Chapter 4

Business Models and Financing Options for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand

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Chapter 4

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Abstract

Business models and financing options play a large role in driving the expansion of rooftop solar markets. In Thailand, even though there is currently a pause in feed-in tariff support for rooftop solar systems, the market is moving forward with new business models and financing options for solar roofs. After reviewing United States-based business models and financing options, this study documents and analyses four emerging business models and one emerging financing option for customers to invest in rooftop solar systems in Thailand. The business models include roof rental, solar power purchase agreements (PPA), solar leasing, and community solar. The financing option includes two types of solar loans. We analyse the business models in terms of their components and structure, drivers for their emergence, and associated risks. In relation to the buying option, we further demonstrate the financial viability of two models – commercial solar PPA and residential solar leasing. When compared to the buying option, the commercial solar PPA model shows more attractive financial results based on the levelised cost of electricity (LCOE), net present value (NPV), internal rate of return (IRR), and payback period. By contrast, the residential solar leasing model is currently unattractive under the leasing conditions currently being discussed in the market. A number of policy recommendations are proposed in order to build an enabling environment for rooftop solar businesses to thrive. Among them include the implementation of net metering and support for residential-scale solar systems, such as in the form of tax incentives.

Keywords: Rooftop solar power, business model, financing, Thailand

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1. Introduction

Thailand leads Southeast Asia in solar power development, not only in terms of capacity growth but also the availability of a capable workforce in the solar power sector. As of December 2014, grid-connected solar power capacity reached 1,354 megawatts (MW). Around 99% of this capacity comes from utility-scale installations whose sizes are greater than 1 MW.

For this reason, business models for solar power prior to 2014 were based on joint ventures for utility-scale solar power plants (solar farms) and the buying model for rooftop solar systems. Financial institutions previously offered no dedicated programmes for rooftop solar since their past experiences have been based mainly on project finance for solar farms. The lack of a stable policy and the relatively high cost of solar power further added to this lack of dynamism in the rooftop solar sector in the past.

Since 2013, however, a new feed-in tariff (FIT) framework along with low prices of solar systems and rising costs of grid electricity have made it possible for businesses to devise new, diverse models, including those that have succeeded in other countries' contexts. Our research is conducted at a time when a new ecosystem for the rooftop solar market is emerging in which existing businesses and new entrepreneurs are forming new partnerships and generating value creation. It is not yet clear which business models will succeed in expanding the rooftop solar market in Thailand, especially in light of current policy uncertainties. Therefore, this research helps build the academic foundation by identifying diverse and emerging business models in the Thai rooftop solar market between 2013 and 2015 and describing the conditions that enable their emergence. We review international rooftop solar business models and financial options that originated mainly from the United States and then surveyed emerging business models and financing options in Thailand. From the list of emerging business models, we then quantitatively analyse two selected models, which have the potential to rapidly scale-up the rooftop solar photovoltaic (PV) expansion. We conduct financial analysis of the two business models, solar leasing (solar leasing model) and solar power purchase agreement model (solar PPA model), and offer recommendations on policy and regulatory changes that will create a friendly environment for new business models to succeed.

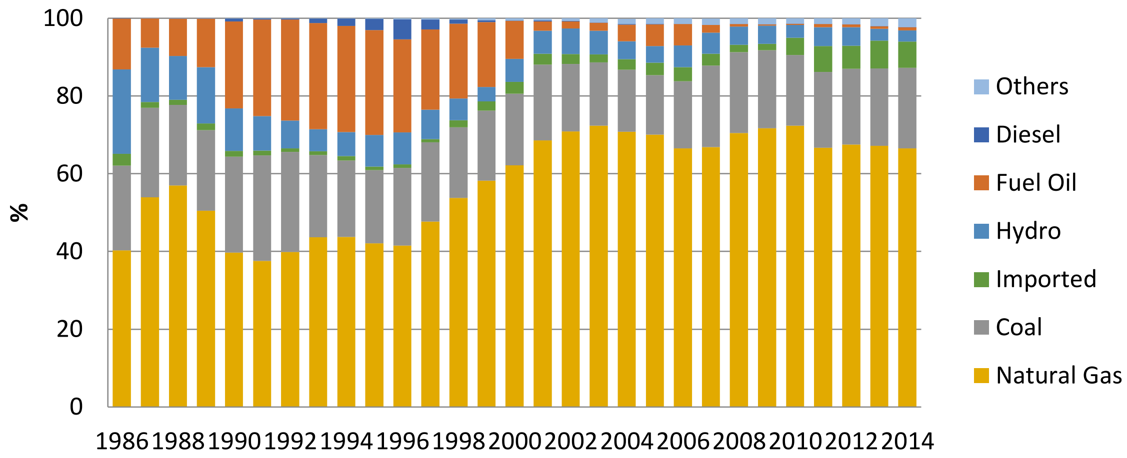
This report is structured as follows. After the introduction of Thailand's solar power policy and status described in Section 2, Section 3 discusses insights from a literature review on solar business models. Section 4 discusses the methodologies for our interviews and for financial modelling. Research results are discussed in Section 5, followed by policy recommendations in Section 6.

2. Thailand's solar power status and solar policy

2.1. The status of electric power in Thailand

Over the past 2 decades, Thailand has been increasingly dependent on natural gas for power generation. The Thai power sector currently uses natural gas for approximately 70% of its power generation (Figure 4.1).

Figure 4.1: Fuel Share in Thailand's Power Production, 2000–2014



Source: EPPO (2015).

Thailand has therefore set ambitious plans to develop its local renewable energy sources, as evidenced in the increasing targets for all types of renewable energy.

2.2. Policy and regulation to support solar power

2.1.1 Previous support scheme

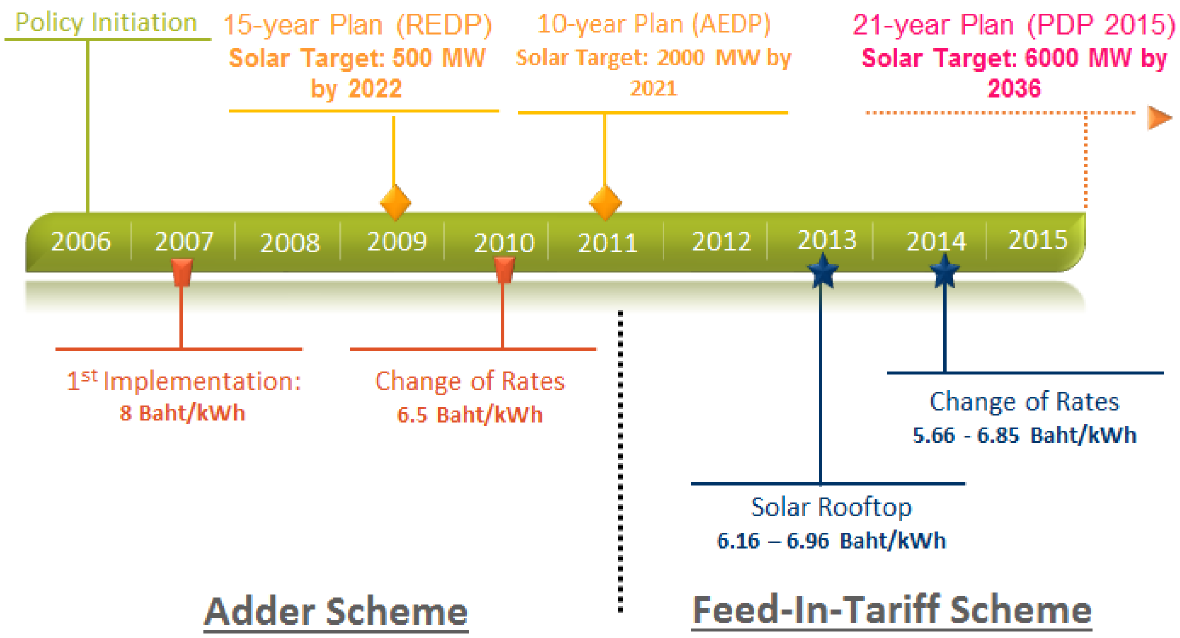
The first policy to support solar energy, along with other types of renewable energy (RE), in Thailand was initiated in 2006. Since then Thailand has combined a number of support measures, as shown in Figure 4.2, resulting in substantial growth in the installation of solar power systems.

The first scheme to support the growth of solar was called the 'adder scheme,' which was implemented in 2007. The adder scheme gives incentives to power producers selling electricity produced by RE at a certain tariff for a specified period of time (Tongsopit and Greacen, 2013). For every kilowatt hour (kWh) of electricity produced, the power producer will receive an adder rate on top of the utility electricity price; this is also termed as premium-price feed-in tariff (FIT) (Cory et al., 2009).

In 2007, power producers using solar energy received a power purchase agreement (PPA) from Thailand's electric utilities at an adder rate of B8 per kWh with a contract term of 10 years. Two years after the implementation, Thailand announced its first 15-Year Renewable Energy Development Plan (REDP 2008–2022). The target for solar energy was 500 MW of installed capacity to be achieved by 2022 (NEPC, 2009). Shortly after the announcement of the REDP, in 2009, there were a large number of requests from investors for PPAs in solar energy. In conjunction with falling market prices of solar PV systems, the situation led to a dramatic change of rates and regulations in 2010. The rates were reduced to B6.5 per kWh and strict regulations were implemented. By 2011, a large number of PPAs were given to investors leading to the capacity in the pipeline that far exceeded the 500 MW target in the REDP. Therefore, the REDP was replaced by the Alternative Energy Development Plan (AEDP 2012–2021) (NEPC, 2011). The AEDP aimed to increase the share of RE to 25% of the final consumption with a target of 2,000 MW for solar energy's installed capacity by 2021 (DEDE, 2012). This target was recently updated to 6,000 MW to be achieved by 2036.

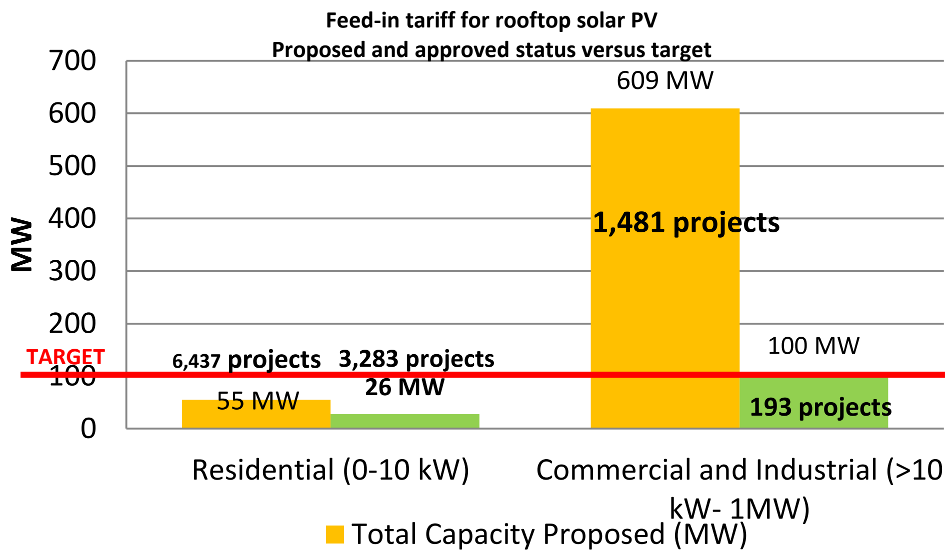
Due to concerns on the impacts to ratepayers, the adder scheme was discontinued in 2012 and replaced by the FIT scheme. The FIT scheme changed the structure of the incentives from a 'premium FIT' to a 'fixed-price FIT'. The FIT scheme was used to specifically support rooftop solar installations with a quota of 200 MW of PPA available. Within the 200 MW quota, 100 MW were allocated to residential roofs (≤10 (kilowatt peak [kWp]) and the remaining 100 MW were allocated for commercial roofs (10 kWp – 1 megawatt peak [MWp]).

Figure 4.2: Timeline of Thailand's Solar Power Policy



AEDP = Alternative Energy Development Plan; kWh = kilowatt hour; REDP = Renewable Energy Development Plan; PDP = Power Development Plan.
Source: Authors' analysis.

Figure 4.3: Number of Projects Applied for the Feed-in Tariff Scheme in 2013 (data as of May 2014)



kW = kilowatt; MW = megawatt, PV = photovoltaic.
Source: Analysed from MEA (2014) and PEA (2014).

Figure 4.3 shows the number of projects and its proposed installation capacity that applied for the FIT scheme in 2013. For commercial roofs there were 1,481 project proposals for a total of 609 MW, out of them only 100 MW of PPA were given to 193 projects. While residential rooftops received no more than 30 MW of PPA approval; this did not reach 50% of the intended 100 MW quota.

2.1.2 Future support scheme

After the military coup in May 2014, the policy and regulatory landscape for solar power in Thailand changed with the priorities set by political incumbents. In January 2015, the National Reform Council approved a quick win project entitled 'A Project to Support a Free Market for Solar Roof'. The main idea of the proposal was to eliminate quotas on solar rooftops and establish a new support scheme, net metering. With net metering, the electricity will have to first be self-consumed by the building, then excess electricity will be exported to the grid at a certain tariff or credited to the next bill. In addition to net metering, the proposal also includes other support measures such as import duty and income tax incentives. The approved proposal focuses only on rooftop solar for households (<10 kWp systems) and commercial buildings (<500 kWp systems). As an initial step, the Department of Alternative Energy Development and Efficiency, the distribution utilities, and the Energy Regulatory Commission (ERC) are charged by the Energy Policy Administration Committee to define a pilot area for first installations.

2.1.3 Other support incentives

Thailand's Board of Investment (BOI) also supports investment in the utilisation of solar energy. The BOI serves as the main government agency for encouraging investment in various sectors. In 2009, investment in the renewable energy sector was included for investment promotion. BOI investment promotion offers different types of tax incentives that will help promote activities in that sector. There are two investment promotion incentives that can be captured by using solar energy.

1) Production of electricity from solar energy

Activity 7.1.1.2: Production of electricity or electricity and steam from renewable energy, such as solar energy, wind energy, biomass or biogas, except from garbage or refuse derived fuel. Under the list of qualified businesses, 'Section 7: Service and Public Utilities' of the 'Announcement of the Board of Investment No. 2 /2557 Policies and Criteria for Investment Promotion':

The incentives include (BOI, 2014a):

- 8-year corporate income tax exemption, accounting for 100% of investment (excluding cost of land and working capital)
- Exemption of import duty on machinery
- Exemption of import duty on raw or essential materials used in manufacturing export products for 1 year, which can be extended as deemed it appropriate by the Board
- Other non-tax incentives

2) Utilisation of solar energy to improve production efficiency

Under the 'Announcement of the Board of Investment No. 1/2557 Measure to Promote Improvement of Production Efficiency', announced in September 2014. For existing projects that are eligible for investment promotion by the BOI, which utilise solar energy as an alternative to conventional sources, the incentives include (BOI, 2014b):

- Exemption of import duty for machinery regardless of zone
- Three-year corporate income tax exemption on the revenue of an existing project, accounting for 50% of the investment cost under this measure, excluding the cost of land and working capital.

The BOI incentive that grants 8-year corporate income tax exemption has produced a strong impact on solar farms since 2009. As of 31 December 2014, there are 364 projects with a total installed capacity of 1,383 MW approved by the BOI; 51 projects (121 MW) in this group are commercially operating. However, for solar rooftops this incentive is of smaller impact, as the BOI investment promotion can only be applied and granted to corporations. Rooftop solar projects can potentially benefit from the BOI's September 2015 announcement, but the eligible parties have to be corporations with an investment cost in the rooftop solar system greater than B1 million ($28,571) or small and medium enterprises with an investment cost greater than B500,000 ($14,286).

3. Literature review

3.1 Definitions of business model

Since the mid-1990s, the concept of the business model has gained increasing interest among business practitioners and academics (Zott et al., 2010; Huijben and Verbong, 2013). Business models serve many functions, including bringing new technologies such as renewables to the market (Huijben and Verbong, 2013) and serving as management tools to design, implement, operate, change, and control their business (Johnson, 2010; Wirtz et al., 2010, cited in Richter, 2013). Innovative business models help spread solar technology swiftly by reducing or removing adoption barriers, for example, for new demographics to adopt PV (Drury et al., 2012).

There is no common definition of the 'business model' concept (Burkhart et al., 2011; Klang et al., 2010). However, numerous writings on solar business models are coalescing around the definition of business models by Osterwalder and Pigneur (2009) (for example, Richter, 2013; Huijben, 2013; IIED, 2013; GVEP International, 2013). The business model conceptualisation by Osterwalder and Pigneur (2009) is defined as follows:

- Value proposition: refers to the bundle of products and services that creates value for the customer and allows the company to earn revenue;
- Customer interface: comprises the overall interaction with the customer. It consists of customer relationship, customer segments, and distribution channels;
- Infrastructure: describes the architecture of the company's value creation process. It includes assets, know-how, and partnerships; and
- Revenue model: represents the relationship between costs to produce the value proposition and the revenues that are generated by offering the value proposition to customers.

3.2 Business model canvas

The business model canvas concept, developed by Osterwalder and Pigneur (2009), has been widely used by many authors in energy-related business model literature. The need for a canvas-like framework arose because it is 'simple, high level and easy to construct' for people with little prior business knowledge (Leschke, 2013). It has been successfully applied in many energy related fields such as renewable energy (Okkonen and

Suhonen, 2010) and energy efficiency (Paiho et al., 2015). The Business Model Canvas Framework defines a business model in terms of the nine 'building blocks' as listed in Table 4.1.

Table 4.1: The Nine Business Model Building Blocks

Business Model Canvas Building Blocks	Description
Value Propositions	the goods and services offered and their distinguishing advantage
Key Activities	the most important activities in executing the value proposition
Key Resources	the resources necessary to create value for the customer
Partner Network	relationships considered essential to accomplishing the value proposition
Customer Segments	the specific target market(s) intended to be served
Channels	the proposed channels of distribution
Customer Relationship	the type of relationship the firm wants with its customers
Cost Structure	characteristics of the cost and expense structure
Revenue Streams	the way the firm will make money, how it is paid, and pricing

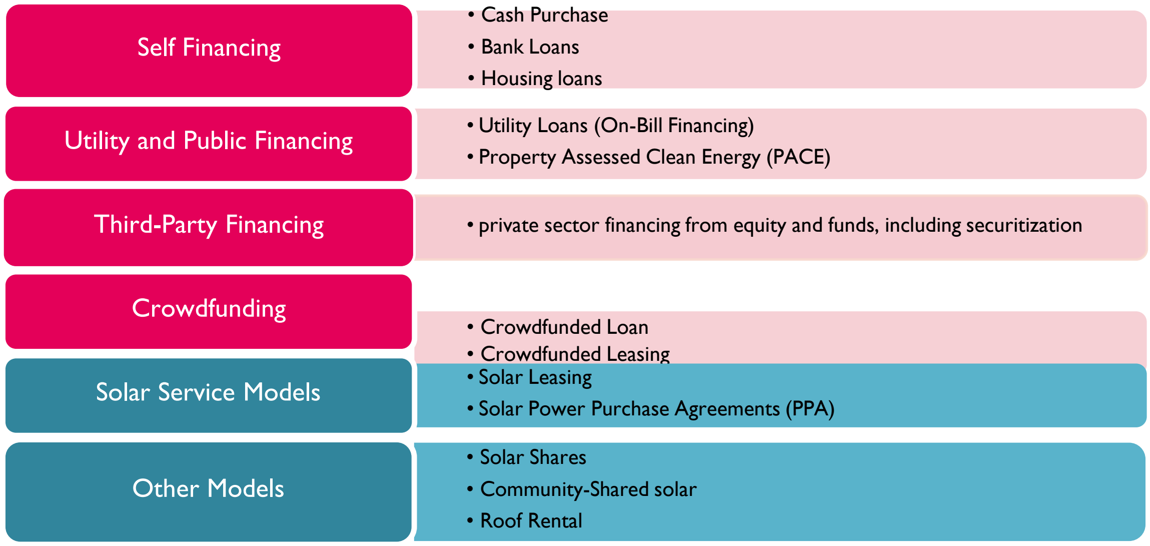
Source: Osterwalder (2010) cited in Leschke (2013).

This study uses the business model canvas to decompose the elements of the emerging rooftop solar PV business in Thailand and design the interview questions.

3.3 PV business models and financing options that exist internationally

A review of financing options for the solar rooftop market can be categorised into four types based on their sources of finance and two types based on the structuring of the business models (Figure 4.4). They include the conventional financing option of self-financing, localised municipal financing, utility financing, a more complex structure such as third-party financing, or a new and innovative financing mechanism called crowd-funding. The structure of business models includes solar service models and others. The section below summarises the concepts of these business models and financing options.

Figure 4.4: Categorisation of Financing Options and Business Models for Rooftop Solar Power Development



Note: Pink indicates the types of financing; blue indicates business models.

Source: Authors' analysis.

3.4 Financing options

Self financing

Self financing is used all over the world as the conventional way of financing, where the purchaser acquires an asset with their own money. Homeowners or building owners takes full liability of the cost in installing and maintaining the solar PV systems, resulting in high upfront costs that have prohibited widespread adoption of PV rooftop installations, especially in developing countries.

Utility and public financing

Local governments and municipalities have played a key role in accelerating the adoption of distributed solar power. Several municipalities have initiated programmes to increase the affordability of rooftop solar projects through the provision of financial incentives such as low-interest loans, rebates, and subsidies. In order to make such programmes possible, municipalities may need to initially raise capital through the issuing of bonds or find matching funds. The low-cost capital is then passed on either directly to the customer or to a developer to install systems on the customer's roofs. An example of a successful municipal financing is the Property-Assessed Clean Energy Program in the United States (US). However, these options are subject to the policies initiated by the local government. In addition to local governments, power utilities have begun to offer their customers the options of owning solar power systems. In this model, utilities would find a source of finance on behalf of its customers. The finance will be used either to install a large-scale solar farm in which customers can have a share or to lend directly to customers. This source of financing has several advantages including low-cost capital access by the utility, lower transaction costs of billing since the payments can be included in monthly customers' bills (on-bill financing), and guaranteed grid integration since utilities are able to assess good grid integration locations for solar. This financial scheme is offered in the US by Southern California Edison, San Diego Gas & Electric, SoCalGas, and Hawaiian Electric Co.

Third-party financing

The third-party financing or third-party ownership model has been responsible for the rapid scale-up of the residential solar market in the US since 2008. Third-party financing includes solar leasing and solar PPA (SEIA, 2015). According to Litvak (2014), third-party ownership represents 66% of the US residential solar market and a considerable portion of the commercial market (Litvak, 2014).

The solar leasing model in the US is financed by private or equity funds. Existing tax incentives in the US incentivised this type of financing by allowing the transfer of tax benefits from a portfolio of projects to the investors. Large players such as Google, CitiBank, and the Bank of America are financing rooftop solar through solar leasing and solar PPA companies.

While solar leasing may be considered a form of financing, it can also be considered a business model. In the US context, solar leasing offers financing for customers to own or have access to solar systems requiring monthly instalments and no upfront cost. However, it can be considered a business model at the same time since it is structured to provide value to customers through a combination of access to financing, operations and maintenance (O&M) service, and performance guarantee.

Solar crowdfunding

Solar crowdfunding is a new financing mechanism in which investment funds in solar systems are raised from individual investors through the internet. The companies that run solar crowdfunding platforms pool small investments from many individual investors, and the individual investors receive interests and are paid back in full over a specified number of years. The invested solar projects are commercial-scale rooftop systems on the properties of the customers, who pay for the electricity through solar PPAs or solar leases.

3.5 Business models

Solar service models

In solar service models, solar power is offered as a service, where the system is owned by a third party. Customers receive value from the service, in the form of cheaper electricity (compared to electricity purchased from power utilities), guaranteed performance, and O&M service. Solar service models have been a major driving force for rooftop solar market expansion in the US. In this model, a commercial company owns and operates PV systems on the customer's property. The electricity generated from the PV system is either used by the customer (solar leasing model) or sold to the customer (solar PPA model) (Bolinger, 2009). The structuring of the third-party financing model in the US also enables developers or investors to reap the benefits of tax incentives.

Other Models

There are various other business models offered by both the private and public enterprises. A programme offered by the Sacramento Municipal Utility District is called SolarShares, where customers can pay a monthly fixed fee to have shares in a local solar farm in exchange for a credit that can be used to offset their electrical bill (Coughlin and Cory, 2009). Private companies have also started offering similar business model, under the name community-shared solar. Roof rental is also a popular model in countries with FIT incentives. The developer company rents a roof to install and operate a solar system and sells the electricity for the FIT. The roof owner will receive benefits either through profit sharing or roof rental payments.

3.6 Solar business models in the literature

Much of the literature on solar business models in industrialised countries has drawn attention to the 'solar service' models. Overholm (2015) defines a solar service firm as 'a business model whereby firm builds, owns, and maintains solar panels on the premises of end-customers, only selling the electricity to the customer.' Solar service firms are believed to have originated in the US around 2005 (Drury et al., 2012) and has since grown to serve new geographical locations across the U.S. (Cather, 2010). Another term used to represent the solar service model is 'third-party financing' (NREL 2010). Two examples of the solar service models include solar leasing and solar PPAs.

Solar service models or third-party financing account for over 70% of all residential installations, in three major US solar markets: California, Arizona, and Colorado (GTM Research, 2014). Due to the fact that net electricity prices supplied from cash purchase system are considerably higher at $0.37/kWh when compared to $0.23/kWh supplied by the leasing option, the option to buy will only be more competitive to leasing when the homeowner can access tax breaks from depreciating capital equipment (Liu et al., 2014). Studies show that in California third-party ownership is more highly correlated to the lower-income household, and customer owned PV systems are positively correlated to the higher household income segment (Drury et al., 2012). In contrary, another study conducted in Texas found that buyers and lessees of PV systems do not differ significantly along socio-demographic variables (Rai and Sigrin, 2013). Within the same socio-demographic groups, those with tighter cash flow situations opt for leasing if the option is available. Therefore, Rai and Sigrin findings suggest that solar leasing helps accelerate solar PV adoption by opening up the cash-strapped but information-aware segment of the population.

Solar leases offered in the US typically require zero-down payment, have a long lease term (typically 20 years), and provide the option to buy at the end of the contract[11] (Coughlin and Cory, 2009). Overholm (2015) described how solar service ventures created value for their customer in several ways: removing customers' upfront cost, selecting, installing, and securing permits for the technology, and taking full responsibility for the long-term operation and maintenance of the solar system.

In addition to solar leasing and solar PPAs, other models are emerging in the US, including community solar. A community-owned solar system is defined by Asmus (2008)

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[11] Examples of solar leasing terms can be found from the leasing packages offered by US based SolarCity, SunRun, Sungevity, SunPower, and Real Goods Solar.

as a business model with ‘the ability of multiple users – often lacking the proper on-site solar resources or fiscal capacity or building ownership rights – to purchase a portion of their electricity from a solar facility located off-site’ (Asmus, 2008; p.63). It leverages the volume purchasing by collective participation of locals and internalises the market segments, like tenants or vacant community space, which used to be excluded from the commercialised activities (Huijben and Verbong, 2013).

In developing countries’ context, the majority of research on solar business models and financing options has been focused on off-grid applications for the low-income market. Literature focuses on the design elements of off-grid models, such as the requirement of down payment and after-sales service. Friebe et al., (2013), conducted quantitative research of solar home system (SHS) markets in Africa and Asia and found that entrepreneurs prefer 30% down payment instead of no down payment at all for credit sales and service models (leasing and fee-for-service). A 30% down payment or 100% cash payments are evaluated to be equally reasonable for businesses. Business owners highlighted that down payments are necessary to show the end user’s commitment to the solar systems. Results also reveal that businesses prefer to provide only 1 year of maintenance service (Friebe et al., 2013) contrary to longer offers in the US of 20 years. However, for the rural population in developing countries, Pode (2013) concluded that fee-for-service models are popular in sub-Saharan Africa due to unaffordable finance and the requirements for collateral. The study further suggested that rural customers are different to urban customers, those businesses with strong after sales service would be more successful than the sale and forget method (Pode, 2013).

All of the reviewed business models above remain relatively new in developing countries’ urban context, and hence we found no published papers on this topic. Our research finds that different models of solar services are being studied and experimented upon in Thailand. While some models help address many barriers that exist in the market, other models’ widespread adoption depends on setting clear regulations and getting clarification on its legality.

4. Methodology

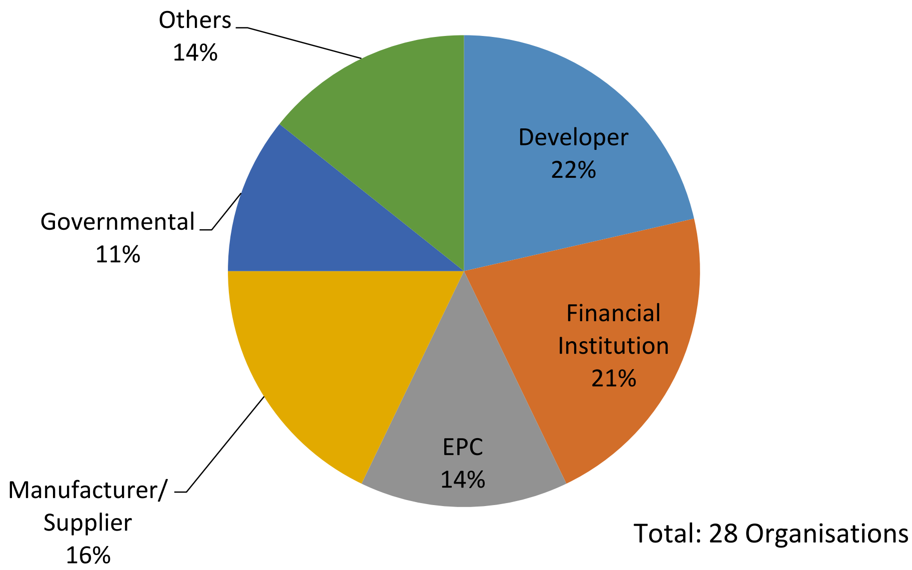
4.1 Interviews

After an extensive literature review of academic and non-academic sources, we compiled a list of solar business models that exist in Thailand for rooftop solar PV systems and the active players in the Thai market associated with the identified models. We then used Osterwalder (2009)'s 'blocks' in the business model canvas to decompose the business models into major elements, from which we used as a basis to develop interview questions. We then conducted semi-structured interviews with the business model pioneers to verify the elements of the business models that are emerging in Thailand. The respondents included chief executive officers and management-level staff from banks, solar manufacturers, solar power developers, leasing companies, and government agencies (listed in Appendix A).

The interviews comprised five parts. First, we asked the respondents to describe their company's role in the solar value chain – whether they were a manufacturer, developer, equipment supplier, engineering, procurement, and construction (EPC) contactor, or a combination of these roles and how different roles complement each other in their businesses. Then, we referred to the changing policy context for rooftop solar power development in Thailand and asked them to describe their current rooftop solar business activities and plans. During this process, we also sought understanding of the elements of the models as categorised by Osterwalder and Pignuer (2009). After the interview, respondents described current and planned business models, and identified the drivers, barriers, opportunities, and risks of their emerging or planned business models. We also asked them to provide key financial parameters essential for the companies' business plans, including expected IRRs and payback period. Other financial parameters that are not completely under their control were verified with them, such as system costs and O&M costs. And lastly, we asked the interviewees to identify policy and regulatory issues that are supporting or constraining their business model expansion.

We conducted a total of 30 interviews with 28 organisations. The informants included five manufacturers, six developers, four EPC contractors, four banks, two leasing companies, two government officials, one industry group representative, one representative from the Energy Regulatory Commission, and three other types of informants. The informants were manager-level or in higher positions. Figure 4.5 show the composition of the informants and Appendix A lists the names and companies of the informants.

Figure 4.5: Share of Interviewees by Type of Organisation



EPC = engineering, procurement, and construction.

Source: Authors' analysis.

We then described the results of the business models that have been identified in Section 5.1. Two business models are selected and chosen for the development of financial models, whose results we describe in Section 5.2. Criteria for defining business models for rooftop solar scale-up are as follows:

- Potential to rapidly scale up market
- Broad-based reach: the business models can be used for residential, commercial, and industrial scale and the typically unreached sector of the population, that is, low-income
- Potential to continue without the presence of FIT

4.2 Financial model methodology

We investigated the viability of two business models from the customer's perspective – the solar leasing model and the solar PPA model. The analysis was conducted in comparison to the results from the buying model. Hence, we had to develop three cash flow models (leasing, PPA, and buying) to examine detailed costs and benefits through the projects' lifecycle. The assumptions used to run the models were drawn from our market studies and interviews. We present the results in terms of levelised cost of electricity (LCOE), net present value (NPV), internal rate of return (IRR), payback period, and net cash flow. The detailed methodology for the solar PPA model and solar leasing models are described in following sections.

4.2.1 System cost and benefit structure

1) System cost structure

The cost structure for the roof owner varies according to the business models. The owner incurs the upfront cost in the buying model and no upfront cost in the solar PPA and leasing model.

In the buying model, the structure includes the system installation cost (also referred to as capital expenditure or CAPEX), the annual operation and maintenance costs (also referred to as O&M, operating expenses or OPEX) that includes the cost of system maintenance such as cleaning and electrical checks, inverter replacement cost, and insurance cost, as shown in Equation (1).

$$Annual\ O\&M\ Cost_{Buying,n} = System\ Maintenance_n + Inverter\ Replacement\ Cost_n + Insurance\ Cost_n \qquad (1)$$

As for the solar PPA model, there is no initial cost to the customer as the developer takes up the investment. The cost for the customer is the agreed price per kWh produced from the PV system according to the PPA contract. The price per kWh is offered at a discount from the retail electricity rate, hereafter referred to as the PPA deduction rate.[12]

$$Annual\ Cost\ _{PPA,n} = \ E_n \times T_n \times (1 - PPA\ deduction\ rate) \qquad (2)$$

For the solar leasing model, the down payment is considered as the initial cost or CAPEX, while the remaining system cost is included in the lease payment. Consequently, the annual costs, or OPEX, are the combinations of lease payment cost, O&M cost, inverter

[12] The PPA deduction rate in this paper is referred to as the 'pre-tax discount rate for a PPA' by Feldman and Margolis (2014). The cost per kWh paid by the roof owner is the PPA price.

replacement cost as Equation 3. The insurance cost is not taken into consideration in our study.

$$Annual\ Cost\ _{Lease,n} = Lease\ payment_n + O\&M\ Cost_n + Inverter\ Replacement\ Cost_n \qquad (3)$$

2) System benefit

In our study, the benefit of a rooftop solar system is considered as the electrical cost saving based on PV generation in all cases. The saving is derived from the avoided cost of paying electrical tariffs to the utility and hence the benefit can be expressed as shown in equation 4.

$$Total\ Benefit = \sum_{n=0}^{N} (E \times T)_n \qquad (4)$$

Where:

T_n is the electrical tariff by the utility at year n (THB/kWh)

4.2.2 Economic indicators: NPV, IRR, LCOE, and payback period

After accounting for the savings and expenses incurred annually by the rooftop owner, we can then find the net benefit derived from the solar system each year, as shown in Equation (5):

$$Net\ Benefit_n = Total\ Benefit_n - Total\ Cost_n \qquad (5)$$

1) Net present value (NPV)

To account for the time value of money, yearly net benefit was discounted and then summed, to see how present value of benefit compares to the other.

$$NPV = \sum_{n=0}^{N} \frac{B_n - C_n}{(1+r)^n} \qquad (6)$$

Where:

N is lifetime of solar PV system (25 years)

n is point in time (n=0 means present)

B is benefits gained by rooftop solar system owner

C is cost incurred by the rooftop solar system owner

r is discounted rate

2) Levelised cost of electricity (LCOE)

As described in Hernández-Moro and Martínez-Duart (2013), the LCOE of the system is calculated from the sum of the initial cost and discounted annual cost divided by the sum of the discounted energy over the economic lifetime of the rooftop solar system. A constant annual value for the LCOE is shown in Equation (7).

$$LCOE = \frac{(Initial\ Costs + \sum_{n=1}^{N} \frac{Annual\ Costs_n}{(1+r)^n})}{\sum_{n=1}^{N} \frac{E_n}{(1+r)^n}} \qquad (7)$$

Where:

E_n is produced energy of solar PV system at year n (kWh)

3) Internal rate of return (IRR)

The IRR is the discount rate that ‘forces NPV to equal zero’ (Brigham and Ehrhardt, 2010) as expressed in Equation (8).

$$NPV = \sum_{n=0}^{N} \frac{CF}{(1+IRR)^n} \qquad (8)$$

Where:

CF = Cash flow

IRR = Internal Rate of Return

4) Payback Period

Payback period is an indicator that measures when the investment will pay off for itself, as shown in Equation (9) (Brigham and Ehrhardt, 2010):

$$Payback = Number\ of\ years\ prior\ to\ full\ recovery + \frac{Unrecovered\ cost\ at\ start\ of\ year}{Cash\ flow\ during\ full\ recovery\ year} \quad (9)$$

Lastly, sensitivity analyses were conducted to observe the effect of five parameters on the LCOE and the NPV, as will be discussed in more details in the next section.

4.3 Assumptions

To reflect the actual economic environment in Thailand, we conducted a system price survey for residential-scale systems in June 2015 and obtained other assumptions related to the CAPEX and OPEX of the systems from direct interviews with solar developers and EPC contractors. The list of adopted assumptions and their sources are shown in Table 4.2.

Table 4.2: Assumptions of Financial Models

Parameters	Values		Units
	Commercial Scale (120kWp)	Residential Scale (5kWp)	
Technical Assumptions			
System Assumptions			
System Size	120	5	kWp
System Life	25	25	year
Performance Ratio	79.6	77.8	%
Capacity Factor	17.06	16.71	%
Module Degradation Rate	0.5	0.5	%/year
Site Assumptions			
Irradiation Values	1,805	1,805	kWh/m²/year
Load Consumption	1,642,684	10,288	kWh/year
Consumption Growth	0.73	0.73	%/year
Financial Assumptions			
Costs Assumptions			
System Installation Cost*	60	83	B/Wp
Inverter Cost	5	6	B/Wp
O&M Cost	0.5	0.5	B/Wp/year
Insurance Cost	0.14	0.14	% of EPC cost
Benefits Assumptions			
Tariff rate			B/kWh
On Peak	4.27	4	B/kWh
Off Peak	2.77	4	
Tariff Escalation	3.5	3.5	%/year

Discount Rate	10	10	%
Specific Assumptions Related to Each Business Model			
<u>Solar PPA Assumptions</u>			
PPA Deduction rate	10	-	% per kWh
Contract Term	25	-	year
<u>Solar Leasing Assumptions</u>			
Down Payment	-	30	% of EPC cost
Contract Term	-	8	year
Interest Rate (Effective Rate)	-	8.88	%/year

B= baht; EPC = engineering, procurement, and construction; kWp =kilowatt peak; O&M = operations and maintenance; PPA = power purchase agreement; Wp = watt peak.
Source: Compiled by the authors.

To account for variations in real-market conditions, the chapter also selects and analyses the sensitivity of our indicators (LCOE, NPV) to certain variables. The variables selected are ones that have high uncertainty or volatility that may have an effect on the LCOE. These parameters are summarised in Table 4.3 and discussed below:

- **PPA deduction rate:** This is the agreed rate of deduction from the utility prices between the developer and customer – the higher the PPA deduction rate the more savings the customer can obtain. As developers in the market offer different deduction rates, ranging from 5% to 15%, the chapter explores the impact of these variations on the LCOE and NPV.
- **Down payment:** it is an initial upfront portion of the total amount due in the leasing scheme. A down payment reduces financial institute's risk and demonstrates that the borrower's finance is sound enough to service the debt. The size of down payment determines by how financial institution or lender is protected from various risks. This chapter explores the impact of varying levels of down payment (0%, 30%, and 50%) on the LCOE and NPV.
- **Retail electrical tariff:** Tariff's from the utility could be volatile over the next 25 years, and the historical trend has shown that it is on the rise. Therefore, this chapter explores a varying escalation rate between 0% and 5%, with 3.5% being the base case.
- **Energy yield:** The annual energy output from the system was assumed as a base case referring to the PV Syst Photovoltaic Software output that yields a system performance ratio of 79.60%, equivalent to a capacity factor of 17.06%. The positive case is +5% and the negative case is +–5%.
- **Discount rate:** The discount rate is used to predict the present value; discount rates can vary depending on the customer's circumstances. Other literature has reported to use a discount rate between 3.5% and 15% (Rai and Sigrin, 2013; Branker et al., 2011).

Table 4.3: Sensitivity Assumptions

Parameters	Best Case, %	Base Case, %	Worst Case, %
Discount Rate	5	10	15
Retail Tariff	5	3.50	0
Yield	5	0	–5
PPA Deduction Rate	15	10	5
Down payment	0	30	50

PPA = power purchase agreement.
Source: Authors' analysis.

5 Results

Our interviews revealed four types of emerging rooftop solar business models and one type of financing option – solar loans – in Thailand.

Business Models:

- Roof rental
- Solar PPA (or solar shared saving)
- Solar leasing
- Community solar

It should be noted that solar leasing can be considered a business model and financing option. It is a business model in the sense that it is structured to enable value creation for the business owner and the customer. It is also a financing option because it provides the capital needed for the customers to own a solar system.

5.1 Description of the business models and financing option

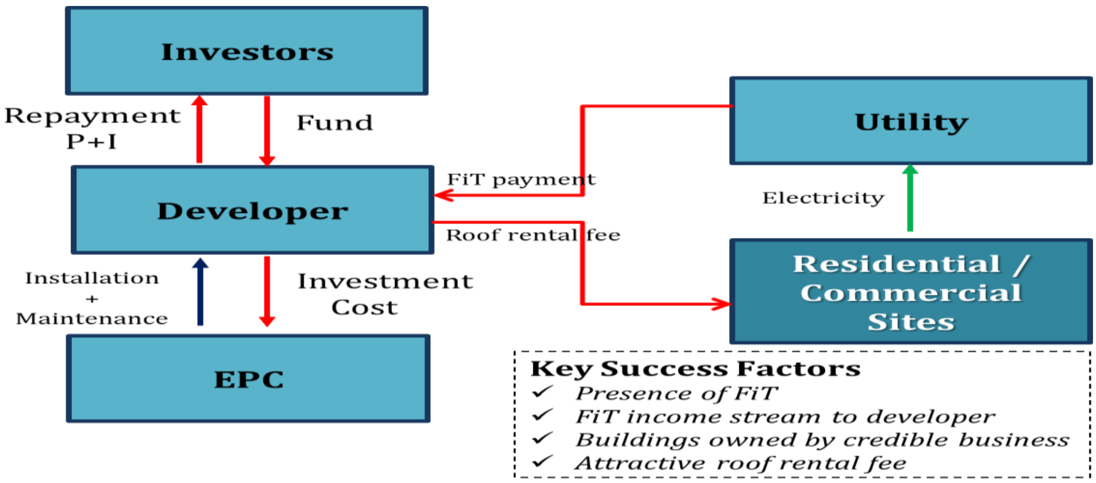
5.1.1 Roof rental business model

1) Components and structure

In 2013 when the government announced a 200 MW feed-in tariff (FIT) quota exclusively for rooftop solar systems, a new business model emerged – the roof rental model. Developer companies saw an opportunity to rent existing roofs, install and own the solar system, and sell electricity to the grid to receive a constant FIT income stream. The model consists of three key players 1) the roof owner, 2) the developer company, and 3) the utility. As shown in Figure 4.6 and described below:

1. The roof owner agrees on a 25-year roof rental contract with the developer company.
2. The developer company acquires a 25-year power purchase agreement (PPA) from the utility.
3. The developer then installs and operates the solar system on the rented roof.
4. Every kWh produce by the system will be exported to the grid.
5. Revenue from the sales of electricity will go to the developer.
6. The roof owner will receive a rental fee as agreed in the contract.

Figure 4.6: Structure of Roof Rental Business Model



EPC = engineering, procurement, and construction; FIT = feed-in tariff.
Source: Authors' analysis.

In this model, the roof owner does not have a liability in the rooftop solar system; therefore all the cost, including the investment cost, insurance cost, and O&M cost are born by the developer. It is beneficial to roof owners who want solar on their roof but do not want to take liability in the system. Another benefit of this model is that the roof owner does not consider solar PV part of their core business and therefore would not like to invest in it. The developer company looks for the following criteria:

1. A credible roof owner that will be able rent out the roof for 25 years.
2. Large roof area: an installation capacity of 1MW requires approximately 8,000 square metres.
3. Strong roof structure, which can withstand the additional load from the solar panels.

2) Drivers

In Thailand, those rooftops that fall into the criteria are mostly commercial rooftops including warehouse roofs, industrial and/or factory roofs, and shopping mall roofs. The roof owners benefit from the rental fee and the reduction of heat absorption to the roof, thereby reducing power consumption. There are concerns by roof owners about the risk of roof damage that may affect the assets under the roofs, for example leaking of the roof, building structural damage, or roof collapse. These risks are covered by the developer company through an all-risk insurance, which insures against all damages from installing the solar system.

3) Barriers

The main barrier that is limiting the widespread use of this model is the quota of PPA given. Developer companies have suggested that even with a reduction of FIT rates from B6.16/kWh to B6.01/kWh, the roof rental will still be attractive. Currently, the roof rental model is only successful for commercial roofs even though there have been attempts to apply this model to residential rooftops in certain parts of Thailand.

4) Risks

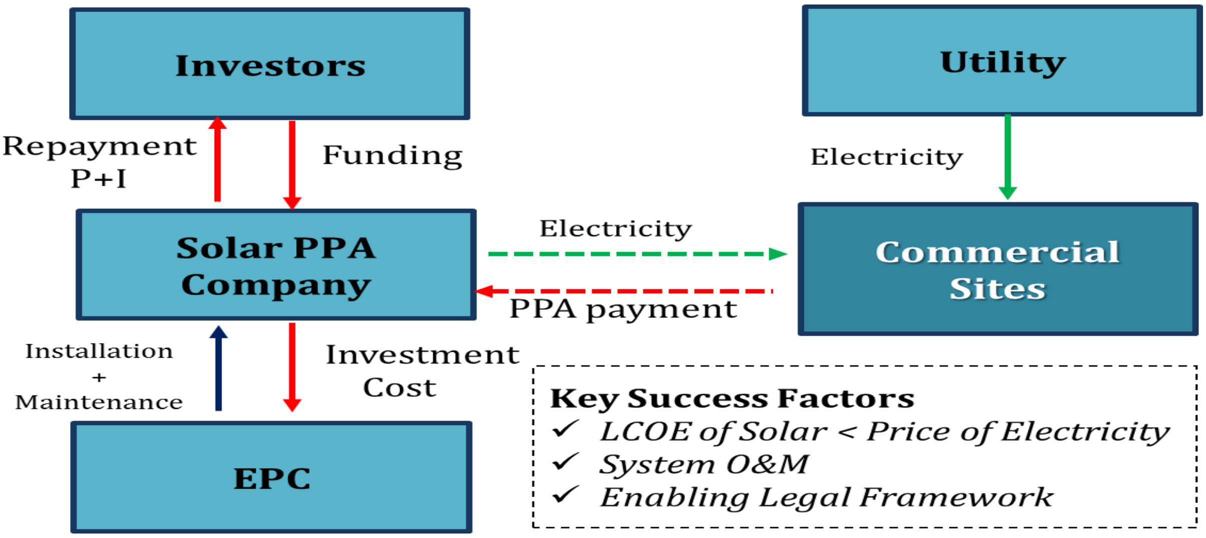
From the developer's perspectives, risks are associated with the use of the building, including cases in which the buildings are taken over, retrofitted for other purposes, or demolished. These anticipated risks are covered in the contract between the developer and the customer. From the customer's perspectives, the risk of roof damage or collapse is already mitigated by an insurance (all-risk insurance) paid for by the developer.

5.1.2 Solar shared saving or solar PPA business model

1) Components and structure

Because of policy uncertainties on the continuation of the feed-in tariff and a lack of clear regulation on selling electricity to the end-user by the third party, some Thai developers devised an innovative business model that fits the current investment climate. The solar shared-saving model is proposed for energy-intensive buildings and factories in order to reduce electricity cost. Based on time-of-use electricity rate, theses consumers have to pay for peak and/or off peak electricity rates and demand charges every month, which constitute a substantial share of their yearly expenses. As a result, the solar shared-saving business model is expected to provide a win-win solution for developers and energy intensive consumers. The structure of this model is shown in Figure 4.7.

Figure 4.7: Structure of Solar PPA Model



EPC = engineering, procurement, and construction; LCOE = levelised cost of electricity; O&M = operations and maintenance; PPA = power purchase agreement.
Source: Authors' analysis.

The main players in this model consist of the customer (roof owner), the developer, and the utility. The roof owner, who wants to reduce electricity costs, agrees on a shared-saving contract with the developer company. The contract typically lasts 20 to 25 years. The developer installs, owns, and operates the commercial-scale solar PV system on the site. Then, PV electricity units are sold at a discount, typically 5–10% lower than the grid electricity tariff. In this sense, it appeared as if the roof owner could lower his consumption by 5% to 10%, which is the reason for the term 'shared saving.'

The solar shared-saving model can be interpreted as a variation of the solar PPA model, which is now common in the US. Under the solar PPA model, the developer also installs, owns, and operates the solar system on the customer's site. The difference lies in the contract. Under the solar PPA model, the customer agrees to purchase electricity from the developer at a certain tariff (B/kWh) for a specified number of years. The tariff is offered as a discount of 5%–10% in comparison to the retail tariff rate. This is different from the PPA model in the US in which the PPA tariff is set by the developer with a built-in escalation rate. For example, in the case of SolarCity's residential solar PPA contract (as of

June 2015), the price per kWh increases by 2.9% per year after the first year's rate of $0.15 per kWh (SolarCity, 2015).

Another difference lies in the legal precedent of the solar PPA model. Since the developer owns the solar system and sells power to the customers, it essentially acts as a retail utility. Because Thailand's electric power industry structure remains partially deregulated, the retail utilities (the Provincial Electricity Authority and the Metropolitan Electricity Authority) have traditionally been the only parties that sell power in their service territories. Though not stated in the law that no party other than the utilities can sell power to customers, the legality of the model in which a third party provides power to customers in competition with the utilities remains unclear to many developers. This lack of clarity was confirmed by our conversation with two developers who are pursuing a solar PPA model. One developer then sought a formal letter from the regulator to confirm that the model is legal. However, an ERC senior staff member stated in the interview with us that the model could be pursued legally. The solar PPA model developers are regulated by the ERC and would only be required to get permits that are associated with the sizing of the solar system.

For both the solar shared-saving model and solar PPA model, proper system sizing is important to ensure that all of the PV electricity is consumed and not fed to the grid. The excessive amount of power that is not used and fed to the grid is not compensated for under the current regulation.

2) Drivers

There are two major drivers for the solar shared-saving model and solar PPA model: policy uncertainties and economics. Uncertain prospects of continuous FIT for commercial-scale installations urge businesses to adopt a model that is shielded from government policies. Solar PPA is a model that has succeeded in the US and Australia, and hence the subsequent knowledge transfer through multinational corporations. Furthermore, solar economics in Thailand is beginning to become feasible for large electricity users with high energy consumption and daytime peak. The solar shared-saving model and solar PPA companies hence can market their plans based upon expectation of rising electricity costs. Another driver is common of solar service models – the fact that the O&M burden is borne by the service provider, who owns the PV system and has more proficiency at managing the risks associated with ownership.

The concept of the solar shared-saving model is very similar to the energy service companies (ESCO) concept, in which the ESCO's share the income stream that comes from energy savings with the client. By extending this logic, it seems reasonable that ESCOs that typically share the income stream from energy savings with building owners may be in the position to add rooftop solar to their energy efficiency (EE) retrofit. Indeed, we found an EE project that included rooftop solar as a component of the project. The project combines energy efficiency upgrade to a commercial building and a rooftop solar installation. Because the payback period of an EE project of this size is typically 3–4 years, when combined with the payback period of a solar project of around 10 years, it is expected that a payback period of 7 years can be achieved. The financing that is currently being structured will likely come from 100% loan or 100% equity. The combination of EE and solar offers new business opportunities for solar developers as well as ESCOs. However, both types of players have so far been focused in their fields and such combination of EE and solar offered in one package to commercial buildings is still rare.

3) Barriers

The only barrier identified by the interviewees includes the uncertainty surrounding the legality of this model as discussed earlier. Furthermore, in our research study period, we have not yet identified a solar shared-saving model/solar PPA model for the residential sector. The high investment cost and high transaction cost may be the main barriers preventing developers' interest in the residential scale.

4) Risks

The risks from the solar PPA model developer's standpoint are few since most of them, if materialised, can be remedied in the contract between the developer and the roof owner. However, a risk that remains inherent in the solar PPA model is the rate of electricity price rise. If the price of grid electricity does not rise as fast as was predicted in the assumption, the lower income stream will affect profitability.

From the roof owner's standpoint, there are a few risks to consider. For example, the load pattern may change due to the change in activities of the buildings or factory. The change in load pattern along with a lack of a net metering regulation can result in PV electricity that exceeds consumption and flows back to the grid without being credited for. The roof area may be required in the future for other purposes – this is especially true for flat roofs on university campuses.

5.1.3 Solar leasing

1) Components and structure

Solar leasing is a structure that allows the consumers to pay for the solar system over time and avoid the high upfront cost. The structure of solar leasing is shown in Figure 4.8. The leasing company (or solar lessor) enters into a leasing contract with the customer (solar lessee), allowing the lessor to own, install, and operate a rooftop solar system on the customer's roof. The solar lessee pays for the solar system through a combination of down payment and monthly instalments and uses the solar electricity or sell it to receive feed-in tariff. Therefore, the customer receives benefits from the solar PV system in the form of energy saving or feed-in tariff income. The leasing model that thrives in the US and pioneered by SolarCity has a leasing term of 15–20 years and is driven by the presence of federal investment tax credit. However, the leasing model in Thailand is emerging in the context of transitioning away from feed-in tariffs. The leasing terms being offered or planned by the interviewed stakeholders range from 6–8% with a leasing term not exceeding 7 years. Some potential leasing companies are of the view that the leasing term cannot exceed 5 years in Thailand. These stated leasing terms affect the economics and are discussed further in Section 5.2.

2) Drivers

In Thailand, there are interests in the leasing model from both the supply and demand side. From the supply side, the major driver for the solar leasing model is the interest from financial institutions and existing leasing companies that have already offered leasing services for other kinds of products, such as cars, factory machinery, and office equipment. They already have the business infrastructure to offer leasing services, including customer acquisition, marketing, logistics, and payment collection. Solar leasing presents market expansion opportunities as well as allowing the companies to provide green investment options to their customers. When the first solar leasing product was marketed to commercial-scale customers in 2014, there was still an availability of feed-in tariffs for rooftop solar PV investment. Therefore, the company's solar leasing package could be designed to receive feed-in tariff income or for self-consumption.

Another driver for this model from the demand side is that there is a huge, untapped group of potential customers that typically would not be able to afford solar PV upfront. According to the Chairman of Thailand's Solar PV Industries Association, '99% of the households that joined the feed-in tariff programme are from the high-income segment' (Sano and Tongsopit, 2014). Our interviews also revealed that the rural farming population has a strong interest in leasing solar technologies. If the solar leasing model becomes available, it can potentially make solar power more widespread among building owners and households.

3) Barriers

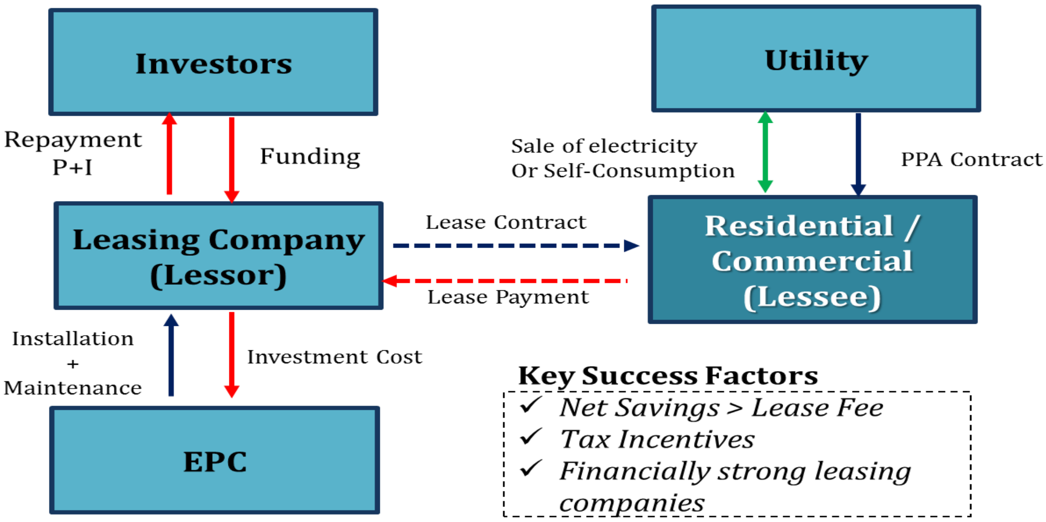
– Lack of feasibility at small scale

Given the fact that the solar leasing model is currently emerging in a non-subsidised (no FIT) environment, a major barrier is the economics of the leasing scheme, especially for smaller-scale systems. As we will see in the financial analysis in Section 5.2, the saving from leasing a residential system is not enough to pay the monthly leasing fee. In addition, the net present value is negative in the base case and in most sensitivity cases. For residential-scale leasing, especially, the terms currently discussed by potential leasing companies will not be attractive to customers unless additional incentive is given, such as in the form of tax incentives or subsidised interest rates.

– Lack of an equipment registration system and a secondary market

Another major concern that some potential leasing companies and financial institutions raised is the lack of a third-party registration system for solar system components. A third-party registration system would give each set of equipment (modules and inverters) serial numbers that would allow the lenders and/or lessors to track its history and evaluate resell values. In the case of default, such a system can help the companies take over the system and resell them in a secondary market just like cars. Despite this concern by the potential leasing company, however, we note that the current legal framework and associated regulation in Thailand allows for such registration.

Figure 4.8: Structure of Solar Leasing Business Model



EPC = engineering, procurement, and construction; PPA =power purchase agreement.
Source: Authors' analysis.

4) Risks

The risk to the solar lessor is mainly the risk of default or non-payment, which is then associated with the lack of a third-party equipment registration system that some of the potential lessors are concerned about. Non-payment results in the repossession of the solar system, for which a secondary market is still not extensive. One interviewed leasing company said that they would prevent the risk of default by choosing only credible commercial-scale customers. On the other hand, another respondent whose company aims to focus on individual customers would prefer to see a third-party registration system and an active secondary market before the company can launch a leasing product. These limitations result in the potential lessors' predetermination on leasing terms that are unattractive from the customers' perspectives, as a way to mitigate the lessor's risks.

From the lessee's perspective, if the leased system does not perform well, then the lessee will suffer from low saving or low feed-in tariff income. While the released commercial leasing product offers a form of performance guarantee that can help mitigate this risk for the customer, it remains to be seen what type of performance guarantee the Thai residential leasing schemes will offer.

5.1.4 Community solar

1) Components and structure

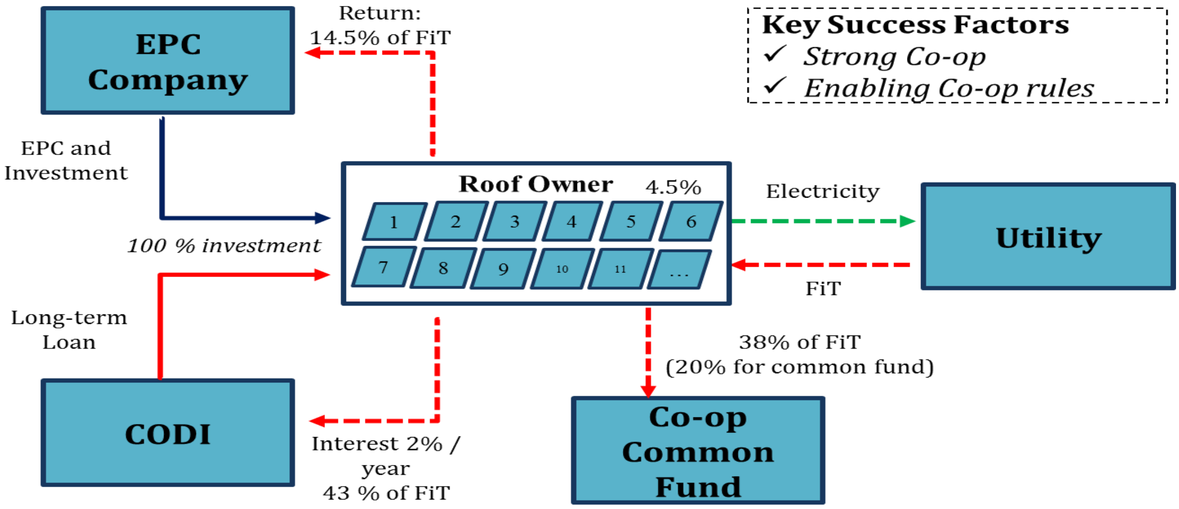
Since the launch of rooftop FIT in 2013, there has been a group of savings cooperatives that were interested in producing solar electricity and selling it to the grid. The group comprises approximately 40 households with a total installed capacity of 120 kilowatts (3 kW per household). However, delays caused by the interpretation of cooperative objectives resulted in the failure to pursue the business model that they previously planned on a large scale. Nevertheless, this model is worth reviewing because it represents the first attempt at designing a community solar scheme to benefit from feed-in tariffs. It can potentially be adapted for future self-consumption schemes.

The proposed business model resembles project financing. The project represents a community that receives financing from the Community Organizations Development Institute (CODI) (loan) and the EPC contractor (equity). The loan offers a low interest (2%) and a long-term loan of 15 years. The equity investor provides 14.5% of the total investment cost, and the other 85.5% is lent by CODI. The FIT income is therefore used to pay back to the investor, the lender, and kept in the community for O&M cost and profit. The monthly FIT income is split as follow (Figure 4.9):

- 43% to CODI, as a loan payment
- 38% to the co-op common fund
- 14.5% to investor/EPC as a return of investment
- 4.5% is kept by the roof owner

This structure enables the community to acquire and manage the residential rooftop system as a combined portfolio, sharing the capital cost and O&M cost. The participation of the EPC company as an investor ensures that systems of high quality are chosen and installed at the highest standard. At the same time, combining many households together into one community allows economies of scale that can help bring down the cost for PV system. In addition, the agreement also included training community members to install solar systems.

Figure 4.9: Proposed Solar Cooperative Business Model



CODI = Community Organizations Development Institute; EPC = engineering, procurement, and construction; FIT = feed-in tariff.

Source: Authors' analysis.

2) Drivers

Urban and rural residents that have a strong local network of neighbours can adopt this model. And it is possible that one successful community model could inspire other communities to adopt the model, as demonstrated in the 'peer effect' of solar power adoption (Bollinger and Gillingham, 2012). This particular model was developed together by five communities of housing cooperatives and many more communities expressed interest in the investment in solar power. The current government also has proposed a policy framework that in principle favours the development of community solar cooperatives since a main driving force for the policy design is to distribute solar access and income to a wider group of population.

3) Barriers

The structuring of business models for a group of households faces the challenge of financing. What would be the potential source of low-cost capital, considering that the returns also have to be shared with many households? In this unique case, we find that membership to CODI enables access to very low-cost capital, which is not available elsewhere. Therefore, scalability of this model is only applicable to CODI communities. Elsewhere we have also found efforts to structure community business models for large-scale solar farms in Thailand, but up until 2014 the projects failed to secure financing even with the presence of FIT (Thansetakit, 2014).

4) Risks

From the investor's perspective, there is a risk of non-sharing of income since the FIT income flows directly into the account of individual rooftop owners who are contractual partners with the utility. This risk is mitigated by adding a three-way contract between the roof owners, the community (which is a housing co-op in this case), and the investor. From the community members' perspective, poor products can lower their incomes, which would then have to be shared to the community and the investor. These risks may not make the scheme attractive since the transaction costs of banding together and jointly managing the system are already high.

5.1.5 Solar loans

Up to the date of this writing, two solar loans are available in Thailand as shown in Table 4.4.

Table 4.4: Existing Solar Loans in Thailand (as of 30 June 2015)

	K-Energy Saving Guarantee Program	Krung Thai Bank
Launch date	December 2014	April 2015
Customer segments	Commercial buildings, factories	Households (with minimum income of B50,000)
Financial programmes	Loan	Personal loan
Range of interest rate	MLR (6.63%)	8–9%
Maximum credit line	100% of investment cost	70–80%
Down payment to contractor	N/A	20–30%
Maximum term	12 years (maximum)	8 years
Partners	Solventia +Yingli+Huawei	SPCG+HomePro
Role of partners	Solventia = EPC and performance guarantee Yingli, Huawei = suppliers	SPCG = EPC
Collateral	Yes (may be less than conventional loan	No collateral but must meet

	K-Energy Saving Guarantee Program	Krung Thai Bank
	due to deduction from energy saving benefit and performance guarantee by the EPC contractor)	the following criteria: • Income>B50,000 • Good credit history • Must have PPA

B= baht; EPC = engineering, procurement, and construction; MLR = minimum loan rate; N/A = not applicable; PPA = power purchase agreement; SPCG = Sun Power Company Limited.
Sources: SPR (2015); K-Bank (2014).

The K-Energy Saving Guarantee Program is designed for commercial-scale solar installations. The uniqueness of this loan is that it can offer up to 100% financing at a term that can be extended up to 12 years. The reason why the bank is able to offer these attractive terms is because the EPC contractor is able to guarantee performance of the system through the loan term, thereby reducing the risk to the lender.

For the residential sector, the only available loan is through Krung Thai Bank. The loan is offered at an effective interest rate of 8–9% for up to 8 years. There is a specific target group of the clients, including those with incomes above B50,000 per month and never have had bad credit history. The Thai Military Bank recently signed an agreement with Solartron to provide loans for solar rooftops. But the details are yet to be released at the date of this writing.

5.2 Financial model results and discussions

5.2.1 Solar PPA model versus buying model results

1) Base case results

The base case results for our 120 kWp commercial-scale case show that the solar PPA model is more feasible in terms of NPV and LCOE values. The IRR and payback period cannot be calculated for the solar PPA model because there is no initial investment and therefore no negative NPV (Table 4.5).

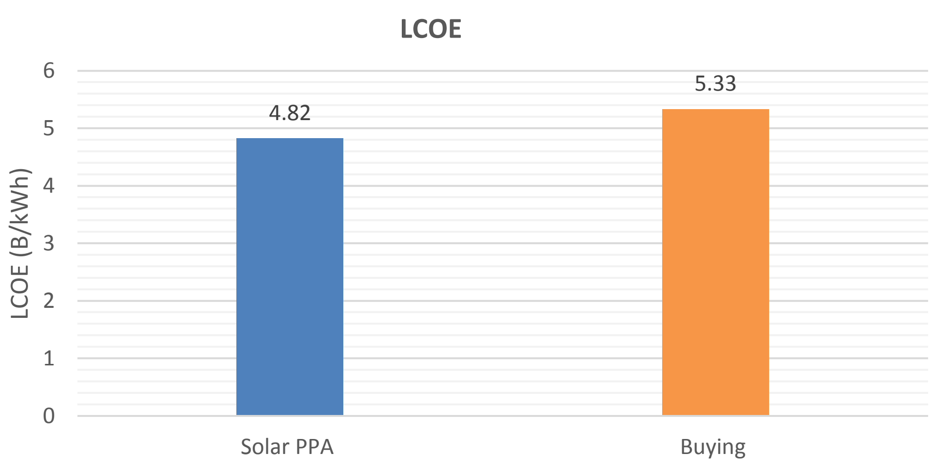
Table 4.5: Solar PPA Model Compared to Buying Model (base case results)

Base Case – Commercial Scale (120 kWp)		
Financial Indicators	Solar PPA model	Buying model
NPV (baht)	839,903	41,335
IRR (percent)	-	10.06%
Payback period (years)	-	9.73
LCOE (B/kWh)	4.82	5.33

kWp = kilowatt peak; IRR = internal rate of return; LCOE = levelised cost of electricity; NPV = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

The LCOE for the solar PPA model is B4.82/kWh ($0.14/kWh) or 9.56% less than buying the system at B5.33/kWh ($0.16/kWh) (Figure 4.10). The difference is the cost structure for each model. The buying model has a significantly high upfront cost with relatively low annual cost. Upfront cost, or hereby denoted as 'initial costs', is of present value and is not discounted. On the other hand, the solar PPA model has a zero upfront cost but the customer pays for the electricity produced by the system, reflected as 'annual cost', to be discounted over 25 years.

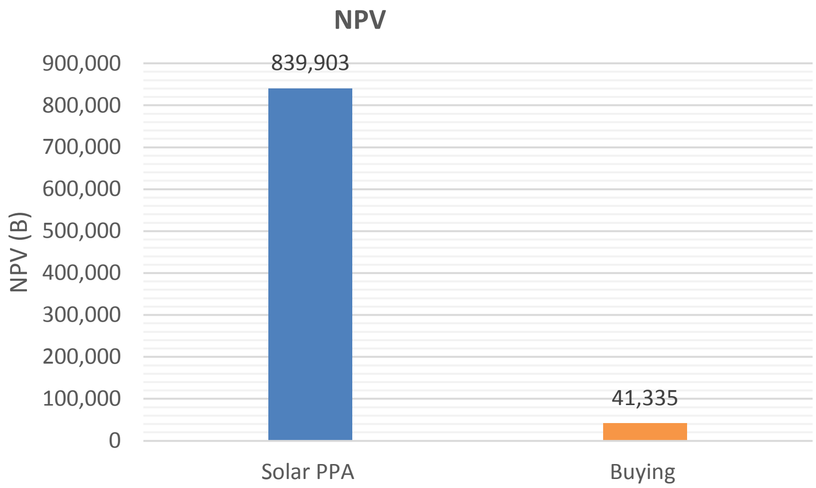
Figure 4.10: Base Case – LCOE of Solar PPA Model versus Buying Model



B =baht; kWh = kilowatt hour; LCOE = levelised cost of electricity; PPA = power purchase agreement.
Source: Authors' analysis.

For the NPV, both models show a positive NPV at B839,903 ($24,796) and B41,335 ($1,220) for the solar PPA model and buying model respectively (Figure 4.11). The higher NPV in the solar PPA case results from the customer never having an annual net negative cash flow. The high upfront cost in buying the system results in a negative net cumulative cash flow with a payback period of 9.73 years.

Figure 4.11: Base Case – NPV of Solar PPA Model versus Buying Model

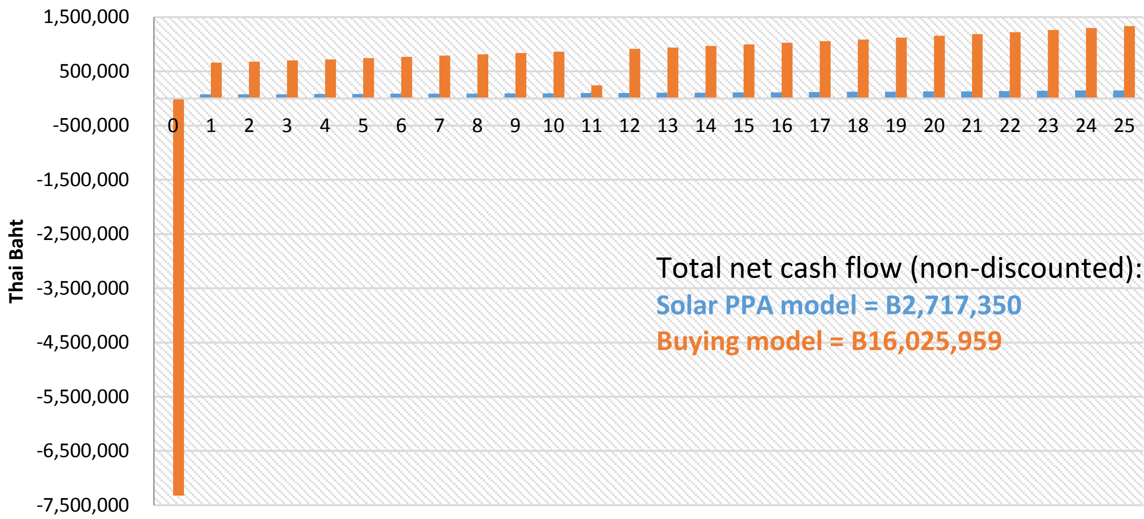


B = baht; NPV = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

Figure 4.12 illustrates the difference in annual net cash flow (non-discounted) for the customer. The buying model (orange) has an initial investment cost of B7,325,000 ($216,921) (for a 120kW system). After the installation, the customer benefits through cost-savings and, once deducted by some O&M cost, will leave the customer with a positive annual net cash flow throughout the project life cycle. In the 11th year, as mentioned in our assumptions, we included the cost for inverter change of B642,000 ($19,012). Even though it is a significant cost, the saving outweighs the cost and yields a positive net cash flow within a year. In total, the cumulative net cash flow of the buying model is B16,025,959 or $474,590 (including deduction of investment cost).

For the solar PPA case, as the customer always buys electricity at a lower price than the grid prices they will never have a negative cash flow. The PPA deduction rate agreed with the developer therefore determines how much savings the customer will receive over the years. For the base case, we assumed that developers will give a 10% deduction from the utility prices. The results are that over 25 years, the customer will have saved B2,717,350 ($80,471). When compared to the buying model, this value may appear small, but considering that the customers have little to no liability, from not having to invest, operate, and maintain the system, it may be a better option for some customers.

Figure 4.12: Annual Net Cash Flow Solar PPA Model versus Buying Model (non-discounted)



B = baht; PPA = power purchase agreement.
Source: Authors' analysis.

2) Sensitivity analysis results

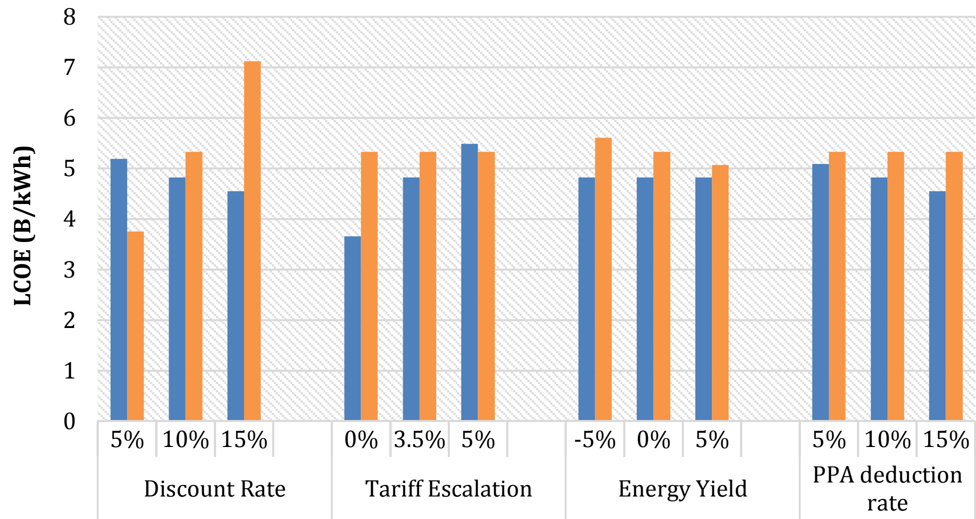
The sensitivity analysis reveals the impacts to the expected values of LCOE and NPV in the base case when certain parameters change. As shown in Table 4.3, the parameters tested were: discount rate, retail tariff escalation, energy yield, and PPA deduction rate.

LCOE and NPV sensitivity analysis results are summarised in Figure 4.13 and Figure 4.14. The following points were found:

- The solar PPA model offers a lower LCOE in all cases except two, that is, in the case of a 5% discount rate and a 5% retail tariff escalation. In these two cases, the buying model provides a lower LCOE.
- Both the NPV and LCOE for the buying model are highly sensitive to the varying discount rate. The lower the discount rate the more attractive is the investment for buying the system. It is clear for the NPV, a 5% discount rate yields a high NPV whereas a 15% discount rate shows a negative NPV.
- Retail tariff escalation has a positive correlation with the solar PPA's LCOE, the higher the escalation, the higher the LCOE. This is because the agreed PPA price is linked with the retail tariff rates – as the tariff increases the amount paid to the developer increases as well. This is not the case with the buying model, in which the cost structure is not influenced by tariff escalation.

- In contrast, the NPV of the buying model is very sensitive to the retail tariff escalation due to the fact that retail tariff escalation directly effects the amount of cost saving benefit for the consumer.
- The results show that energy yield had no influence on the LCOE for the solar PPA model, but is negatively correlated with the LCOE in the buying model.
- As expected, higher PPA reduction rate is more beneficial and attractive to the customer, yielding a higher NPV and a lower LCOE.

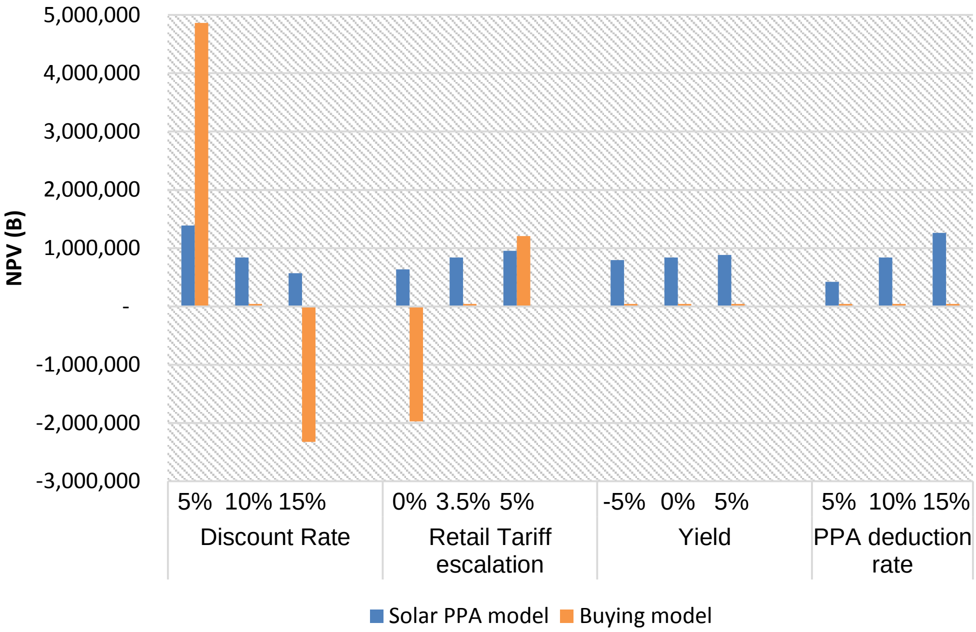
Figure 4.13: Sensitivity Analysis – LCOE Solar PPA Model versus Buying Model



	Discount Rate			Tariff Escalation			Energy Yield			PPA deduction rate		
	5%	10%	15%	0%	3.5%	5%	-5%	0%	5%	5%	10%	15%
Solar PPA Model	5.19	4.82	4.55	3.66	4.82	5.49	4.82	4.82	4.82	5.09	4.82	4.55
Buying Model	3.75	5.33	7.12	5.33	5.33	5.33	5.61	5.33	5.07	5.33	5.33	5.33

B = baht; kWh = kilowatt hour; LCOE = levelised cost of electricity; PPA = power purchase agreement.
Source: Authors' analysis.

Figure 4.14: Sensitivity Analysis – NPV Solar PPA Model versus Buying Model



B= baht; PPA = NPV = net present value; power purchase agreement.
Source: Authors' analysis.

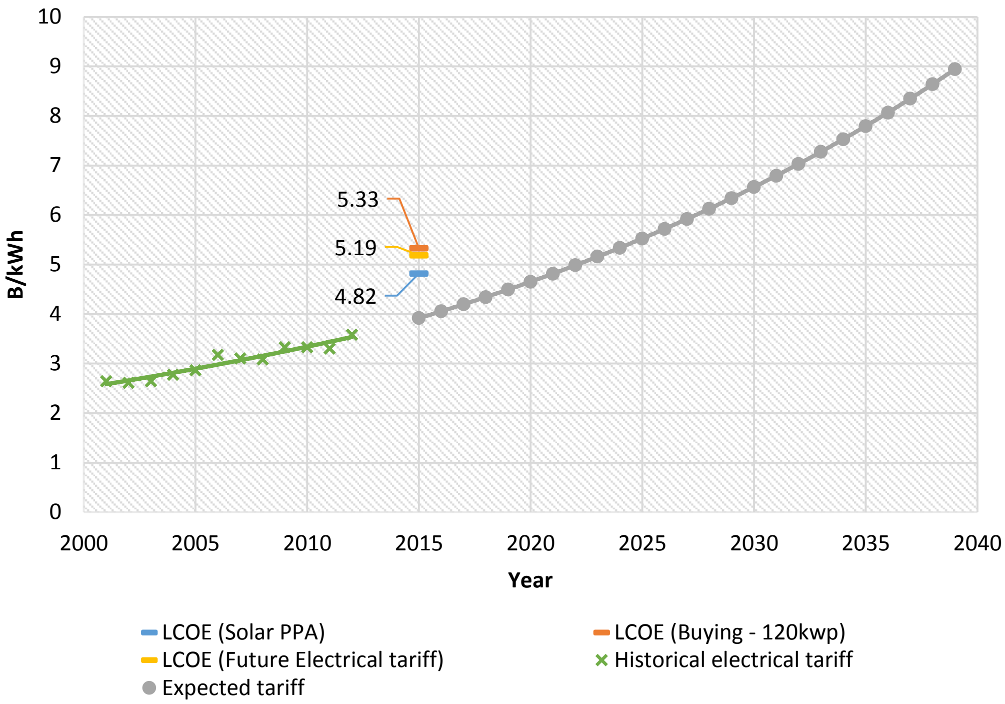
5.2.2 Solar PPA model versus buying model discussions

1) LCOE versus retail tariff

The results have shown that the solar PPA model has a lower LCOE than the Buying model in the base case and most sensitivity cases. So from a cost perspective, the solar PPA model proves to be a more attractive option since the cost of solar electricity over its lifetime is lower in the PPA case than the buying case. Figure 4.15 compares the LCOE of both options to historical and projected retail tariff, with the current average prices (2015), at just under B4.00/kWh ($0.12/kWh), both models have a higher levelised cost per kWh than the retail tariff. Future retail tariff rates here are shown according to our assumptions at a projected escalation rate of 3.5% year on year.

However, for a fair comparison, the future retail tariff should be levelised to present value as well. Therefore, the LCOE for buying electricity from the grid over the next 25 years is equal to B5.19/kWh ($0.15/kWh) (Figure 4.15). This means that the LCOE for the solar PPA model, B4.82/kWh ($0.14/kWh), is lower than buying from the grid over 25 years. This result further confirms the attractiveness of the PPA option over the buying option. Following the current assumptions, the buying model will reach grid parity by 2024. To reach grid parity means that the LCOE from solar energy is less than or equal to the prices purchased from the grid. Upon reaching grid parity, solar power will not only be cheaper than grid tariffs, but will act as a tool to hedge against escalating retail tariff in the future.

Figure 4.15: LCOE versus Retail Tariff Rates for a 120 kWp

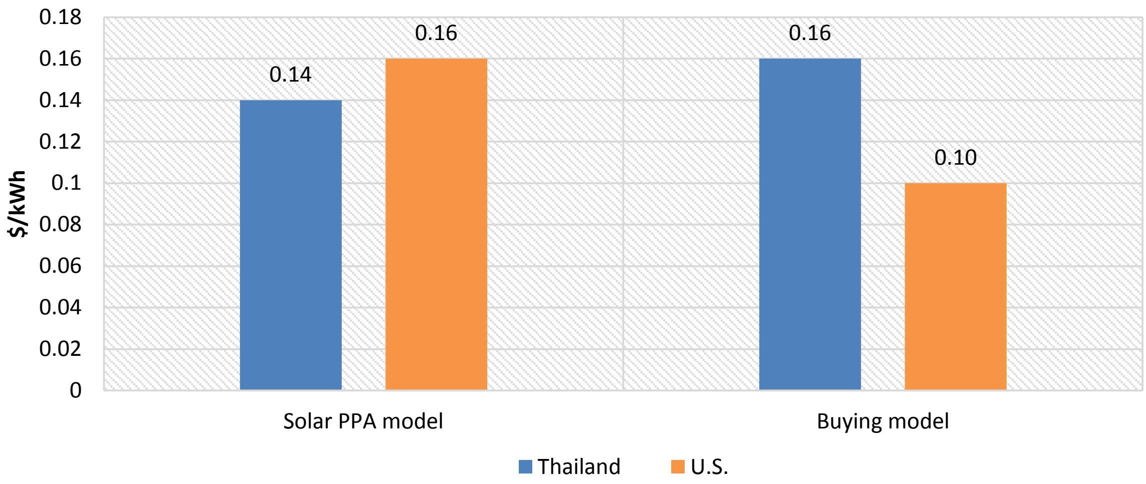


B = baht; kWh = kilowatt hour; kWp = kilowatt peak; LCOE = levelised cost of electricity; NPA = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

2) Comparison to the United States

To see how the LCOE for the solar PPA model in Thailand compares to the US, an impressive market for solar PPA, we compare our results to that of Feldman and Margolis (2014), which reported an LCOE of $0.16/kWh for the solar PPA model and $0.10/kWh and for the buying model (Figure 4.16). Based on these numbers, Thailand's solar PPA LCOE is 12.5% lower than LCOE for the US solar PPA model. In the buying model, the Thai LCOE is 60% higher than the US case. This is due to the difference in terms policy support, the investment tax credit has been taken into account, which is up to 30% of the investment cost (Feldman and Margolis, 2014). The LCOE in this chapter does not include any kind of additional incentives, mainly because policies are not stable. Shifting and unstable policy was one of the reasons for the emergence of solar service models in Thailand.

Figure 4.16: LCOE of Solar PPA Model versus Buying Model in Thailand and the United States



kWh = kilowatt hour; LCOE = ; PPA = power purchase agreement.
Source: Authors' analysis.

3) Influential factors in decision-making

Even though the results suggest that between the solar PPA model and the buying model, solar PPA has a lower LCOE, there are two cases in the sensitivity analysis that lowered the LCOE of the buying model below the solar PPA model. The two cases highlight the major factors that influence the decision in buying the system or buying the service – the discount rate and retail tariff escalation rate.

The first case happens when using a 5% discount rate. For customers with low discount rates, or low opportunity cost for other alternative investment, buying the system is more feasible than the solar PPA. For higher discount rates, the solar PPA model is more attractive because the costs are spread out into the future, leaving available cash for higher-return investments at the present time.

The second case in which the buying model appears more attractive is when there is a 5% retail tariff escalation. This is because the cost structure for the solar PPA model is linked with retail tariffs. The higher the tariff, the higher the cost per kWh of electricity. This is not the case with the buying model, as the initial cost is fixed and annual costs are mainly O&M costs. So from the cost perspective only, the buying model is indifferent to the escalation of tariff prices.

4) Other economic factors

Overall, the solar PPA model financial indicators look to be more attractive to customers. But as our assumptions for the buying model are based on 100% equity financing from the customer, which may not be true in real investment situations, we may not have captured a comprehensive view of the buying model. Though not yet widespread, forms of financial product specifically designed for rooftop solar investment are beginning to emerge for the commercial scale, they are offered in terms of long-term loans with high debt-ratio (up to 100% debt). These types of financing can significantly help in reducing the weighted average cost of capital through increasing the debt to equity ratio. By lowering the cost of financing it will reduce the LCOE of the buying model. In that case, commercial-scale grid parity of the buying model may be even closer than our prediction at 2024.

5.2.3 Solar leasing model versus buying model results

1) Base case results

Similar to the commercial-scale (120 kWp) analysis, we show a comparison between buying the system (buying model) and leasing the system (solar leasing model) for residential scale (5 kWp). The results are shown in Table 4.6. Using NPV as an indicator, both models yield unattractive results. However, the IRR and the payback period show favourable results for the customers buying the system instead of leasing.

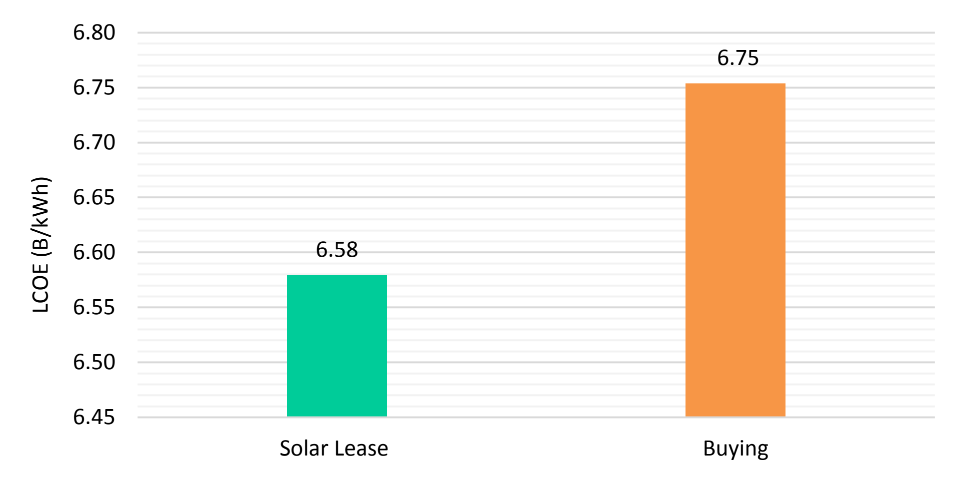
Table 4.6: Solar Leasing Model Compared to Buying Model (base case results)

Base Case – Residential Scale (5 kWp)		
Financial indicators	Buying model	Solar leasing model
NPV (baht)	–71,910	–60,123
IRR	7.96%	5.99%
Pay back period (years)	12.23	16.04
LCOE	6.75	6.58

IRR = internal rate of return; kWp = kilowatt peak; LCOE = levelised cost of electricity; NPV = net present value.
Source: Authors' analysis.

Interestingly, the solar leasing model has a slightly lower LCOE at B6.58/kWh (\$0.19/kWh) or 2.5% less than the buying model at B6.75/kWh (\$0.20/kWh), as shown in Figure 4.17. This is because, when discounting all values to the present, the relatively high initial cost of buying the system far outweighs the combination of the down payment and lease payments in the leasing option. As a result, the LCOE of the buying model is higher than solar leasing model.

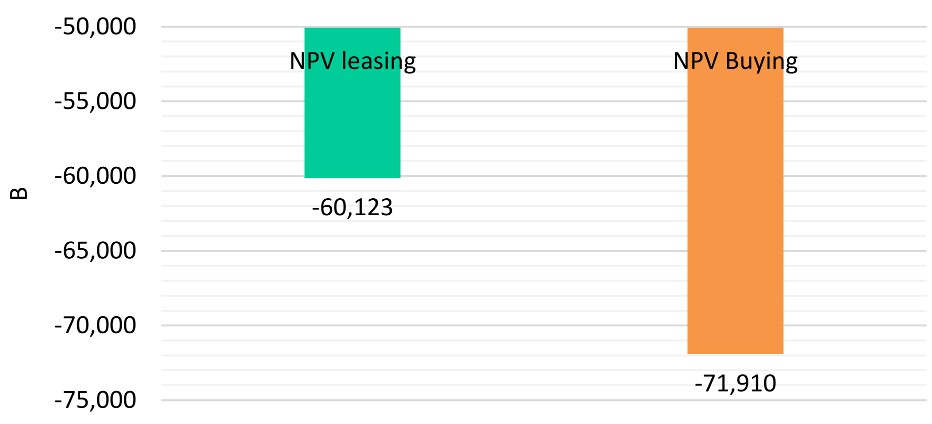
Figure 4.17: Base Case – LCOE of Solar Leasing Model versus Buying Model



B = baht; LCOE = levelised cost of electricity.
Source: Authors’ analysis.

In this study, the NPV takes into account annual operating costs and electricity saving from a 5kWp system production that occur in different time periods. When given a discount rate of 10%, the NPV (Figure 4.18) are negative in both the buying and leasing cases. Yet, the NPV of the solar leasing model is slightly greater than that of the buying model at –B60,123 and –B71,910, respectively, due to smaller non-discounted initial cost.

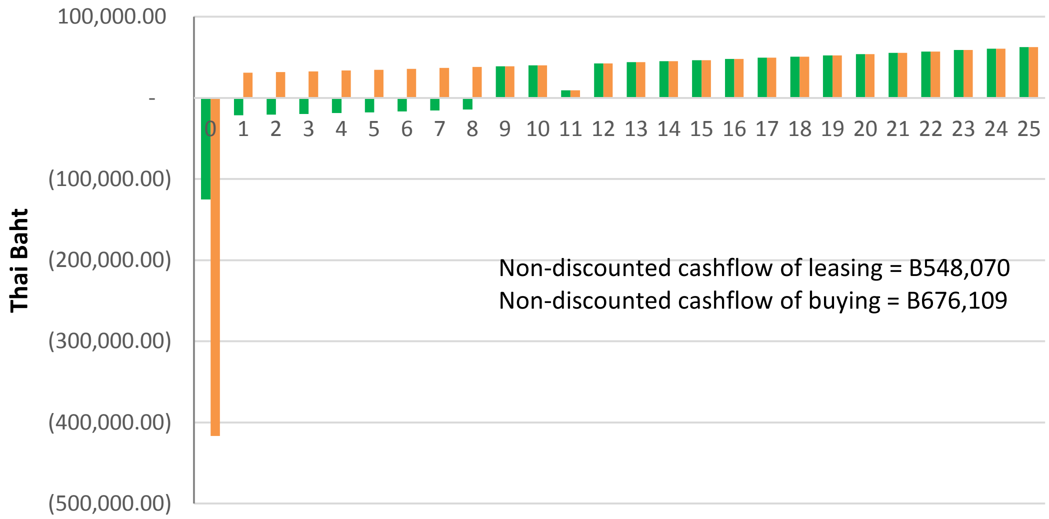
Figure 4.18: Base Case – NPV of Solar Leasing Model versus Buying Model



B =baht; NPV = net present value.
Source: Authors' analysis.

Even though cost structures of both business models are similar, the differences are in the size of initial cost and annual cost structure. For the solar leasing model, down payment is considered as an initial cost, which is 30% of total solar PV system cost. By having an 8.88% effective interest rate, the average annual lease payment is B52,466 ($1,640), which is then combined with an annual O&M cost of around B3,000 ($88). At the same time, average electricity saving amounts to B37,163 annually ($1,161). This annual saving is insufficient to pay the annual cost. Hence, the net cash flow from years 1–8 is negative, as shown in Figure 4.19. This may not attractive to the customers and may require additional incentives. Nevertheless, the sum of non-discounted cash flow of the solar leasing model is B548,070 which is slightly less than buying at B676,109 (Figure 4.19).

Figure 4.19: Annual Net Cash Flow of Solar Leasing Model versus Buying Model (non-discounted)



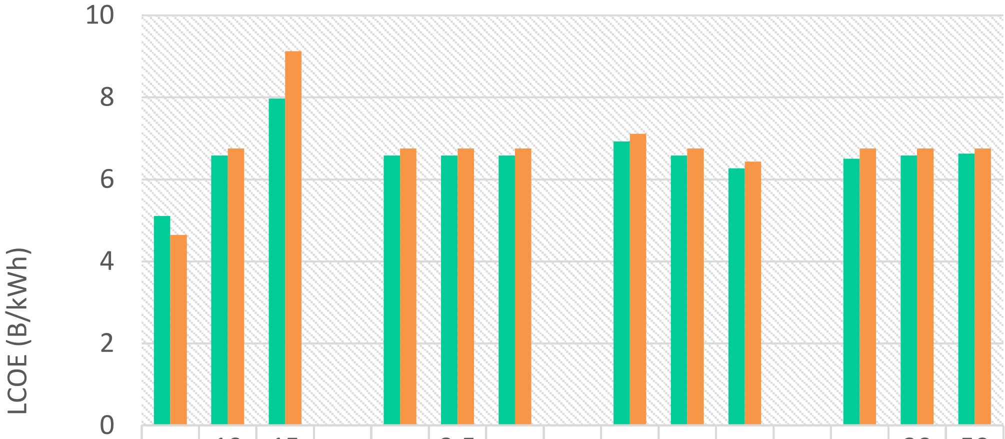
B = baht.
Source: Authors' analysis.

2) Sensitivity analysis results

The results of sensitivity analyses for the comparison of the buying model versus the leasing model are displayed in Figures 4.20 and 4.21. The following points are found:

- Solar leasing model provides lower LCOEs than buying in most of the cases. An exception is the case of a 5% discount rate, in which the LCOE of the solar leasing model is slightly higher than the buying model.
- Both leasing and buying models are most sensitive to the discount rate, as can be seen in LCOE and NPV. Between these two models, the buying model is more responsive to the changes of this parameter. As expected, the best case for leasing appears when discount rate is at 5%, which results in a minimum LCOE and a maximum NPV.
- Electric tariff escalation has no effect on the LCOE of all cases. In contrast, it has a positive correlation with the NPV, the higher the retail tariff escalation, the greater NPV. The reason is because the value of electric saving is considered as the income stream that offsets the costs. Thus, a higher electricity price means more money to be saved from PV production.
- The system yield has inverse relationships to the LCOE for both the solar leasing model and the buying model. However, it has no impact on the NPV.
- Changes of down payment cause small changes to the solar leasing model LCOE. The greater the down payment, the higher the LCOE.

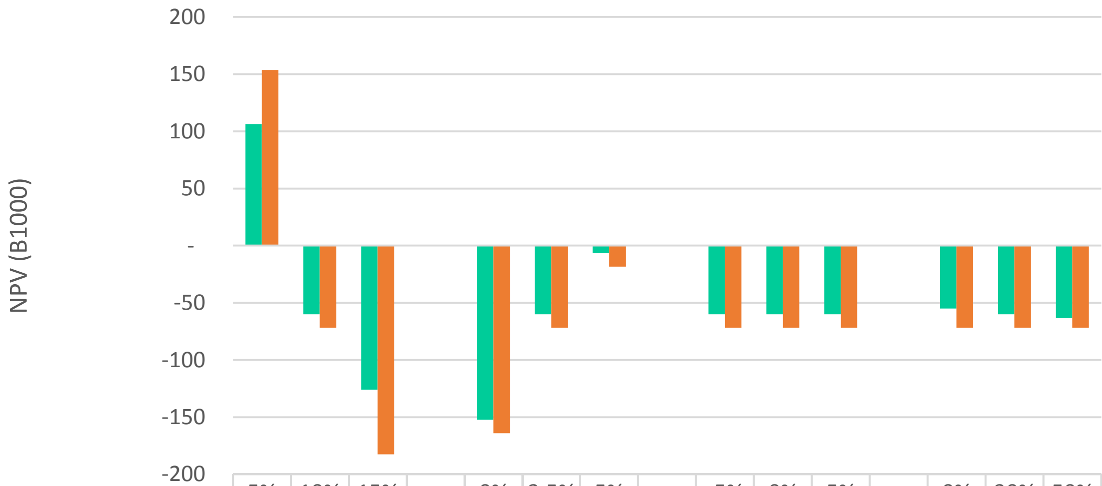
Figure 4.20: Sensitivity Analysis – LCOE Solar Leasing Model versus Buying Model



	Discount rate			Retail Tariff escalation			Yield			Down Payment		
	5%	10 %	15 %	0%	3.5 %	5%	-5%	0%	5%	0%	30 %	50 %
Lease (Baht/kWh)	5.1	6.5	7.9	6.5	6.5	6.5	6.9	6.5	6.2	6.5	6.5	6.6
Buying (Baht/kWh)	4.	6.	9.	6.	6.	6.	7.	6.	6.	6.	6.	6.

B = baht; kWh = kilowatt hour; LCOE = levelised cost of electricity
Source: Authors' analysis.

Figure 4.21: Sensitivity Analysis – NPV Solar Leasing Model versus Buying Model



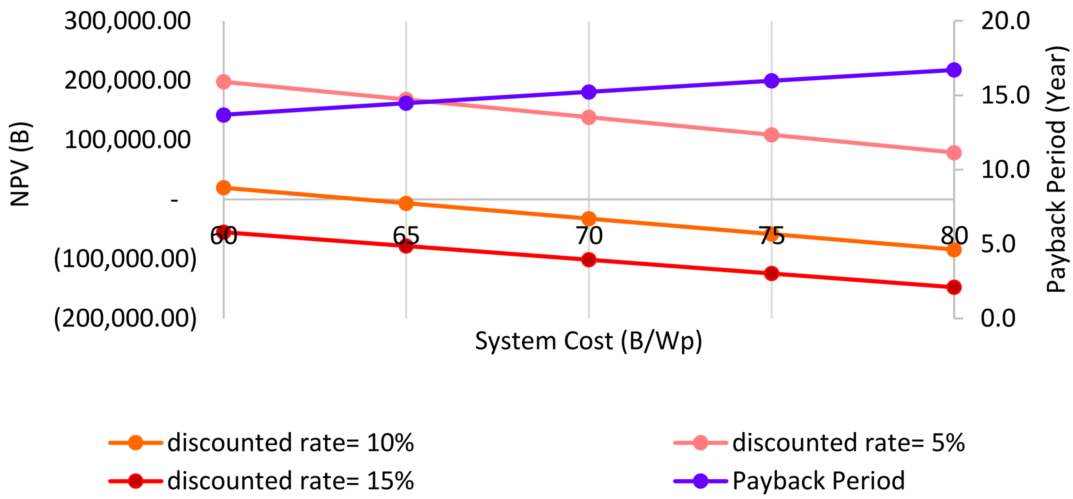
	Discount rate			Retail Tariff escalation			Yield			Down Payment		
	5%	10%	15%	0%	3.5%	5%	-5%	0%	5%	0%	30%	50%
Lease (Baht/kWh)	106	-60	-126	-152	-60	-7	-60	-60	-60	-55	-60	-63
Buying (Baht/kWh)	154	-72	-182	-164	-72	-18	-72	-72	-72	-72	-72	-72

B = baht; kWh= kilowatt hour; NPV = net present value.
Source: Authors' analysis.

3) Sensitivity analysis on system costs

Since the high upfront cost is the main barrier of PV rooftop adoption, system cost is a major factor that needs to be taken into consideration. According to our market price survey (Appendix B), the current installation cost of a residential-scale (5 kWp) PV system ranges from as low as B44/watt to a B104/watt high). The interviews with EPCs and developers revealed that the investment cost may potentially reduce to B60/Wp in future. Taking into consideration the continued decline in PV module costs and businesses' diverse ability to reduce their PV module purchase price, it would be worthwhile to analyse the results' sensitivity to system costs. To see the impact of the system installation cost on leasing, our study varied system cost from B60 to B80/Wp as shows in Figure 4.22. With a 10% discount rate, the system cost below B64/Wp results in a zero NPV which mean this leasing scheme will yield exactly 10%. As expected, the investment becomes less valuable when the discount rate moves higher to 15% and becomes more valuable with a lower discount rate of 5%. Besides, the system cost is positively correlated to the payback period. For instance, the payback period is 13.7 years at B60/W, 15.2 years at B70/W and 16.7 years at B 80/W of system cost.

Figure 4.22: System Cost Variation – NPV Solar Leasing Model and its Payback Period under different discount rates



B/Wp = baht/watt peak; NPV = net present value.
Source: Authors' analysis.

5.2.4 Solar leasing model versus buying model discussions

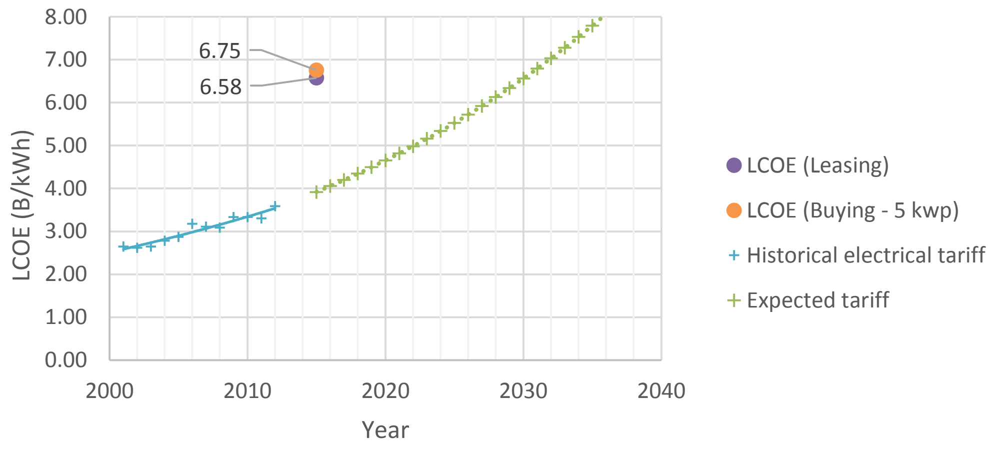
Key stakeholders with the potential to offer solar leasing model products, including financial institutions and leasing companies, have expressed interest in the solar leasing model due to its potential to capture a wide base of customers. However, as of the date of this writing, the banks and leasing companies cannot yet design a leasing programme for residential PV rooftop systems because of the lack of feasibility and their concerns of the risks. Risk factors for the lessors include the lack of a second hand market, potential rapid changes in PV technology, and the ease of PV system dismantlement. The presence of these risks results in higher interest rates and short lease terms. Based on these leasing terms, our financial analysis shows that that this investment is not attractive from the residential customer's viewpoint.

1) LCOE versus retail tariff

The results show that the LCOE of leasing is slightly lower than buying over its lifetime. From the cost perspective, the leasing LCOE proves to be slightly better option than buying as shown in Figure 4.23. With the current average electricity price at just below B4/kWh [$0.12/kWh], there is a big gap between the current electric tariff and the levelised cost per kWh of both the leasing and buying model. The LCOEs of both models remain far from grid parity, which is expected to happen as far as 2030.

There are two main factors that can accelerate the approach to grid parity, the first condition is if the future electrical tariff rises more than our assumptions at 3.5% year on year. The other case is when the cost assumptions can be significantly decreased, mainly for the investment cost which is assumed at B80/kWp for a 5 kWp system. The decrease in investment cost can come from continuous decline in PV module prices, the increase in economies of scale, or the reduction of soft cost.

Figure 4.23: Comparison between Electric Tariff and LCOE of Solar Leasing Model and Buying Model



B = baht; LCOE = levelised cost of electricity.
Source: Authors' analysis.

2) Results of support policies on solar lease

To solve the inflexible leasing conditions, governmental policies may help by offering support schemes to address the main barriers such as investment cost and short lease term. We therefore took into consideration whether having an investment tax credit and extending the lease term will help financially.

The results (Table 4.7) show that a tax return of 25% of total investment cost enables a positive NPV with a value of B41,105 ($1,213). In addition, this scheme results in a decline of LCOE to B5.08/kWh ($0.15/kWh), which is 23% less than the base case. Though the LCOE of the case that incorporates the tax credit is still not competitive when compared to the current electrical tariff, B4/kWh ($0.12/kWh), it can shorten the gap of the anticipated grid parity from the year 2030 to the year 2022. On the other hand, if the 20-year lease time is adopted, the lease investment is viable with an NPV of B25,114 ($741), LCOE of B5.32/kWh ($0.16/kWh) and is expected to reach grid parity by 2025. Regarding payback periods, the support policies can shorten it to approximately 13 years.

Table 4.7: Results of Sample Support Scheme on Solar Leasing Model

Solar Leasing Model Support Schemes			
Financial Indicators	Base case – leasing	Tax Credit – 25% of total investment	20-year lease term
LCOE (B/kWh)	6.58	5.08	5.32
NPV (B)	−60,123.06	41,105	25,114
Payback period (years)	16.04	13.04	13.80
IRR (%)	6.0	10.5	9.7

B= baht; IRR = internal rate of return; LCOE = levelised cost of electricity; NPV =net present value.
Source: Authors' analysis.

In summary, the investment on residential-scale solar leasing is currently unattractive in the customer's perspective, given the current lease terms being discussed in the market. Because of inflexible lease conditions, the model results in insufficient annual saving to repay lease payment and O&M cost. Furthermore, the LCOE of solar lease may not competitive with retail electricity tariff. However, additional incentives in the form of tax credits or long-lease terms can solve these issues. Thus, governmental support is a key to drive residential PV rooftop adoption from current emerging stage to rapid growth stage.

6Policy recommendations

Based on the results from the interviews and financial analysis, we conclude our study with two important messages about the Thai rooftop solar market:

1) The Thai rooftop solar market is still in a formation stage. With the current policy and regulatory conditions, we predict that the market could not take off and expand rapidly on its own.
2) Further support is needed, but the support should be different for different scales of installations.

The government and regulatory agencies play a large role in helping to build conditions that will help new business models to emerge and expand the market. Broadly speaking, these conditions include driving down the costs and reducing risks for the private sector. The results of our study indicate that the different scales of PV rooftop system require different support measures. Due to the lower investment cost and the projection of rising electricity price, commercial-scale solar PPA can exist without any form of government subsidy. On the other hand, residential-scale solar leasing can be more attractive with government support in the form of tax credits, which are expected to ease the leasing terms for customers. We hereby provide recommendations for the rapid scale-up of the rooftop PV market, with views of grid parity in the horizon.

Recommendation 1: Implement net metering regulations

Even without any form of subsidy, our study demonstrates that commercial-scale solar PPA is now emerging and expected to reach grid parity in the near term (within 5 years). In addition, residential solar leasing for self-consumption can potentially emerge with additional incentives. Therefore, the government should be ready to support the expansion of rooftop solar especially in the post-grid parity era by introducing net metering. As the LCOEs of rooftop solar systems in Thailand are approaching grid parity, the government should consider removing existing subsidies that may distort the market for rooftop solar PV. Aside from the FIT, developers or installers of commercial-scale rooftop solar can qualify for tax incentives from the Board of Investment.

Net metering is a practice by which owners of PV units may offset electricity consumed against their production during a certain period of time (Eid et al, 2014). Unlike the FIT, net metering is a milder incentive that gradually changes power consumers' behaviour to use less energy and enjoy the benefit of PV production more. But the details of net metering can affect project economics as well as the sustained regulatory support for solar PV in the long run. Detailed regulations on rates, rolling credit timeframe, and cap of capacity need to be designed carefully to ensure fairness between net metered and non-net metered customer. As already happening in several states in the US, there is a debate on how much to pay and to charge the net-metered customers. Some studies (for example, Borlick and Wood, 2014, pp.7–8), suggest that utilities increase the charges to the distributed generation owners or reduce the payment to the distributed generation owner to the level equal to utility's avoided costs, that is, the cost that the utility otherwise had to incur through generation or purchase to supply the distributed generator if there was no generation by distributed generator. While Thailand is in the initial stage of its net metering study, we recommend that the net metering scheme is designed with the balancing goals of speeding market expansion for rooftop solar while preventing sudden impact on the utilities' ability to recover their investment cost.

Recommendation 2: Provide more support for residential rooftop PV

For the residential-scale, there is no existing incentive apart from the FIT that elicited weak responses from consumers during its two rounds of application periods. The lack of economies of scale coupled with the lack of strong competition in the market result in a relatively high upfront cost for residential-scale rooftop solar – that is, at the cost between B43.55–104/w ($1.29–3.08/w) as of June 2015. Aside from global market forces that continue to drive down PV module costs, the Thai government should aim to drive down the cost of PV systems through a combination of measures, including lowering information cost for consumers and simplifying the permit process. Information about costs, installers, and processes that is made widely available to the public can help build an enabling business environment of rooftop solar at any scale.

In addition, the tax incentive for solar customers that was proposed by the National Reform Committee in January 2015 should be further pursued to make it a reality. This will help the residential leasing model to be more financially feasible as discussed in our financial analysis section.

Recommendation 3: Simplifying permit processes

The permit process for solar PV has continuously been improved since 2013 but it can be improved further for future net metering regulation. Rooftop PV systems so far have experienced a permit process designed under the FIT context. For rooftop solar, the process of getting FIT starts with the application to the utility to get FIT approval, to sign a contract with the utility, to acquire building and zoning permits, and an ERC licence exemption. All of these steps can take over a year, which increases the cost for the installers and consumers. In moving toward the net metering regulation, Thailand should redesign the permit process because the focus is no longer on ensuring that there is a PPA between the utility and the customer to guarantee payment. Following international best practices, the permit process for net metering should provide:

- ✓ A one-stop online platform to apply for all permits
- ✓ A clear flowchart of the process, a clear response time, and allow the tracking of the process within the online platform
- ✓ The minimisation of inspection trips to one to two trips
- ✓ The minimisation of total time it takes from applying to synchronising with the utility’s grid

Recommendation 4 :Build a qualified installation workforce

A good programme for solar installation certification not only helps increase the number of qualified installation workforce but also increase consumers' confidence, making it easier for consumers to decide whether they would like to invest in a solar system. To date, the certification system of solar installers in Thailand has not been designed to meet these goals. Poor quality can occur both during the design and installation stages, resulting in lower consumers' confidence. Poor designs mean that consumers will not receive as many benefits as expected from the solar system. Inadequate workmanship that results in damage to properties or lives can severely impact the adoption rate of rooftop solar. A better certification programme would include training for the design and installation to the highest standard before accreditation.[13] We therefore recommend that the government should aim at building a qualified installation workforce, which is an important factor that will help expand the rooftop solar market.

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Appendix A: List of Interviewed Experts

	Date of Visit	Title	Company
1	12 Jan 2015	Chairman	Thai Photovoltaic Industries Association
2	14 Jan 2015	CEO and COO	Solartron Plc
3	14 Jan 2015	Executive VP Sales and Marketing	GoldenSun Solar
4	15 Jan 2015	Acting Managing Director	PEA Encom
5	15 Jan 2015	Purchasing and Procurement Manager	Thai Solar Energy (TSE)
6	20 Jan 2015	CEO	Solar D
7	22 Jan 2015	Managing Director	SE Sun
8	22 Jan 2015	Business Development Manager	SCB
9	27 Jan 2015	Vice Managing Director/Business Development Manager	G Capital
10	2 Feb 2015	Chairman and Chief Executive Officer	SPCG Public Company Limited
11	3 Feb 2015	CEO Business Development Associate	Symbior
12	3 Feb 2015	Chief Wholesale Banking Officer	TMB Bank Public Company Limited
13	5 Feb 2015	Director and Executive VP	Thai ORIX Leasing Co., Ltd.
14	5 Feb 2015	Business Development Manager	Gunkul Engineering
15	17 Feb 2015	Deputy Secretary	Federation of Thai Industries
16	19 Feb 2015	Vice President, Corporate Credit Product Management Department Corporate and SME Products Division	Kasikornbank
17	20 Feb 2015	Business Development Manager – ASEAN	Solventia Solar Co., Ltd.

	Date of Visit	Title	Company
18	23 Feb 2015	Managing Director	Ekarat Engineering Public Co.
19	25 Feb 2015	Director of Environmental Engineering Group, Vice President Business Development & Strategy (Weng Group)	Eco-Kinetics Company Limited
20	11 Mar 2015	Investment Promotion Office, Professional Level	Thailand Board of Investment (BOI)
21	13 Mar 2015	Thailand Sales Manager	Jinko Solar Co., Ltd.
22	24 Mar 2015	COO	Solartron Plc.
23	3 April 2015	Community Leader	Bang-Bua Chersapanmai 1 Community
24	26 May 2015		Green Power Industries, Co. Ltd
25	10 June 2015	Business Development Manager, Senior Sales Executive Sales and Marketing	TUV Rheinland
26	16 June 2015	Director Bureau of Solar Energy Development	Department of Alternative Energy Development and Efficiency
27	19 June 2015	Deputy Secretary General	Office of Energy Regulatory Commission
28	24 June 2015	Country Manager – Thailand USAID Contractor	Private Financing Advisory Network for Asia Program (PFAN-Asia)
28	26 June 2015	CEO	Climate Change Solutions Co., Ltd
29	26 June 2015	Director Bureau of Solar Energy Development	Department of Alternative Energy Development and Efficiency

Appendix B: Solar System Installation Cost Survey

Residential Scale (5 KWP)

Company	Investment Cost (B/Wp)
1	43.55
2	72.20
3	62.00
4	75.97
5	55.00
6	83.10
7	100.00
8	70.00
9	76.00
10	84.44
11	104.00
12	64.20
13	87.50
14	65.00
15	46.00
16	88.59
17	65.00
18	66.00
19	80.25
AVERAGE	**73.09**

Source: Project's prices survey as of June 2015.

COMMERCIAL SCALE (>100 KWP)

COMPANY	Investment Cost (B/Wp)
1	70
2	50
3	50
4	55
5	60
6	65
7	50
8	60
9	52
10	70
11	52
12	62
13	60
14	58
AVERAGE	**58.14**

Source: Authors' compilation.