feasibility for residential-scale investment under real market conditions in 2013.

#### Feasibility analysis of residential-scale investment

The investment in residential-scale solar rooftop systems is currently still limited. Beside the short application submission period, the lack

of widespread campaign, and the complicated permitting process, another major reason for its underdevelopment is due to the relatively high cost and lack of feasibility of residential-scale projects. This paper provides a comparison of the feasibility of three scenarios. The first scenario, “NEPC Assumptions”, is based on the assumptions used by policymakers as inputs into the FiT design.<sup>7</sup> The second scenario, “Current Market”, is based on the market conditions that happened during the time of market opening between October–November 2013. The market conditions include investment cost and financing options. The third scenario, “Market Stimulation”, is based on a tax return that is provided as an additional incentive to FiT. A tax return is chosen as an additional incentive on top of the FiT because it is an option that has been discussed among stakeholders in the solar PV industry, and the momentum for its implementation is growing. Table 3 summarizes the differences between the three scenarios.

#### Financial viability of three scenarios of rooftop solar investment

The financial viability of investment under the three scenarios are compared using the net present value (NPV), internal rate of return (IRR), and payback period (PB), and the total subsidy required by ratepayers or taxpayers to support each scenario. A discounted cash flow analysis was performed in Excel in order to determine the NPV, IRR, and the payback period of the representative solar PV system. The NPV is the sum of discounted annual cash flow over the lifetime of the PV system less the capital cost as shown in Eq. (1).

$$NPV = \sum_{t=1}^n \frac{Cash\ Flow}{(1+i)^t} - C. \quad (1)$$

t is the year; n is the system lifetime; i is the discount rate; and C is the initial capital cost.

Each year's cash flow is obtained from the revenue generated from the FiT income subtracted by a sum of the cost of operating the system and the cost of financing the system. All cash flows are then discounted over the system's lifetime of 25 years. The discount rate used in this study is 5.02% and is calculated from the Weighted Average Cost of Capital (WACC), which is shown in Eq. (2).

$$WACC = \frac{E}{E+D} k_E + \frac{D}{E+D} k_D. \quad (2)$$

E is the amount of equity; D is the amount of debt;  $k_E$  is the return on equity; and  $k_D$  is the cost of debt or the interest rate (Breyer & Gerlach, 2013).

The IRR can be calculated by Eq. (3).

$$C = \sum_{t=1}^n \frac{Cash\ Flow}{(1+IRR)^t}. \quad (3)$$

The payback period represents the year in which the cumulative cash flow equals the initial investment. Eq. (4) shows the calculation of the payback period.

$$Payback\ Period = \frac{Initial\ Investment}{Annual\ Net\ Cash\ Inflow}. \quad (4)$$

<sup>7</sup> The National Energy Policy Commission (NEPC) is the commission tasked with proposing major Thai energy policies, including feed-in tariffs.

**Table 1**  
Thailand's Adder rates (exchange rate: 1 US Dollars = 30 Thai Baht).

Type of RE	Unit: US Dollars per kWh					Years supported
	2007 Adder rate	2009 Adder rate	2010 Adder rate	Special Adder for diesel replacement	Special Adder for three southernmost provinces	
Biomass						
Installed capacity ≤1 MW	0.010	0.017	0.017	0.033	0.033	7
Installed capacity >1 MW	0.010	0.010	0.010	0.033	0.033	7
Biogas						
Installed capacity ≤1 MW	0.010	0.017	0.017	0.033	0.033	7
Installed capacity >1 MW	0.010	0.010	0.010	0.033	0.033	7
Waste						
Landfill and digester	0.083	0.083	0.083	0.033	0.033	7
Thermal process	0.083	0.117	0.117	0.033	0.033	7
Wind						
Installed capacity ≤50 kW	0.117	0.150	0.150	0.050	0.050	10
Installed capacity >50 kW	0.117	0.117	0.117	0.050	0.050	10
Small/micro hydro						
50 kW < installed capacity < 200 kW	0.013	0.027	0.027	0.033	0.033	7
Installed Capacity ≤ 50 kW	0.027	0.050	0.050	0.033	0.033	7
Solar	0.267	0.267	0.217	0.050	0.050	10

Note: the current (July 2014) Adder rate remains at 2010 levels, with the exception of solar power Adder program, which no longer accepts new applications.

However, because the annual cash inflows are uneven due to varying O&M expenses and declining loan payments, Eq. (5) is used to calculate the payback period.

$$\text{Payback Period} = T + \frac{|\text{Cumulative Cash Flow at the End of Year } T|}{\text{Net Cash Flow in the Year } T + 1} \quad (5)$$

T = the last year with a negative cumulative cash flow.

*Technical parameters and system costs*

Key technical and system costs assumptions across the three scenarios are compared in Table 4. The differences between Scenario 1 and Scenario 2 are the investment cost and financial parameters. While the system costs are discussed in this section, the financial parameters are discussed in the Financial Parameters section. System prices used in Scenario 1, which were used as inputs into the rooftop FiT calculation, would more accurately reflect a mature market with experienced

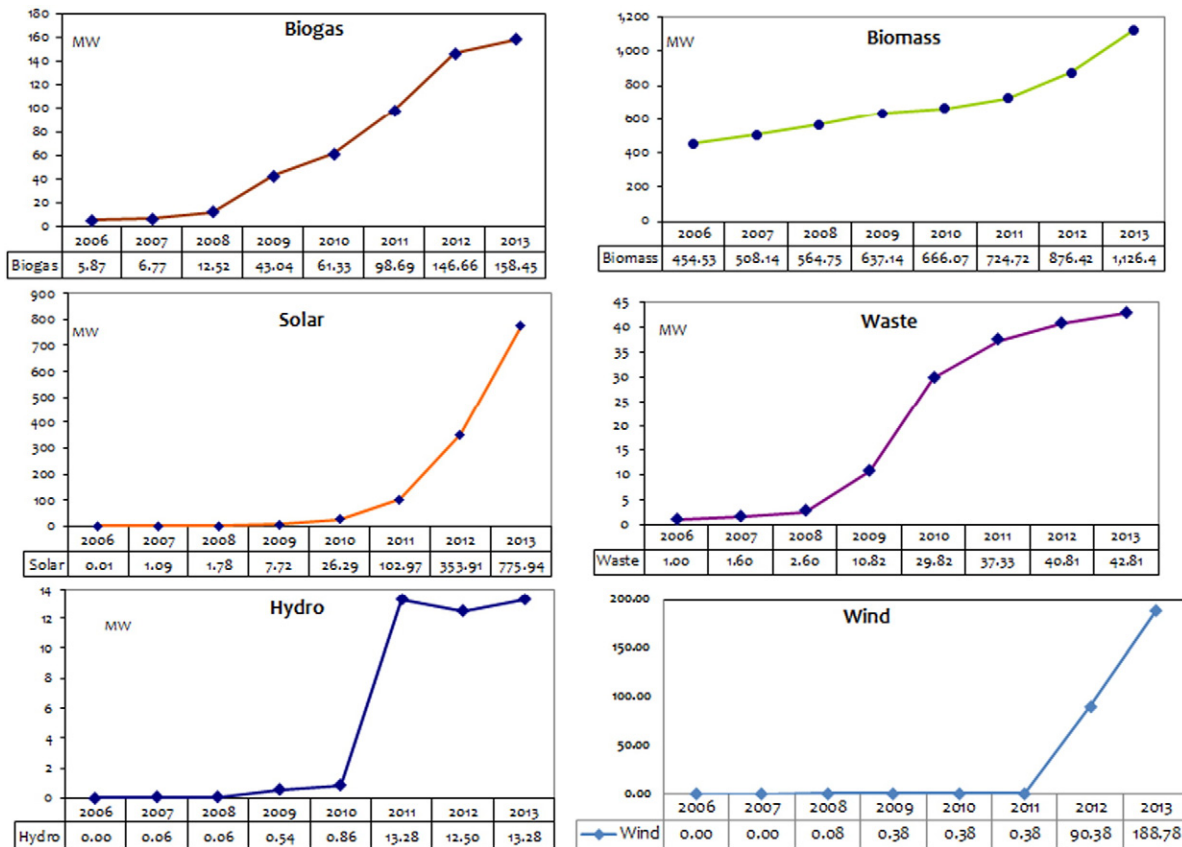
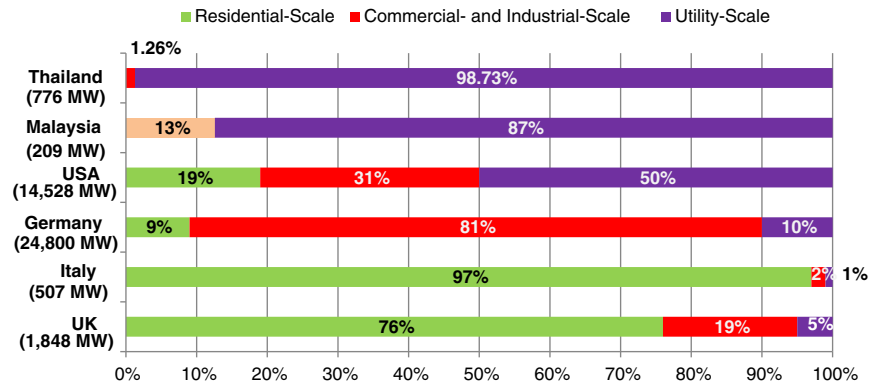


Fig. 1. The growth of renewable power in Thailand between 2006 and 2013Z.

Source: (EGAT – Electricity Generating Authority of Thailand, 2013; MEA – Metropolitan Electricity Authority, 2013; PEA – Provincial Electricity Authority, 2013).





**Fig. 2.** Solar power development in different countries grouped by size of installations. Notes: 1. Definitions of residential-, commercial-, industrial- and utility-scale solar power installations in different countries vary. This paper uses the data that match each country's source's definitions of scales. For example, Thailand's residential scale goes up to 10 kW, whereas Italy's residential scale goes up to 20 kW. 2. The three legends in colors apply to all countries except Malaysia, in which the legend in tan color represents both residential- and commercial-scale installation. 3. The number in each parenthesis under each country's name is the total cumulative installed capacity in each country in the quoted year. Source: Author's analysis from Thailand (EGAT – Electricity Generating Authority of Thailand, 2013; MEA – Metropolitan Electricity Authority, 2013; PEA – Provincial Electricity Authority, 2013); Malaysia (Malek, 2014); USA (SEIA – Solar Energy Industries Association, 2014); Germany (Schoenfeld, 2012); Italy (GSE – Gestore Servizi Energetici, 2014); UK (DECC – Department of Energy & Climate Change, 2014).

system integrators. However, a survey of system prices during the time of market opening in 2013 shows much higher prices than that used in the NEPC assumptions for the residential rooftop market. The average system price was 39% higher than that used in the NEPC. In addition, offered prices were quite diverse, which is common for nascent rooftop markets. Players in the residential rooftop markets are new and have limited experiences of system design and installation. With few exceptions, large-scale players with extensive experiences in utility-scale installations were more focused on the commercial- and industrial-scale rooftop solar installations and did not enter the residential market.

Capacity factor is used as a parameter to reflect the performance of the systems. A capacity factor is the ratio of the actual energy output to the amount of energy the PV system would generate if it were to operate at full rated power for a year. The capacity factor of 14.84% was used as an input assumption into the feed-in tariff design process of the NEPC. The capacity factor is kept constant across the three scenarios to elicit responses to different levels of incentives. However, it should be noted that published capacity factors in the literature based on the performance evaluation of residential-scale poly-crystalline PV systems in Thailand are somewhat lower, ranging from 10.48–13% (Sasitharanuwat et al., 2007; Ketjoy et al., 2013; Chaichuangchok et al., 2013). Expert opinions based on field testing revealed capacity factors of 15–17% for solar farms and less than 16% for residential-scale solar systems (Chaichuangchok et al., 2013; Ketjoy, 2014). Therefore, the power production from rooftop solar systems can be lower than what policymakers predicted under the FIT framework, rendering the FIT rates too low for the expected level of return on investment.

The degradation rate of 1% per year was used as an NEPC assumption and is used in this study across three scenarios. This corresponds to most manufacturers' performance warranties of 20 years, with maximum loss of no more than 20% of the rated power. It should be noted that the degradation rate for crystalline technologies based on field testing may be lower than this number. For example, Makrides et al. (2014) found an average annual performance loss rate (PLR) of 0.64%/year for mono-crystalline silicon (mono-c-Si) PV modules 0.62%/year for the

multi-crystalline silicon (multi-c-Si) systems (Makrides et al., 2014). Jordan and Kurtz (2012)'s review of 112 publications found a median degradation rate in the range of 0.23%–0.90% per year for crystalline technologies tested in diverse geographical locations (Jordan & Kurtz, 2012).

The yearly cost of operating and maintaining a rooftop solar PV system is typically minimal and set at 0.68% of the initial investment cost. However, an escalation rate based on inflation is included in the O&M cost of Scenario 2–3 (3% according to the Bank of Thailand in the year 2013).

*Financial parameters*

Other major differences between scenarios are the presence of income tax and income tax incentive, whereas the loan interest rate and loan term are kept constant. The NEPC did not include the payment of income tax in its calculation of the FiT, so Scenario 2 adds the income tax to account for actual cash flows of the project. Scenario 3 adds an additional incentive by providing an income tax return of 20% of the total investment cost.

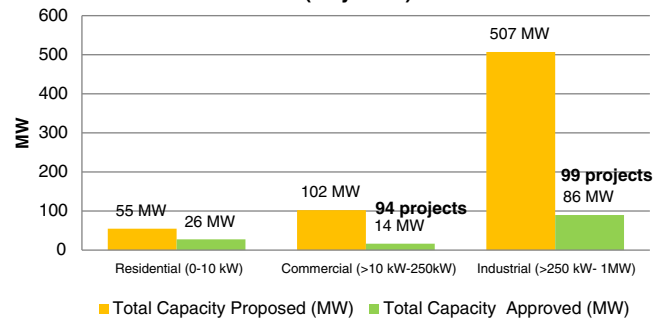
Financing options for residential rooftop investment are still limited in Thailand today even after the launch of the rooftop FiT measure. At the time of market opening and to the date of this writing, no special loan was available from commercial banks that would be targeted for solar power investment. According to NEPC assumptions, the interest

**Table 2**  
Feed-in tariff rates for rooftop solar power approved by the NEPC in 2013.

Scale	FiT rate (Baht/kWh)	FiT rate (USD/kWh)	Quota
0–10 kW	6.96	0.22	100 MW
>10–250 kW	6.55	0.20	100 MW
>250 kW–1 MW	6.16	0.19	

Note: exchange rate 1 USD = 32 Thai baht.

**Approval Status of Feed-in-Tariff for Rooftop Solar PV (May 2014)**



**Fig. 3.** The approval status of feed-in tariffs for rooftop solar power systems (Data as of May 2014).

Source: Author's analysis from (MEA, 2014; PEA – Provincial Electricity Authority of Thailand, 2014).

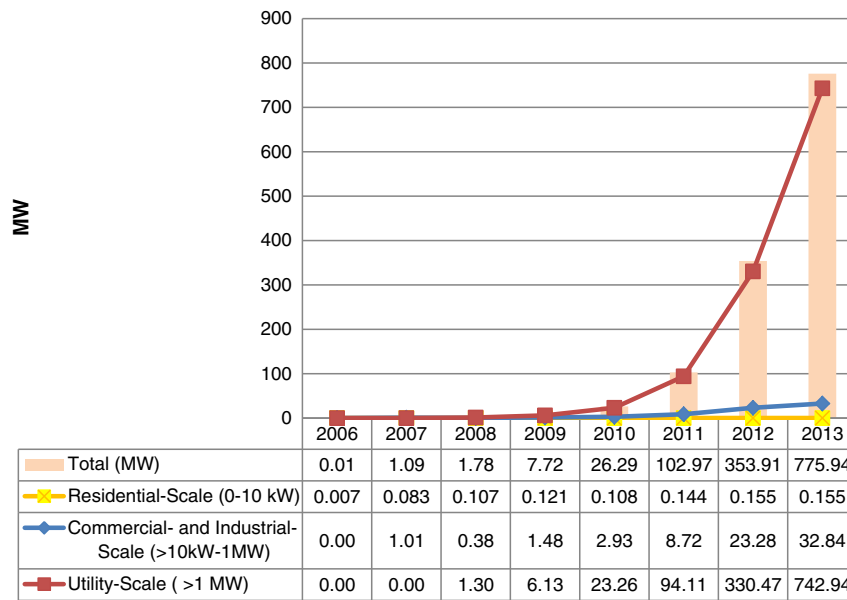


Fig. 4. Trends in grid-connected solar PV status (MW) distinguished by scale.

Source: (EGAT – Electricity Generating Authority of Thailand, 2013)–(PEA – Provincial Electricity Authority, 2013).

rate of 6.15% represents the minimum available MLR rate during the month of July 2013 (when NEPC meeting occurred) (BOT – Bank of Thailand, 2014). This Minimum Lending Rate (MLR), however, may not be a good representative of the loan rate that an average household would receive because it reflects the loan rate for lenders with the best credit ratings. The loan term of 8 years was proposed by the NEPC but the actual loan term that the banks offer would also be varied depending on the credit rating of the household. Nevertheless, to control the financial variables, the loan rate and the loan term are kept the same through the three scenarios.

To summarize, the assumptions are used to match the NEPC scenarios, except for the income tax, and income tax incentives, as shown in Table 5.

## Results and discussion

By keeping technical parameters constant and varying the financial parameters to match real market conditions for rooftop solar power investment in Thailand in 2013, the Internal Rate of Return (IRR), Net Present Value (NPV), and payback period (PB) can be found in Table 6. The NEPC Scenario results in a project IRR of 10.51% and equity IRR of 12.02%. This appears to be a very attractive investment since it is much higher than other alternative forms of investment by households, including the average saving account interest and the average yield of a

Table 3  
Key elements of the three scenarios.

Scenario	Description
1. NEPC assumptions	<ul style="list-style-type: none"> <li>&gt; Assumptions used to craft the 2013 rooftop FiT policy, including assumptions on system cost (\$/W), performance of the PV systems, and financial assumptions</li> </ul>
2. Current market	<ul style="list-style-type: none"> <li>&gt; System prices are based on a survey from 10 system integrators available in Bangkok during Oct–Nov 2013.</li> <li>&gt; Financial assumptions reflect available financing options for residential consumers.</li> <li>&gt; Additional assumptions not included in the NEPC: income tax 10%, inverter change at year 11; escalation of O&amp;M expenses at inflation rate (3%)</li> </ul>
3. Market stimulation	<ul style="list-style-type: none"> <li>&gt; System prices are based on a survey from 10 system integrators available in Bangkok during Oct–Nov 2013.</li> <li>&gt; A tax return amounting to 20% of the investment cost is provided in addition to the FiT.</li> </ul>

25-year government treasury bond (Table 7). However, actual market conditions revealed the project IRR to be a low of 4.51% in comparison to the expected IRR predicted by the FiT policy study of 10.51%. In addition to the IRR, NPV, and PB, the net cash flow for households look unattractive. Annual debt service is higher than the FiT income resulting in negative cash flows until the 8th year under real market conditions.

For these reasons, the investment in residential rooftop solar power may not be as attractive as announced by the government. And only when a tax return of 20% of the total investment cost is given will the project become more attractive than investing in the government's bond.

The major contribution to the lack of feasibility under the real market conditions in 2013 was the relatively high costs of residential solar PV systems in the market, which were significantly higher than the system costs used in policy assumptions. The relatively high costs result from the lack of competition in the market. The application period lasted only from October to November 2013, and the successful applications were given a short timeframe of a few months to complete their projects. This short application period did not allow for consumers and businesses to adjust and hence the market to grow. Market competition was lacking since there were only a few system integrators in the residential market, while other established system integrators in the market have focused on commercial-scale and industrial-scale rooftops. Larger-scale installations enable economies of scale which allow the investment cost to decline. For commercial and industrial-scale rooftop, the system cost declined by as much as 30% compared to the investment cost of residential systems. Lower investment costs make commercial- and industrial-scale projects more feasible than residential-scale projects. In 2014, the investment cost in a commercial-scale solar PV rooftop project was around 2 USD/W, corresponding to a payback period of 10 years, project IRR of 9.81%, and equity IRR of 10.69%.

Another reason for the lack of feasibility under real market conditions in 2013 was the lack of favorable financing options for households. There was no special loan program offered by the government or financial institutions. Extended loan term more than 8 years could result in a more favorable condition in which the yearly FiT income is enough to cover the debt service obligation.

The Thai rooftop FiT scheme also came with the presence of a targeted quota of 100 MW. For the residential sector, this quota was not reached but it is worth mentioning that quotas are not presented in advanced solar markets reviewed earlier. A quota that is too low

**Table 4**

Technical and system cost assumptions across three scenarios.

Assumptions – system characteristics/scenario	NEPC	Current market	Market stimulation
1. System size	3.73 kW	3.73 kW	3.73 kW
2. System cost	2.12 USD/W (63.7 THB/W)	2.96 USD/W (88.8 THB/W)	2.96 USD/W (88.8 THB/W)
3. O&M Cost (% of investment cost pa.) (Escalation per year)	0.68% (No escalation)	0.68% (Escalation of 3%)	0.68% (Escalation of 3%)
4. Capacity factor	14.84%	14.84%	14.84%
5. Degradation rate (% per year)	1%	1%	1%
6. System lifetime	25 years	25 years	25 years

**Table 5**

Financial parameters of the three scenarios.

Assumptions – financial parameters	NEPC	Current market	Market stimulation
1. D/E ratio	1:1	1:1	1:1
2. Interest rate	6.15%	6.15%	6.15%
3. Loan term	8 years	8 years	8 years
4. Income tax	0%	10%	10%
5. Income tax incentive	None	None	20% of investment cost
5. FiT rate	6.96 Baht/kWh (0.22 USD/kWh)	6.96 Baht/kWh (0.22 USD/kWh)	6.96 Baht/kWh (0.22 USD/kWh)
6. FiT term	25 years	25 years	25 years

would prevent the market to reach economies of scale required for cost reduction. In Germany, there are no overall caps on solar PV that comes in under their FiT program. Instead, quantities are controlled through price signals. Another barrier that prevents residential-scale solar projects in Thailand from moving forward is the complicated permitting process. A typical residential-scale solar project sized larger than 3.7 kW is required to acquire as many permits as a utility-scale solar system. By May 2014, one year after the rooftop FiT scheme was launched, only 5 MW of residential solar systems were connected to the grid and receiving FiT payment (EPPO – Energy Policy and Planning Office, 2014d).

## Conclusions

The residential rooftop market in Thailand remains small with an expected volume of less than 26 MW by the end of 2014. This paper has found that feed-in tariff, which is the main incentive designed to stimulate this market segment, was not strong and continuous enough to allow a significant market growth. Characteristics of Thailand's 2013 feed-in tariffs for rooftop solar, including a short application period, a lack of widespread campaign, and complicated permitting processes, have resulted in a slow response by the residential market. Furthermore, the system costs used as assumptions for the calculation of FiT did not match available system costs in the markets after the launch of the FiT, thereby resulting in a lack of feasibility for residential-scale systems. This paper further suggests that investment in residential-scale solar PV systems can be stimulated by a tax incentive given as rebates amounting to 20% of the investment cost.

**Table 6**

Feasibility of residential rooftop solar investment under three scenarios.

Scenarios	NEPC	Current market	Market stimulation
Project IRR	10.51%	4.51%	6.83%
Equity IRR	12.02%	3.67%	6.70%
NPV	4033.9 USD (121,018 THB)	1096.4 USD (32,892 THB)	1085.6 USD (32,568 THB)
Payback period	9.70 years	17.09 years	13.71 years
Energy produced	103,355 kWh	103,355 kWh	103,355 kWh
Total subsidy	23,978 USD (719,352 THB)	23,978 USD (719,352 THB)	26,270 USD (788,097 THB)

This paper also discusses how policy uncertainties and discontinuity have been the main element of Thailand's solar FiT support because policy-makers do not see the benefits of continuous domestic solar market expansion. Therefore, they have justified discontinuous support on the ground that the continuous payment to finance solar FiT would hurt ratepayers. However, FiT should not be a stand-alone policy and should instead be used as a tool to further economic and social development goals. In this sense, future solar support programs in Thailand should be a package of parallel initiatives that are designed to produce tangible benefits of solar PV to communities and the country's economy. Examples of parallel initiatives include solar PV R&D programs, technology transfer, installers training and certification, the simplification of the permitting process, and financing for communities and low-income households. If implemented successfully in combination with another solar subsidy program, these kinds of initiatives can produce benefits in the long term that help outweigh the cost of solar subsidy.

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**Table 7**

A comparison of expected returns from different forms of investment.

Source: (BMA – Thai Bond Market Association, 2014)–(Morningstar Thailand, 2014).

Investment options	Expected IRR on equity
Zero coupon bond (25 years)	4.5%
Real estate	8.68%
Equity	13.37%
Rooftop solar system (Thai government's assumptions)	12%

Notes: 1. The bond yield is based on the government's 25-year bond yield on November 1, 2013.

2. The real estate IRR is based on the return of a major Thai property fund with cash flow from rental fees in shopping malls.

3. The return of the equity fund is based on the 10-year average return of 4 mutual funds in Thailand.

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