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International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(2), 226-233.

An Assessment of the Economic Viability of Delivering Solar PV Rooftop as a Service to Strengthen Business Investment in the Residential and Commercial Sectors

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Received: 20 October 2023 **Accepted:** 05 February 2024 **DOI:** https://doi.org/10.32479/ijeep.15505

ABSTRACT

The creation of significant power from PV technology has resulted from the growth of the solar PV business and industry and the lowering of PV costs. The electricity market is open broader for PV and other involved device technology. The goal of cumulative capacity drives Thailand's solar PV investment compass. The learning curve projection shows that the prediction's learning curve reliability can provide a clearer view for PV investment and policymakers. This paper shows the creation of the opportunity for the solar PV rooftop as a service (RaaS) business model, designed for four customers: residential and commercial, with small, medium, and large scales depending on their electricity consumption. The result reveals that if no grid is allowed, the medium- and large-scale are more likely to be feasible as they show grid parity. With the PV cost reduction trend, all the customers are economically viable in the grid sale allowed. Besides that, the electricity tariff rate from the grid also significantly impacts the PV rooftop investment and customer decision-making.

Keywords: Solar Rooftop, Energy-as-a-service, Electricity Sector, Economic Analysis, Energy Service Company
JEL Classifications: C8, G0, Q4

1. INTRODUCTION

Since 2000, the world's total amount of photovoltaic (PV) capacity has increased steadily. With over 239 gigawatts (GW) of additional PV capacity built in 2022, the total cumulative PV capacity deployed worldwide was 1,177 GW (Statista, 2023; IRENA, 2022; Simon, 2023). The increase in PV usage indicates a movement in the global markets away from fossil fuels and toward distributed energy sources. The Asia Pacific region's newly installed PV capacity was the greatest. With a total PV capacity of 307 and 122 GW, respectively, China and the US topped the world PV market as of 2021. However, as of 2022, Chile and Honduras were the nations with the most significant percentages of their electricity consumption derived from solar power. One of the main reasons for PV's dominance is due to decreasing generation costs. However, prices can vary by region, where PV prices tend to be much higher in developing countries than in other countries. The growth in the PV market represents a shift of global markets towards renewable and distributed energy technologies.

The size of the worldwide PV rooftop market was estimated at USD 101.55 billion in 2022 and is projected to reach over 434.63 billion USD by 2032. From 2023 to 2032, the market is predicted to develop at a compound annual growth rate (CAGR) of 15.70%. Asia-Pacific region is leading the global PV rooftop market during the forecasting period 2023-2032 (Precedence Research, 2023). According to Beatriz (2023) in PV magazine, 239 GW of additional solar capacity were built worldwide in 2022. With 49.5% of additions, the PV rooftop sector had the most significant proportion in the previous three years. The rooftop industries in Brazil, Italy, and Spain expanded by 193%, 127%, and 105%, respectively. The main drivers of the expanding demand for photovoltaic systems in the residential sector are the need for backup power supplies, the desire to lessen the danger of climate change, and the expectation of lower electricity costs. The driving factors in residential buildings are the small size and ease of installation of the PV rooftop. Furthermore, residential PV rooftop application costs have decreased dramatically in the last several years. Cost reductions have resulted in significant growth in global residential PV capacity.

1.1. The Solar PV rooftop program in Thailand

Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy reported that in 2020, PV systems installation added 143.6 MWp, resulting in the total PV installation capacity reaching 3,939.8 MW. Most are ground-mounted PV system projects with power purchase agreements under Thailand's Alternative Energy Development Plan (AEDP). PV systems for self-consumption of private sector power purchase agreements are increasing continuously. There are 3,076.5 MW of ground-mounted, 842.4 MW of rooftop, and 14.8 MW of floating systems. Off-grid PV systems have an installed capacity of 6.1 MW. AEDP2018 targets 18,696 MW of renewable energy by 2037 and 12,139 MW of solar energy target, resulting in renewable energy per electricity demand of 34.23%. In 2020, the government continued support through the solar PV rooftop systems for the Thai People project and introduced the pilot project of solar systems for schools and hospitals and solar pumping systems for agriculture. The continued growth of PV system installation in Thailand occurred due to government policy support and the private sector's market drive. This can be attributed to the cost of PV module reduction and global climate change policy. The national power development plan has set the renewable energy target of 2725 MW of floating PV systems installed in major dams by 2037 (IEA, 2022). This electricity energy will play an important role in the digital era with the ongoing preparation of the smart grid infrastructure, including the Thai people's project of rooftop PV systems. The story of Thailand's PV rooftop program is shown in Figure 1.

1.1.1. Rooftop solar self-consumption program issues and challenges in 2016

The self-consumption solar PV rooftop pilot project in 2016 (August-November 2016) revealed issues and impediments that resulted in poor performance, as shown in Table 1. The lack of a defined method for promoting solar rooftop installations and the absence of a financial rule to encourage investment are given as the causes. Due to the policy changes, the investors are uncertain about the potential hazards. According to data in 2020 from the DEDE, there were 5.63 MW of self-consumption solar rooftop pilot projects in 2016 throughout the residential and commercial sectors, with 3.934 MW in the Metropolitan Electricity Authority (MEA) and 1.696 MW in the Provincial Electricity Authority (PEA).

1.1.2. The Prosumer program during 2019-2022

The government continues to support the buyback of excess household electricity consumption during 2019-2021 at different purchasing rates of 1.68 Thai Baht (THB)/kWh, which is the Short Run Marginal Cost (SRMC) of electricity generation and 2.20 THB/kWh, respectively. The ongoing project demonstrates the increasing amounts of 469.5 MW, 558.2 MW, and 654.3 MW that were self-consumptions in 2018, 2019, and 2020, respectively. The target of PEA was 35 MW; however, at the end of 2021, there was 2.94 MW. Along with this program was a pilot project for buyback solar PV electricity generation at 1 THB/kWh for 10-200 kW capacity installed from schools—academic institutes, hospitals, and pumping for agricultural purposes. In 2021, the government launched 2.20 THB/kWh with 10 years of buyback contracts. The announcement of the Energy Regulatory Commission (ERC) on the invitation to purchase electricity from the solar rooftop for the residential sector shows that the open for applications from 2022 onwards, with a target of annual power purchase for each power plant at 5 MW per year (according to the Schedule Commercial Operation Date (SCOD)) was closed. Currently, the government offers subsidies for residential prosumers (<10 kW) with a buyback rate of 2.2 THB/kWh and a maximum contract duration of 10 years. The quota is introduced for 5 MW in each PEA and MEA. The commercial sector is already up and running and is not eligible for subsidies.

1.2. Grid parity and solar PV system competitiveness

From the data survey, Figure 2 shows that the number of solar PV systems installed has declined steadily, making its way close to grid parity. In the last 6–8 years, the situation is still far and likely to take far longer with competition with other energy and any renewable energy. As data mentioned, in the last 2–3 years, the sale price of solar modules has decreased to a disadvantage. Solar

Figure 1: Thailand solar PV rooftop program

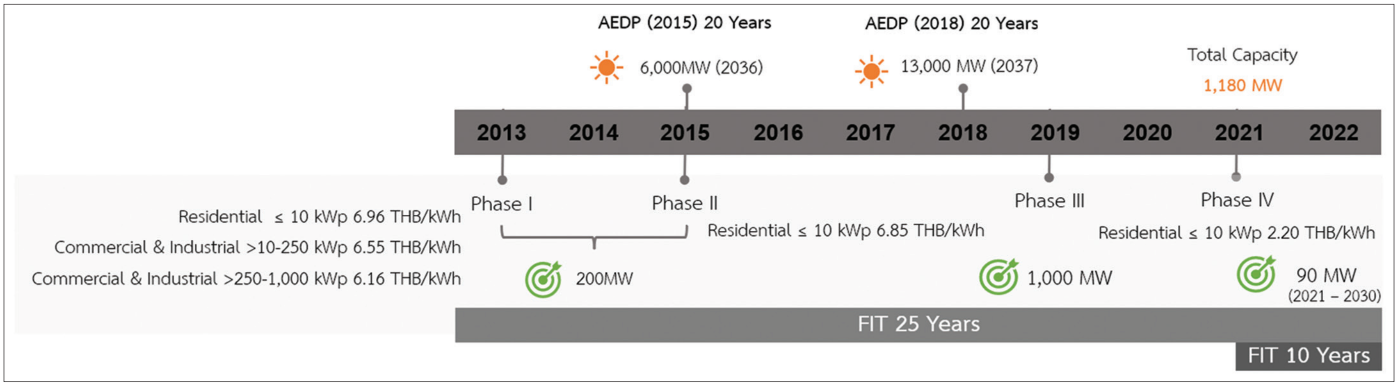


Table 1: Self-consumption solar rooftop in 2016. (DEDE, 2020)

Sector	Goal (MWp)	Total of registration		Approval		
		Number (System)	Production Capacity (kWp)	Number (system)	Production Capacity (kWp)	July 2016 MW
Residential	10	67	321.04	43	201.09	0.0617
Commercial	40	133	31,297.04	87	20,260.69	28.90
Total	50	200	31,618.08	130	20,461.78	28.97

Figure 2: Trend of solar PV module price in Thailand

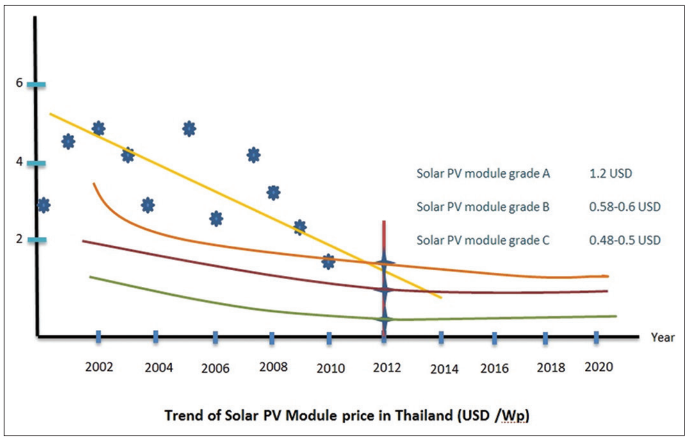
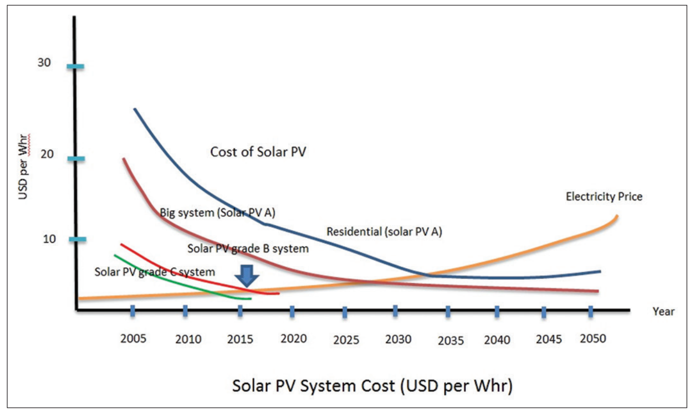


Figure 3: Solar PV system cost with electricity price in Thailand



PV is expensive, but on the other side of the green, easy to install, easy to use, low maintenance cost. A change in the price of solar PV is a competitive advantage to this situation. The situation has dramatically lowered the price of solar modules and equipment related to the solar PV system to a point close to competitiveness. On the side of the Thailand market, survey data in sectors of the company included experts from the fields of business, such as Thai Future Solar, SP Solar, Charnin Energy, and other companies that the price in Thailand is based on prices in the global market solar Module and related accessories. The price is comparable to other countries and can be learned from the conditions of countries like Germany, the U.S.A., etc.

In the Grid Parity and competitiveness of solar PV residential system cost, the study concluded that Thailand could compete with the grid as much as possible. Consumers can choose the type of solar PV, such as solar PV panels Grade A, B, or C, according to budget and appropriate technology. However, the competitiveness of solar PV systems and introductory electricity prices has a big gap. On the other hand, the study of a foreign country analyzed in the same direction that the solar PV system cost is competitive. Figure 3 shows the trends of PV system cost compared with electricity price.

1.3. Policy implication for policy maker adoption

The benefits of PV rooftops for self-consumption will result from the supervision in motion. It must be considered to increase the potential and use of self-consumption methods. Self-consumption Solar PV rooftop installation necessitates residential and business setup in addition to the electrical load. Additionally, it should have an energy-saving and energy-efficient method before the solar rooftop has the necessary size. Instead of limiting the installation of solar roofs to a certain quota, the solutions offered for self-consumption solar rooftops should have a technical study.

The quality of the distribution utility system and other power consumers is unaffected by the setup. The financial regulation incentive is just for the producer and the utility of the distribution. Aside from that, the regulation should not affect anyone who consumes electricity, such as people who buy it at wholesale prices. The security of a system is important while selling power. The process is made faster by removing obstacles and simplifying the stages for seeking a license. The procedure must be handled like a distribution utility request for an electric meter.

The owner of the solar rooftop may occasionally have an energy retention system. The initiative will cause the distribution utility's customers to lose more and more in the coming years. Each step's process session must be exact. Customers may use a website to request an installation, and they will receive a response by email and phone. For businesses or solar rooftop service providers, a guideline establishes norms. The distribution utility or ERC will certify the standard. ERC is a one-stop shop that can build a website for customers who want to install solar rooftops and collect primary data.

Additionally, ERC evaluates proposals from other service providers regarding cost, assurance, and customer support. Teaching how to choose, employ, and maintain solar rooftop tools is necessary for advancing theory and practice. People interested in installing solar panels on rooftops can attend basic training. The distribution utility controls electricity that does not return to the transmission line. They also try to limit the outcomes that could occur.

Distribution utility maintenance and operating systems often include a service charge based on unusual events, brief durations, or an annual price. For instance, the cost of replacing the battery, the inverter, the controller, and other equipment. A smart meter was created as a tool for data collection. It will enable the power consumption forecast and preserve client energy production data. Access to the right financial resources, the creation of the required regulatory framework, legal counsel, underpinning R&D, education, and other consulting services are all vital supporting procedures that must go hand in hand with the actions done to realize a project (Chaianong and Pharino, 2015; Lang et al., 2016; Tongsopit et al., 2016; Angel et al., 2022; Amanda and Ingrid, 2022; Frank, 2023). In order to improve the solar PV market in Thailand, a solar PV rooftop growth route that is consistent with Thailand's reality and goals may be suggested. This would involve a "technology push" from industry and a "market pull" backed by the Government.

As a recommendation, this study proudly presented the economic viability of delivering the Rooftop as a Service (RaaS) in the residential and commercial sector as the current situation. The RaaS market was designed with the continuously decreasing solar PV from technology development and low maintenance costs. Variable cost is meager. The other advantage of solar PV systems is that the first investment and the price reduction trend will be less than now. Regarding cost-benefit analysis, the variable cost of the solar PV system is meager compared to that of the electricity from the grid system. The variable cost of solar PV is 5.45% of the fixed cost. The RaaS will be business opportunities focusing on customers in residential and commercial sectors.

2. MARKET DESIGN TO SUPPORT RAAS

2.1. Solar Rooftop Value Chain

The value chain of solar rooftops is shown in Figure 4 and Table 2 by applying the study of the Multilateral Working Group on Solar and Wind Energy Technologies, International Renewable Energy Agency (IRENA), and Connect Americas (2015), as shown in Figure 4. It consists of the project realization and supporting process. The first part starts with project development, which consists of studying or preparing necessary information to develop the project and lead to the project, such as the potential of solar energy (Solar Radiation Value), roof area installed PV rooftop, and environmental impact assessment planning for management. Next is the production (manufacturing), such as solar panels, inverters, batteries, materials, equipment, etc. The installation process involves installing various equipment to connect to the transmission line (grid connection) after it can be implemented. A maintenance plan (operation and maintenance) has been in use for some time. In case of improvements or changes to the equipment or additional installations (replacement), the system can operate efficiently and dispose of scraps or reusing equipment or parts in the system (recycling).

As the value chain that supports the project to be able to operate sustainably, especially access to financial services, the development of a regulatory framework, appropriate regulations, or policies (policymaking), including supporting the development of research and development, promoting and supporting education or various education and related consulting, these operations should add other options that required in the operation process of the solar rooftop project.

2.1.1. Project development

Value added can be created at each stage of the business chain depending on the solar rooftop development situation. Therefore, various factors are involved in Thailand's Development of Solar Rooftop projects according to the business chain and start-up since

Figure 4: Business chain of solar PV rooftop project implementation in Thailand

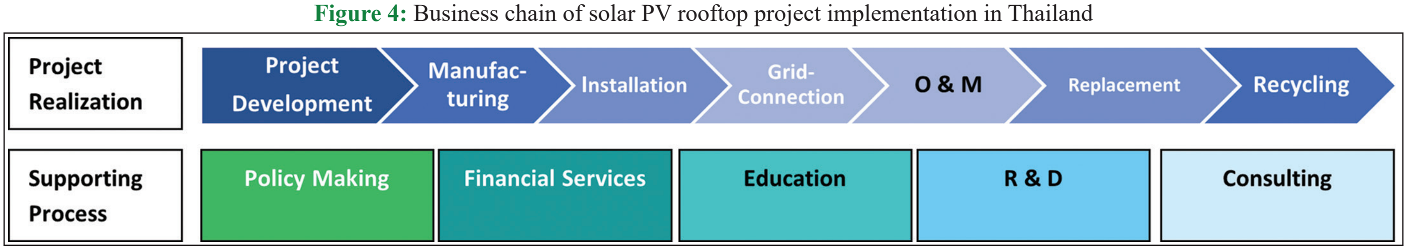


Table 2: Potential for adding value in the country of Solar Rooftop (IRENA, 2012)

Potential for domestic value creation	Development status		
Value Chain	Beginning of solar energy development	First projects realized; local industries suitable for participating	Many projects have been realized, and the national solar industry is developing
Project realization			
Project development	Low	Medium	High
Manufacturing	Low	Medium	Medium/High
Installation	Low	Medium	High
Grid connection	High	High	High
Operation and maintenance	Medium	High	High
Reconstruction and recycling	Medium	High	High
Supporting processes			
Consulting	Low	Low	Medium
Education	Low	Medium	Medium/High
Research & development	Low	Low/Medium	Medium
Financial services	Medium	Increasing	High
Policy making	Required	Required	Required

2013. On the other hand, the considered factors are roof space, calculation or estimation of the electricity that will be produced from the installation of the system, and information that must be returned to the original Solar Rooftop installer and those who want to install a new one, monitoring and evaluation of power generation efficiency, etc.

2.1.2. Manufacturing

The production of equipment or parts or other accessories is available both in the country and imported from abroad; if there is a large enough solar industry, parts can be imported from those countries. From preliminary information, it was found that solar panels and inverters are imported equipment that can be ordered quickly and conveniently delivered. Thailand has many manufacturers of parts such as panel support frames and electrical equipment. Photovoltaic power generation systems also create service jobs in this industry, such as installing, maintaining, monitoring, and evaluating power generation efficiency.

2.1.3. Installation

Most installations by companies in central and provincial areas still need engineers or technicians and short-term training courses with expertise. Training leads to increasing skills and professionalism that build credibility and trust among solar rooftop installers. Increasing the number of installation companies in various provinces also creates added value locally.

2.1.4. Grid connection

Grid connecting of the solar rooftop system and Thailand's electricity distribution system in the past in both cases, the first the case of promoting Feed-in-Tariff (FiT) and the case of promoting free installation of solar rooftops by the requirements and a fee to connect of the Electricity Distributor. New businesses from implementing both projects are in the solar rooftop project's value chain. This new business manages documents for the connection of electricity generation from the solar rooftop to reduce the steps, but the installer will have to pay the company for this service fee.

2.1.5. Operation and maintenance

As a small solar rooftop system, it does not require as much maintenance as an extensive system, but any system has to plan for changing other devices, such as inverters, which have a service life of about 10 years, and other electronic devices, about 2–5 years, etc. However, the installer of the solar rooftop may risk the warranty period for the equipment of the solar rooftop system, which is unable to generate electricity or produce less and can lead to loss of revenue or increased expenses.

2.1.6. Replacement and adjustment

Most of the adjustments or replacements of solar rooftop equipment are performed by the installation company that is doing the first installation.

2.1.7. Recycling

Solar rooftop projects and power generation from solar cells are constantly increasing. At the end of project life, there is much waste from solar cells, inverters, electrical cables, support structures, etc. Different disposal methods, such as inverters and electrical cables, will recycle e-waste disposal processes and structural steel for the annealing process and reuse. In the case of old solar panels, currently in Thailand, there is no definite management.

2.1.8. Development of the regulations or policies (Policymaking)

From the past study of solar energy development both in Thailand and abroad, it was found that appropriate government policy and promotion frameworks influence the success of the utilization and the growth of economic value. Therefore, the government sector needs to develop support processes in various forms to drive investment for solar rooftop projects in phases 1 and 2. The FiT promotion plan is attractive to new investors and operators to build a value chain, but regulations need to be improved and more transparent and not redundant in practice, including the understanding of the staff involved in the process. The goal of the free Solar Rooftop project cannot be achieved because of a lack of support or definite government policy, which is the risk factor for investors in solar rooftops.

2.1.9. Financial services

The well-performing financial service for the solar rooftop project is important for successful development. The networking of international financial institutions is essential, too. Value creation in financial institutions can create and offer new financial models. Including a bank with experience in Solar energy projects will reduce the risk. In addition, other investors may benefit from investing in the value chain of solar rooftop installations.

2.1.10. Research and development/education and knowledge/consulting

Most of the research and development and solar energy consulting is operated by specialized institutes with experience, especially value chain, in providing knowledge or consulting such as training on installation, maintenance, and regulations related to solar rooftops that create enormous value and income. However, investing in solar rooftops increases the value of domestic research and development as it may be limited. The government can develop research and development strategies, providing expert agencies with more detailed step-by-step consultation. It will help increase skills to a higher level, expand opportunities, and create more value for the personnel in the country.

The potential for value-added with the value chain can be presented as an opportunity for the Energy-as-a-Service (EaaS) business model, as shown in the case of solar promotion in Spain, which creates an additional 28,000 positions annually, directly and indirectly, involved in the solar PV industry. 2010, the solar PV industry's development, installation, and maintenance grew. The REN21 report (IRENA, 2012) shows that employment in solar PV installation processes is 38 people per year and per MW installed. The maintenance service process generates employment of 0.4 people per MW, which can analyze and create the production–output model factors (Input-Output Model) to study the related effects on a macro level, as shown in Table 3.

3. ECONOMIC ASSESSMENT OF SOLAR ROOFTOP-AS-A-SERVICE INVESTMENT

3.1. Market Model and its Assumption for the Residential and Commercial Sector

The RaaS was applied to the EaaS concept. It offers energy and associated services such as asset installation, management, and consultation. The study begins by examining four categories of electricity consumers in the residential and commercial sectors to determine whether installing a solar rooftop investment is worthwhile for each energy user and would encourage them to invest, as presented in Table 4.

The assumption of this economic viability criteria is detailed as follows:

- The period to calculate for impacts is 2018-2036
- Electricity capacity (capacity: kW) for residents and small and medium-sized businesses is set from statistics of average electricity use in 2016. For large businesses, the maximum production capacity is 1 MW, according to the policy set by the PEA and promoted by the Board of Investment (BOI)
- The price of investment in solar rooftops is based on the market price in 2017, which includes installation costs. Medium and large businesses can buy lower-priced solar PV panels and equipment because of higher quantities
- Connection fees according to PEA rate
- The average and peak electricity rates in 2018 are estimated with the assumption that they will increase at 1.89% per year (according to PDP). The average and peak electricity rates in 2016 are the actual values from the PEA report
- The levelized energy cost is calculated from Homer's simulation and presented for comparison
- The average monthly electricity consumption of each type of user is referred to as the electricity consumption in 2016.

As comparing the levelized costs from the HOMER simulation, the cost of electricity and generated electricity from a solar rooftop compared to the investment that found the cost of producing electricity from a solar rooftop is lower than the electricity price from the grid. However, the investment decision of users may need to consider additional options by analyzing the worthiness of the investment, as shown in Table 5.

Table 6 shows the results of the HOMER simulation according to the size of the solar PV, electricity usage, and weather conditions in Thailand. The data on the ability to generate electricity from solar rooftops, self-consumption, and excess self-consumption can be analyzed for the worthiness of investment. This analysis data is divided into 2 cases: the case of no grid sales allowed and the case of grid sales allowed.

The assumption of this Table 6 is shown as

- The total annual benefit in case of no grid sales allowed is calculated from the electricity bill saved from self-consumption
- The total annual benefit in case of grid sales allowed is calculated from the electricity bill saved from self-

Table 3: Overview of positive and negative impacts caused by economic stimulus

Effect	Positive effects	Negative effects
Investment effect	Direct and indirect impacts* from investment in solar rooftop system	Direct and indirect effects of avoiding investment in traditional electricity generation
O&M effect	Direct and indirect effects from maintenance of the solar rooftop system	Direct and indirect effects by avoiding maintaining the traditional electrical system
Fuel effect	Direct and indirect effects of fuel demand	Direct and indirect effects* by avoiding the consumption of fuel
Price effect	Including the impact of compensation for additional expenses**	Impact of increasing spending on households (budget impact) and industry (impact on cost)
Solar Rooftop income effect	Effects on revenue in the solar rooftop industry	Avoid expected industry earnings***
Trade effect	Trading in technology and renewable energy	Avoid trading traditional technologies and energy.
Dynamic effects	Add-on effects: Changes in effectiveness, learning effect, multiplier effect, etc.	

*Indirect impacts included impacts on industries and upstream and downstream services. The direct impact on the Solar Rooftop equipment manufacturing industry or the direct servicing operations of solar rooftop installations. ** Solar rooftop installation costs are favorable, and CO2 pricing or order effect offsets the impact. *** Not mentioned in other studies

Table 4: Residential and commercial customer sector

Residential	Commercial		
	Small (S)	Medium (M)	Large (L)
The customer uses electricity in residential homes by connecting through a single electrical meter	Small business refers to any electricity consumption <30 kW with a maximum average power demand in 15 min. This includes businesses, businesses combined with residential homes, industries, government agencies, any offices, local government organizations, state enterprises, embassies, foreign government agencies, offices of international organizations, and others	State enterprises, embassies, offices of foreign government agencies, offices of international organizations, and related areas are considered medium-sized businesses that use electricity for more significant purposes. These businesses have an average power demand for electricity between 30 and 1000 kW in 15 min at any given time, and their average monthly electric power consumption over the previous three months did not exceed 250,000 units by connecting through a single electrical meter	Large businesses that use electricity include industry, government agencies, offices of other government agencies, state enterprises, embassies, offices of foreign government agencies, offices of international organizations, and related areas. These businesses must have a maximum average power demand of 1000 kW in 15 min at any time, or their average monthly electrical energy consumption for the previous three months must have been 250,000 units connected through a single electrical meter

Table 5: Assumption of solar PV rooftop investment for customers in different scales

Detail	Residential	S	M	L
Capacity (kW)	3	10	250	1,000
Price (THB/kW)	40,000	35,000	30,000	25,000
Connection fee	10,000	15,000	100,000	100,000
Total Initial Investment	130,000			
Annual O&M cost (as of total system cost)	0.50	0.50	0.50	0.50
Project Life (years)	25	25	25	25
Average electricity tariff (including ft)	3.87	4.08	3.80	3.36
Average electricity tariff at peak rate (including ft)	5.31	5.31	4.29	4.29
Levelized cost of energy (THB/kWh)	3.55	3.02	3.87	3.83
Average monthly consumption (kWh/m)	300	700	25,000	750,000
Average monthly electricity bill	1160	2856	95,038	2,519,530

Table 6: Electricity generation from solar rooftop system and economic results

Detail	Residential	S	M	L
Capacity (kW)	3	10	250	1000
Electricity generation (kWh/year)	4089	13,630	340,752	1,363,008
AC primary load-Annual load (kWh/year)	3650	9,125	400,000	9,140,333
Self-consumption from Solar Rooftop (kWh/year)	1520	4549	340,252	1,362,671
Saving electricity per month (THB)	672	2012	95,038	486,681
Revenue from grid sales/month	693	2451	135	91
Required rate of return (%)	8	12	12	12
No grid sales allowed				
Annual benefits	7469	22,149	1,096,707	5,665,169
NPV (THB)	(50,269)	(241,283)	(248,373)	9,332,706
IRR (%)	3	2.35	11.59	15.72
Payback (years)	17.4	18.7	8.1	6.2
Grid sales allowed				
Annual benefits	15,790	51,563	1,098,327	5,666,260
NPV (THB)	38,557	(10,586)	(235,671)	9,341,267
IRR (%)	11.31	11.63	11.61	15.72
Payback (years)	8.6	8.4	8.4	6.4

consumption, Including income from electricity that PEA or MEA purchases

- Calculation of electricity price
  - In saving electricity from the peak time rate according to the assumptions in Table 5
  - In the case of electricity income from PEA or MEA purchases, it is calculated based on the peak time price purchased from EGAT by the price base of 3.12 baht per unit in 2016 and an annual increase of 1.89% to be 3.24 THB/kWh in 2018.

The worthiness analysis was applied to the cost-benefit analysis, and decisions are based on three criteria:

- Net Present Value (NPV) is more significant than zero, so the project is worth investing in
- The Internal Rate of Return (IRR) is greater than the required rate of return or discount rate in which the project is worth investing
- The payback period is shorter than the lifespan of solar PV (25 years), so the project is worth investing more in.

From Table 6, in the case of no grid sales allowed, the investors will only benefit from the electricity cost saved from a small amount of solar PV. The investment is not worth it for residential electricity users and small and medium-sized businesses (NPV <0 and IRR lower than the required rate of return). PEA or MEA purchasing excess electricity (grid sales allowed) will invest more worthiness by not including medium and small business electricity users, who say the investment is not worth it. Therefore, the government should set a stable policy to purchase electricity from private sector investment in solar rooftops, that is, investment incentives.

3.2. Sensitivity Scenario

According to the likelihood of the price of solar PV decreasing, the sensitivity of the investment's net present value at different solar PV price levels was analyzed, and the results are shown in Table 7. As for the residential group, the analysis results show that the investment will be worthwhile only if the electricity is sold to PEA or MEA. The investment will be worthwhile for small businesses if two options are sold to PEA or MEA, and the price of solar PV must be lower than 39,000 THB/kW. For the medium-sized business and the power produced from solar rooftops as much as almost electrical usage, the NPV of the investment in both cases is very close and resulting in almost the same line that the investment will be worthwhile if the price of solar PV is lower than 34,000 THB/kW.

As shown on the current solar PV price level, PEA and MEA will have to purchase electricity from solar rooftop users to make the project worth investing in electricity users. Therefore, analyzing the impact option from now will be based on the assumption that PEA and MEA purchase excess electricity from investors at the same price as EGAT.

Table 7: Sensitivity analysis of net present value for PV module price change

Cost (THB/kW)	Residential	S	M	L
No grid sales allowed				
30,000	(18,668)	(137,362)	1,050,647	14,528,784
32,500	(26,568)	(163,342)	401,137	11,930,745
35,000	(34,468)	(189,322)	(248,373)	9,332,706
37,500	(42,369)	(215,303)	(897,883)	6,734,666
40,000	(50,269)	(241,283)	(1,547,392)	4,136,627
Grid sales allowed				
30,000	70,158	93,335	1,063,349	14,537,345
32,500	62,258	67,355	413,839	11,939,306
35,000	54,358	41,374	(235,671)	9,341,267
37,500	46,457	15,394	(885,180)	6,743,228
40,000	38,557	(10,586)	(1,534,690)	4,145,188

4. CONCLUSIONS AND RECOMMENDATIONS

This study has given an overview of the PV cost reduction and showed the potential for cost reduction over the last decade. PV technology should relate to suitable investments that positively impact the user. The study enhances the understanding of solar PV investment as competitive with grid-connected. Remarkably, the government is the leading player in the energy flow chart, which showed that three partners are directly linked to the government for policy and regulation. The government should be driven by renewable energy, including solar PV, which is needed for supported policy in any measures such as renewable energy funds, tax incentives, soft loans, feed-in-tariff, customs duty, and subsidy installation.

The stable policy and regulation could increase the confidence of investors, entrepreneurs, end users, etc. Therefore, the government should plan the energy strategy for renewable energy in the short and long term, especially solar PV. The supported measures and clear policy are the keys to starting up commercial users, and the business sector is confident in investing in this business. The RaaS model can be deployed as a business model for Thailand. However, some barriers to solar PV can be solved soon, such as electricity prices and buyback at the net metering, not only net billing. These barriers will be more apparent if people understand and use solar PV conveniently in daily life.

5. ACKNOWLEDGEMENT

This work was partially supported by Global and Frontier Research University Fund, Naresuan University (NU), with Grant No. R2567C002.

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